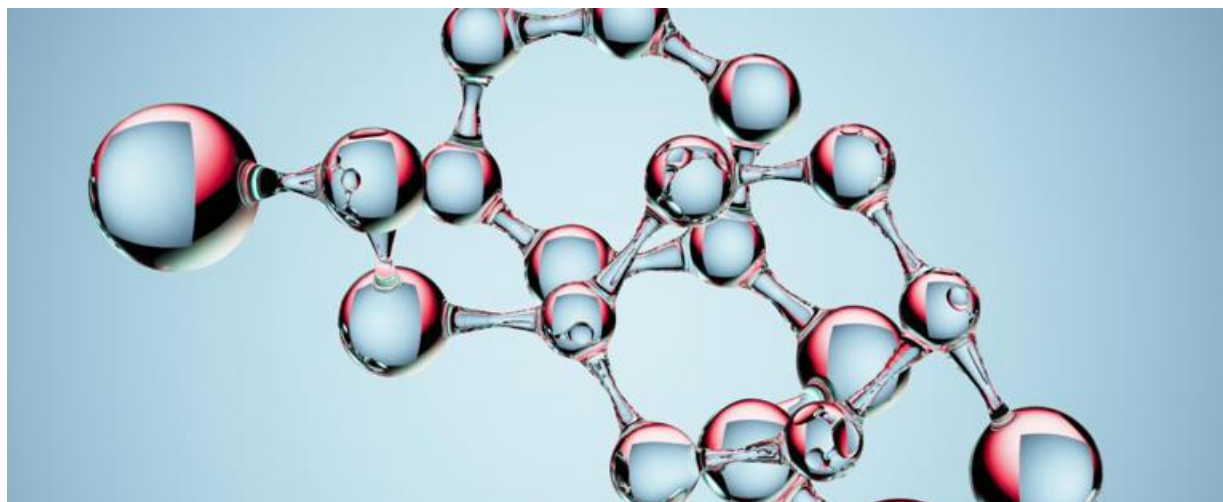


MANUFACTURING TECH VOL 2



Glass molecular structure© Provided by ScienceAlert

An analysis of a vast database of compounds has revealed a curious repeating pattern in the way matter composes itself.

Of more than 80,000 electronic structures of experimental and predicted materials studied, a whopping 60 percent have a basic structural unit based on a multiple of four.

What's so strange about this is that the research team that discovered this pattern couldn't figure out why it happens. All we know at the moment is that it's real and observable. It just evades explanation.

"Through an extensive investigation, in this work we highlight and analyze the anomalous abundance of inorganic compounds whose primitive unit cell contains a number of atoms that is a multiple of four, a property that we name rule of four," [write a team](#) led by physicist Elena Gazzarrini, formerly of the Swiss Federal Institute of Technology Lausanne in Switzerland, now at CERN.

"The study provides a starting point for future investigations on the rule's emergence, given that a fully satisfactory explanation of such anomalous distribution is as yet lacking."

One of the most basic questions about the Universe around us is why some properties are more abundant than others. Why is there [more matter than antimatter](#)? Why are the [building blocks of life left-handed](#)? And why do materials behave the way they do?

This last one is of keen interest in materials science, which seeks to understand the properties and behavior of different combinations of atoms to help develop and refine them. But it's a question that's difficult to approach, since there's just such a vast variety in the way particles can come together.

This is why Gazzarrini and her colleagues became intrigued when they noticed a pattern seeming to emerge in two databases of materials, the Materials Project (MP) database and the Materials Cloud 3-dimensional crystal structures 'source' database (MC3Dsource). The majority of inorganic compounds in both databases have unit cells – that is, the smallest possible unit that repeats within a crystal structure – based on multiples of four.

This was concerning, because theoretically all structure types should be equally represented in these databases. Having such a dominant pattern emerge could mean that there is a flaw in the data somewhere, an error that hasn't been noticed.

"A first intuitive reason could come from the fact that when a conventional unit cell (a larger cell than the primitive one, representing the full symmetry of the crystal) is transformed into a primitive cell, the number of atoms is typically reduced by four times," Gazzarini explains. "The first question we asked was whether the software used to 'primitivize' the unit cell had done it correctly, and the answer was yes."

Once they ruled out obvious errors, they had to dig deeper, and look for other patterns that might explain the rule of four.

One possible explanation was silicon, which can bind four other atoms to its central atom. If all the rule of four compounds contained silicon, that would solve the mystery... but not all the materials had silicon in them. Similarly, there was no rhyme or reason to the formation energies of the rule of four compounds.

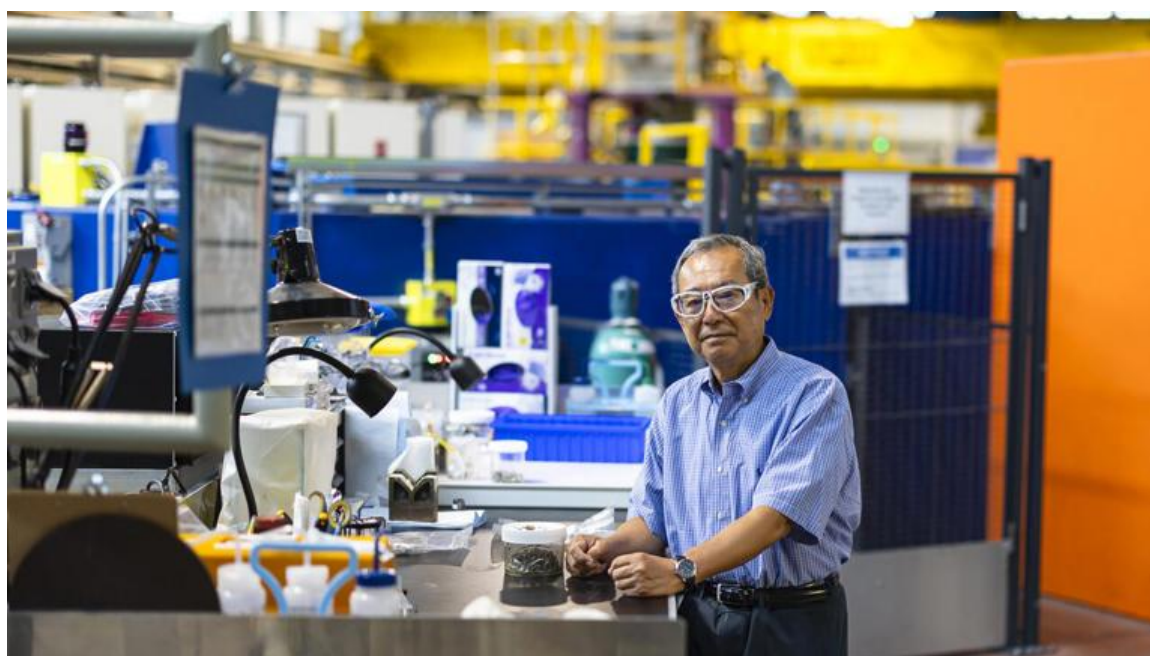
So, the next step was to build a more powerful algorithm. This was accomplished with the aid of engineer Rose Cernosky of the University of Wisconsin. The algorithm grouped the compounds together according to similarities in their atomic properties. Once again, there was no discernible pattern.

No matter what the team tried, nothing stuck. The pattern is real, and doesn't appear to be an error, but there was no other property that could accurately

predict whether or not a compound will follow the rule of four – at least when a person was the one doing the predicting.

When the team ran the data through a [machine learning algorithm](#) that can achieve high-accuracy predictions from datasets, the output results predicted whether or not a compound would obey the rule of four with up to 87 percent accuracy. This suggests that there may be something that we're missing about the rule of four compounds that could help explain what produces the pattern.

It may be currently difficult to study patterns in materials; but the findings suggest that, with ever more powerful computational techniques, we might be able to start making some fascinating headway.



Takeshi Egami stands at his workstation at ORNL's Spallation Neutron Source where he used novel experimental methods to propose the density wave theory. Credit: Carlos Jones/ORNL, U.S. Dept. of Energy

In 1543, Copernicus pitched the heliocentric idea that the Earth orbited the sun. His theory took 150 years to catch on and more than 400 years for the Vatican to officially accept it. Likewise, distinguished materials scientist Takeshi Egami has spent his career revealing the complex atomic structure of metallic glass and

other liquids—sometimes sharing theories with initially resistant minds in the scientific community. However, he is willing to go the distance to bring his colleagues on board to his latest discoveries.

Takeshi Egami uses synchrotron X-ray and neutron scattering to see dynamic atomic correlation in liquids. Credit: Carlos Jones/ORNL, U.S. Dept. of Energy

The noncrystalline, amorphous atomic structure of liquids and glasses is, quite literally, all over the place. The landscape is chaotic: disorderly atoms are scattered about like tapioca pearls in a freshly shaken boba tea.

Egami studies these materials at the Department of Energy's Oak Ridge National Laboratory and the University of Tennessee, Knoxville, or UTK. He directed the UT-ORNL Joint Institute for Neutron Sciences from 2008 to 2015. Egami and his colleagues in ORNL's Materials Science and Technology Division use neutron scattering and synchrotron X-ray to see, with increasing clarity, the structure, dynamics, transition and deformation of noncrystalline materials.

In crystalline solids, atoms bond together and are arranged in a rigid, jungle gym-like structure called a lattice. This lattice is what makes most solids—such as jewelry, refrigerators and high-rise buildings—solid.

"There's not much freedom for atoms to move around," said Egami. "A crystalline structure is like an autocracy where each atom must behave like every other atom. A liquid is like a democracy where atoms may move about more." Structural analysis is challenging since atoms are in constant disarray.

The typical method of atomic modeling is a bottom-up approach in which each atom connects with its closest neighboring atoms. This method works reliably for most solids, but bottom-up analysis of noncrystalline materials has always made Egami uneasy because of their unstable, chaotic nature.

"The bottom-up approach is very self-centered, like the geocentric view of the universe where the Earth is at the center," he said. Like Copernicus, Egami has been looking for the cosmic truth about these materials his whole career.

After completing undergraduate studies in applied physics at the University of Tokyo, a doctorate in materials science from the University of Pennsylvania and postdoctoral studies at the University of Sussex and the Max Planck Institute,

Egami taught at the University of Pennsylvania for 30 years. In 2003, he came to ORNL to focus on the underdeveloped field of liquid physics.

"Water itself is a major mystery," said Egami. "The classical physics of water is well understood, but there are many things about water we don't understand. It's such basic stuff, right? Life came out of that, and we don't know why."

Egami uses enigmatic metallic glass to study the structure, function and deformation of noncrystalline materials.

Metallic glass presents itself as solid, but its disorganized atomic structure makes it technically a frozen liquid. The opaque substance is made of metal alloys—made by mixing two or more metallic elements—that are supercooled so atoms do not have a chance to organize themselves into a lattice structure.

This lack of structure makes metallic glass highly elastic, extremely strong and easy to magnetize. Since entering the marketplace in the 1970s, metallic glass has been used in products such as sporting goods, smartphones and medical devices. Still, not much is known about the source of its mechanical properties, which has limited its commercial use.

For example, for all its strength, metallic glass is extremely fragile. Give a golf ball one too many whacks with a club made of it, and the club will shatter. Current theories about metallic glass cannot describe this kind of weirdness.

Egami's research has begun to suggest structural and functional behavior of noncrystalline materials that defies prevailing theory. He hopes these findings lead to changes in analysis that have a wide scientific impact.

In 2017, using synchrotron X-rays at the SPring-8 facility in Japan, [Egami and his group showed](#), for the first time, dynamic atomic correlation in water. The correlations are measures of how much the movement of one atom is influenced by the presence of others.

"Everybody knows about these correlations, but no one had seen them before," said Egami. "Now, we can see how atoms relate in space and time, for the first time."

The journey to a new density wave theory began with Egami's uneasiness with bottom-up atomic modeling. With a wider look, his new approach began with the

medium-range order—the correlation of a single atom and its surrounding atoms at a distance up to 10 times the atomic size.

"I always thought maybe there's a global way of looking at it, not just local," he said. "Why can't we look at the whole system at once?" [A 2022 paper](#) by Egami and UTK's Chae Woo Ryu described a density wave state, or ripple. Evidence of this ripple had been observed before but was interpreted as noise in the experimental data caused by X-ray scattering.'

In 2019, Egami's team used a novel experimental method of liquid levitation under vacuum that removed the noise and confirmed that the ripples are real. This finding ushered in the density wave theory and a new hypothesis on the relationship between the bottom-up and top-down methods.

"Sometimes the conflict can create something totally new," said Egami. The competition between the bottom-up and top-down observations prompted Egami and colleagues to propose a new [medium-range order](#) that may hold the key to viscosity and deformation in liquids and glasses. Egami hopes these findings will shatter the metallic glass ceiling and gain traction beyond the world of the samples they were tested on.

Scientists calculate and predict electron behaviors of complex systems using density functional theory. "Chemists use this all the time because it's easier than running an experiment," said Egami. But the calculation is not ideal for materials in which electrons are strongly correlated, such as magnets or high-temperature superconductors.

Using the same approach for electrons as he used for liquids, Egami has succeeded in seeing electron correlation. "Since we can see dynamic electron correlation, we no longer need to rely on density functional theory."

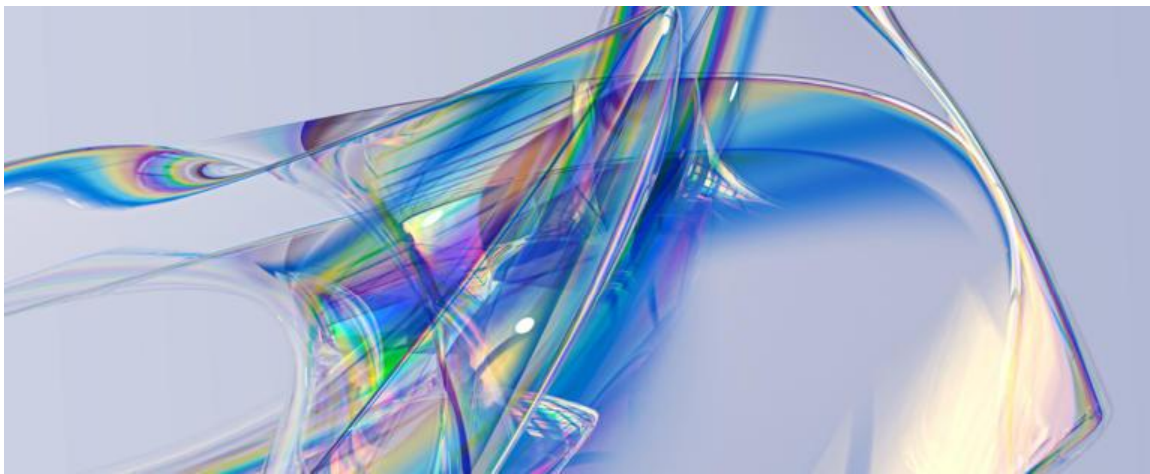
The esteemed materials scientist is taking his findings on the road and has embarked on a one-man talking tour.

"I know this will take some time to catch on," he said. Although his findings have met resistance in other disciplines, he is used to it. "It's not my first rodeo," Egami said, speaking of his co-authored book that proposed—initially to great resistance—a new method of analyzing disorganized crystals.

After 10 years of persuasion, colleagues finally came around. Egami's analysis technique, [detailed in Underneath the Bragg Peaks](#), is now standard in the field.

Regarding the proposed density wave theory and medium-range order of metallic glasses, "I'm in no hurry," Egami said. He is optimistic that his theory's acceptance will not take as long as it did for Copernicus.

Provided by Oak Ridge National Laboratory



Flexible, translucent material refracting light into a visible spectrum of rainbow colors.© Provided by ScienceAlert

Scientists have discovered an exception to a 200-year-old scientific law that governs how heat diffuses through solid materials.

Known as [Fourier's law](#), it describes how heat is transferred, or [conducted](#), through solid materials. As molecules vibrate and electrons shuttle about, the heat diffuses from the hotter end of an object to the colder end, at a rate that is proportional to that temperature difference and the area through which the heat flows.

However, in the [past few decades](#), researchers have found that on the nanoscale, this model of diffusion doesn't work; [Fourier's law breaks down](#) and [no longer predicts](#) how fast or slow heat will move through a solid material.

Polymer physicist Kaikai Zheng from the University of Massachusetts, Amherst and colleagues wondered if there might be similar exceptions to Fourier's law to

be found at the macroscale, in see-through materials such as translucent polymers and inorganic glasses.

Being [translucent](#), these materials let some wavelengths of light pass through. Although the light doesn't get totally absorbed like in opaque materials, it does scatter, bouncing off impurities in the material structure.

This led Zheng and colleagues to hypothesize that as well as heat diffusing through these solid materials, their translucence might also allow heat energy to travel through the materials in the form of thermal radiation as well. [Radiant heat](#) is carried through the air as electromagnetic waves, mainly infrared radiation, and an example is the heat we feel from the Sun's rays.

"This research began with a simple question," [explains](#) senior author Steve Granick, a materials scientist also at the University of Massachusetts, Amherst. "What if heat could be transmitted [through solids] by another pathway, not just the one that people had assumed?"

So the researchers clamped strips of test materials and suspended them, one by one, inside a custom-made vacuum chamber. The vacuum removed the possibility of heat dissipating from the materials through air.

"To find violations [in Fourier's law] at macroscopic scales would be startling as this would go beyond standard textbook thinking," the researchers [write in their paper](#), reflecting on their thinking going into the experiments.

The team fired split-second pulses of laser at the materials to heat them up, and measured how heat spread through each of the materials using three methods: a temperature sensor placed directly on the material surface; measuring the color change of a temperature-sensitive coating painted onto the sample; and an infrared camera.

"The data show heating [occurred] faster than can be attributed to diffusion," the researchers [write](#), "indicating that radiation contributes significantly to heat flux during early times after a heat pulse, though the relative contribution of radiation diminishes as diffusion becomes dominant at later times."

"It's not that Fourier's Law is wrong," Granick [clarifies](#), "just that it doesn't explain everything we see when it comes to heat transmission."

The team [suggests](#) that translucent materials radiate heat internally because structural imperfections act as heat absorbers and sources, allowing the heat to propagate from point to point rather than diffusing slowly.

They [add](#) that their findings could help engineers design new strategies for heat management in translucent materials, now that their study provides an expanded understanding of how heat spreads in solids – some 200 years after this phenomenon was first described in mathematical terms.

The study has been published in [PNAS](#).

IT'S A LIVING THING
JUN 3, 2025

Scientists Create Living Plastic Alternative

And it's edible, too!

/ [Earth & Energy](#)/ [Biodegradable](#)/ [Fungi](#)/ [Mushrooms](#)

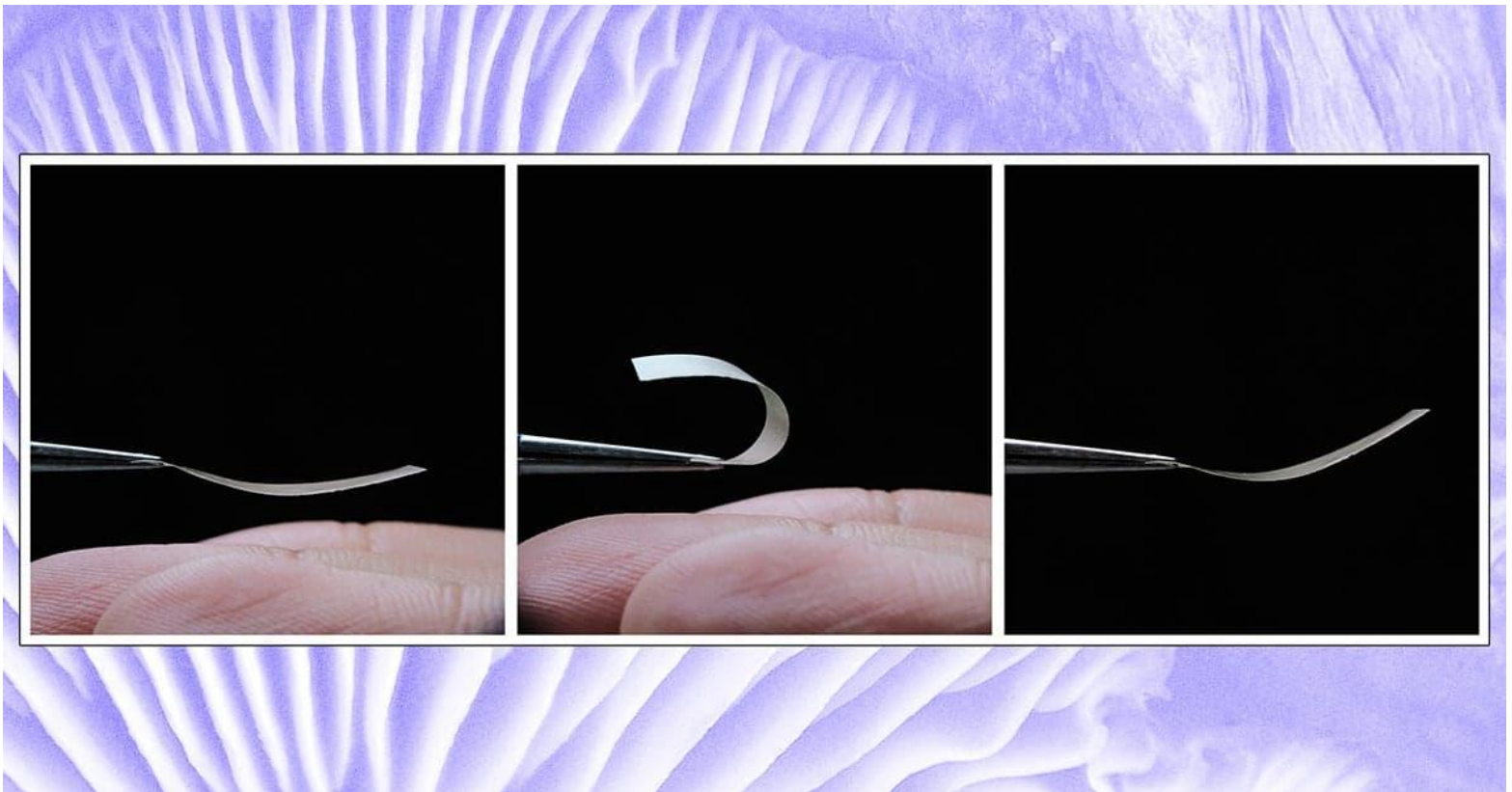


Image by Empa / Getty / Futurism

Using mushrooms, scientists have created a living, plastic-like compound that uses the fungi's unique properties to mold it into almost any form.

Researchers out of the Swiss Federal Laboratories for Materials Science and Technology, better known as Empa, have used the common split-gill mushroom to create what they're calling "living fiber dispersions" or LFD, a gel-like material that can be used as a plastic alternative in all manner of applications.

The new material's unique strength and versatility come courtesy of fibers from the split gill mushroom's mycelia, or root-like structures — a popular subcomponent used in everything from [eco-friendly packaging and textiles](#) to [green building materials](#) and [nutrient-dense food](#).

In [most modern applications](#), mycelial fibers are chemically treated and cleaned, which the [team says in a press release](#) results in a "trade-off between performance and sustainability."

Instead of treating the mycelial fibers, the Swiss researchers kept them whole and allowed them to grow an extracellular matrix, the "network of various fiber-like macromolecules, proteins and other biological substances" that gives fungi their structures and [helps protect them from the outside world](#).

"The fungus uses this extracellular matrix to give itself structure and other functional properties," explained Empa researcher Ashutosh Sinha in the release. "Why shouldn't we do the same?"

After selecting a particularly sturdy and flexible strain of split-gill mushroom, the scientists whipped up their concoction in the lab and began experimenting with ways it could be used.

Along with drying it into thin, tear-resistant strips that can be used for sustainable shopping bags, the researchers also demonstrated that their new material could be used as an emulsifier, or mixer, for food or cosmetic products. Because the split-gill mushroom is edible, that means any products made with it would be safe to eat and apply to the skin.

Because this "living fiber dispersion" is still alive, the fungus at its base continues to emit the molecules that stabilize it, making it different from [most emulsions that degrade pretty rapidly](#).

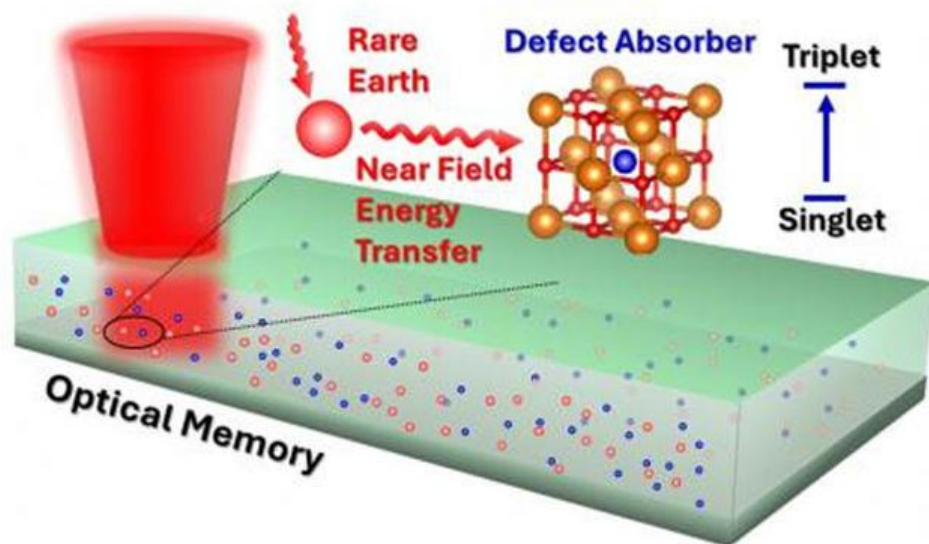
"This is probably the only type of emulsion," Sinha said in the press release, "that becomes more stable over time."

As plastic waste continues to [pollute the planet](#) — [and our bodies](#) — developing biodegradable alternatives like this one has never been more important. And heck, the idea of buying products made from a living mushroom is pretty cool, too.

Scientists claim to have revealed a pathway to a new kind of "efficient, ultra-high-density optical memory storage." A recently published paper, penned by researchers from the U.S. Department of Energy's (DOE) [Argonne National Laboratory](#) and the University of Chicago Pritzker School of Molecular Engineering (PME), says an optical memory breakthrough harnessed classical physics and quantum modeling. Specifically, the researchers hope to revive the fortunes of [optical storage](#) with the help of a mix of rare earth elements and quantum defects.

To address the data storage crunch, researchers are always looking for faster, high-density, more efficient, and more affordable ways to store the ever-increasing digital information deluge. Optical storage was a popular and widespread solution, even becoming standard in laptops where device space is seriously constrained. However, only people of a certain age now remember the sacred ritual of burning DVDs.

In their research paper, the scientists highlight a “new type of memory, in which optical data is transferred from a rare earth element embedded within a solid material to a nearby quantum defect.” The diffraction limit of light limited most prior optical storage methods. However, the new work multiplies the bit storage density of optical media by wavelength multiplexing and quantum spin state transitions.



Researchers at Argonne and the University of Chicago combined classical physics with quantum modeling to show how rare-earth elements (red dots) and defects (blue dots) within solids can interact to store optically encoded classical data. (Image credit: The University of Chicago)

You might already have a good idea about how the researchers are boosting storage capacity here. Still, the above diagram will perhaps make things clearer – as far as rare earth metals and quantum physics are involved. The diagram shows a light beam hitting an optical memory surface infused with rare earth elements manganese, bismuth, and tellurium (red dots). You can also see quantum defects in the media highlighted (blue dots). Excited atoms near quantum defects can flip their spin states to record data, and rare earth metals facilitate tiny light wavelengths.

The researchers admit that some basic questions remain unanswered and must be addressed to move forward. To develop this next-gen optical memory, for example, it will be important to verify how long excited states persist in the new material. Nevertheless, the scientists assert this is a “huge first step.”

While the Argonne / Chicago scientists seem incredibly bullish about their quantum research into optical storage and the capacity boost it could provide, we didn't see any next-gen optical disc capacity estimates in the materials we looked at. It would have been enlightening if the researchers touted 2X, 10X, and 1,000X of known [ODD capacities](#), for example. Alternatively, byte capacity estimates for a next-gen 120mm optical disc would have been welcome. For now, the boast of "ultra-high-density optical memory" is all we get.

The biological marvels of the seabed are being mined to create commercial products—here are the risks

Thousands of genes from deep-sea marine life are being used to create new commercial products ranging from pharmaceuticals to cosmetics. Genes are segments of DNA that provide instructions for making other molecules that are essential for the structure and function of living organisms.

In a paper we [recently published](#) with other colleagues, we investigated how bioprospecting—the search and discovery of potential products from animals, plants and microbes—could serve as a less destructive alternative to deep-sea mining.

Notably, [all of the largest companies](#) using marine genes have sourced them from deep-sea organisms in some capacity. Deep-sea animals possess unique genes that allow them to live in an environment unlike anything else on Earth, with its intense cold, crushing pressure and total darkness.

What are these organisms? Most are microbes that have evolved over millions of years to thrive in extreme conditions. Among the most uniquely adapted are those found around hydrothermal vents, where mineral-rich seawater, superheated by magma, erupts from cracks in the ocean floor.

Deep-sea enzymes, a type of molecule encoded by the genes of organisms that live in extreme environments, are stable in conditions that other enzymes

often [cannot function](#). Their ability to catalyze chemical reactions under high pressure and a wide range of temperatures makes them commercially valuable for making industrial and consumer products, including drugs, food, detergents and biofuels.

Bioprospecting in the deep sea

One remarkable example involves the bacteria that live in very salty habitats. This microbe was isolated from marine sediments collected at a depth of 1,050 meters near the Iheya ridge, 130 kilometers offshore from Iheya Island, Japan.

One of its enzymes has been shown to enhance the conversion of farm waste into glucose by helping break down cellulose into easily degradable pulp. This is [a crucial step](#) for converting biomass into ethanol, [a renewable biofuel](#).

Another enzyme extracted from a bacterium that exists under extremely high temperatures has been found to be highly efficient in [completely removing lactose from milk](#).

Some organisms contribute to multiple inventions, like a deep-sea worm collected at a depth of 2,625 meters from a hydrothermal vent on the East Pacific Rise, about 600 km off the Mexican coast. The worm hosted a bacterium that produces a molecule that was used to develop a [skin cream](#), as it helps make skin less susceptible to damage from the sun and pollution. The unusual ability of this bacterium to live at temperatures above 100°C also made it a model organism for overcoming [overheating in small satellites](#) in Earth's orbit.

This is just a few examples among over 16,000 proteins derived from deep-sea species and used in technology, catalogued in [this database](#).

The potential for innovation from deep-sea species has not been fully explored. As of 2024, only a quarter of the seabed has been [mapped](#) and most deep-sea species [remain undiscovered](#).

The dangers of mining

But the essential role of deep-sea life in the functioning of Earth's systems may be far greater than previously understood.

Researchers recently discovered an unusually high concentration of oxygen on the seafloor in the Pacific Ocean, referred to as "[dark oxygen](#)." This oxygen may be being produced by electrolysis—when an electric current separates water into hydrogen and oxygen.

Where might an electrical charge be generated at the bottom of the ocean? Perhaps on the surfaces of polymetallic nodules, rock-like formations composed of lots of different metals which can create differences in electrical potential when interacting with seawater. The formation of these metals is influenced by the activity of microbes living on them, which in turn affects the chemical properties of the surrounding environment. The production of dark oxygen could be vital for the respiration of other species living in the ocean where there is no sunlight.

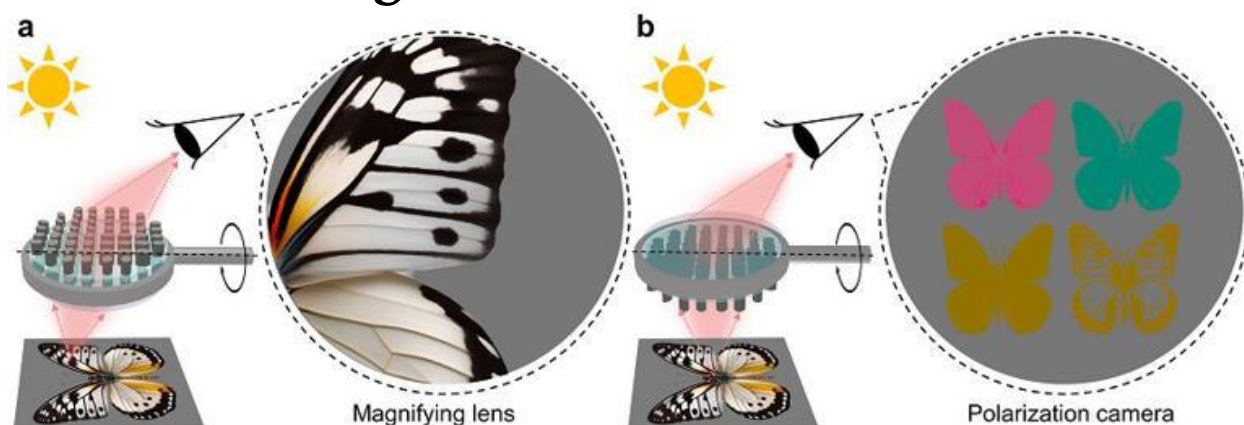
Unfortunately, deep-sea ecosystems are under threat from seabed mining for minerals. Polymetallic nodules are considered [potential resources](#) for manganese, nickel, and rare earth elements—materials used to make electronics and computers. The Clarion-Clipperton Zone, a Pacific region where dark oxygen was recently discovered, has already been divided into [16 mining claims](#).

Researchers and campaigners [have warned](#) that deep-sea mining could severely damage marine ecosystems and have highlighted the lack of scientific consensus on the long-term consequences of these operations. Once disturbed, the evolutionary history these ecosystems represent could be lost forever.

The International Seabed Authority oversees the management of mining activities in international waters. Although it has not yet authorized any commercial mining, it has faced criticism for allegedly [dismissing environmental concerns](#). The recent election of the new [ISA secretary-general](#), Leticia Carvalho, offers an opportunity to safeguard vital areas of the world's oceans, crucial for both nature and human well-being.

We must rethink the true value of the deep sea and consider what losing it may mean for the rest of the world.

Janus-like metasurface technology shows different optical responses according to the direction of light



Schematics of a device featuring asymmetric transmission. a) Device operating as a magnifying lens for back-side illumination. b) Device operating as a polarization camera for front-side illumination. Credit: Advanced Materials (2024). DOI: 10.1002/adma.202406717

Metasurface technology is an advanced optical technology that is thinner, lighter, and more capable of precisely controlling light through nanometer-sized artificial structures than conventional technologies. KAIST researchers have overcome the limitations of existing metasurface technologies and successfully designed a Janus metasurface capable of perfectly controlling asymmetric light transmission. By applying this technology, they have also proposed an innovative method to significantly enhance security by only decoding information under specific conditions.

The team's research is [published](#) in the journal *Advanced Materials*. The research team was led by Professor Jonghwa Shin from the Department of Materials Science and Engineering.

Asymmetric properties, which react differently depending on the direction, play a crucial role in various fields of science and engineering. The Janus metasurface developed by the research team implements an optical system capable of performing different functions in both directions.

Like the Roman god Janus with two faces, this metasurface shows entirely different optical responses depending on the direction of incoming light, effectively operating two independent optical systems with a single device (for example, a metasurface that acts as a magnifying lens in one direction and as a polarized camera in the other). In other words, by using this technology, it's possible to operate two different optical systems (e.g., a lens and a hologram) depending on the direction of the light.

This achievement addresses a challenge that existing metasurface technologies had not resolved. Conventional metasurface technology had limitations in selectively controlling the three properties of light—intensity, phase, and polarization—based on the direction of incidence.

The research team proposed a solution based on mathematical and physical principles, and succeeded in experimentally implementing different vector holograms in both directions. Through this achievement, they showcased a complete asymmetric light transmission control technology.

Additionally, the research team developed a new optical encryption technology based on this metasurface technology. By using the Janus metasurface, they implemented a vector hologram that generates different images depending on the direction and polarization state of incoming light, showcasing an optical encryption system that significantly enhances security by allowing information to be decoded only under specific conditions.

This technology is expected to serve as a next-generation security solution, applicable in various fields such as quantum communication and secure data transmission.

Furthermore, the ultra-thin structure of the metasurface is expected to significantly reduce the volume and weight of traditional optical devices, contributing greatly to the miniaturization and lightweight design of next-generation devices.

Professor Jonghwa Shin from the Department of Materials Science and Engineering at KAIST stated, "This research has enabled the complete asymmetric transmission control of light's intensity, phase, and polarization, which has been a long-standing challenge in optics. It has opened up the possibility of developing various applied optical devices.

"We plan to continue developing optical devices that can be applied to various fields such as augmented reality (AR), holographic displays, and LiDAR systems for autonomous vehicles, utilizing the full potential of metasurface technology."

More information: Hyeonhee Kim et al, Bidirectional Vectorial Holography Using Bi-Layer Metasurfaces and Its Application to Optical Encryption, *Advanced Materials* (2024). DOI: [10.1002/adma.202406717](https://doi.org/10.1002/adma.202406717)

Provided by KAIST

Neutrons illuminate environmental and biological mysteries

Neutron techniques have long been valued in various scientific fields for their ability to penetrate materials without altering their structure. However, their use in environmental and biological sciences has been limited. Complex systems like soil-water interactions and plant physiology are challenging for traditional methods. Due to these challenges, there is an urgent need to enhance neutron techniques to gain a deeper understanding of these intricate processes.

Researchers at Oak Ridge National Laboratory conducted this perspective, which was [published](#) in *Frontiers of Environmental Science & Engineering* on April 15, 2024. It explores the application of neutron methods in environmental and biological sciences, focusing on recent advancements and their potential to address key research challenges. The study emphasizes the capabilities of neutron scattering, imaging, and other techniques in studying complex biological and environmental systems across multiple scales.

The study identifies several key areas where neutron techniques are invaluable. Neutron imaging, for example, has been critical in visualizing soil-root interactions, offering detailed insights into water and nutrient transport within the rhizosphere. Neutron scattering techniques have allowed researchers to probe the nanoscale structure of porous materials, providing essential data on fluid dynamics and material behavior under various conditions.

The development of new instruments, such as those at the Spallation Neutron Source's Second Target Station (STS), has broadened the scope of neutron research, enabling time-resolved studies and smaller sample sizes. These

advancements open new possibilities for in situ studies, offering a more comprehensive understanding of processes crucial for tackling global challenges like climate change and sustainable agriculture.

Dr. Alexander Johs, a leading expert in the field, remarked, "The advancements in neutron techniques are not just incremental; they represent a paradigm shift in how we study complex environmental and biological systems. With new capabilities emerging at neutron facilities worldwide, we're on the brink of uncovering insights that were once beyond our reach, crucial for addressing some of the most pressing challenges in environmental science and biology."

The implications of this research are extensive, particularly in sustainable agriculture, environmental conservation, and bioenergy. By enabling more detailed and accurate analysis of complex systems, neutron techniques can significantly advance the development of sustainable solutions for global challenges.

Continued development and application of these methods could lead to breakthroughs in understanding how environmental and biological processes interact, ultimately contributing to more effective strategies for managing natural resources and mitigating climate change impacts.

More information: Alexander Johs et al, New Opportunities for Neutrons in Environmental and Biological Sciences, *Frontiers of Environmental Science & Engineering* (2024). DOI: [10.1007/s11783-024-1852-z](https://doi.org/10.1007/s11783-024-1852-z)

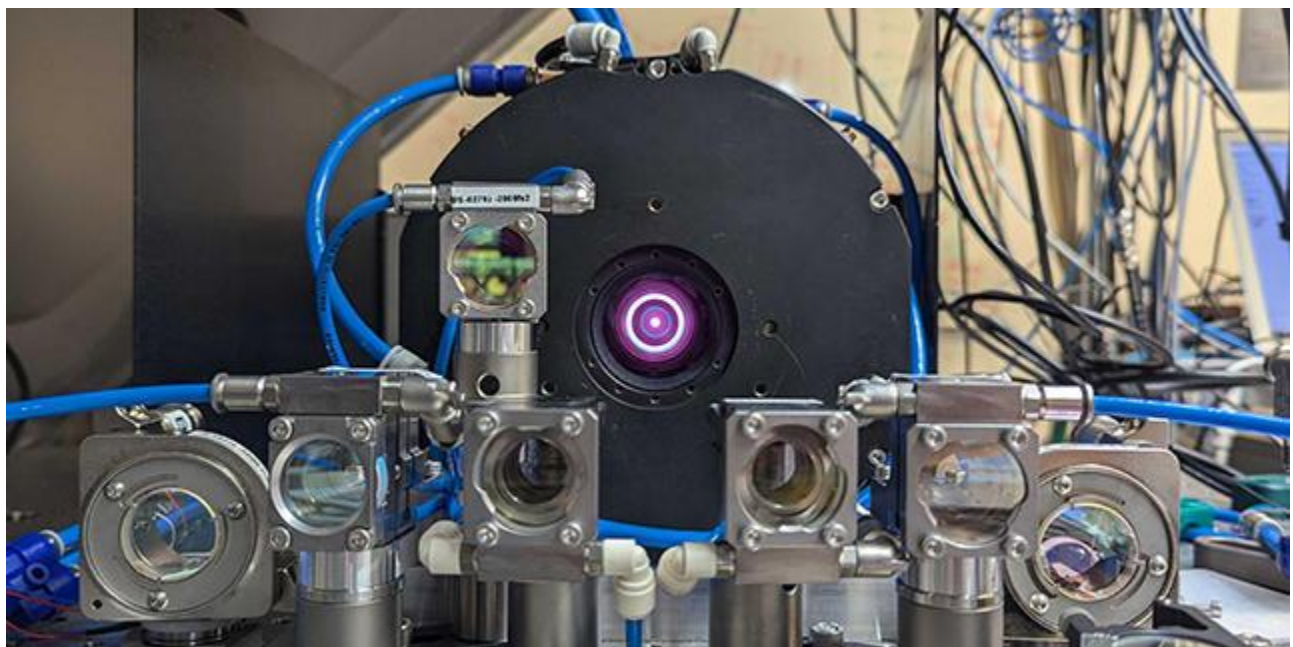
Provided by Oak Ridge National Laboratory

The Most Powerful Picosecond Laser Yet Was Just Unveiled by Scientists

Any advance in [laser tech](#) has huge potential across a whole range of fields – from [space comms](#) to [fusion power](#) – and we just got a big one: ultra-short laser pulses of up to 100 megawatts, the most powerful of their type ever produced from a human-made system.

These pulses last less than a picosecond (a millionth of a millionth of a second), and the 100 megawatt maximum would be enough to briefly power 100,000 vacuum cleaners, from a single pulse. Even the average power output, 550 watts, is more than 50 percent higher than anything previously seen in experiments.

The new technology could find all kinds of uses in [high-precision measurements](#), monitoring, and the machining of other materials, according to the team behind the research, from ETH Zurich in Switzerland.



The laser setup. (Moritz Seidel/ETH Zürich)

"This record is the result of a long and exciting journey with lots of interesting laser physics," [says](#) physicist Ursula Keller, from ETH Zurich.

We're dealing with what are known as short pulsed disk lasers here, based around super-thin disks that hold a crystal containing [ytterbium atoms](#). This disk creates a laser beam when those atoms are excited.

There are two innovations at work here: first, a special arrangement of mirrors to form an improved 'replicating cavity', which is able to bounce around and amplify the laser light to greater levels without losing instability.

Second, there's the semiconductor mirror used in the laser – called a Semiconductor Saturable Absorber Mirror or SESAM. It helps shape the laser light into short, intense pulses. This was upgraded by the team in a number of ways, including the addition of a thin [sapphire window](#).

This kind of laser light amplification has previously involved more energy and bigger instruments, often outside the laser itself. The technology used here, in contrast, is more compact and efficient.

"Pulses with powers comparable to the ones we have now achieved could, up to now, only be achieved by sending weaker laser pulses through several separate amplifiers outside the laser," [says](#) physicist Moritz Seidel, from ETH Zurich.

The researchers responsible for the record-breaking laser have plenty of ideas about how it could be used. One potential application is in the [frequency combs](#) used in [ultra-precise clocks](#), which could mean more accuracy in measuring time and natural phenomena.

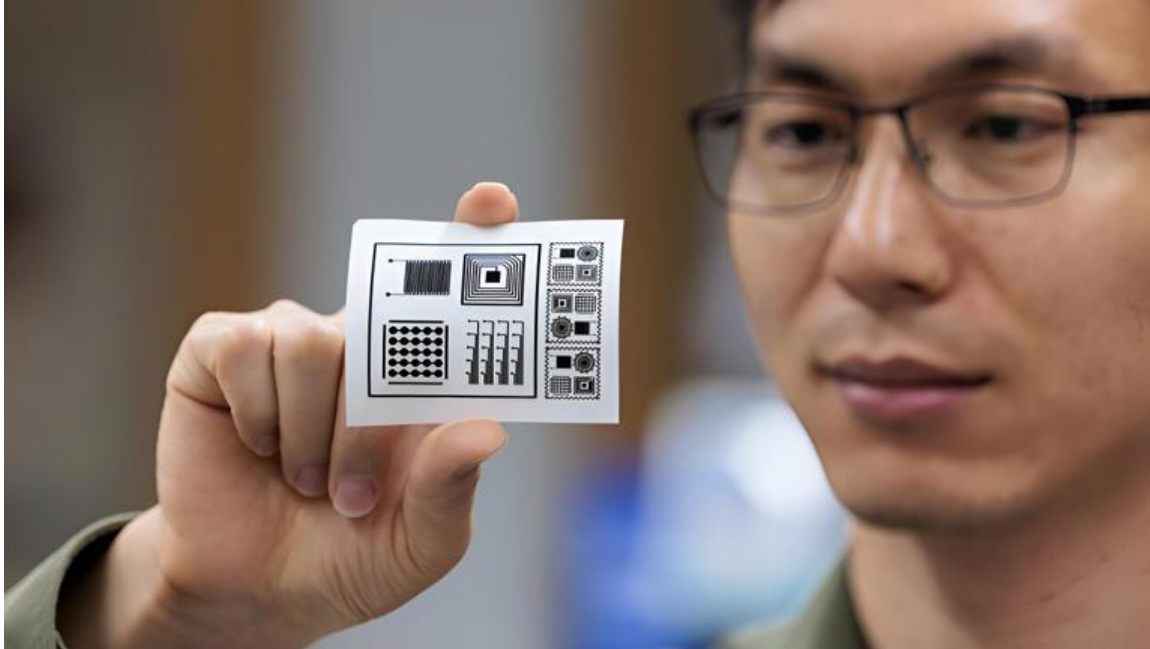
These types of lasers can also be used in [testing materials](#) without cutting into them: looking for defects in objects, for example, or scanning the human body. This setting of new records is just the start for the improved laser technology.

And it's another great example of the detailed and dedicated work scientists do in the lab, to develop lasers that [go above and beyond](#) what we've seen before, and using them to [examine the Universe](#) around us.

"When it finally worked and we watched how the laser created pulses – that was really cool," [says](#) Seidel.

The research has been published in [Optica](#).

Scientists develop eco-friendly microfabrication method using water and paper



University of Chicago chemists developed an environmentally sustainable method of microfabrication that uses water and natural materials—including paper—to create and transfer patterns. Above, study author Chuanwang Yang holds an example of the printing process. Credit: Tian lab

Imagine being able to create incredibly tiny structures with the same ease and sustainability as printing on paper. This is the frontier of microfabrication—the process of making microscopic structures that are crucial for the operation of everything from computer chips to medical devices.

Traditionally, microfabrication has been an intensive process that involves environmentally toxic chemicals that are difficult to safely dispose of. However, scientists at the University of Chicago are hoping to change that.

In their latest publication in [*Nature Sustainability*](#), the laboratory of Prof. Bozhi Tian has developed an environmentally sustainable method of microfabrication that uses water and natural materials—including paper—to create and transfer patterns.

The process draws inspiration from nature—mimicking, for example, how geckos naturally stick and unstick from walls, according to Tian.

A new use for water

Traditional microfabrication, which creates tiny patterns on a microscopic scale using a process called photolithography, has long relied on harmful chemicals for manufacturing integrated circuits found in most home and consumer electronics.

However, UChicago investigators discovered a more eco-friendly approach to microfabrication by using water as a green activation agent instead of traditional toxic agents.

Their innovative technique is a new spin on an old process known as salt-assisted photochemical synthesis. The new version utilizes lasers to create patterns on paper, which can then be easily transferred using water.

"We discovered that water could gently and effectively separate the tiny patterns from their base materials," said Tian.

Using this technique, the team was able to improve the process of turning cellulose in paper into conductive carbon. They could then turn that carbon into advanced sensors by carefully adjusting the carbon's surfaces and using stimulators to efficiently boost reactions in nanoscale materials.

This valuable carbon, created through water and laser writing, has been shown to have diverse applications, ranging from advanced sensors to intricate medical devices.

Chuanwang Yang, a postdoctoral researcher with the Tian lab and first author of

Making the machine

To further enhance their method, Yang developed an innovative tool called a "Roll-to-roll Laser Writer." This device automates laser-based writing and pattern transfer, making the process faster and more dependable.

"It took about six months to design and build this machine, but it has significantly improved our fabrication speed for large-scale applications," said Yang.

While acknowledging their method may not replace the precise techniques needed for creating intricate computer chips, the researchers are optimistic about its use for other applications, such as affordable, disposable sensors for medical testing or wearable devices.

"We see this being particularly useful for devices that don't need the extreme precision of silicon chips but still require high functionality," said Tian.

Pengju Li, a graduate student with the Tian lab who also worked on the project, added, "Our design enhances the fabrication efficiency of ultrathin medical devices, including those used for cardiac and neural stimulation and sensing."

the paper, added, "Using water instead of toxic solvents is a major step forward."

By tapping into nature's power and using simple, eco-friendly materials, the team's innovative method is poised to reshape the microfabrication process, contributing to the growing wave of green technology that is defining the future of the science-tech industry.

More information: Chuanwang Yang et al, A bioinspired permeable junction approach for sustainable device microfabrication, *Nature Sustainability* (2024). DOI: [10.1038/s41893-024-01389-5](https://doi.org/10.1038/s41893-024-01389-5)

Provided by University of Chicago

Self-healing metal experiment astonishes scientists with unprecedented repair capabilities

A team of researchers from Sandia National Laboratories and Texas A&M

University made this remarkable observation while conducting a study on metal resilience. Using a specialized transmission electron microscope technique, they subjected a 40-nanometer-thick piece of platinum to repeated stress, pulling it 200 times per second. The experiment, carried out in a vacuum environment, yielded surprising results.

After approximately 40 minutes of observation, the scientists noticed something extraordinary : the crack in the platinum began to **fuse back together**, effectively mending itself. This self-healing process then repeated, with the crack reappearing in a different direction. Brad Boyce, a materials scientist from Sandia National Laboratories, expressed his astonishment, stating, "This was absolutely stunning to watch first-hand. We certainly weren't looking for it."

The implications of this discovery are far-reaching. If fully understood and controlled, this self-healing property could revolutionize various industries, potentially reducing the need for costly repairs in structures ranging from bridges to engines and even electronic devices.

Scientific foundations and theoretical predictions

While the observation of self-healing metal is unprecedented, it's not entirely unexpected. A decade ago, Michael Demkowicz, a materials scientist from Texas A&M University, conducted a study that predicted the possibility of nanocrack healing in metals. His research suggested that tiny crystalline grains within metals could shift their boundaries in response to stress, potentially leading to self-repair.

Demkowicz's involvement in the recent study allowed him to validate his earlier theories. Using updated computer models, he demonstrated that his decade-old predictions about metal's self-healing behavior at the nanoscale aligned with the observed phenomenon.

The scientific community is particularly intrigued by several aspects of this discovery :

- The self-healing process occurred at room temperature
- The experiment was conducted in a vacuum environment
- The metal exhibited an intrinsic ability to repair fatigue damage

Exploring potential mechanisms and future applications

Researchers are now investigating the underlying mechanisms that enable this self-healing behavior. One possible explanation involves a process known as **cold welding**. This phenomenon occurs when metal surfaces come into close proximity, allowing their atoms to intertwine. Typically, thin layers of air or contaminants interfere with this process, but in environments like the vacuum of space, pure metals can be forced close enough together to literally stick.

The potential applications of self-healing metals are vast and could transform various industries. Here's a table highlighting some possible areas of impact :

While the current findings are promising, further research is needed to determine if this self-healing process can occur in conventional metals under typical environmental conditions. Scientists are eager to explore the possibilities and potential limitations of this groundbreaking discovery.

A new era in materials science

The observation of self-healing metal marks a significant milestone in materials science and engineering. It challenges our understanding of material behavior and opens up new avenues for research and innovation. As Demkowicz noted, "My hope is that this finding will encourage materials researchers to consider that, under the right circumstances, materials can do things we never expected."

This discovery could lead to the development of more resilient and longer-lasting materials, potentially reducing the environmental impact of manufacturing and waste. As scientists continue to unravel the mysteries of self-healing metals, we may be on the cusp of a new era in engineering, where materials can repair themselves, extending their lifespan and revolutionizing countless industries.

New yeast could help recycle common plastics

Plastics are surely the marvel of modern engineering, yet the very properties that make them so useful also make them an [environmental nightmare](#). Polyolefins, a type of plastic found in everything from disposable bags to sturdy car parts, are particularly resistant to degradation. This means they languish in landfills or pollute our environment. But now, a new study suggests that a humble microorganism – yeast – could provide a solution.

Yeast: Turning plastic into useful products

Scientists have discovered that a yeast species called *Yarrowia lipolytica* can use the hydrocarbons found in polyolefin plastics as a food source. To do this, the yeast alters its metabolism, focusing on energy production and the formation of

lipids. The yeast also produces byproducts like citric acid, which can create biodegradable plastics like polyesters and polyurethanes. Published in the journal [mSystems](#), this research has major implications for a more sustainable future.

Why this matters

Biological upcycling – using natural organisms to break down and reuse plastics – is a complex challenge. This study identifies yeasts that can act as catalysts, potentially providing an elegant and eco-friendly way to tackle plastic waste. It's a vital step towards reducing pollution and creating a more circular economy where resources are continually reused.

How the yeast works

The scientists focused on how *Y. lipolytica* metabolizes plastics to unlock its potential. Detailed analysis revealed that, when growing on hydrocarbons, the yeast produces specific proteins involved in plastic breakdown pathways. Notably, energy production, lipid formation, and even unexpected metabolic processes become crucial for the yeast's survival on a plastic diet. However, while the yeast can handle simplified [plastic components](#), there's still a hurdle: growing the yeast on complex, real-world plastic mixtures requires such a metabolic investment that its growth is limited.

Path to real-world plastic recycling

This study provides a robust understanding of how *Y. lipolytica* processes plastics. It establishes this yeast as a strong candidate for the biological upcycling of plastic waste, although research must continue to optimize the process. Future work will likely enhance the yeast's growth under more challenging conditions.

This breakthrough is an exciting development. By harnessing the power of a tiny yeast, we might one day dismantle the mountains of plastic waste that threaten our planet.

Startling Exception Discovered to 200-Year-Old Law of Physics

Scientists have discovered an exception to a 200-year-old scientific law that governs how heat diffuses through solid materials.

Known as [Fourier's law](#), it describes how heat is transferred, or [conducted](#), through solid materials. As molecules vibrate and electrons shuttle about, the heat diffuses from the hotter end of an object to the colder end, at a rate that is proportional to that temperature difference and the area through which the heat flows.

However, in the [past few decades](#), researchers have found that on the nanoscale, this model of diffusion doesn't work; [Fourier's law breaks down](#) and [no longer predicts](#) how fast or slow heat will move through a solid material.

Polymer physicist Kaikai Zheng from the University of Massachusetts, Amherst and colleagues wondered if there might be similar exceptions to Fourier's law to be found at the macroscale, in see-through materials such as translucent polymers and inorganic glasses.

Continue reading

Being [translucent](#), these materials let some wavelengths of light pass through. Although the light doesn't get totally absorbed like in opaque materials, it does scatter, bouncing off impurities in the material structure.

This led Zheng and colleagues to hypothesize that as well as heat diffusing through these solid materials, their translucence might also allow heat energy to travel through the materials in the form of thermal radiation as well. [Radiant heat](#) is carried through the air as electromagnetic waves, mainly infrared radiation, and an example is the heat we feel from the Sun's rays.

"This research began with a simple question," [explains](#) senior author Steve Granick, a materials scientist also at the University of Massachusetts, Amherst.

"What if heat could be transmitted [through solids] by another pathway, not just the one that people had assumed?"

So the researchers clamped strips of test materials and suspended them, one by one, inside a custom-made vacuum chamber. The vacuum removed the possibility of heat dissipating from the materials through air.

"To find violations [in Fourier's law] at macroscopic scales would be startling as this would go beyond standard textbook thinking," the researchers [write in their paper](#), reflecting on their thinking going into the experiments.

The team fired split-second pulses of laser at the materials to heat them up, and measured how heat spread through each of the materials using three methods: a temperature sensor placed directly on the material surface; measuring the color change of a temperature-sensitive coating painted onto the sample; and an infrared camera.

"The data show heating [occurred] faster than can be attributed to diffusion," the researchers [write](#), "indicating that radiation contributes significantly to heat flux during early times after a heat pulse, though the relative contribution of radiation diminishes as diffusion becomes dominant at later times."

"It's not that Fourier's Law is wrong," Granick [clarifies](#), "just that it doesn't explain everything we see when it comes to heat transmission."

The team [suggests](#) that translucent materials radiate heat internally because structural imperfections act as heat absorbers and sources, allowing the heat to propagate from point to point rather than diffusing slowly.

They [add](#) that their findings could help engineers design new strategies for heat management in translucent materials, now that their study provides an expanded understanding of how heat spreads in solids – some 200 years after this phenomenon was first described in mathematical terms.

The study has been published in [PNAS](#).

Lifechanging robotic exoskeleton walks autonomously and puts itself on

[KAIST](#) researchers recently unveiled the latest version of their wearable robot, WalkON Suit F1, specifically designed to support individuals with complete paralysis. Unlike previous models, the F1 version can approach users and allow them to don the suit independently, removing the need for assistance from others.

This innovative advancement enables users to transfer directly from their wheelchairs into the suit seamlessly, marking a major milestone in the evolution of wearable technology for paraplegic individuals.

Developed by Professor Kyoungchul Kong, founder and CEO of [Angel Robotics](#) and a professor at KAIST's Department of Mechanical Engineering, WalkON Suit F1 represents the culmination of nearly a decade of research aimed at enhancing mobility for people with severe spinal injuries.

<https://www.youtube.com/watch?v=kQ2fSap1E2I>

Since 2015, Kong's team has focused on improving WalkON to assist those with the most severe grade of paraplegia according to the American Spinal Injury Association (ASIA) Impairment Scale – grade A, which denotes complete paralysis. Unlike other [wearable robots](#) designed for rehabilitation or muscle assistance, the WalkON Suit is uniquely tailored for full paraplegic support, setting it apart in the wearable robotics field.

The journey of WalkON began with its first prototype in 2016 and advanced significantly with the release of WalkON Suit 4 in 2020, which enabled users to walk at a speed of 3.2 km/h, a pace comparable to the average walking speed of an able-bodied person.

That model could [navigate obstacles](#) typically encountered in daily life, such as narrow hallways, doors, and stairs. However, it shared a common limitation with other wearable robots: users required external assistance to put it on. Once in the suit, users could move independently, but initial setup always needed a helping hand.

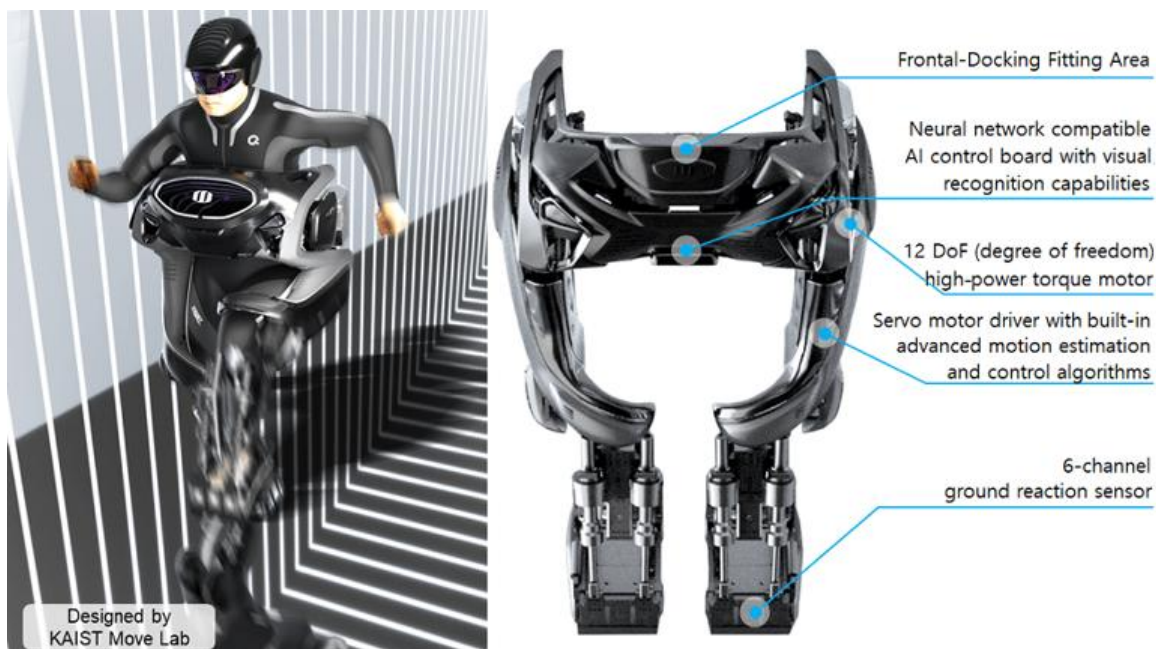
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[Space-age exosuit is revolutionizing workplace safety and productivity](#)
[Soft robotic exosuit offers hope and mobility for 9 million Parkinson's patients worldwide](#)
[Unleashing human potential: Next-gen exoskeleton turbocharges walking speed](#)

WalkON Suit F1 addresses this limitation by incorporating a “frontal-docking” approach, a method that lets the user transfer directly from a wheelchair to the suit without assistance. The suit itself approaches the user autonomously, thanks to advanced robotic mobility functions.

It’s also equipped with an active [weight balance system](#), allowing it to maintain stability, even when the user exerts force against it. Professor Hyunjoon Park from KAIST’s Department of Industrial Design contributed to the suit's unique aesthetic, blending a humanoid robot's appearance with functional elements to create a cutting-edge wearable device.

In addition to user independence, WalkON Suit F1 includes improved balance control, allowing wearers to use both hands freely in an upright position without relying on a cane. This advancement enables users to take several steps at a time with greater stability, offering a level of autonomy previously unavailable to people with complete paralysis.



WalkON Suit F1 shape and main specifications. (CREDIT: KAIST)© The Brighter Side of News

At a technological level, WalkON Suit F1 introduces numerous performance upgrades. In partnership with Angel Robotics, the team ensured that all core components, including the motor, reducer, motor driver, and main circuit, are domestically produced.

The motors and reducers in F1 are twice as efficient as those in previous models, based on power-to-weight ratios, while the motor driver's control speed has tripled, surpassing the best available international technologies. Additionally, a refined software system [stabilizes the suit's advanced motion control](#) without the need for costly high-level controllers.

New features such as a visual recognition system for obstacle detection and an AI board for neural network applications enhance the suit's capacity to adapt to real-world environments.



WalkON Suit F1 - walking demonstration. (CREDIT: KAIST)© The Brighter Side of News

Professor Kong emphasized the significance of WalkON Suit F1, describing it as "the culmination of wearable robot technology for the disabled." He added, "The numerous components, control, and module technologies derived from WalkON

Suit are setting the standard for the entire wearable robot industry.” WalkON’s technological advancements mark a leap forward not only for individual users but also for the [wearable robotics](#) field at large.

The launch of WalkON Suit F1 coincides with KAIST’s participation in the 3rd Cybathlon, an international competition often referred to as the “cyborg Olympics.” Kong’s lab, known as the Exo Lab, won first place in this event’s wearable robotics category in 2020, and the team now returns with the F1 suit, hoping to demonstrate the advanced capabilities of their technology.

Jeongsu Park, a Ph.D. student leading the KAIST team, expressed their goal to “show the technological gap rather than competing for rankings,” reflecting the team’s confidence in WalkON Suit F1’s capabilities.



(From left) Professor Kyoungchul Kong of the Department of Mechanical Engineering, Researcher Seunghwan Kim (the competing athlete), and PhD candidate Jeongsu Park (the leader of Team KAIST). (CREDIT: KAIST)© The Brighter Side of News

This year’s [Cybathlon](#), which was held on October 27, introduced tougher challenges and an increase in tasks from six to ten, a change some had criticized

as overly challenging. KAIST's entry was be piloted by Seunghwan Kim, a staff researcher with complete paralysis.

The competition was held in a hybrid format, with some teams participating in person in Switzerland and others, including KAIST, broadcasting live from their own facilities. The KAIST team will compete from Angel Robotics' Advanced Research Institute in Daejeon, South Korea, showcasing the WalkON Suit F1 in real-time as it navigates a course designed to test the limits of [wearable robotics technology](#).

As the wearable robotics field evolves, the innovations seen in the WalkON Suit F1 underscore KAIST's commitment to advancing mobility solutions for those with severe disabilities. By enabling greater independence and improving performance, WalkON Suit F1 not only enhances users' quality of life but also pushes the boundaries of what wearable robotics can achieve.

Soft robotic shorts could assist older adults and people with limited mobility while walking

Recent technological advances have opened new valuable opportunities for assisting senior adults and individuals with physical disabilities. For instance, they have enabled the development of new interactive systems designed that can assist users with everyday activities, such as eating, reading or practicing their memory.

Researchers at Heidelberg University (now in force at the Technische Universität München–TUM) recently introduced WalkON, a new assistive system that could improve the walking efficiency of older adults and people with limited mobility. This system, presented in a paper [published](#) in *Nature Machine Intelligence*, consists of a pair of soft robotics shorts that can support the flexion of hips while walking.

This project is part of a broader research effort involving two different consortia, namely SMARTAGE and HEIAGE, that focuses on developing digital technology and intelligent assistive systems for older adults.

The WalkOn shorts were developed by post-graduate students under the supervision of Lorenzo Masia, before with Heidelberg University and now a Professor of intelligent bio-robotic systems at Technische Universität München (TUM), Deputy Director of the Munich Institute of Robotics and Machine Intelligence (MIRMI) and lead of the Assistive Robotics and Interactive ExoSuits (ARIES) Lab.

"Our recent paper was inspired by the growing need for solutions to help older adults maintain mobility and independence as they age," Enrica Tricomi, Ph.D. student at Heidelberg University and first author of the paper, told Tech Xplore.

"Walking becomes more challenging and energetically demanding with age, which can limit a person's ability to move freely and enjoy daily life. Recognizing the potential of wearable assistive technologies, we set out to design a device that could address these challenges in a practical, everyday setting, not just within controlled laboratory environments."

The primary objective of the recent work by Tricomi, Masia and their colleagues was to develop a lightweight and soft robotic system that could improve the walking efficiency of older adults in real-world settings. Notably, this device should be clothing-like and unobtrusive, reliably enhancing the mobility of users without limiting their movements.

WalkON, the system developed by the researchers, consists of a pair of soft and lightweight robotic shorts that can support the hip movements required to swing the legs forward while walking. These robotic shorts can simplify walking for frail individuals and people with limited mobility, without being bulky and intrusive.

"We also wanted to test our device in real-world scenarios, assessing its ability to reduce the energy required for walking and how users felt while using it," said Tricomi. "We tested WalkON in outdoor paths, with young adults hiking uphill and older adults walking on flat ground. The results demonstrated that WalkON significantly reduced the energy needed for walking, allowing participants to move more efficiently while still feeling in full control of their movements."

In initial tests involving both younger and older adults, the WalkON shorts were found to significantly reduce the energy required by users to walk. Overall, the team's findings suggest that their system could be a valuable technology for improving mobility in everyday settings.

"In terms of real-world applications, WalkON could be used as a daily assistive device for older adults or individuals with mobility challenges," explained Tricomi. "It could help improve walking efficiency during routine activities like walking in the park, grocery shopping, or even more physically demanding tasks like hiking. The energy savings provided by WalkON may enhance endurance, allowing users to remain more active, preserve their independence, and maintain a higher quality of life."

The most notable advantage of the WalkON system is that it can improve mobility without causing any discomfort to users, which could significantly facilitate its widespread adoption. Tricomi, Masia and their colleagues are now planning to build on their research findings to conduct further tests, aimed at assessing their system in more challenging scenarios.

"Our research group, led by Professor Masia, has relocated from Heidelberg to the Technical University of Munich (TUM), where we now have access to the Geriatrics Center in Garmisch-Partenkirchen, which is part of the Munich Institute for Robotics and Machine Intelligence (MIRMI) at TUM and Prof Masia is the Deputy Director with specific scientific responsibility of on the Geriatrics Project," said Tricomi. "This center is dedicated to developing assistive tools to enhance the quality of life for older adults, and its beautiful surroundings offer ideal outdoor hiking terrain."

The researchers are now preparing to dispense several WalkON devices to the Geriatrics Center in Germany, where older adults will test them as they take walks on nearby hills or walking up and down flights of stairs. This will allow them to assess their system's performance across a wider range of environments and mobility tasks.

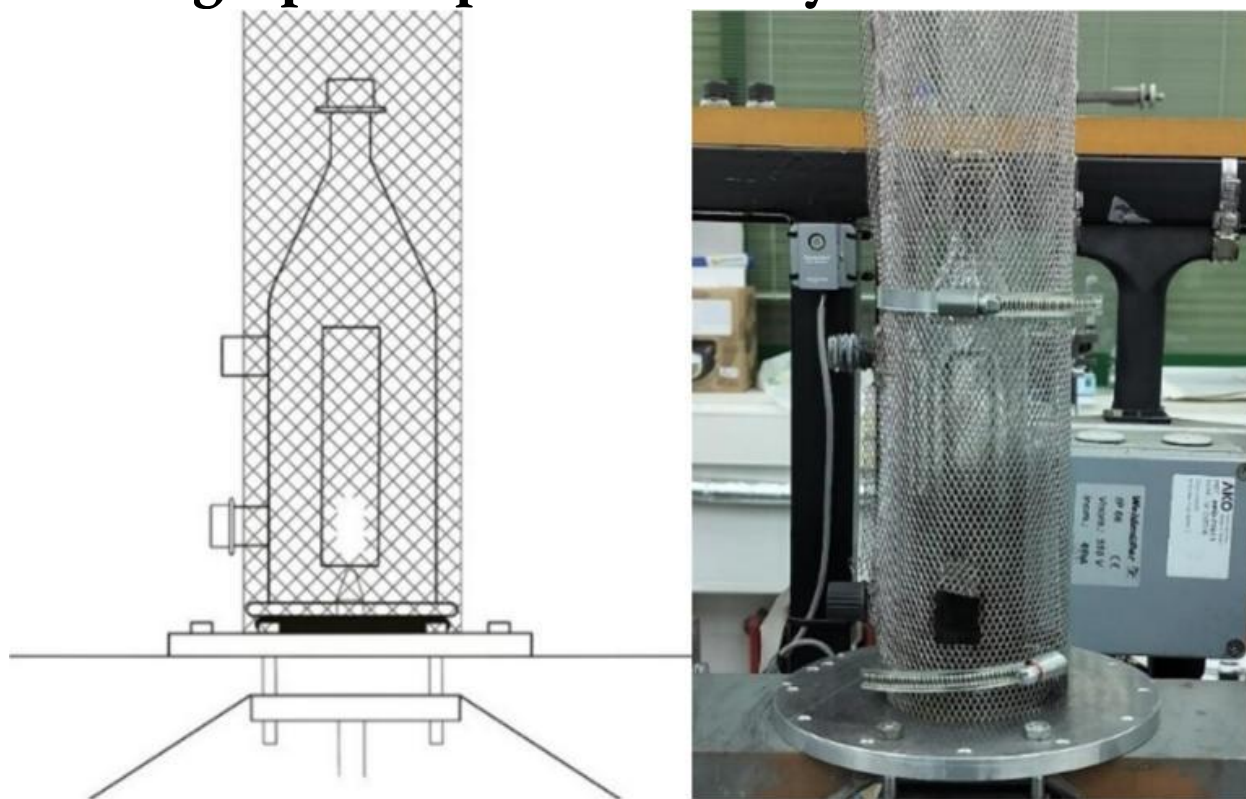
"In parallel, we are also testing different versions of the robotic shorts designed to support other movements for frail individuals, such as sit-to-stand transfers," added Tricomi. "This work is being carried out in collaboration with the Bethanien Clinic in Heidelberg. These additional trials aim to expand the application of

WalkON to assist with a wider range of mobility challenges, further enhancing its potential to improve daily life for those with limited physical capabilities."

More information: Enrica Tricomi et al, Soft robotic shorts improve outdoor walking efficiency in older adults, *Nature Machine Intelligence* (2024). DOI: [10.1038/s42256-024-00894-8](https://doi.org/10.1038/s42256-024-00894-8).

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A new plasma-based technological design boosts graphene production by more than 22%



Shielded TIAGO torch reaction chamber: conceptual illustration (left) and realized prototype (right). Credit: Chemical Engineering Journal (2024). DOI: 10.1016/j.cej.2024.155088

Harder than a diamond, stronger than steel, as flexible as rubber and lighter than aluminum. These are just some of the properties attributed to graphene. Although this material has sparked great interest in the scientific community in

recent years, there is still no cheap and sustainable enough method for its high-quality manufacturing on an industrial scale.

A research team from the University of Córdoba (UCO) has just [published](#) a new prototype in the journal *Chemical Engineering Journal* that could precisely represent a great step forward towards the large-scale production of this material, first synthesized in 2004, with those responsible winning a Nobel Prize six years later.

This new technological design, which has already been registered for evaluation as a patent and is based on a previous patent of the team itself, increases the production of graphene by more than 22%, with the process maintaining the high quality that characterizes graphene synthesized with this technology.

The work is based on plasma technology, a partially ionized gas often referred to as the fourth state of matter. Although there are natural plasmas, such as lightning and the Northern Lights, they can also be artificially generated in a laboratory.

One of its great advantages, highlighted the study's lead author, Francisco Javier Morales, is that "it is a highly energetic medium that is capable of breaking down organic molecules very easily." Specifically, the team used this plasma torch to break down ethanol and rearrange the molecule's carbon atoms, resulting in the creation of graphene.

A Faraday cage to optimize energy

Although this graphene synthesis process is already protected under the group's patent, the study's novel innovation is its great increase in graphene production thanks to the process's energy optimization.

As explained by the team's principal investigator, Rocío Rincón, previous studies by the group had shown that almost 43% of the energy supplied was dissipated and went to waste. This is a clear example of how, as is often the case in science, one finding leads to another, and applied research is built on the foundations of basic research.

To avoid, precisely, this valuable loss of energy, around the plasma the research team built a Faraday cage, a metal mesh that acts as an electromagnetic shield, similar to the one used by microwaves to insulate the system from the outside. In this way, according to the results of the study, while 4.3 milligrams of graphene were previously generated per minute and watt, with this new shielding, which takes maximum advantage of the plasma energy, 5.2 milligrams are produced with the same amount of time and power.

The study was carried out by the Plasma Innovation Laboratory research group at the University of Cordoba, in collaboration with the Chemical Institute for Energy and the Environment (IQUEMA), which was partly responsible for the evaluation of the quality of the graphene produced.

More information: F.J. Morales-Calero et al, Increasing the production of high-quality graphene nanosheet powder: The impact of electromagnetic shielding of the reaction chamber on the TIAGO torch plasma approach, *Chemical Engineering Journal* (2024). DOI: [10.1016/j.cej.2024.155088](https://doi.org/10.1016/j.cej.2024.155088)

Provided by University of Córdoba

Researchers observe stick-slip phenomenon in carbon nanotube fibers

The shapes of simple polyatomic molecules such as carbon dioxide and methane are characterized by a specific symmetry depending on the manner of linking of the atoms. Nano- to micrometer-sized particles that mimic the shapes of such polyatomic molecules are referred to as colloidal molecules, which can form soft materials. However, conventionally synthesizing colloidal molecules with such specific symmetry requires a multi-step synthetic process.

Carbon nanotubes (CNTs) are known for their exceptional mechanical strength and have good potential for application as impact-resistant materials and construction supplies in the aerospace industry. For practical viability, CNT-based materials must achieve a breaking strength of at least 10 GPa, which is equivalent to the strength required to support 10 kg weight using a fiber as thin as a strand of human hair. However, when CNTs are spun into fibers, intermolecular slippage substantially reduces their strength to approximately 1 GPa.

Researchers at University of Tsukuba investigated the mechanism underlying this slipping phenomenon from experimental and theoretical perspectives. For the first time, they observed the stick-slip phenomenon—a repetitive transition between static and dynamic friction—occurring between CNT molecules. The research is [published](#) in the journal *Carbon*.

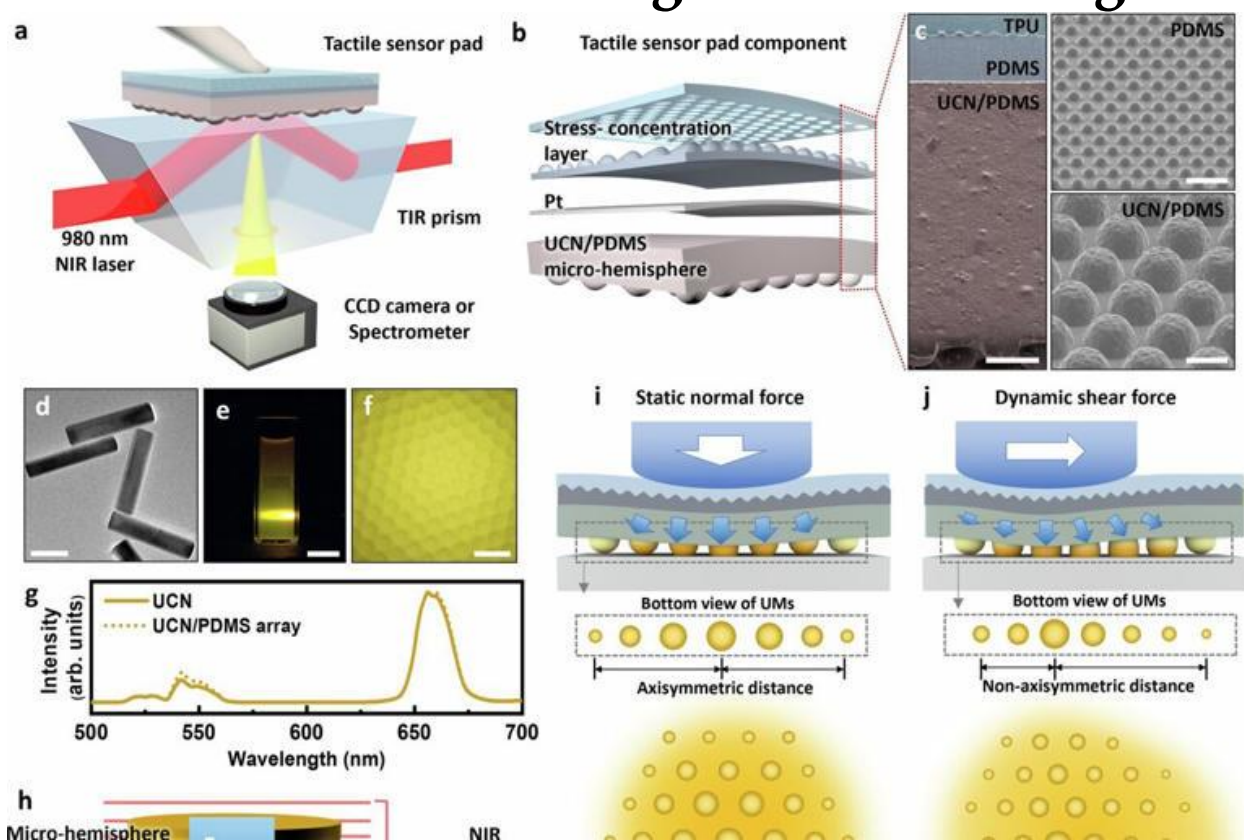
The results revealed that this phenomenon considerably influences intermolecular slipping. Their findings also demonstrate that electron irradiation enhances the strength of these CNTs by promoting the formation of stronger bonds between molecules, resulting in more robust CNT bundles.

These findings suggest that nitrogen doping combined with electron irradiation is an effective strategy for fabricating high-strength CNT-based materials. This breakthrough is anticipated to pave the way for new impact-resistant materials and lightweight, high-strength structural components, contributing to the production of safer and lighter vehicles and more efficient infrastructure in the future.

More information: Samuel Jeong et al, Elucidating slipping behaviors between carbon nanotubes: Using nitrogen doping and electron irradiation to suppress slippage, *Carbon* (2024). DOI: [10.1016/j.carbon.2024.119693](https://doi.org/10.1016/j.carbon.2024.119693)

Provided by University of Tsukuba

Novel optical tactile sensors pave the way for advanced biometric recognition technologies



Upconversion nanocrystals (UCNs)-based optical tactile sensor resembling human skin. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-52331-4

Optical tactile sensors are gaining significant attention as next-generation biometric recognition technologies. Capable of analyzing dynamic forces from a single image, these sensors transcend the limitations of existing optical systems, creating potential applications in diverse fields, such as handwriting emotion analysis, surface characterization, and anti-counterfeiting measures.

A collaborative research team, comprising Professor Jiseok Lee, Professor Hyunhyub Ko, and Professor Donghyuk Kim from the School of Energy and Chemical Engineering at UNIST, alongside Professor Jungwook Kim from Seoul National University, has developed an optical tactile sensor that analyzes dynamic touch signals in real time. The work is [published](#) in *Nature Communications*.

Previous sensors were limited to measuring either static or dynamic forces; however, this research team has pioneered a technology that can separate and analyze these forces simultaneously. Notably, this advancement opens new possibilities for visually representing variations in handwriting speed and pressure, as well as for individual identification through machine learning analysis.

At the core of this innovative technology are upconversion nanoparticles, which facilitate high-resolution measurements of dynamic forces and accurately detect external stimuli by absorbing near-infrared light.

To enhance data analysis, the research team incorporated machine learning techniques to process the data collected by the sensors more precisely. Their machine learning algorithm effectively separated vertical pressure from frictional shear forces within dynamic touch signals and accurately identified the direction of these forces. The validity of the force transmission path and signal changes within the sensor was further confirmed through finite element analysis.

The sensor's design mimics the sensory structure of human skin, providing an amplification of force detection. It distinguishes vertical pressure and frictional shear forces concurrently from a single optical image, capable of detecting minute forces as low as 0.05 N generated by gentle pressure on an object, and boasts an impressive response time of 9.12 milliseconds.

The developed sensor has potential applications not only for handwriting analysis but also for fingerprint recognition and braille interpretation. In practice, the research team has implemented a system that converts braille to voice, demonstrating the sensor's utility in dynamic biometric systems and anti-counterfeiting scenarios.

Professor Lee noted, "This is the first study to simultaneously visualize static pressure and dynamic friction by mimicking the sensory structures of human skin,

enabling real-time analysis through the separation of these two forces via machine learning."

First author Changil Son emphasized, "This simple sensor structure holds promise for future applications in dynamic pressure quantification, particularly in high-sensitivity handwriting detection."

Co-author Chaeyong Ryu said, "These advancements will contribute to the development of AI learning-based sensors applicable in robotics."

More information: Changil Son et al, Behavioral biometric optical tactile sensor for instantaneous decoupling of dynamic touch signals in real time, *Nature Communications* (2024). DOI: [10.1038/s41467-024-52331-4](https://doi.org/10.1038/s41467-024-52331-4)

Provided by Ulsan National Institute of Science and Technology

With NASA-level tech, Vollebak's latest creation might just be the ultimate jacket for Earth, Mars, and beyond

If you've ever dreamt of owning a jacket as advanced as the tech in your favourite sci-fi films, Vollebak's incredibly lightweight Martian Aerogel Jacket is here to make that dream a reality.

Instead of just following the trend in the outdoor industry that compels brands to use the most outlandish materials in their jackets (see [here](#) and [here](#)), Vollebak's latest release is built from materials designed to survive the brutal conditions of outer space – literally.

Weighing only 700 grams, the Martian Aerogel Jacket's outer shell is crafted from the exact fabric used in NASA's hypersonic parachutes, designed to withstand the fiery plunge through Mars's atmosphere.

And it's not just marketing; it really is the same parachute material that landed the first probe on Titan and the last rover on Mars – exceptionally durable, heat-resistant, and, frankly, impressive.

While it might be a bit overqualified for your average ski trip, it's all part of the jacket's ultra-premium appeal.

Inside, the jacket boasts a brand-new type of aerogel insulation designed by the same team behind the heat shields for the next Mars Rover.

The aerogel used here is incredibly lightweight – only three times denser than air – but it's packed with tiny nanopores 10,000 times thinner than a human hair, trapping warmth and blocking out the cold like nothing else on Earth (or Mars).

Plus, it's flexible, waterproof, and still insulates even when wet, making it a worthy upgrade over standard [down jackets](#). However, the Martian Aerogel isn't a [waterproof jacket](#).



((Image credit: Vollebak))

Luxury Meets NASA-Level Performance

Vollebak has designed the Martian Aerogel Jacket with the explorer in mind. Available in Rover Orange, Stealth Black, and Mercury, it's a piece you'll reach for on cold-weather outings, safe in the knowledge that your outerwear can handle temperatures well below freezing or even -20°C if you're feeling brave.

Of course, this luxury jacket comes at a luxury price, but when you consider the tech inside, it's clear why.

The Martian Aerogel Jacket isn't just functional; it's practically over-engineered, with details like laser-drilled micropores for breathability, a fabric that's been spun, washed, coloured, and baked to withstand unimaginable conditions, and taped seams for durability.

It's the kind of high-end craftsmanship that makes you feel like you're donning a wearable work of art.

While you may never need a jacket that can survive an interstellar mission, there's something undeniably appealing about wearing tech designed to push the boundaries of human exploration.

The Martian Aerogel Jacket will be available now at [Vollebak UK](#), [Vollebak US](#) and [Vollebak AU](#) for the recommended price of £2,495/ \$2,995/ AU\$4,650. You can join the waiting list now.

AI-enhanced technique illuminates materials reactions at nanoscale

Kory Burns, a professor at the University of Virginia School (UVA) of Engineering and Applied Science, is a materials science researcher who is using artificial intelligence to improve materials characterization. He and his collaborators, representing multiple universities and national labs, detailed their innovative new technique studying how to better determine the nanoscale effects of radiation on materials [in a paper](#) in *APL Machine Learning*.

UVA collaborates with Oak Ridge National Laboratory, which co-hosts Burns' research. The research features one of the largest labeled datasets of its kind and promises to advance the understanding of how materials behave not only under irradiated conditions, but potentially under other types of extremes as well.

Industries such as renewable energy, space exploration and advanced electronics stand to benefit from improved materials that can better withstand harsh environments.

For everyday consumers, the breakthrough could mean longer-lasting batteries, more reliable electronics and safer medical devices.

"Defects caused by radiation at the nanoscale can significantly affect performance and structural longevity," said Burns, who became an assistant professor in August after joining the Department of Materials Science Engineering in 2022 as a Rising Scholar Research Scientist. "By examining the fundamental interactions within materials, we can devise better strategies to extend their lifetime."

Tiny and fast changes

Transmission electron microscopy, or TEM, is an imaging technique that uses a beam of electrons to pass through very thin samples, often referred to as thin films because they're so flat.

TEM can reveal atomic-level, nanoscale details about a specimen that are impossible to view with a light microscope. That might include crystal structures or small changes that occur due to surface interactions, making TEM an essential tool in materials science.

Scientists can also employ convolutional neural networks, or CNNs, to study changes over time. Unlike traditional models, CNNs learn from large groups of data all at once.

Burns' team combined the two approaches, comparing its CNN results with traditional TEM images to assess the model's effectiveness at capturing nanoscale interactions.

"Our model reduces human error, accelerates analysis and quantifies rapid reactions," Burns said. "However, accurate results depend on proper data preparation and fine-tuning model settings."

Metals differ in their defects

Using advanced time-series imaging techniques with the transmission electron microscope, the team compiled over 1,000 images capturing more than 250,000

defects formed during ion irradiation. These defects included helium bubbles and planar defects known as "dislocation loops."

Key findings from the research highlight the complexities of defect classification. The study revealed that defects in materials such as copper and gold exhibit different behaviors compared to those in palladium. This distinction underscores the need for specialized analytical models to accurately study these materials under radiation.

One major challenge the researchers encountered was "drift," where images can shift due to changes in the experimental environment, leading to potential inaccuracies. To address this, the team proposed the use of advanced techniques like denoising autoencoders, which help clean up images and improve data reliability.

Burns collaborated on the research with engineers and other experts from the University of California-Berkeley, Sandia National Laboratories, Massachusetts Institute of Technology, Los Alamos National Laboratory, University of Florida, University of Michigan, Lawrence Berkeley National Laboratory and the University of Tennessee-Knoxville.

More information: Kory Burns et al, Deep learning-enabled probing of irradiation-induced defects in time-series micrographs, *APL Machine Learning* (2024). DOI: [10.1063/5.0186046](https://doi.org/10.1063/5.0186046)

Provided by University of Virginia

'A mobile phone as thin as a credit card': How massless batteries, similar to the human skeleton, could give rise to the world's strongest power cell and change the future of our society forever

Researchers at Chalmers University of Technology in Sweden have made significant strides in developing a structural battery that could drastically reduce the weight and energy consumption of vehicles and electronic devices.

The structural battery, made from a carbon fiber composite, functions as both a power source and a load-bearing component, making it ideal for a range of purposes. "We have succeeded in creating a battery made of carbon fiber composite that is as stiff as aluminum and energy-dense enough to be used commercially. Just like a human skeleton, the battery has several functions at the same time," said Richa Chaudhary, lead author of a paper recently published in *Advanced Materials*.

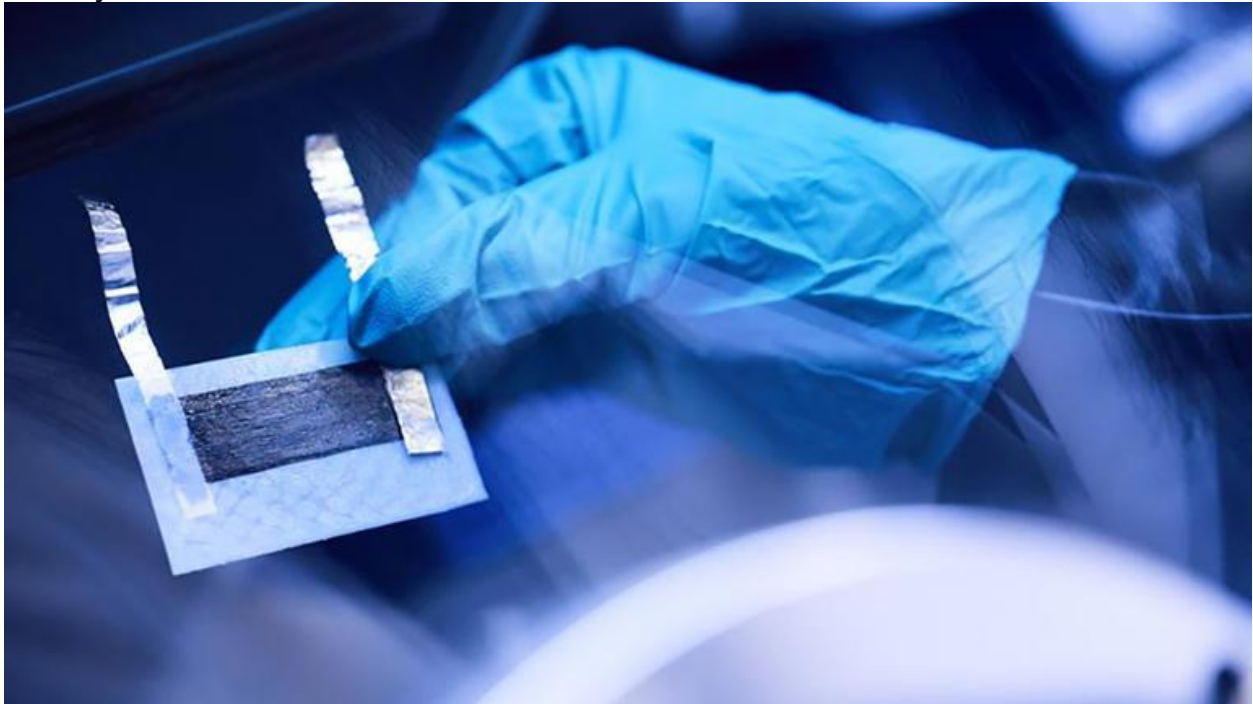
The battery offers an energy density of 30 watt-hours per kilogram (Wh/kg), which is lower than standard lithium-ion batteries but allows for a significant reduction in overall weight.

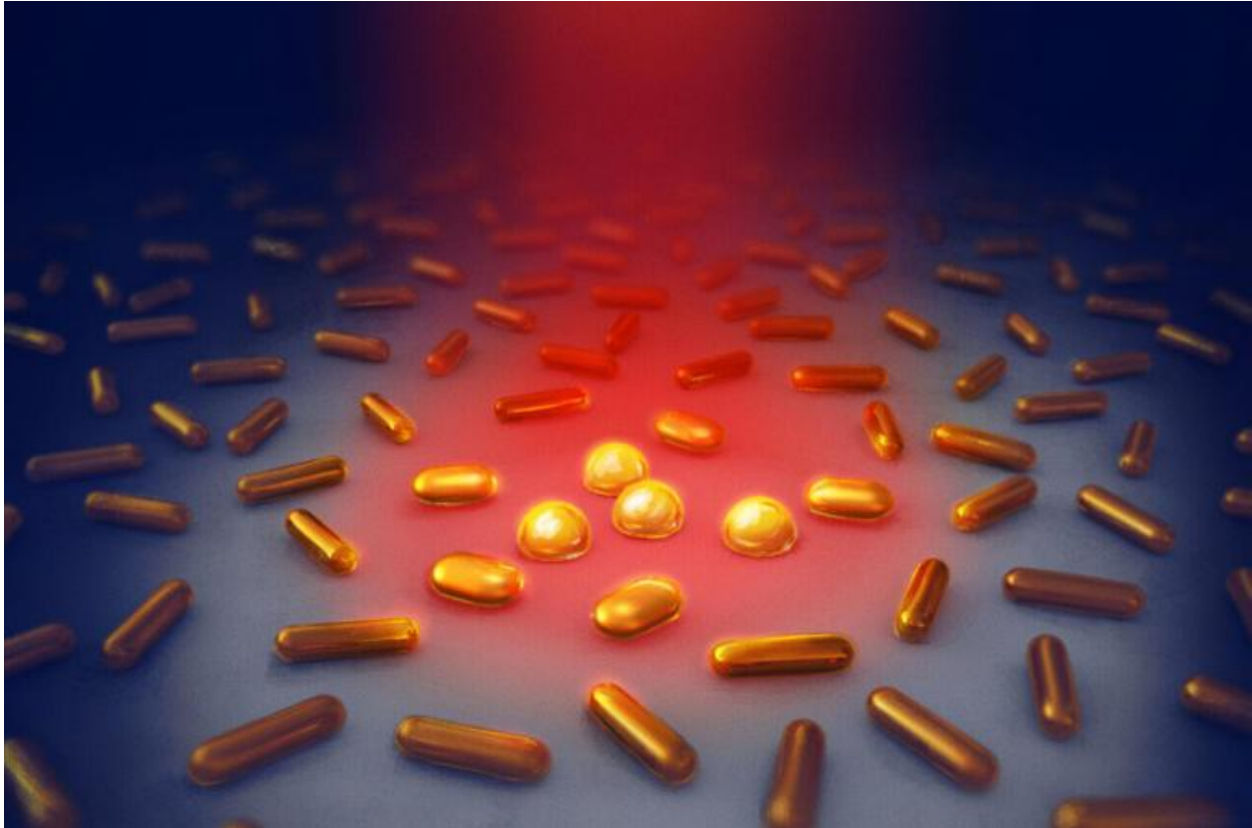
A huge boost for electric cars

Professor Leif Asp, who leads the research, explained that electric cars using this battery could see a huge boost in driving range. "Investing in light and energy-efficient vehicles is a matter of course if we are to economize on energy and think about future generations," said Asp. "We have made calculations on electric cars that show they could drive for up to 70 percent longer than today if they had competitive structural batteries."

The structural battery also has improved stiffness, now reaching 70 gigapascals (GPa), allowing it to carry loads as effectively as aluminum while being much lighter. Asp stated, "In terms of multifunctional properties, the new battery is twice as good as its predecessor – and actually the best ever made in the world."

Although the technology is still under development, Sinonus AB, a spin-off from Chalmers Ventures, is working to bring this innovation to the market. Asp envisions that lightweight laptops, mobile phones, and electric vehicle components will be among the first products to benefit from the structural battery.





The illustration shows how the gold nanorods heat up when illuminated with NIR light. At temperatures above 120 degrees Celsius, the gold rods begin to change shape, and their optical properties change. Credit: Daniel Spacek, Neuron Collective, neuroncollective.com

In the fight against antibiotic resistance, a new technology developed at Chalmers University of Technology, in Sweden, can be of great importance when, for example, hip and knee implants are surgically inserted. By heating up small nanorods of gold with near-infrared light (NIR), the bacteria are killed, and the surface of the implant becomes sterile. The researchers are now presenting a new study that increases the understanding of how the gold rods are affected by light and how the temperature in them can be measured.

Infections can occur during surgical procedures, with the risk increasing significantly when foreign materials, such as knee prostheses, are implanted into the body. The presence of the material weakens the body's immune system and antibiotic treatments are commonly used. If infected, high doses of antibiotics are often required with long treatment times, sometimes lifelong. This entails a risk of

increased antibiotic resistance, which is seen by the WHO as one of the greatest threats to human health.

Heat kills the bacteria on the implant surface

The technology developed by the researchers at Chalmers is a method in which nanometer-sized rods of gold are attached to the implant surface. When near-infrared (NIR) light hits the surface of the implant, the rods heat up and act as tiny heating elements. Because the heating elements are so small, there is a very local heating, which kills any bacteria on the surface of the implant without heating the surrounding tissue.

"The gold rods absorb the light, the electrons in the gold are set in motion, and finally the nanorods emit heat. You could say that the gold nanorods work like small frying pans that fry the bacteria to death," says Maja Uusitalo, doctoral student at Chalmers and lead author of the study, which has been [published](#) in the journal *Nano Letters*.

NIR light is invisible to the naked eye but has the ability to penetrate human tissue. This property allows the gold nanorods to be heated on the surface of the implant inside the body by illuminating the skin. The gold rods are sparsely distributed and cover only about ten percent of the implant's surface. This means that the material's beneficial properties, such as the ability to attach to bone, are largely retained.

"The trick is to tailor the size of the rods. If you make them a little smaller or a little bigger, they absorb light of the wrong wavelengths. We want the light that is absorbed to penetrate skin and tissue well. Because once the implant is inside the body, the light must be able to reach the surface of the prosthesis," says Martin Andersson, Professor and research leader at Chalmers.

Precise measurements for gold rod temperature

To increase the understanding of how the technology works, and how the NIR-heated gold nanorods affect both bacteria and human cells, the researchers needed to measure the temperature of the rods. Due to their tiny size, it is

impossible to measure with a regular thermometer, so the researchers used X-rays instead to study how the gold atoms move. The method enables precise measurement of the temperature of the gold rods and how the temperature can be regulated using the intensity of the NIR light.

"The temperature must not exceed 120 degrees Celsius, as higher temperatures cause the nanorods to lose their shape and transform into spheres. As a result, they lose their optical properties and can no longer absorb NIR light effectively, which prevents the rods from heating up," says Uusitalo.

She points out that the heating is very local with low energy transfer to the surroundings. This is crucial to avoid causing any damage to the surrounding tissue.

The researchers hope that the method can be used on many different implant materials, such as titanium or different plastics.

Gold rods become antibacterial when activated

The gold nanorods themselves are completely passive on the surface before the NIR light heats them. Only then are the rods activated, becoming hot and triggering the antibacterial effect.

"We can control when the surface should be antibacterial and when it should not. When we turn off the light, the surface is no longer antibacterial and reverts to its original state. This is an advantage because many antibacterial surfaces usually have negative effects on healing," says Andersson.

The goal is to eventually bring this technology into health care.

"We primarily believe in using NIR light for heating shortly after the implant is placed and the wound is sutured. By heating up the gold nanorods, we can eliminate any bacteria that may have settled on the prosthesis during surgery," says Andersson.

All bacteria die from the heat from the gold nanorods, but even ordinary cells can be damaged during treatment.

"If a few human cells are destroyed during the NIR heating process, the body quickly regenerates new ones, so the impact on healing is minimal," says Andersson.

The technology with NIR-heated gold nanorods has previously been studied in cancer research, but the research group at Chalmers is the first to use the technology to create an antibacterial surface on implants with high precision and control.

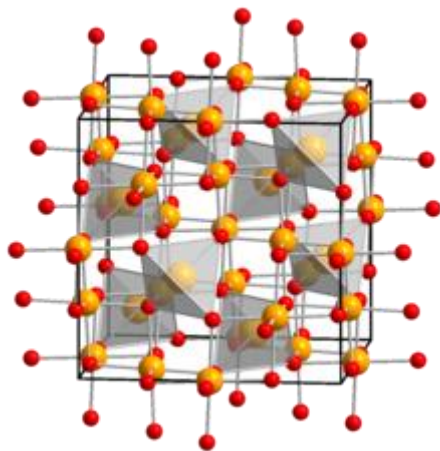
More information: Maja Uusitalo et al, Photothermal Properties of Solid-Supported Gold Nanorods, *Nano Letters* (2024). DOI: [10.1021/acs.nanolett.4c03472](https://doi.org/10.1021/acs.nanolett.4c03472)

Provided by Chalmers University of Technology

Aluminium oxynitride

"ALON" redirects here. For other uses, see [Alon \(disambiguation\)](#).

Aluminium oxynitride



Spinel structure of ALON

Names

[Systematic IUPAC name](#)

Aluminium oxynitride	
Identifiers	
CAS Number	12633-97-5 ✓
Abbreviations	ALON
Properties	
Chemical formula	$(\text{AlN})_x \cdot (\text{Al}_2\text{O}_3)_{1-x}$, $0.30 \leq x \leq 0.37$
Appearance	White or transparent solid
Density	3.691–3.696 g/cm ³ [1]
Melting point	~2150 °C[1]
Solubility in water	insoluble
Refractive index (<i>n</i> _D)	1.79[2]
Structure	
Crystal structure	cubic spinel
Lattice constant	<i>a</i> = 794.6 pm[2]
Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa). ✓ verify (what is ✓ ✗ ?) Infobox references	

Aluminium oxynitride (marketed under the name **ALON** by [Surmet Corporation](#)^[3]) is a [transparent ceramic](#) composed of [aluminium](#), [oxygen](#) and [nitrogen](#). Aluminium oxynitride is optically transparent (≥ 80%) in the [near-ultraviolet](#), visible, and mid-wave-[infrared](#) regions of the electromagnetic spectrum. It is four times as hard as [fused silica glass](#), 85% as hard as [sapphire](#), and nearly 115% as hard as [magnesium aluminate spinel](#). It can be fabricated into transparent windows, plates, domes, rods, tubes, and other forms using conventional ceramic powder processing techniques.^[*citation needed*]

Aluminium oxynitride is the hardest polycrystalline transparent ceramic available commercially.^[2] Because of its relatively low weight, distinctive optical and mechanical properties, and resistance to oxidation or radiation, it shows promise for applications such as [bulletproof](#), blast-resistant, and optoelectronic windows.^[4] Aluminium oxynitride-

based armor has been shown to stop multiple armor-piercing projectiles of up to .50 BMG.^[5]

Properties

Aluminium oxynitride is resistant to various acids, bases, and water.^[6]

Mechanical

Aluminium oxynitride has the following mechanical properties:^[2]

- [Compressive strength](#) 2.68 GPa
- [Flexural strength](#) 0.38–0.7 GPa
- [Fracture toughness](#) 2.0 MPa·m^{1/2}
- [Knoop hardness](#) 1800 kg/mm² (0.2 kg load)
- [Poisson ratio](#) 0.24
- [Shear modulus](#) 135 GPa
- [Young's modulus](#) 334 GPa

Thermal and optical

Aluminium oxynitride has the following thermal and optical properties:^[7]

- [Specific heat](#) 0.781 J/(g·°C)
- [Thermal conductivity](#) 12.3 W/(m·°C)
- [Thermal expansion coefficient](#) ~4.7×10⁻⁶/°C
- [Transparency range](#) 200–5000 nm

Applications

Aluminium oxynitride is used for infrared-optical windows, with greater than 80% transparency at wavelengths below about 4 micrometers, dropping to near zero at about 6 micrometers.^[8] It has also been demonstrated as an [interface passivation](#) layer in some [semiconductor](#)-related applications.^[9]

Aluminium oxynitride has less than half the weight and thickness of glass-based transparent armor.^[10] Aluminium oxynitride armor of 1.6-inch (41 mm; 4.1 cm) thickness is capable of stopping .50 BMG armor-piercing rounds, which can penetrate 3.7 inches (94 mm; 9.4 cm) of [traditional glass laminate](#).^{[8][11]}

In 2005, the [United States Air Force](#) began testing aluminium oxynitride-based armor.^[12]

Manufacture

Aluminium oxynitride can be fabricated as windows, plates, domes, rods, tubes and other forms using conventional ceramic powder processing techniques. Its composition can vary slightly: the aluminium content from about 30% to 36%, which has been reported to affect the bulk and shear moduli by only 1–2%.^[13] The fabricated greenware is subjected to heat treatment (densification) at elevated temperatures followed

by [grinding](#) and [polishing](#) to [transparency](#). It can withstand temperatures of about 2,100 °C (2,370 K) in inert atmospheres. The grinding and polishing substantially improves the [impact resistance](#) and other mechanical properties of armor.^[7]

Patents

Patents related to aluminium oxynitride include:

- Aluminium oxynitride having improved optical characteristics and method of manufacture TM Hartnett, RL Gentilman [U.S. patent 4,481,300](#), 1984
- Process for producing polycrystalline cubic aluminium oxynitride JW McCauley [U.S. patent 4,241,000](#), 1980
- Transparent aluminium oxynitride and method of manufacture RL Gentilman, EA Maguire [U.S. patent 4,520,116](#), 1985; [U.S. patent 4,720,362](#), 1988
- Transparent aluminium oxynitride-based ceramic article JP Mathers [U.S. patent 5,231,062](#), 199

Eco-friendly nanofibrous cellulose matrix has diverse applications ranging from textiles to medical devices

A scanning electron microscope image of new cellulose nanofiber. Credit: Kaunas University of Technology

The efficient use of cellulose—the primary plant scaffold and a major natural building block—could address many issues associated with petroleum-based polymers across various industries. In the search for more sustainable uses of cellulose, Lithuanian scientists have developed a production method for a nanofibrous cellulose matrix, which has the potential to replace non-renewable industrial even in biomedical applications.

Textile, clothing, toys, and sports equipment made from synthetic petroleum-based materials have a significant negative impact on the environment through their entire life cycle, from production to waste management.

Scientists argue that it is necessary to replace petroleum-based materials with environmentally friendly materials and to demonstrate to consumers that products that have been in use for many years can be replaced while retaining their effectiveness. According to Ingrida Pauliukaitytė, a Ph.D. student at Kaunas University of Technology (KTU) and one of the creators of the new environmentally friendly cellulose nanofiber, the invention is a step towards a more sustainable industry.

A paper describing this work is [published](#) in the *Journal of Biomedical Materials Research Part A*.

A unique production method

Cellulose is the Earth's most abundant and widespread natural polysaccharide, commonly found in plant cell walls, algae or synthesized by certain bacteria.

"I chose cellulose as a research object because of its natural origin and favorable properties: its biocompatibility and degradability, variety of chemical strains, and wide range of applications," says the inventor.

The invention was developed using the wet-type electrospinning method, whereby cellulose is dissolved in special solvents—ionic liquids—and the solution is then converted into fibers.

"This is a method that allows the creation of cellulose matrices with a unique gel-like structure, similar to cellulose fibers naturally synthesized by bacteria," says the Ph.D. student at the KTU Faculty of Chemical Technology (CTF).

This method of creating cellulose has an advantage in the market due to its environmental friendliness. In particular, the dissolution method used is more environmentally friendly due to the use of "green solvents."

Also, the raw material for this production process can be either raw cellulose or cellulose waste. Depending on the purity of the material, the resulting fiber can be used for different products. The recycled cellulose can be used to produce new polymer composite products such as toys, sports equipment, household items. If the raw material is pure plant cellulose, biomedical applications have

great potential, where this type of nanofibrous structure has unique biocompatibility properties.

A significant boost for cancer research

"Our invention—a nanofibrous cellulose matrix—is like a scaffold, a structural support that helps cells to divide and grow," explains Pauliukaitytė.

The biocompatibility Pauliukaitytė mentions is very important in tissue engineering to prevent the living organism's immune response to a material used for cell reproduction other than the one naturally synthesized by the organism.

"In addition, cellulose has very favorable mechanical properties, so that the fibers developed are strong and can withstand the high stresses that arise when cells proliferate. Since cellulose absorbs water, the use of cellulose fibers in wound healing can control the amount of moisture that occurs during the healing process," says Pauliukaitytė.

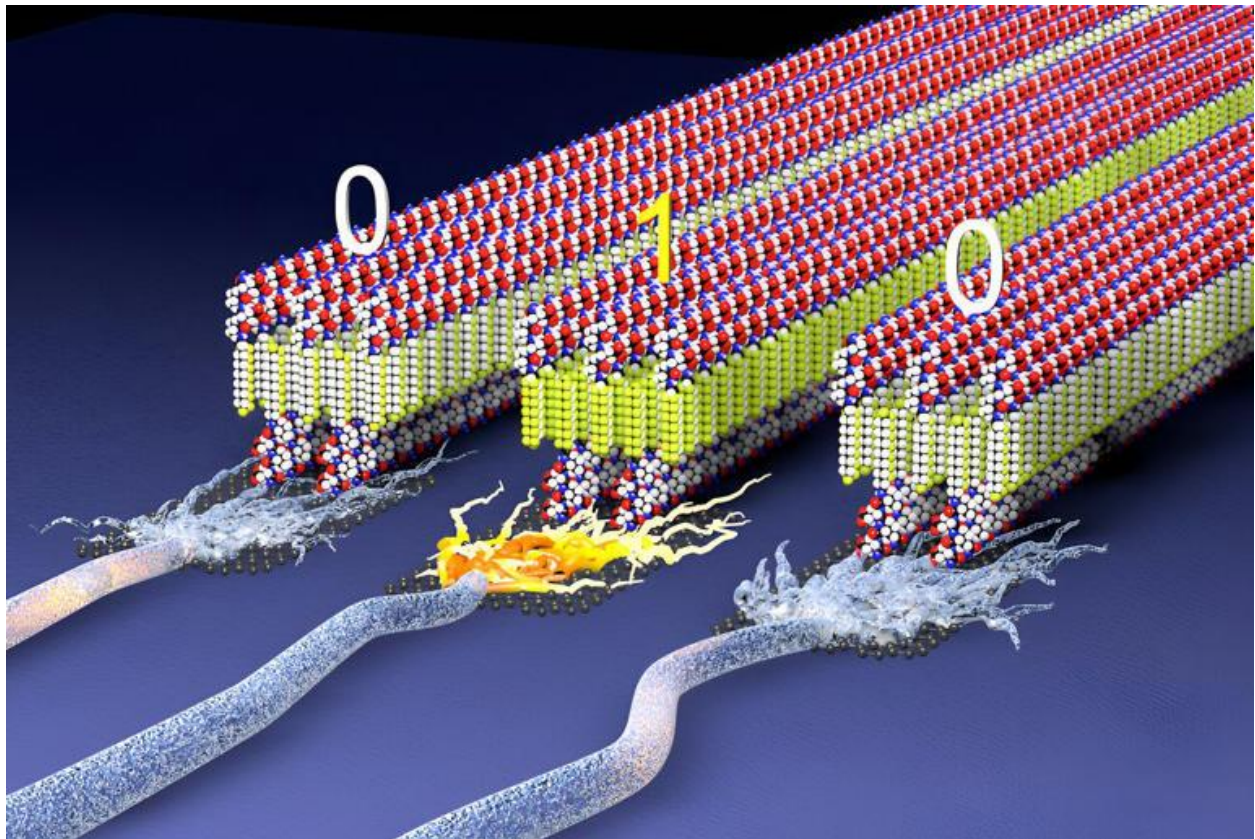
So far, the applicability of cellulose in tissue engineering has been tested for the reconstruction of cartilage, bone and vascular structures. However, given the biocompatibility, structural and moisture retention properties of cellulose, this polymer has great potential for use in regenerative medicine, which aims to stimulate the body's natural recovery mechanisms and restore lost biological functions, and for organ growth.

In addition, the cellulose nanofibers developed are not only biocompatible and environmentally friendly, but also have the potential to form three-dimensional (3D) cell models that better reflect cell behavior in the natural environment.

"This is a significant advantage, especially in tissue engineering and cancer research, as 3D cultures allow for more precise experiments and a better understanding of cell growth and interactions," says Pauliukaitytė.

More information: Ingrida Pauliukaitytė et al, Regenerated nanofibrous cellulose electrospun from ionic liquid: Tuning properties toward tissue engineering, *Journal of Biomedical Materials Research Part A* (2024). DOI: [10.1002/jbm.a.37798](https://doi.org/10.1002/jbm.a.37798)

Peptides and plastics combine for energy-efficient materials



This illustration shows a future vision of assemblies of molecules formed by peptides and miniature molecular segments from a plastic material to create ferroelectric structures that switch polarity to store digital information or signal neurons. Credit: Mark Seniw/Center for Regenerative Medicine/Northwestern University

Step aside hard, rigid materials. There is a new soft, sustainable electroactive material in town—and it's poised to open new possibilities for medical devices, wearable technology and human-computer interfaces.

Using peptides and a snippet of the large molecules in plastics, Northwestern University materials scientists have developed materials made of tiny, flexible

nano-sized ribbons that can be charged just like a battery to store energy or record digital information.

Highly energy efficient, biocompatible and made from sustainable materials, the systems could give rise to new types of ultralight electronic devices while reducing the environmental impact of electronic manufacturing and disposal.

The study, "Peptide programming of a supramolecular vinylidene fluoride ferroelectric phase," was [published](#) on Oct. 9 in the journal *Nature*.

With further development, the new soft materials could be used in low-power, energy-efficient microscopic memory chips, sensors and energy storage units. Researchers also could integrate them into woven fibers to create smart fabrics or sticker-like medical implants.

In today's wearable devices, electronics are clunkily strapped to the body with a wristband. But, with the new materials, the wristband itself could have electronic activity.

"This is a wholly new concept in materials science and soft materials research," said Northwestern's Samuel I. Stupp, who led the study.

"We imagine a future where you could wear a shirt with air conditioning built into it or rely on soft bioactive implants that feel like tissues and are activated wirelessly to improve heart or brain function.

"Those uses require electrical and biological signals, but we cannot build those applications with classic electroactive materials. It's not practical to put hard materials into our organs or in shirts that people can wear. We need to bring electrical signals into the world of soft materials. That is exactly what we have done in this study."

Stupp is the Board of Trustees Professor of Materials Science and Engineering, Chemistry, Medicine and Biomedical Engineering at Northwestern.

He has also served over the past decade as director of the U.S. Department of Energy-supported Center for Bio-Inspired Energy Science, where this research began. Stupp has appointments in the McCormick School of Engineering, Weinberg College of Arts and Sciences and Northwestern University Feinberg

School of Medicine. Yang Yang, a research associate in Stupp's laboratory, is the paper's first author.

Peptides meet plastics for true innovation

The secret behind the new material is peptide amphiphiles, a versatile platform of molecules previously developed in Stupp's laboratory. These self-assembling structures form filaments in water and have already demonstrated promise in regenerative medicine. The molecules contain peptides and a lipid segment, which drives the molecular self-assembly when placed in water.

In the new study, the team replaced the lipid tail with a miniature molecular segment of a plastic called polyvinylidene fluoride (PVDF). But they kept the peptide segment, which contains sequences of amino acids. Commonly used in audio and sonar technologies, PVDF is a plastic with unusual electrical properties.

It can generate electrical signals when pressed or squeezed—a property known as piezoelectricity. It is also a ferroelectric material, which means it has a polar structure that can switch orientation by 180 degrees using an external voltage. The dominant ferroelectrics in technology are hard materials and often include rare or toxic metals, such as lead and niobium.

"PVDF was discovered in the late 1960s and is the first known plastic with ferroelectric properties," Stupp said.

"It has all the robustness of plastic while being useful for electrical devices. That makes it a very high-value material for advanced technologies. However, in pure form, its ferroelectric character is not stable, and, if heated above the so-called Curie temperature, it loses its polarity irreversibly."

All plastics, including PVDF, contain polymers, which are giant molecules typically composed of thousands of chemical structural units. In the new study, the Stupp laboratory precisely synthesized miniature polymers with only 3 to 7 vinylidene fluoride units. Interestingly, the miniature segments with 4, 5 or 6 units are programmed by nature's beta-sheet structures, which are present in proteins, to organize into a stable ferroelectric phase.

"It was not a trivial task," Stupp said. "The combination of two unlikely partners—peptides and plastics—led to a breakthrough in many respects."

Not only were the new materials equally ferroelectric and piezoelectric as PVDF, but the electroactive forms were stable, with the ability to switch polarity using extremely low external voltages. This opens the door for low-power electronics and sustainable nanoscale devices.

The scientists also envision developing new biomedical technologies by attaching bioactive signals to the peptide segments, a strategy already used in Stupp's regenerative medicine research. This offers the unique combination of electrically active materials that are also bioactive.

Just add water

To create the sustainable structures, Stupp's team simply added water to trigger the self-assembly process. After dunking the materials, Stupp was amazed to find that they achieved the highly sought-after ferroelectric properties of PVDF.

In the presence of an external electric field, ferroelectric materials flip their polar orientation—similar to how a magnet can be flipped from north to south and back again. This property is a key ingredient for devices that store information, an important feature for artificial intelligence technologies.

Surprisingly, the investigators found that "mutations" in the peptide sequence could tune properties related to ferroelectricity or even transform the structures into materials that are ideal for actuation or energy storage known as "relaxor phases."

"Peptide sequence mutations in biology are the source of pathologies or biological advantages," Stupp said. "In the new materials, we mutate peptides to tune their properties for the physical world."

"Using nanoscale electrodes, we could potentially expose an astronomical number of self-assembling structures to electric fields. We could flip their polarity with a low voltage, so one serves as a 'one,' and the opposite orientation serves as a 'zero.' This forms binary code for information storage. Adding to their

versatility, and in great contrast to common ferroelectrics, the new materials are 'multiaxial'—meaning they can generate polarity in multiple directions around a circle rather than one or two specific directions."

Record-breaking low power

To flip their polarity, even soft ferroelectric materials like PVDF or other polymers typically require a substantial external electric field. The new structures, however, require incredibly low voltage.

"The energy required to flip their poles is the lowest ever reported for multiaxial soft ferroelectrics," Stupp said. "You can imagine how much energy this will save in increasingly energy-hungry times."

The new materials also have innate environmental benefits. Unlike typical plastics, which linger in the environment for centuries, the Stupp laboratory's materials could be biodegraded or reused without the use of harmful, toxic solvents or high-energy processes.

"We are now considering the use of the new structures in non-conventional applications for ferroelectrics, which include biomedical devices and implants as well as catalytic processes important in renewable energy," Stupp said.

"Given the use of peptides in the new materials, they lend themselves to functionalization with biological signals. We are very excited about these new directions."

More information: Samuel Stupp, Peptide programming of supramolecular vinylidene fluoride ferroelectric phases, *Nature* (2024). DOI: [10.1038/s41586-024-08041-4](https://doi.org/10.1038/s41586-024-08041-4). www.nature.com/articles/s41586-024-08041-4

Provided by Northwestern University

Chalcogenide perovskite film generates electricity when squeezed or stressed

The RPI team developed a polymer film infused with a special chalcogenide perovskite compound that produces electricity when squeezed or stressed. The device could be used in consumer goods, such as a shoe that lights up when the user walks, though it has potential applications in transportation and infrastructure. Credit: Rensselaer Polytechnic Institute

Imagine tires that charge a vehicle as it drives, streetlights powered by the rumble of traffic, or skyscrapers that generate electricity as the buildings naturally sway and shudder.

These energy innovations could be possible thanks to researchers at Rensselaer Polytechnic Institute that are developing environmentally friendly materials that produce electricity when compressed or exposed to vibrations.

In a [recent study](#) published in the journal *Nature Communications*, the team developed a polymer film infused with a special chalcogenide perovskite compound that produces electricity when squeezed or stressed, a phenomenon known as the piezoelectric effect.

While other piezoelectric materials currently exist, this is one of the few high-performing ones that does not contain lead, making it an excellent candidate for use in machines, infrastructure as well as bio-medical applications.

"We are excited and encouraged by our findings and their potential to support the transition to green energy," said Nikhil Koratkar, Ph.D., corresponding author of the study and the John A. Clark and Edward T. Crossan Professor in the Department of Mechanical, Aerospace, and Nuclear Engineering.

"Lead is toxic and increasingly being restricted and phased out of materials and devices. Our goal was to create a material that was lead-free and could be made inexpensively using elements commonly found in nature."

The energy harvesting film, which is only 0.3 millimeters thick, could be integrated into a wide variety of devices, machines, and structures, Koratkar explained.

"Essentially, the material converts mechanical energy into electrical energy—the greater the applied pressure load and the greater the surface area over which the pressure is applied, the greater the effect," Koratkar said. "For example, it could be used beneath highways to generate electricity when cars drive over them. It could also be used in building materials, making electricity when buildings vibrate."

The piezoelectric effect occurs in materials that lack structural symmetry. Under stress, piezoelectric materials deform in such a way that causes positive and negative ions within the material to separate. This "dipole moment," as it is known scientifically, can be harnessed and turned into an electric current.

In the chalcogenide perovskite material discovered by the RPI team, structural symmetry can be easily broken under stress, leading to a pronounced piezoelectric response.

Once they synthesized their new material, which contains barium, zirconium and sulfur, the researchers tested its ability to produce electricity by subjecting it to various bodily movements, such as walking, running, clapping, and tapping fingers.

The researchers found that the material generated electricity during these experiments, enough to even power banks of LED's that spelled out RPI.

"These tests show this technology could be useful, for example, in a device worn by runners or bikers that lights up their shoes or helmets and makes them more visible. However, this is just a proof of concept, as we'd like to eventually see this kind of material implemented at scale, where it can really make a difference in energy production," Koratkar said.

Moving forward, Koratkar's lab will explore the entire family of chalcogenide perovskite compounds in the search for those that exhibit an even stronger piezoelectric effect. Artificial intelligence and machine learning could prove useful tools in this pursuit, Koratkar said.

"Sustainable energy production is vital to our future," said Shekhar Garde, Ph.D., dean of the RPI School of Engineering. "Professor Koratkar's work is a great example of how innovating approaches to materials discovery can help address a global problem."

More information: Sk Shamim Hasan Abir et al, Piezoelectricity in chalcogenide perovskites, *Nature Communications* (2024). DOI: [10.1038/s41467-024-50130-5](https://doi.org/10.1038/s41467-024-50130-5)

Provided by Rensselaer Polytechnic Institute

Why Our Produce Could Soon Be Grown in Total Darkness



Nearly half of the world's land (44%) is used for agriculture, according to data from the [UN Food and Agriculture Organization](#), with one-third of that going to croplands and two-thirds to grazing land. That's a whole lot of space where trees once grew and where people once roamed. While we need to continue to increase our output of food production to serve the growing global population, there may be a way to save a whole lot of land while growing even more food, and it involves some seriously cool science known as "electric farming."

Related: [The 6 Best Indoor Gardens, According to Our Tests](#)

Yes, it's just as futuristic as it sounds. Electric farming, or "electro-agriculture," does something rather unique. It enhances photosynthesis, which is how plants convert the sun's light into energy and replaces sunlight with a solar-powered chemical reaction to "more efficiently converts carbon dioxide into an organic molecule that plants would be genetically engineered to 'eat,'" [Cell Press](#) explains. This would allow plants to grow in complete darkness without the need for light, soil, or a ton of land. Here's what you need to know about the process and how it could change global food production forever.

What is electro-agriculture?

In its simplest terms, electro-agriculture is an alternative way of growing produce that doesn't involve direct sunlight.

"If we don't need to grow plants with sunlight anymore, then we can decouple agriculture from the environment and grow food in indoor, controlled environments," Robert Jinkerson of the University of California, Riverside, who is also a corresponding author of [a new study on the method](#), and biological engineer, shared with Cell Press. "I think that we need to move agriculture into the next phase of technology, and producing it in a controlled way that is decoupled from nature has to be the next step."

How does electro-agriculture work?

The science of electro-agriculture works by placing solar panels on or near the buildings that would absorb radiation from the sun, which would then be used to power a chemical reaction between carbon dioxide and water, which would produce acetate, which Cell Press explained is "a molecule similar to acetic acid, the main component in vinegar." It would then be used to grow the plants in a hydroponic environment.

"The whole point of this new process is to try to boost the efficiency of photosynthesis," Feng Jiao, an electrochemist at Washington University in St. Louis and lead author of the study, shared. "Right now, we are at about 4% efficiency, which is already four times higher than for photosynthesis, and because everything is more efficient with this method, the CO2 footprint associated with the production of the food becomes much smaller."

Related: [The Farm Bill Expired and It Could Cause Dairy Prices to Skyrocket](#)

However, as the [Food Institute](#) noted, this method relies on genetically modified plants that eat acetate. And, to get the plants to eat acetate, they are currently "exploiting a pathway that allows germinating plants to break down food stored in seeds," which naturally switch off during photosynthesis, the institute explained. But, as Jinkerson noted, "Mushrooms and yeast and algae, however, can be grown like this today, so I think that those applications could be commercialized first, and plants will come later down the line." He added that what they are really trying to do is "turn this pathway back on in adult plants and reawaken their native ability to utilize acetate ... It's analogous to lactose intolerance in humans — as babies, we can digest lactose in milk, but for many people that pathway is turned off when they grow up. It's kind of the same idea, only for plants."

How can electro-agriculture be implemented?

All this technology is still in the experimental phase, so producing it at a large scale is still far off on the horizon. And, as Earth.com explained, the team is first focused on testing the methods with tomatoes and lettuce, then will set its sights on "high-calorie" crops like sweet potatoes and grains.

"For plants, we're still in the research-and-development phase of trying to get them to utilize acetate as their carbon source because plants have not evolved to grow this way, but we're making progress," Jinkerson shared with Cell Press.

How much land can electro-agriculture save from becoming farmland?

Again, this is future tech and would require serious investment to get off the ground, but the benefits — at least hypothetically — are astronomical.

"If the United States food supply was produced via electro-agriculture, land usage could be decreased by 88% while substantially streamlining food supply chains by decentralizing food production," the researchers wrote in their study. This means potentially freeing up land from deforestation and placing vertical farms in urban environments, further reducing carbon footprint through lessening the need for distant transportation. It could even be implemented in deserts and, one day, be used in outer space. And, importantly, the researchers added in their conclusion that their system could eliminate food price spikes by "establishing a food system in a controlled environment that is less susceptible to increasingly severe weather, droughts, and flooding due to a rapidly changing climate."

As Jiao shared, "This is just the first step for this research, and I think there's a hope that its efficiency and cost will be significantly improved in the near future."

This is rather an engineering issue, but a lot of scientists are working on this as well; RGB microLED displays. We can currently build fairly efficient blue and green microLEDs from indium gallium nitride, but the red ones are missing. Red LEDs have been available for much longer than their blue counterparts, but we currently cannot make them small enough for a high-ppi display. Many researchers and companies are trying to get the red ones working with several different approaches, and I believe we will see the first commercial applications, starting from smart watches, smartphones and AR/VR goggles within the next five years.

MIT unveils ultra-efficient 3D transistors, could surpass silicon technology

MIT researchers have developed a new type of 3D transistor that could be more energy-efficient and powerful than current silicon-based transistors.

The novel 3D transistors have been designed using ultrathin semiconductor materials.

"This is a technology with the potential to replace silicon, so you could use it with all the functions that silicon currently has, but with much better energy efficiency," said Yanjie Shao, an MIT postdoc and lead author.

The transistors harness quantum mechanics to achieve high performance at low voltage within a nanoscale area.

Their minuscule size paves the way for a new era of ultra-dense, high-performance, and energy-efficient electronics.

Overcoming limitations

Silicon transistors function as electronic switches. A simple voltage application triggers a dramatic state change in the transistor, from off to on. This on/off state represents binary digits, enabling computation.

The efficiency of a transistor is linked to its switching slope. A steeper slope directly correlates to lower energy consumption. This means that the transistor can be switched on and off quickly, requiring less time and, consequently, less energy.

However, a fundamental limitation known as Boltzmann tyranny imposes a minimum voltage requirement for transistor operation at room temperature.

This limit is generally found in silicon transistors.

To overcome it, these new transistors use [ultrathin](#) semiconductor materials and quantum mechanics to achieve high performance at low voltage.

MIT researchers turned to gallium antimonide and indium arsenide semiconductor materials.

Furthermore, they incorporated quantum tunneling principles into their device architecture. In this phenomenon, electrons can penetrate potential barriers.

“Now, you can turn the device on and off very easily,” Shao added.

The transistor’s unique geometry

However, tunneling transistors often suffer from low current output. This limitation hinders their performance in demanding applications that require high currents for efficient operation.

To address this, the engineers worked on the 3D geometry of the transistors. For this, they fabricated nanowire heterostructures with a diameter of only 6 nanometers.

This led to the creation of the “smallest 3D transistors reported to date.”

Thanks to quantum confinement, this technique helped them achieve sharp switching slopes and high current. Quantum confinement occurs when electrons are restricted to tiny spaces.

This confinement unlocks the potential for enhanced tunneling, revolutionizing device performance.

"We have a lot of flexibility to design these material heterostructures so we can achieve a very thin tunneling barrier, which enables us to get very high current," Shao said.

During testing, the devices exhibited sharper switching slopes than conventional silicon [transistors](#). This means they can switch states more rapidly and efficiently, opening the door to faster and more energy-efficient electronic devices.

According to the [press release](#), the MIT devices demonstrated a 20-fold performance improvement compared to similar tunneling transistors.

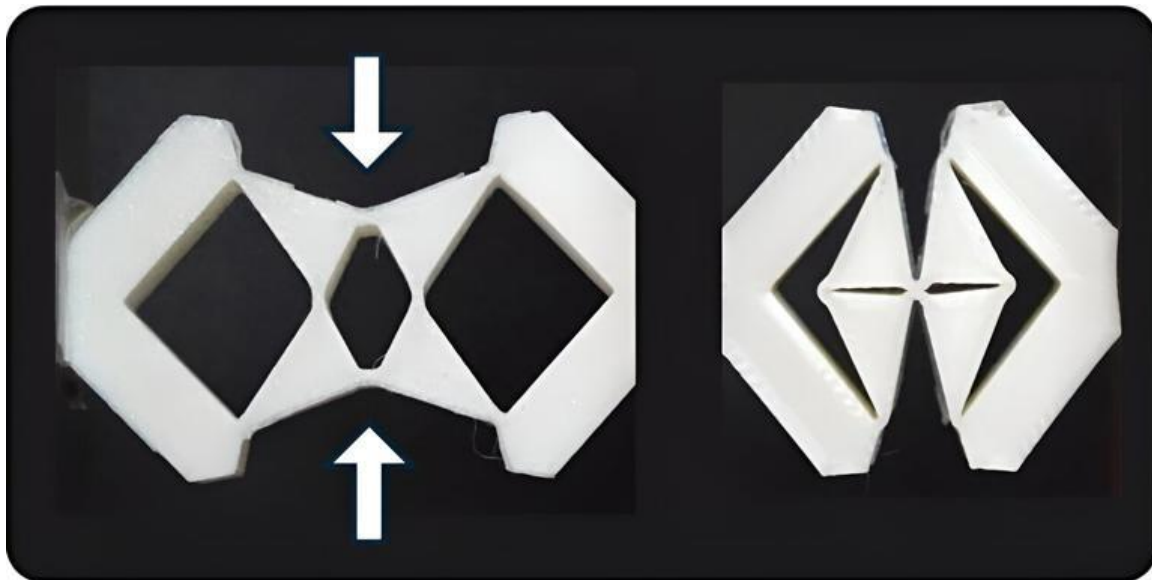
"This is the first time we have been able to achieve such sharp switching steepness with this design," Shao noted.

The researchers are working to improve the fabrication process to ensure consistent transistor performance across the entire chip.

To further enhance uniformity, they are investigating alternative 3D transistor designs, such as vertical fin-shaped structures.

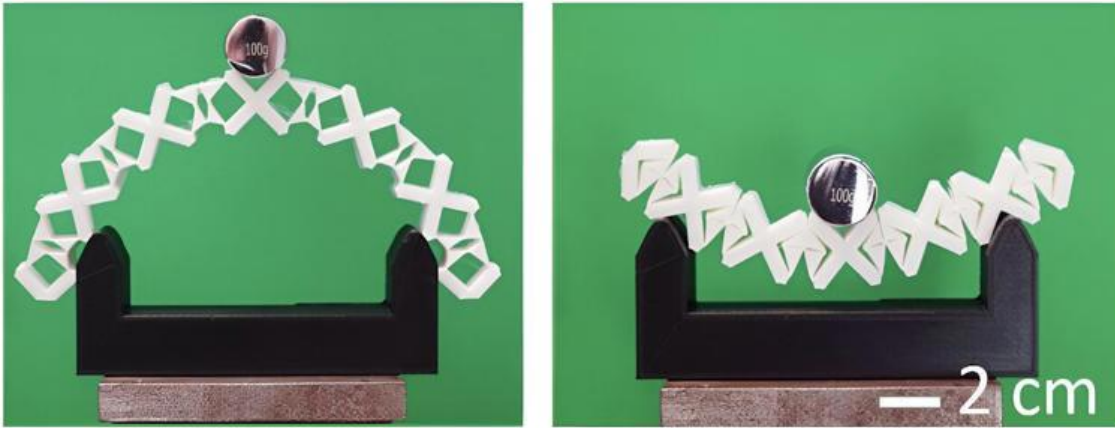
The findings were published in the journal [Nature Electronics](#).

How a futuristic material is able to change its properties from soft to rigid, and back again



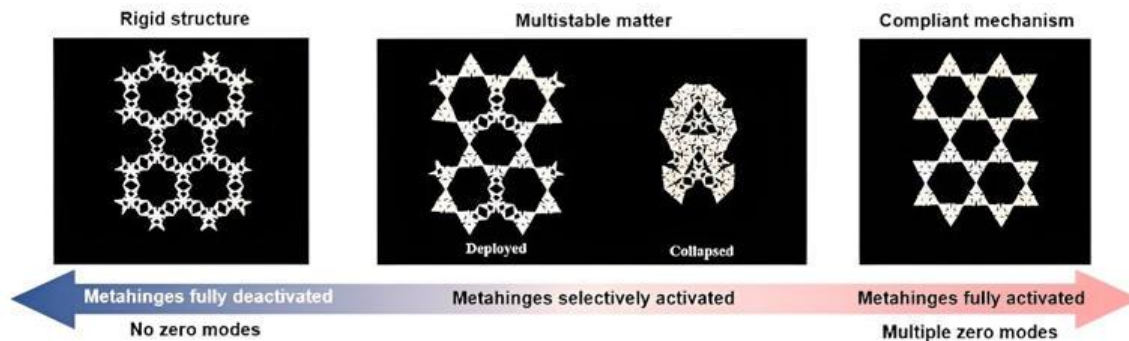
Reconfigurable building block, namely a metahinge. Applying a pair of forces to the rigid structure on the left can form a flexible hinge, generating a flopping mechanism (right) that can rotate around the central pivot. Credit: D. Pasini and L. Wu, CC BY© Provided by Phys.org

In our everyday life, we are surrounded by objects that have properties enabling them to perform certain functions. Rigidity and softness enable an object to perform a specific function. These properties are seemingly opposing in nature, and one property cannot be traded for another.



The metahinge activation can turn a structure into a floppy mechanism: on the left, a rigid curved beam withstands the applied load with negligible deformation, while on the right, the same beam becomes extremely floppy and sag in the opposite direction under the application of the identical load. Credit: D. Pasini and L. Wu, CC BY© Provided by Phys.org

For example, pillows are soft to provide the necessary cushioning and comfort. A rolling pin is rigid and round to be able to roll over dough. Once these objects are fabricated, those properties cannot be changed. A pillow cannot flatten dough, and a rolling pin cannot provide support for a head and neck.

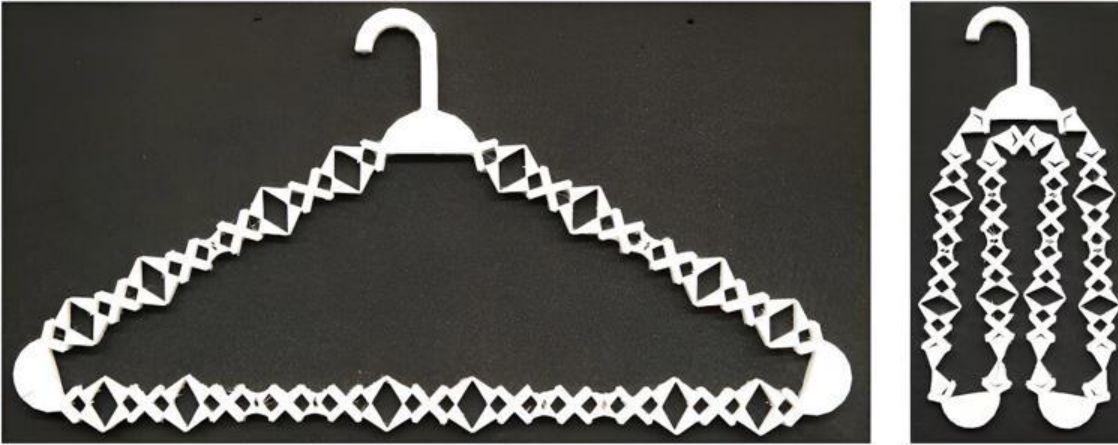


The selective activation of metahinges enables a single metamaterial to acquire seemingly conflicting mechanical properties: rigidity (left), floppiness (right) and multistability when between the two states (middle). Credit: D. Pasini and L. Wu, CC BY© Provided by Phys.org

But imagine if an object as soft as a pillow could transform into an object as stiff as a rolling pin. With a simple switch, that object could acquire the properties and functions of a stiff material and, with another click, those of a soft material.

A material that could do this would allow an object to have multiple functions. This multifunctionality would inherently bring a substantial drop in the use of our resources. It would represent a paradigm shift for the sustainable future of everyday technologies.

Future materials



Fostering sustainability through multifunctional products, such as this reconfigurable coat hanger in different states: fully deployed with a width of 52 cm, and condensed, with a width of 16 cm. Credit: D. Pasini, L. Wu and A. Sitbon, CC BY© Provided by Phys.org

Along with other material scientists, physicists and engineers, my research investigates what we describe as [reconfigurable mechanical metamaterials](#). These are a class of re-programmable multipurpose metamaterials with a transformable internal architecture.

These materials have three antagonist—seemingly counteractive—properties: floppiness, rigidity and multistability. This means that a user can re-program, on demand, their properties to be either stiff or soft or, if needed, even multistable.

An object made by this all-in-one class of metamaterials can become rigid to resist the application of external forces as a stiff structure, shape morph as a floppy mechanism, or trap and absorb energy as a multistable material.

After fabrication

A material that can acquire—post-fabrication—the traits of either a structure, a mechanism or a multistable matter [does so because of the arrangements of its building block](#), in this case, a meta-hinge.

This rearrangement can be [triggered through the application of forces](#) at particular pressure points. During the reconfiguration process, their edges come into contact, eventually merge, and close the central void, forming a flexible hinge. In one configuration, the building block is rigid because the metal hinge is not formed, whereas, in the other, the activation of the meta-hinge generates local rotation around the central pivot, making it floppy.

The reconfigurable building block can be used to create multifunctional structures with re-programmable properties. For example, a one-dimensional beam can be made to behave as either a stiff or floppy structure under a load applied at its midspan.

On the other hand, tessellating the building block in two dimensions allows the creation of three types of reconfigurations, each corresponding to a given class of macroscopic solids, either rigid, floppy or multistable at the verge between the two. Extensions to three dimensions are also possible.

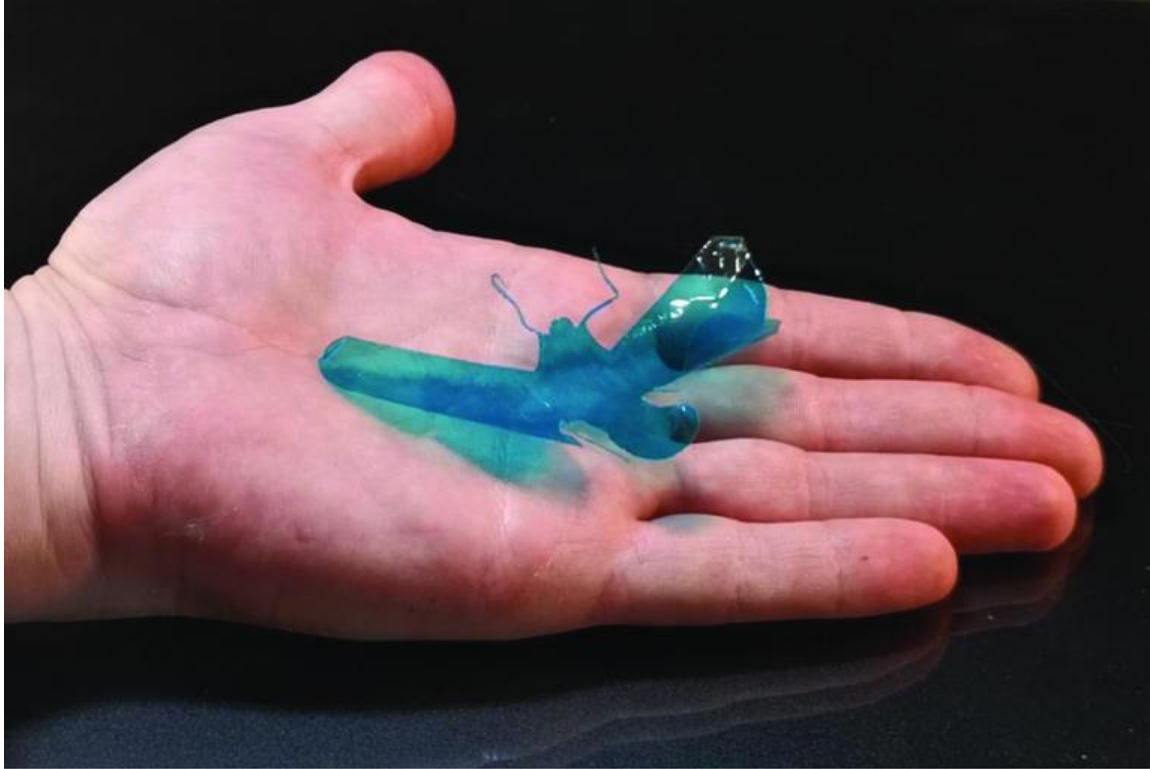
Applications of metamaterials

Multifunctional products that can benefit from property reprogrammability span multiple sectors. In addition to physical properties, other geometric properties can be re-programmed. For example, the reconfigurability of the unit cells can bring overall changes in the size and shape of a product.

A multifunctional coat hanger is just one example. By selectively activating certain hinges, the coat hanger can collapse for space-saving and ease of transportation, as well as be deployed when needed in different sizes and forms to accommodate clothing of different sizes. This provides an unprecedented level of multifunctionality, leading to sustainable resource use.

This all-in-one class of metamaterials helps create multipurpose products. This multifunctionality promises to reduce the use of resources, open a sustainable pathway to our future technology and contribute to attaining the sustainability targets our world has set, thereby paving the way for a greener and more resilient future.

Scientists find key to engineering water-responsive biopolymers



A moth-shaped cutout made of regenerated silk continuously moves on a hand, driven by surface moisture. I. Credit: Darjan Podbevšek

Scientists at the Advanced Science Research Center at the CUNY Graduate Center (CUNY ASRC) have developed a novel approach to better understand and predict the behaviors of water-responsive materials—solid matter that can change shape by absorbing or releasing water in response to humidity fluctuations. These materials, commonly found in nature, have the potential to revolutionize a range of industries, from robotics and smart textiles to bioelectronics and clean energy generation systems.

Despite water-responsive materials' growing popularity in research and development, a gap exists in the theoretical understanding of how these

materials generate mechanical stress when they absorb and release water. A research team led by Professor Xi Chen at the CUNY ASRC Nanoscience Initiative and City College of New York's Chemical Engineering Department has pioneered a new quantitative method to correlate the structure of confined water with the macroscopic water-responsive properties of materials like silk.

"Water-responsive materials that react to humidity changes are highly promising for use as actuators in robotics and for energy harvesting applications, yet we lack the theories to explain or predict the stress they generate," said Chen.

"Our research shows that nanoconfinement of water plays a crucial role in determining the behavior of regenerated silk fibroin films. The important parameters highlighted in the study, will allow us to better predict material performance and engineering for future use in water-responsive actuators" said Darjan Podbevšek, the paper's first author and a postdoctoral research associate in Chen's and Raymond Tu's labs. Tu is a co-corresponding author of the paper and a Chemical Engineering professor at CUNY's City College of New York.

The study, [published](#) in *Nature Communications*, introduces a groundbreaking approach to explain water-responsive materials' behavior, focusing on how water's molecular structure within these materials affects stress generation. Previous studies have only qualitatively explained hydration and dehydration-induced stress in WR materials, but this new approach quantitatively demonstrates that the water structure, rather than the material's structural properties, is the main factor governing stress.

The team discovered that all the samples began to exert force when they reached a critical threshold at which their bound and mobile water ratios reached a specific value, consistent among all samples. This finding highlights the importance of the different water populations in biomaterials and suggests universal guidelines for predicting and engineering water-responsive behavior in biopolymers.

"This breakthrough not only helps us understand how water-responsive materials work, but also opens doors to exciting new applications in tissue engineering, biocompatible materials, optical coatings, and beyond," said Tu.

The study provides key insights that could be applied to a wide range of hygroscopic and water-absorbent materials, with significant implications for industries like biomedical engineering, food preservation, and cosmetics.

More information: Darjan Podbevšek et al, The role of water mobility on water-responsive actuation of silk, *Nature Communications* (2024). DOI: [10.1038/s41467-024-52715-6](https://doi.org/10.1038/s41467-024-52715-6)

Provided by CUNY Advanced Science Research Center

New 'wastewater' jet fuel could cut airplane emissions by 70%



White passenger plane on blue cardboard with a cut out color wedge.© horstgerlach/Getty Images

A new technology can convert wastewater into biofuel to cut plane emissions by 70% versus conventional jet fuel, scientists say.

Sustainable aviation fuel (SAF) currently makes up less than 1% of the fuel used in the aviation industry, but there is a pressing need to find greener fuel solutions as [2.5% of global carbon dioxide emissions](#) come from aviation.

Mainstream aviation fuel options use oil, while alternative options have relied on fat or grease. In a study published April 25 in the journal [ACS Sustainable Chemistry and Engineering](#), scientists outlined a technology that converts wastewater from breweries and dairy farms into the ingredients needed for SAF — namely volatile fatty acids.

The scientists deployed methane-arrested anaerobic digestion (MAAD) — a process pioneered by [Meltem Urgan Demirtas](#), Argonne National Lab's department manager for Sustainable Materials and Processes. In this process,

bacteria, rather than traditional wastewater treatments, break down the organic matter in wastewater via [anaerobic digestion](#), converting the wastewater into butyric acid and lactic acid. These acids could then subsequently be converted into SAF, the scientists said.

However, the process also produces lactic acids, which limit the production of SAF and even lower its carbon efficiency when being converted from volatile fatty acids into SAF. To get around this, the scientists also created an electrochemical separation method, which extracts organic compounds from wastewater.

The final result was the development of an in-situ product recovery process that removes desired waste in complex mixtures through membrane separation. Coupled with anaerobic digestion, these methods enabled the team to create durable microbial communities that produced a large amount of butyric acid.

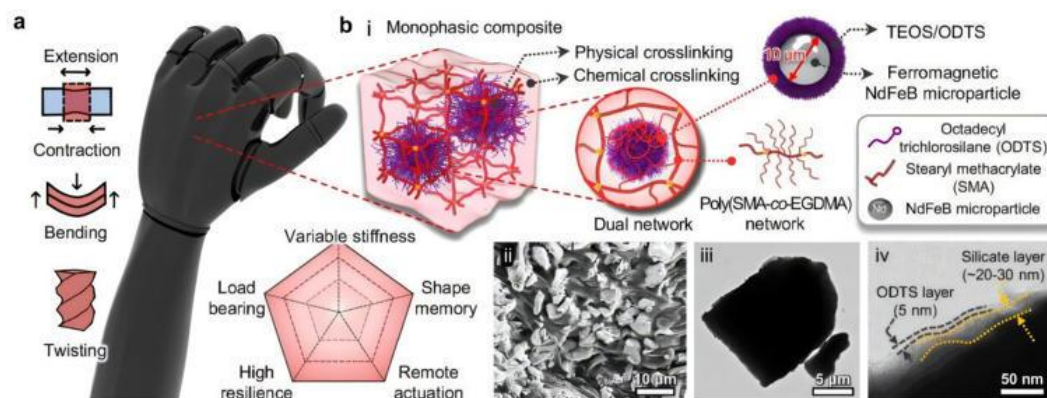
Scientists at Argonne National Laboratory will continue working on improving the sustainability of their findings, and even researching other materials from feedstock that could be used with this technology. These efforts were funded by the DOE's Office of Energy Efficiency and Renewable Energy's Bioenergy Technologies Office. The hope is that by funding the research efforts, scientists will meet their goal of commercializing the process and scaling it to create sufficient SAF to meet 100% of the demand from the commercial sector.

Scientists have previously [highlighted the negative effects of wastewater](#) on ecosystems. Algal blooms that stem from wastewater can "lead to a change in biodiversity," said Anne Jungblut, a life sciences researcher at the National History Museum in the U.K. Changes in biodiversity can trigger harmful consequences for entire rivers.

"Both wastewater streams are rich in organics, and it is carbon-intensive to treat them using traditional wastewater treatment methods," study lead author [Taemin Kim](#), an energy systems analyst at Argonne, said in a [statement](#). "Using our technology, we are not only treating these waste streams but making low-carbon sustainable fuel for the aviation industry."

The membrane-assisted in-situ product recovery process reduces greenhouse gases by 70% while still being a cost-efficient end product. According to the U.S. Environmental Protection Agency, greenhouse gases cause climate change by containing heat, which causes a ripple effect across various biomes. By reducing them significantly with this process, scientists at Argonne could be taking the first steps to fight against climate change and eliminating the need for harmful fuels.

Artificial magnetic muscles can support tensile stresses up to 1,000 times their own weight



Schematic illustration depicting the concept of the monophasic composite muscle and its multifunctionalities. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-52347-w

A research team, led by Professor Hoon Eui Jeong from the Department of Mechanical Engineering at UNIST has introduced an innovative magnetic composite artificial muscle, showcasing an impressive ability to withstand loads comparable to those of automobiles. This material achieves a stiffness enhancement of more than 2,700 times compared to conventional systems. The study is [published](#) in *Nature Communications*.

Soft artificial muscles, which emulate the fluidity of human muscular motion, have emerged as vital technologies in various fields, including robotics, wearable devices, and biomedical applications. Their inherent flexibility allows for smoother operations; however, traditional materials typically exhibit limitations in rigidity, hindering their ability to lift substantial weights and maintain precise control due to unwanted vibrations.

To overcome these challenges, researchers have employed variable rigid materials that can transition between hard and soft states. Yet, the available range for stiffness modulation has remained constrained, along with inadequate mechanical performance.

The team's innovative approach combines ferromagnetic particles with shape memory polymers to create a soft magnetic composite artificial muscle that significantly enhances both load-bearing capacity and elasticity. This new material integrates ferromagnetic particles capable of generating substantial magnetic forces with shape memory polymers recognized as versatile rigid materials.

Through specialized surface treatment, the ferromagnetic particles form intricate physical entanglements with the shape memory polymer. This synergistic interaction not only augments the mechanical properties of the composite but also facilitates rapid and efficient responses to external magnetic fields.

The artificial muscles developed through this advancement exhibit extraordinary adaptability, modifying their stiffness by up to 2,700 times and achieving more than eightfold increases in softness. Under rigid conditions, they are engineered to support tensile stresses of up to 1,000 times their weight and compressive stresses of up to 3,690 times their weight.

In terms of actuation efficiency, these innovative muscles demonstrate remarkable performance capabilities, with energy efficiency reaching an impressive 90.9%.

The research team has also implemented a double-layer architecture, incorporating a hydrogel layer designed to mitigate extraneous vibrations. This structure enables precise control over the soft artificial muscles, even during rapid operations.

Professor Jeong said, "This research opens avenues for transformative applications across diverse sectors, driven by mechanical properties and performance that transcend the limitations of existing artificial muscles.

"Utilizing multi-stimulation methods, including laser heating and magnetic field control, we can remotely execute fundamental movements such as elongation, contraction, bending, and torsion, along with more complex actions like manipulating objects with precision."

More information: Minh Seong et al, Multifunctional Magnetic Muscles for Soft Robotics, *Nature Communications* (2024). DOI: [10.1038/s41467-024-52347-w](https://doi.org/10.1038/s41467-024-52347-w)

Provided by Ulsan National Institute of Science and Technology

Scientists just got 1 step closer to creating a 'superheavy' element that is so big, it will add a new row to the periodic table

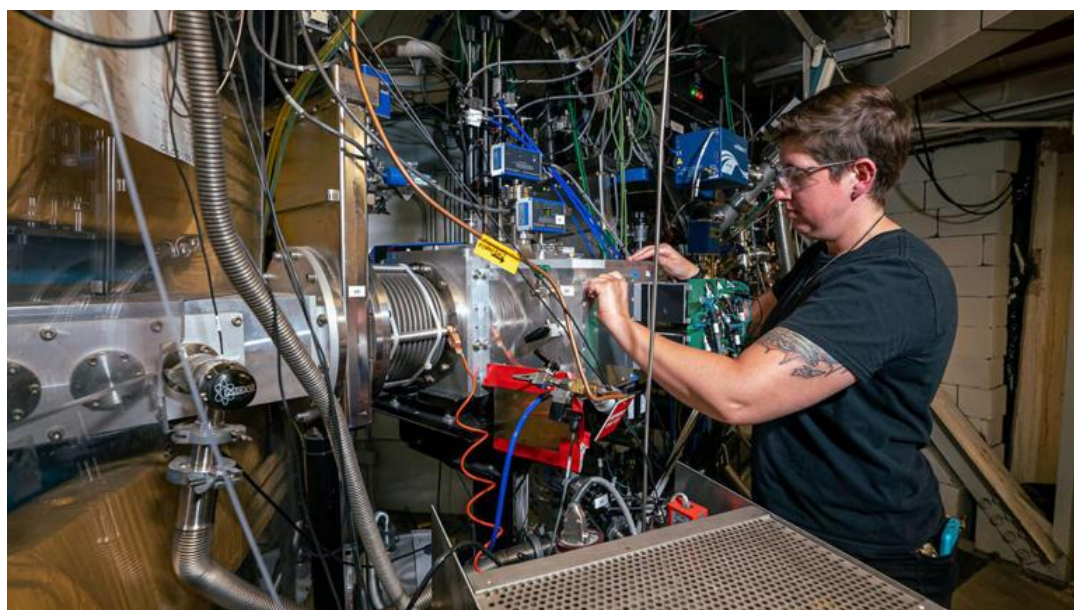
Researchers may have found a way to create a new superheavy element, known as "element 120," which would be so hefty that it would need to be put in a new row on the [periodic table of elements](#). If they can create this hypothetical element, its atoms could represent an "island of stability" that could revolutionize heavy-element chemistry.

There are currently 118 known [elements](#) listed on the periodic table; from [hydrogen](#), which has a single proton in its nucleus, all the way up to [oganesson](#), which was officially named in 2016 and has at least 194 subatomic particles packed into the centers of its [atoms](#) (118 protons and at least 176 neutrons).

However, researchers know that, theoretically, there should be even heavier elements in the cosmos — and they have even predicted what these elements will look like and how they'll act. But to find them, we either have to discover new ways to synthesize them on Earth or [scour the solar system for their potential whereabouts](#).

The two most promising potential element candidates are element 119, tentatively named ununennium, and element 120, aka unbinilium. These elements are so massive that they do not fit in any of the [seven rows that make up the periodic table](#). If they are created, they will be added to a new eighth row on the iconic chart. However, neither has been synthesized, despite multiple attempts.

Related: [Why are rare earth elements so rare?](#)



Researchers created atoms of the superheavy element livermorium using a new technique in the Berkeley Lab's 88-Inch Cyclotron machine. They believe the same technique could be used to make unbinilium. (Image credit: Marilyn Sargent/Berkeley Lab)

In a new study, published Oct. 21 in the journal [Physical Review Letters](#), researchers demonstrated a new technique for creating the superheavy element [livermorium](#) (element 116) by bombarding plutonium-244, an isotope of [plutonium](#) with extra neutrons, with vaporized ions, or charged atoms, of [titanium](#).

The researchers think the same technique can be used to create unbinilium, by shooting titanium ions at isotopes of [californium](#), which is heavier than plutonium. The new study is an important proof of concept that will allow the scientists to step up their search for the hypothetical element, they wrote.

"This reaction had never been demonstrated before, and it was essential to prove it was possible before embarking on our attempt to make [element] 120," study lead author [Jacklyn Gates](#), a nuclear scientist at Lawrence Berkeley National Laboratory (Berkeley Lab) in California, said in a [statement](#). "Creation of a new element is an extremely rare feat. It's exciting to be a part of the process and to have a promising path forward."

However, it could be some time before the researchers can create unbinilium. In this study, it took over 22 days to create just two atoms of livermorium inside Berkeley Lab's 88-Inch Cyclotron machine, which was constantly shooting titanium ions at the plutonium isotope. However, it could take even longer for unbinilium to form.

"We think it will take about 10 times longer to make [element] 120 than [element] 116," study co-author [Reiner Kruecken](#), a nuclear scientist at Berkeley Lab, said in the statement. "It's not easy, but it seems feasible now."

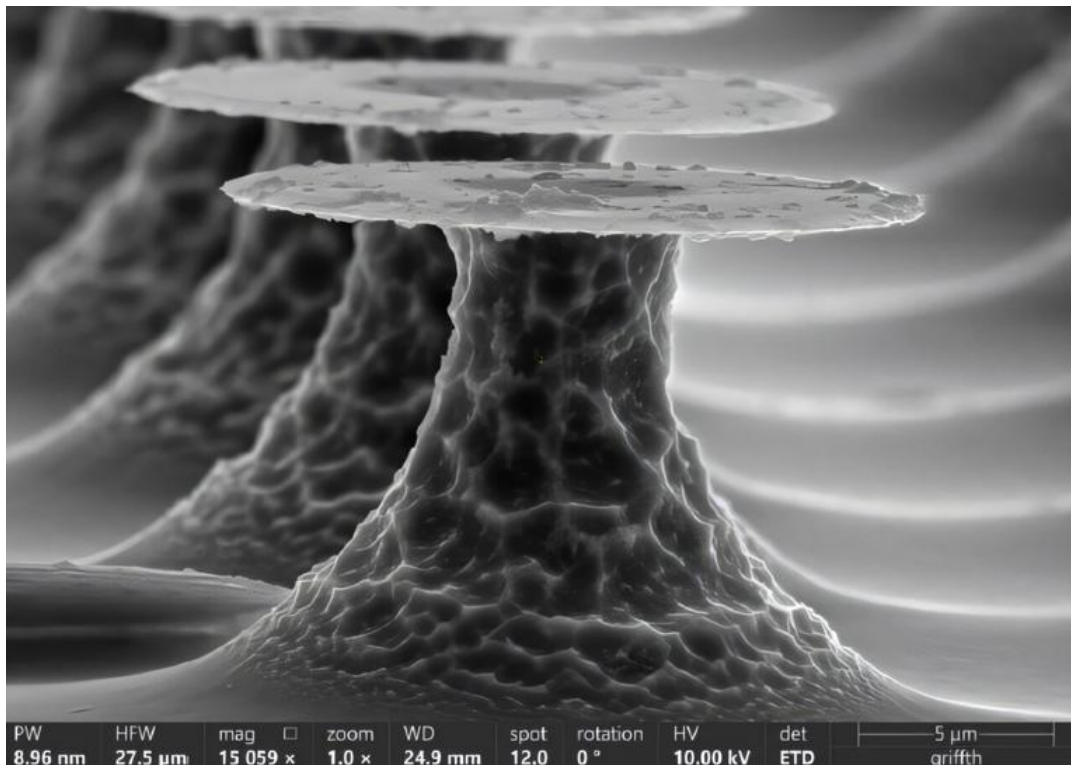
The researchers behind the new study are confident they can eventually create unbinilium. (Image credit: Marilyn Sargent/Berkeley Lab)

Normally, superheavy elements quickly break down once they are formed because they are highly unstable. However, researchers predict that once elements reach a certain size, they will reach an "island of stability" where they will remain intact considerably longer than current known superheavy isotopes.

Unbinilium is expected to reach this island of stability, meaning its creation would open up a range of possibilities for researching superheavy elements, the study authors said. However, there is also a chance that the hypothetical element will not behave as expected.

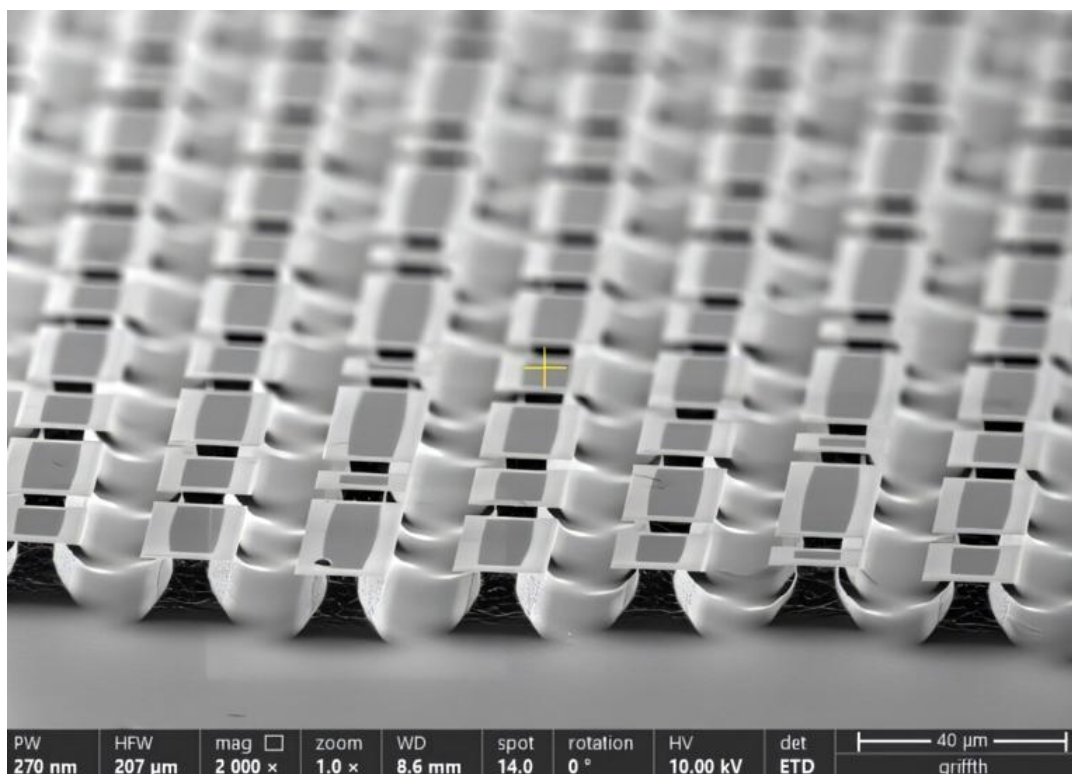
"When we're trying to make these incredibly rare elements, we are standing at the absolute edge of human knowledge and understanding, and there is no guarantee that physics will work the way we expect," study co-author [Jennifer Pore](#), a nuclear scientist at Berkeley Lab, said in the statement.

Scientists unlock mechanisms of liquid-repellent surfaces



Credit: Griffith University

Griffith University scientists have made significant strides in understanding and controlling liquid interactions on tiny, advanced surfaces, a breakthrough that could impact a wide range of industries, from self-cleaning materials to medical devices.



Credit: Griffith University

In a study [published](#) in the journal *Advanced Materials Interfaces*, researchers at Griffith's Queensland Micro- and Nanotechnology Center explored how specific surface structures—called re-entrant microstructures—could repel water and other liquids.

The paper—chosen as the Editor's Choice and set to feature on the journal's cover—revealed how factors such as shape, material, and spacing of these microstructures influenced their ability to resist wetting or liquid spreading.

"Our research dives deep into why some surfaces are better at repelling water than others," said Dr. Navid Kashaninejad, one of the study's lead researchers.

"This understanding allows us to design surfaces that can either repel or attract liquids, which is important for applications like self-cleaning materials or surfaces that avoid fouling."

The team focused on two materials, silicon dioxide (SiO_2) and silicon carbide (SiC), which each offered unique properties.

While SiC is known for its inherent hydrophobic (water-repelling) nature, the researchers found the overall geometry—especially the spacing and shape of these tiny cap-like structures—played a more significant role in influencing liquid behavior than the type of material itself.

They found re-entrant structures with larger gaps between them effectively trapped air pockets, enhancing water repellence and preventing the liquid from fully wetting the surface.

This intricate balance between material properties and structure provided a new perspective on designing highly efficient, liquid-repellent surfaces.

Dr. Kashaninejad said the implications of these findings were wide-reaching. "In environmental technology, self-cleaning surfaces could reduce maintenance costs and improve performance in sectors such as solar panels and water-repellent coatings.

"In the biomedical field, liquid-repellent materials could help develop medical devices that resist bacterial build-up, improving hygiene and patient safety.

"These findings also open doors to creating materials that can withstand extreme conditions, such as high temperatures or harsh chemicals, using materials like silicon carbide.

"This study not only contributes to the growing body of knowledge in surface science but also positions Griffith University at the forefront of innovative materials design."

Dr. Kashaninejad said the team was hopeful further exploration of these properties would lead to even more advanced applications across multiple industries.

More information: Hoang Huy Vu et al, Exploring Wettability of Re-Entrant Microstructures: Effects of Geometry and Material Composition, *Advanced Materials Interfaces* (2024). DOI: [10.1002/admi.202400626](https://doi.org/10.1002/admi.202400626)

Scientists Invented an Entirely New Way to Refrigerate Things



An open fridge

Say hello to ionocaloric cooling. It's a new way to lower temperatures with the potential to replace existing methods of chilling things with a process that is safer and better for the planet.

Typical refrigeration systems transport heat away from a space via a fluid that absorbs heat as it evaporates into a gas, which is then transported through a closed tube and condensed back into a liquid. As effective as this process is, some of the choice materials we use as refrigerants are [particularly unfriendly](#) to the environment.

There is, however, more than one way a substance can be forced to absorb and shed heat energy.

A method unveiled last year, developed by researchers from the Lawrence Berkeley National Laboratory and the University of California, Berkeley, takes advantage of the way that energy is stored or released when a material changes phase, as when solid ice turns to liquid water, for example.

Raise the temperature on a block of ice, it'll melt. What we might not see so easily is that melting absorbs heat from its surroundings, effectively cooling it.

One way to force ice to melt without needing to turn up the heat is to add a few charged particles, or ions. Putting salt on roads to prevent ice from forming is a common example of this in action. The ionocaloric cycle also uses salt to change a fluid's phase and cool its surroundings.

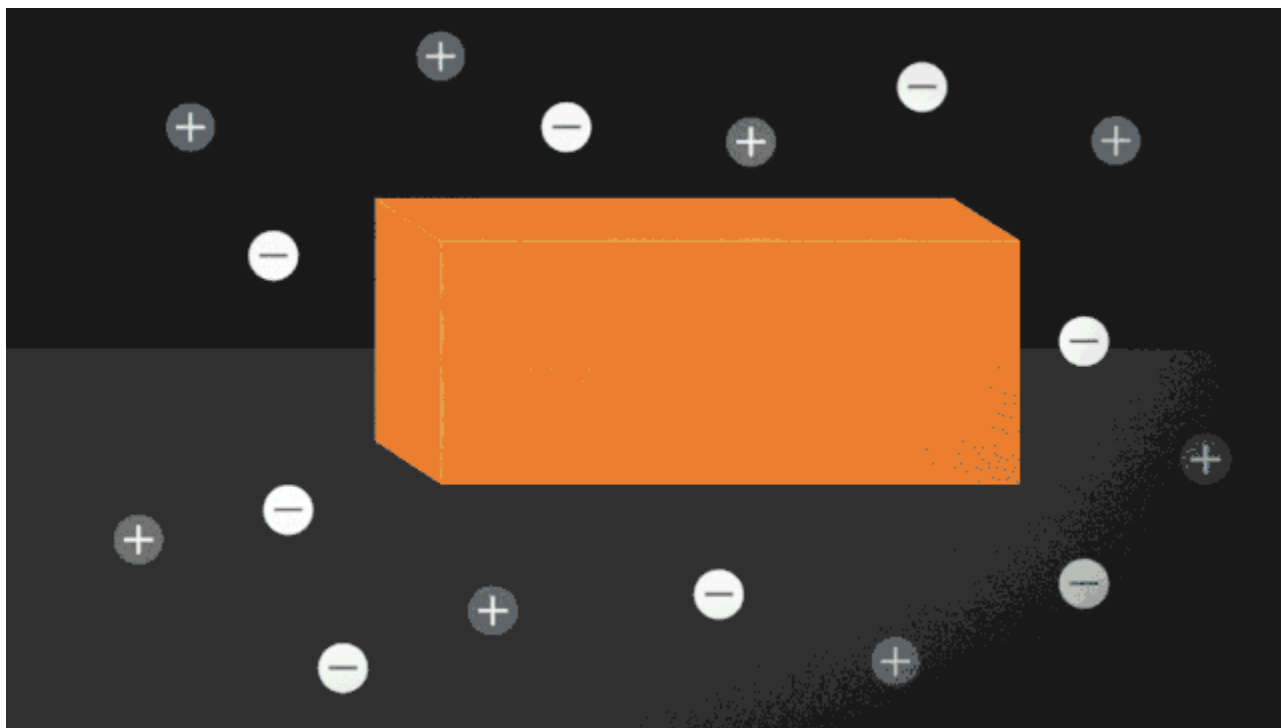
"The landscape of refrigerants is an unsolved problem," [said mechanical engineer Drew Lilley](#) from the Lawrence Berkeley National Laboratory in California in January 2023.

"No one has successfully developed an alternative solution that makes stuff cold, works efficiently, is safe, and doesn't hurt the environment. We think the ionocaloric cycle has the potential to meet all those goals if realized appropriately."

The researchers modeled the theory of the ionocaloric cycle to show how it could potentially compete with, or even improve upon, the efficiency of refrigerants in use today. A current running through the system would move the ions in it, shifting the material's melting point to change temperature.

The team also ran experiments using a salt made with iodine and sodium to melt ethylene carbonate. This common organic solvent is also used in lithium-ion batteries and is produced using carbon dioxide as an input. That could make the system not just GWP [global warming potential] zero but GWP negative.

A temperature shift of 25 degrees Celsius (45 degrees Fahrenheit) was measured through the application of less than a single volt of charge in the experiment, a result that exceeds what other caloric technologies have managed to achieve so far.



The ionocaloric cycle in action. (Jenny Nuss/Berkeley Lab)

"There are three things we're trying to balance: the GWP of the refrigerant, energy efficiency, and the cost of the equipment itself," [said mechanical engineer Ravi Prasher](#) from the Lawrence Berkeley National Laboratory.

"From the first try, our data looks very promising on all three of these aspects."

The vapor compression systems currently used in refrigeration processes rely on gases that have high GWP, such as various hydrofluorocarbons (HFCs).

Countries that signed up to the Kigali Amendment have committed to reducing the production and consumption of HFCs by at least 80 percent over the next 25 years – and ionocaloric cooling could play a major part in that.

Now, the researchers need to get the technology out of the lab and into practical systems that can be used commercially and that scale up without any issues. Eventually, these systems could be used for heating as well as cooling.

"We have this brand-new thermodynamic cycle and framework that brings together elements from different fields, and we've shown that it can work," [said Prasher](#).

"Now, it's time for experimentation to test different combinations of materials and techniques to meet the engineering challenges."

The research was published in [Science](#).

An earlier version of this article was published in January 2023.

LG's bizarre but impressive stretchable prototype display has the 'highest rate of elongation in the industry,' a measurement I had no idea existed



LG's bizarre but impressive stretchable prototype display has the 'highest rate of elongation in the industry,' a measurement I had no idea existed© LG Display

Flexibility could be the next bleeding edge for hardware to thread. Besides the [bendy CPU](#) whose performance leaves much to be desired outside its one party trick, monitor manufacturers are experimenting with pliable projects.

[LG Display](#) is the latest name to explore something with this technical twist, unveiling a stretchy screen prototype that can be expanded by up to 50% with a good tug (via [Tom's Hardware](#)). A prototype demonstration took place in Seoul at LG Science Park as part of a stretchable display national project during an event involving around 100 other South Korean tech stakeholders on November 8th.

This is far from the first bendy screen we've seen, with American company Corsair releasing the [Xeneon Flex OLED Monitor](#) a few years back. The big difference with LG's prototype is that it does a bit more than stretch; you can scrunch it, pull it, and twist it (though there's no word yet on whether you can bop it).

Dated reference aside (does Gen Z know the crushing low of flicking it when you mean to bop it?) LG's prototype is also a darn sight smaller than that Corsair monitor. LG's flexible display first presents RGB colour and 100 PPI at 12 inches, but can then expand up to 18-inches—which LG is quick to note in their press release exceeds "the original national project's target of 20% elongation," and is "the highest rate of elongation in the industry."

As impressive as all of that is, I just can't get past how wrong the idea of scrunching up expensive tech feels; monitors may be hardware but they're historically not the hardiest of wares in the face of, say, a flung controller. Furthermore, in the case of the Corsair monitor, it's not just the fact you've really got to give it some welly to expand the display, but also the horrible sounds of protestation made by the frame that all contribute to the feeling of 'there's something wrong with this picture.'

Besides that, isn't the pliability of LG's prototype and its array of potential form factors just introducing heaps of new points of failure?

On the subject of durability, LG's press release states, "By using a micro-LED light source of up to 40 μm (micrometers), the new prototype's strengthened durability means it can be repeatedly stretched over 10,000 times, maintaining clear image quality even in extreme environments such as exposure to low or high temperatures and external shocks." That might be a bold claim but, if this

prototype ever makes it to market in some form, it could mean cracked phone screens may one day be a thing of the past.

The LG Display prototype remains a ways off any kind of consumer environment, but the company also shared a handful of conceptual use cases. In a bid to further highlight both the prototype's durability and pliability, LG proposed a wearable application where a stretchable display panel attached to a firefighter's uniform could provide a real-time feed of information. While that could end up being a pipe dream, a wearable that actually achieves some real world good [would certainly make a change](#).

The world's first electric running humanoid robot 'Tiangong' open sourced, to accelerate robots into human life



Tiangong, the humanoid robot described as the world's first full-sized humanoid robot capable of running solely on electric drive, is on display at the Beijing-based China's National and Local Co-built Embodied Artificial Intelligence Robotics Innovation Center on November 11, 2024. Photo: Liu Caiyu/GT

The world's first electric running humanoid robot "Tiangong" went open source on Monday, a move that is expected to facilitate secondary development of humanoid robots and accelerate robots' integration into human life.

Developed by Beijing-based National and Local Co-built Embodied AI Robotics Innovation Center, Tiangong is claimed to be the first full-sized humanoid robot driven purely by electric power.

Using "Tiangong" as a foundational platform will advance secondary development in embodied robotics and exploration in various cutting-edge areas like body mechanics and embodied intelligence, Xiong Youjun, the general manager of the center, told the Global Times.

"The 'Tiangong' mother platform has undergone extensive testing and validation. After being open-sourced, other enterprises and research institutions can directly use it, which shortens the industry's development cycle and reduces research and development costs, the Global Times learnt from Liu Yizhang, a manager responsible for Tiangong from the center.

The open-source project covers two versions of the humanoid robot - "Tiangong 1.0 LITE" and "Tiangong Pro," with software development and structural design documents already available to researchers and collaborators, Liu said

By the end of the year, the center plans to release additional open-

source structural blueprints, software architecture, and electrical systems, according to Liu.

"Tiangong" has an average speed of 10 kilometers per hour and a maximum running speed of 12 kilometers per hour, leading in its category. It can move smoothly across diverse terrains such as slopes, stairs, grass, gravel, and sand.

Some representatives from Peking University, Huazhong University of Science and Technology, UBTECH, and Jiangnan University said that they believe the open-source project could drive development across the humanoid robotics supply chain. Liu explained that many core components are independently developed by companies, but performance standards remain inconsistent. Open sourcing the robot will allow development on a unified platform.

Since its official release in April 2024, Tiangong has already been applied in multiple scenarios, including warehouse pick-and-place tasks and patrols for electrical plants, the Global Times learnt.

The industry has been identified by the Ministry of Industry and Information Technology as a new frontier for technological competition and a key driver of economic growth.

Previously, the Shanghai-based National Local Joint Humanoid Robot Innovation Center also unveiled its open-source general-purpose humanoid robot Qinglong. Qinglong stands at 185 cm tall and weighs 80 kg, according to the company.

Giving robots superhuman vision using radio signals



Freddy Liu (EAS'25), Haowen Lai (Gr'28) and Mingmin Zhao, Assistant Professor in CIS, from left, setting up a robot equipped with PanoRadar for a test run. Credit: University of Pennsylvania

In the race to develop robust perception systems for robots, one persistent challenge has been operating in bad weather and harsh conditions. For example, traditional, light-based vision sensors such as cameras or LiDAR (Light Detection And Ranging) fail in heavy smoke and fog.

However, nature has shown that vision doesn't have to be constrained by light's limitations—many organisms have evolved ways to perceive their environment

without relying on light. Bats navigate using the echoes of sound waves, while sharks hunt by sensing electrical fields from their prey's movements.

Radio waves, whose wavelengths are orders of magnitude longer than light waves, can better penetrate smoke and fog, and can even see through certain materials—all capabilities beyond human vision. Yet robots have traditionally relied on a limited toolbox: They either use cameras and LiDAR, which provide detailed images but fail in challenging conditions, or traditional radar, which can see through walls and other occlusions but produces crude, low-resolution images.

A new way to see

Now, researchers from the University of Pennsylvania School of Engineering and Applied Science (Penn Engineering) have developed PanoRadar, a new tool to give robots superhuman vision by transforming simple radio waves into detailed, 3D views of the environment.

"Our initial question was whether we could combine the best of both sensing modalities," says Mingmin Zhao, Assistant Professor in Computer and Information Science. "The robustness of radio signals, which is resilient to fog and other challenging conditions, and the high resolution of visual sensors."

In a [paper](#) to be presented at the International Conference on Mobile Computing and Networking ([MobiCom 2024](#)), held Nov. 18–22 in Washington D.C., Zhao and his team describe how PanoRadar leverages radio waves and artificial intelligence (AI) to let robots navigate even the most challenging environments, like smoke-filled buildings or foggy roads.

The team, from the Wireless, Audio, Vision, and Electronics for Sensing (WAVES) Lab and the Penn Research In Embedded Computing and Integrated Systems Engineering (PRECISE) Center, includes doctoral student Haowen Lai, recent master's graduate Gaoxiang Luo and undergraduate research assistant Yifei (Freddy) Liu.

Spinning like a lighthouse

PanoRadar is a sensor that operates like a lighthouse that sweeps its beam in a circle to scan the entire horizon. The system consists of a rotating vertical array of antennas that scans its surroundings. As they rotate, these antennas send out radio waves and listen for their reflections from the environment, much like how a lighthouse's beam reveals the presence of ships and coastal features.

Thanks to the power of AI, PanoRadar goes beyond this simple scanning strategy. Unlike a lighthouse that simply illuminates different areas as it rotates, PanoRadar cleverly combines measurements from all rotation angles to enhance its imaging resolution. While the sensor itself is only a fraction of the cost of typically expensive LiDAR systems, this rotation strategy creates a dense array of virtual measurement points, which allows PanoRadar to achieve imaging resolution comparable to LiDAR.

"The key innovation is in how we process these radio wave measurements," explains Zhao. "Our signal processing and machine learning algorithms are able to extract rich 3D information from the environment."

Teaching the AI

One of the biggest challenges Zhao's team faced was developing algorithms to maintain high-resolution imaging while the robot moves. "To achieve LiDAR-comparable resolution with radio signals, we needed to combine measurements from many different positions with sub-millimeter accuracy," explains Lai, the lead author of the paper. "This becomes particularly challenging when the robot is moving, as even small motion errors can significantly impact the imaging quality."

Another challenge the team tackled was teaching their system to understand what it sees. "Indoor environments have consistent patterns and geometries," says Luo. "We leveraged these patterns to help our AI system interpret the radar signals, similar to how humans learn to make sense of what they see." During the training process, the machine learning model relied on LiDAR data to check its understanding against reality and was able to continue to improve itself.

"Our field tests across different buildings showed how radio sensing can excel where traditional sensors struggle," says Liu. "The system maintains precise tracking through smoke and can even map spaces with glass walls."

This is because radio waves aren't easily blocked by airborne particles, and the system can even "capture" things that LiDAR can't, like glass surfaces.

PanoRadar's high resolution also means it can accurately detect people, a critical feature for applications like autonomous vehicles and rescue missions in hazardous environments.

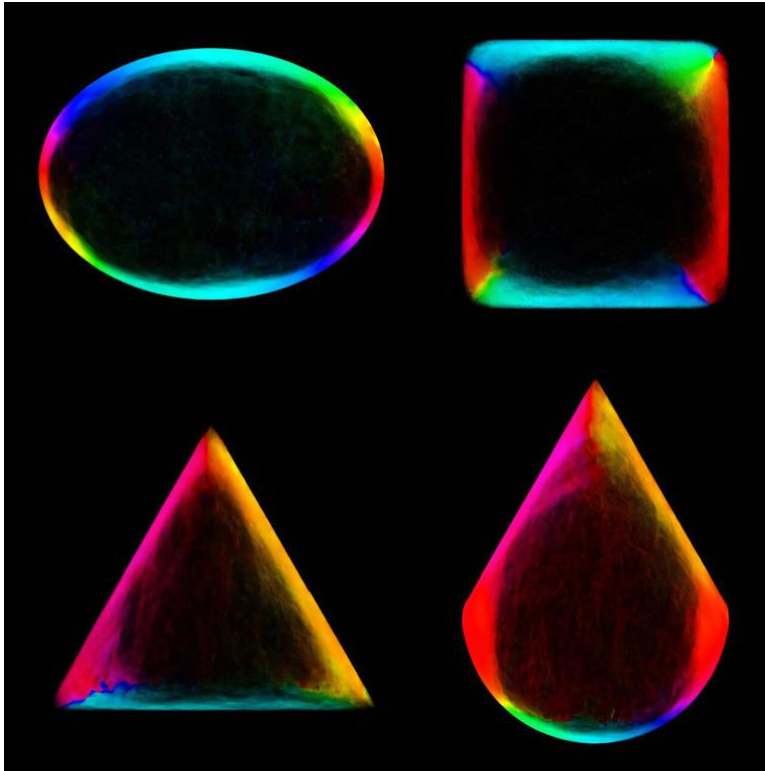
Looking ahead, the team plans to explore how PanoRadar could work alongside other sensing technologies like cameras and LiDAR, creating more robust, multi-modal perception systems for robots. The team is also expanding their tests to include various robotic platforms and autonomous vehicles.

"For high-stakes tasks, having multiple ways of sensing the environment is crucial," says Zhao. "Each sensor has its strengths and weaknesses, and by combining them intelligently, we can create robots that are better equipped to handle real-world challenges."

More information: Haowen Lai et al, Enabling Visual Recognition at Radio Frequency, *Proceedings of the 30th Annual International Conference on Mobile Computing and Networking* (2024). DOI: [10.1145/3636534.3649369](https://doi.org/10.1145/3636534.3649369)

Provided by University of Pennsylvania

Self-organization of living matter into complex structures: How light pattern impacts aggregation of active filaments



Filamentous cyanobacteria form characteristic patterns at the edges of an illuminated shape, although they are only able to move forward and backward on their own. Credit: MPI-DS

When active filaments are exposed to localized illumination, they accumulate into stable structures along the boundaries of the illuminated area. Based on this fact, researchers at the Max Planck Institute for Dynamics and Self-Organization (MPI-DS) developed a model that can be used to simulate the self-organization of thread-like living matter. This model provides important insights for potential technical applications in the formation of structures.

The research is [published](#) in the journal *Nature Communications*.

Filamentous cyanobacteria aggregate in areas with favorable light conditions and use the light energy for photosynthesis. Typically, these microorganisms form long filaments consisting of many cells. However, the thread-like structures can only move forward or backward—when leaving the illuminated area, they reverse their movement and thus remain in the light.

Scientists at MPI-DS have investigated the resulting organizational structures. It was found that only the mutual interaction of several filaments causes the cyanobacteria to align themselves along the inner edge of the illuminated surface, thereby forming stable structures.

To do this, the researchers prepared and illuminated several cultures of cyanobacteria in Petri dishes.

Using slides, they created different light patterns and subsequently observed the self-organization of the bacteria. With a circular light pattern, the bacteria mainly gathered at the edge of the illuminated area. Likewise, when the illuminated area was triangular, trapezoidal or otherwise shaped, characteristic patterns of filaments near the edge of the light emerged.

"The remarkable thing is that the bacteria also arrange themselves along complex structures and curves, although they can only move back and forth," says Stefan Karpitschka, group leader at MPI-DS and professor at the University of Konstanz. "This is a typical example of emergence—a characteristic overall structure arises independently at a higher level from the individual behavior of a single filament."

The insights gained from the scientists' experiments and the resulting model can also be applied to living matter with comparable morphology.

"The model does not include any specific details regarding the biology of the bacteria," says Leila Abbaspour, joint first author of the study together with Maximilian Kurjahn.

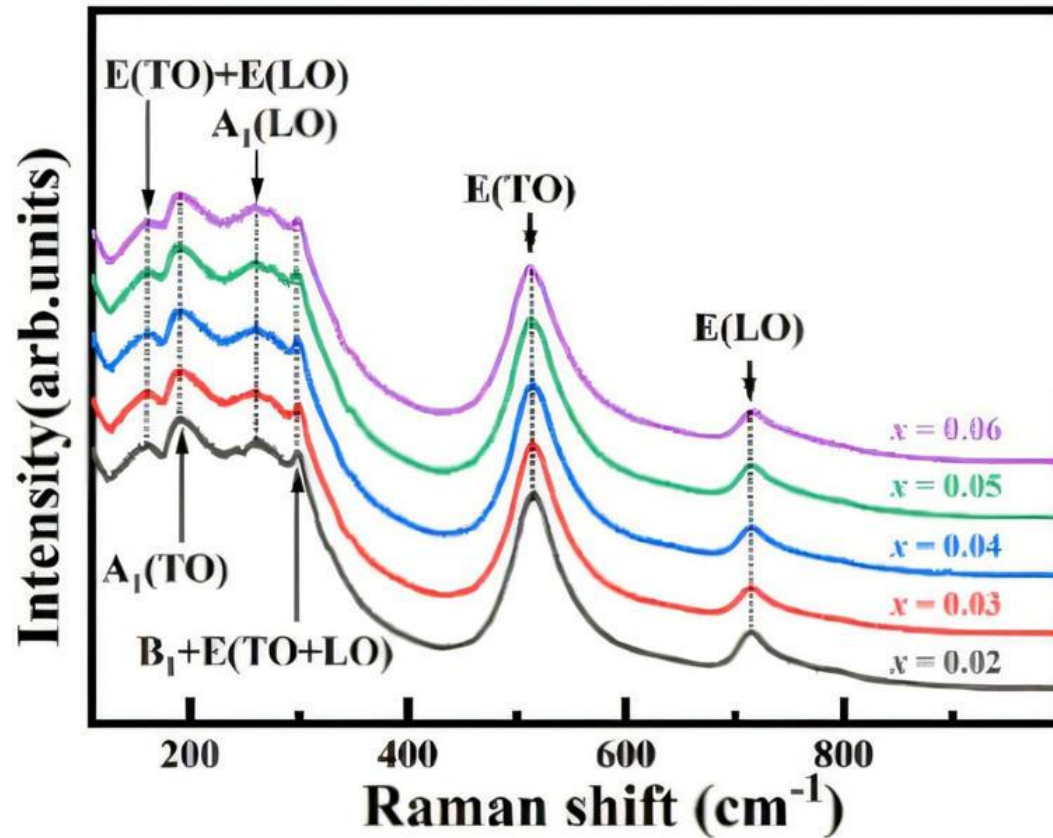
"This collective effect can thus also be observed in similar systems and enable active filaments to structure themselves according to sensory cues from their environment despite one-dimensional motility," says Kurjahn.

The results of this study therefore provide important insights that may be used in the design of so-called smart textiles or materials, for example. These novel structures and tissues are also based on the arrangement of individual fibers and active filaments. Such mechanisms of self-assembly may thus enable the development of new innovative materials.

More information: Maximilian Kurjahn et al, Collective self-caging of active filaments in virtual confinement, *Nature Communications* (2024). DOI: [10.1038/s41467-024-52936-9](https://doi.org/10.1038/s41467-024-52936-9)

Provided by Max Planck Society

Novel ceramic material uses lattice disorder to enhance electrocaloric cooling



The Ramanspectra for BTSZ samples ($x \geq 0.02$) at RT. Credit: Applied Physics Letters (2024). DOI: 10.1063/5.0227301

Electrocaloric (EC) cooling works by using electricity to generate a cooling effect, which is more efficient, cost-effective, and environmentally friendly compared to traditional vapor-compression-based cooling methods.

A research team led by associate Prof. Yin Lihua from Hefei Institutes of Physical Science of the Chinese Academy of Sciences developed a new route based on lattice disorder effect to improve the electrocaloric effect in BaTiO₃-based systems.

Their research is published in [Applied Physics Letters](#).

In their new study, Yin and his team focused on improving the EC effect in BaTiO₃ (barium titanate), which is commonly used in EC cooling systems. They designed materials with a special kind of disorder in their structure, which helps enhance the cooling effect.

The team created a new type of ceramic, BaTi_{1-x-y}Sn_xZr_yO₃, by mixing different elements in ways that introduced both size disorder in the atoms and changes in the material's structure.

Tests showed that these changes resulted in a better EC effect, with an impressive temperature drop of about 0.80 K by using an electric field.

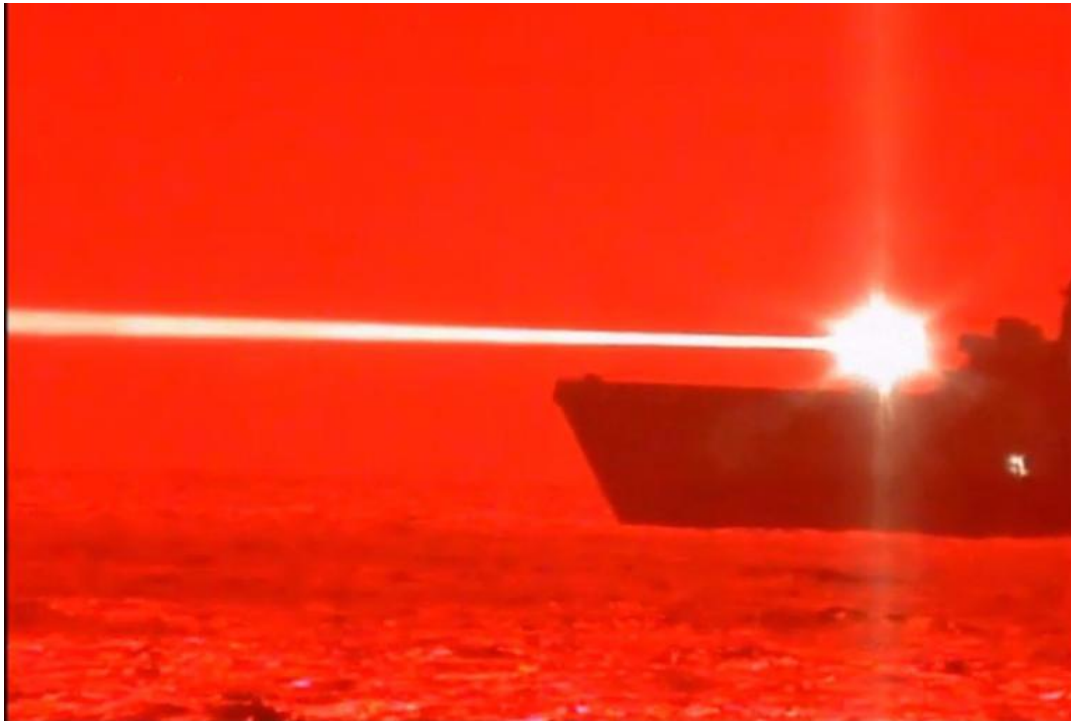
Additionally, they found that the material could maintain a large cooling effect over a wide range of temperatures, which is important for practical applications like cooling devices.

By carefully controlling the lattice disorder and structure of the material, the researchers were able to achieve stronger and more efficient EC effects.

The results suggest a close correlation between the lattice distortion and EC effects and an effective route to improve the EC effects, according to the team.

More information: Lei Xie et al, Large electrocaloric effect by disorder regulated structure in BaTiO₃-based system, *Applied Physics Letters* (2024). DOI: [10.1063/5.0227301](https://doi.org/10.1063/5.0227301)

Combat lasers: From sci-fi to real-world battlefield tech



Tests of American laser weapons; illustrative photo© US Navy

On a daily basis, we typically associate lasers with pointers, industrial laser "blades," or medical instruments. When we hear about laser weapons, our minds primarily turn to weapons from the "Star Wars" universe or other science fiction productions. However, this does not mean that outside the "distant galaxy," combat laser systems are non-existent; they are slowly finding their place in the modern arsenal.

The laser itself, an acronym for Light Amplification by Stimulated Emission of Radiation, is a subset of so-called directed energy weapons. It is, in a sense, a type of lamp that emits electromagnetic radiation in various ranges through the

phenomenon of stimulated emission. Laser radiation is coherent, and the beam is characterized by low divergence.

Laser for the army

Lasers have been used militarily for decades—initially, they were mainly employed as key elements in weapon guidance systems. They continue to serve this function today, as seen in the Polish Pirat/APR-120/155 system. **Additionally, laser rangefinders are standard components of fire control systems.**

There are also lasers designed to injure rather than kill targets. **Their primary role is to permanently blind opponents.** However, such lasers are banned as inhumane under Protocol IV of the Convention on Certain Conventional Weapons from 1980. A slight exception exists for lasers that cause temporary blindness, which law enforcement may use. These lasers typically have a power output well below one kilowatt (kW).

Decidedly more powerful are true combat systems, which remain largely in advanced experimental stages but show promising results. Currently, tested combat lasers generally have power outputs ranging from tens of kW (usually 20-60 kW), with some significantly more powerful systems reaching hundreds of kW. The main goal of developing such "cannons" is to provide the future user with a cost-effective defensive system.

Lasers are often considered potential successors to small-caliber cannons and large-caliber machine guns for defensive applications. However, this requires delivering energy to the target at a rate of 4 kW per square inch of its surface, enabling the laser to burn through the object, damaging or even destroying it.

As for the targets themselves, they generally include all sorts of drones, missile and cruise missile targets, small boats (including unmanned "surface torpedoes"), and similar objects. The proliferation of inexpensive, improvised combat drones (simple FPV drones), despite their low individual effectiveness, is driving the development of laser air-defense systems due to cost-effectiveness.

The cheapest, albeit least effective, suicide drone costs around \$1,000. In comparison, the cost of a single 1.2-inch programmable shell is similar, while that of a rocket projectile is many times higher. This has created a need for a more affordable alternative, and it seems that **lasers might be the answer to this problem**. Various estimates suggest that a single "shot" costs a few to a dozen dollars, generally offering adequate performance in range and accuracy.

Research on laser weapons

Research on combat lasers is being conducted in many countries, often via multiple avenues. Leading the efforts is the USA, which developed the YAL-1 system—a type of oxygen-iodine laser cannon mounted on the nose of a Boeing 747-400F aircraft. The first trials of a similar system were conducted in the 1980s, targeting ballistic missiles. However, it never entered mass production, and the program was abandoned several years ago, although the concept persisted for some time.

A similar project, this time as an anti-satellite weapon, was attempted by Russia under the Sokół-Echelon program. **Smaller lasers, according to some concepts, could form a defensive system for sixth-generation multi-role aircraft (e.g., American NGAD), serving as weapons to destroy anti-aircraft and air-to-air missiles.**

In naval fleets, there is also a trend towards deploying laser weapons. The US Navy tested a laser "cannon" aboard the USS Ponce and later the USS Portland, which successfully shot down an RQ-21 Blackjack drone during tests using the SSL-TM laser. Europe is not far behind. In 2022, the German frigate Sachsen shot down multiple drones using the LWD device developed by MBDA Deutschland and Rheinmetall Waffe Munition.

LWD performed over 100 test launches from the Sachsen frigate, proving that the laser can effectively combat targets in a maritime environment. Meanwhile, the British are intensively testing the DragonFire system, which has a power output of up to 50 kW and is intended for deployment on various Royal Navy surface ships (including Type 32 frigates). The Chinese are also working on a similar system.

Attempts to develop land-based lasers

Developing an effective land-based laser has proven to be most challenging, as the Americans have recently realized. During May tests of the DE M-SHORAD laser air-defense system on a Stryker transporter chassis, it was found that the 50 kW system did not meet expectations in terms of effectiveness at longer distances (up to 6 miles) and was unreliable during on-the-move engagements.

Nevertheless, the US Army is funding several laser weapon programs with power outputs ranging from 10-300 kW for various applications: portable, stationary, and mobile. The most interesting land-based laser system remains the Soviet 1K17 Shatir on the 2S19 howitzer chassis, which was intended to destroy the optoelectronic equipment of enemy vehicles. Its effectiveness is not well-documented, but it was expensive to produce—one unit required about 66 pounds of synthetic rubies.

Beijing has advanced further, producing the fiber laser Silent Hunter, which is effective up to 0.6 miles and was used in combat by Saudi Arabia. It is possible that the Israeli fiber-optic Iron Beam was also used in combat during clashes in the Gaza Strip. Another interesting solution is the American Zeus-HLONS, a lightweight system with a power output of about 10 kW, mounted on the roof of an HMMWV vehicle. It serves to destroy mines and improvised explosive devices, with a range of up to 1,000 feet and the capability to fire up to 2,000 times a day.

Limitations

The lasers mentioned are just selected examples of contemporary (and not only) laser weapons. They differ by country of origin, manufacturer, operational mode, and intended use, but they all share certain limitations. The laser beam is susceptible to "blooming" (beam spread and thus reduced power impacting the target), especially when the air contains impurities such as smog, dust, or dense fog. Consequently, smoke grenade launchers are used on combat vehicles to hinder laser use (usually limited to rangefinders).

Furthermore, the development of laser weapons as a defensive "shield" against missiles and drones ("sword") has led to the creation of a "counter-shield": work on coatings for missiles, drones, or aircraft that can limit the effectiveness of such systems. Lasers, especially higher-powered ones, require significant electrical energy, which must be produced, stored, and then transferred to the "cannon." This entire process generates cooling challenges. Despite these problems, the economic considerations point towards the continued development of laser combat systems. However, it remains uncertain when they will be fully incorporated into military use.

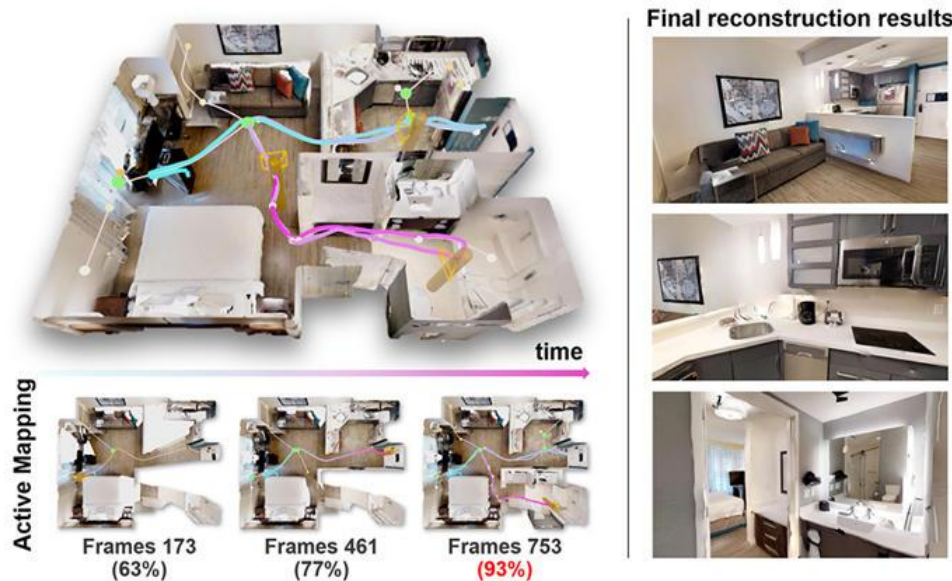
Impressive new tech can automatically map 3D spaces.

We've been writing a lot about Gaussian splatting recently. This high-fidelity alternative to photometry is a relatively new technique for turning 2D photos or video into 3D scenes. Adobe's free new app [Substance 3D Viewer](#) supports it, and we've seen some impressive results for [3D visualisations in Unreal Engine 5](#) (also see our [V-Ray 7 review](#)).

Gaussian splatting can be used to capture accurate lighting and reflections as well as geometry. Now researchers have just described a new tech could mean you don't even need to capture the images or video for gaussian splats yourself. ActiveSplat is an autonomous tool that walks its way around an indoor space and produces a realistic and accurate 3D representation with incredible efficiency.

Developed by researchers from Beijing Institute of Technology and Tsinghua University Institute for Artificial Intelligence, ActiveSplat is "an autonomous high-fidelity reconstruction system leveraging Gaussian Splatting." The [research paper](#) says the system can "build a 3D map on the fly" using a Gaussian map and Voronoi graph for "efficient and complete exploration with high-fidelity reconstruction results."

The hybrid map representation makes use of both dense information about the environment and a sparse abstraction of the space, using sparse topology for efficient viewpoint sampling and path planning while also using view-dependent dense prediction to select viewpoints, "facilitating efficient decision-making with promising accuracy and completeness." A hierarchical planning strategy based on the topological map helps mitigate repetitive trajectories and the system can adjust its yaw and pitch to deal with invisible or high-loss areas.



((Image credit: Yuetao Li et al))

What is 3D gaussian splatting?

Gaussian splatting is a relatively new technique that has taken the 3D industry by storm in the last couple of years. It's a method for scanning objects in the real-world via video or photo and reconstructing them in 3D. Blending rasterization and optimisation, it can model the real world with incredible detail and fidelity, accurately capturing geometry, lighting and reflections .

While triangle-based meshes have traditionally been the way to represent objects in 3D via photogrammetry , splats are based on volume. 3D data is defined using gaussians which are each defined by a position, covariance, colour and an alpha channel, and gaussian splats can be created automatically from just a few smartphone photos or videos using machine learning in apps like Polycam and

Luma AI (also see our pick of the [best 3D scanners](#) and the [best 3D modelling software](#)).

Gaussian splatting allows real-time photo realism and direct editing and the ability to re-light them. Since the tech is so new, there are still many potential applications that have yet to be developed, including in the integration of 3D with VR and AR, and GUI-based production pipelines, like Postshot in beta, are only just starting to emerge.

Scientists Invent Giant Dishwashing Machine for Entire Human Bodies



Japanese showerhead company Science Co. will debut the

Rinse Cycle

A Japanese showerhead maker called Science Co. is planning to debut what it's calling the "human washing machine of the future" at the Osaka Kansai Expo in April — and while we have no idea who the target customer might be, consider us morbidly fascinated.

The washing machine, which pretty much looks like a [hypersleep chamber](#) from *Aliens* (1986), will wash and dry willing humans in about 15 minutes, Japanese newspaper [The Asahi Shimbun reported](#). And if getting scrubbed down like a frying pan isn't a compelling sell, the washing machine of the future purportedly offers therapeutic benefits, too.

A separate Japanese paper, *The Mainichi Shimbun*, [reported that](#) "sensors scanning the person's back measure their levels of stress and fatigue, and in response, the device outputs imagery in pace with their state of body and mind to create a relaxing space for them."

Blast From the Past

Sure, it all sounds very futuristic. But the human washing machine concept is actually based on an idea from over 50 years ago.

The first-ever human washing machine was shown off at the Osaka expo in 1970. It was pod-like, made by Sanyo Electric Co. — that's now part of the electronics giant Panasonic — and worked by filling with hot water to clean its test subjects with popping underwater bubbles and emitting ultrasonic waves.

"We aimed for small bubbles, which we thought would remove more dirt, but it was technically difficult," former Sanyo engineer Eiji Yamaya told *The Mainichi Shimbun*.

In any case, Sanyo's tub never made it to mass production. But 84-year-old Yamaya, along with 90-year-old, former Sanyo designer Manatsu Ueda, are advising Science Co. with the hope of a different outcome.

After allowing 1,000 participants to test out its oblong shower at the Osaka expo, Science Co. plans to prepare the human washing machine for home use.

"We're about 70 percent there," company chairman Yasuaki Aoyama said during a lecture this fall.

No problem, as long as the washing machine makes its users 100 percent clean.

HADRAN-X

FBR designs, develops, builds and operates dynamically stabilised robots to address global needs.

The journey so far...

1994

- **1994**
- **Mark Pivac** has the idea for a mobile dynamically stabilised robot - a highly accurate system that continuously adjusts the position of the robot's end effector.

2005

- **2005**
- **Mark Pivac** files patents for an 'automated bricklaying system' and creates the first Hadrian prototype. After successfully demonstrating the build of a wall using ground-mounted robots and mortar, production of the **Hadrian 105** system begins.

2016

- **2016**
- After FBR lists on the ASX, the **Hadrian 105** builds the world's first multi-room block structure from a 3D computer-aided design model with no human intervention, providing proof of concept for what would become **Hadrian X®**.

2018

- **2018**
- **FBR** has completes mechanical assembly of the first **Hadrian X®** and demonstrates its capability by constructing a home structure in under three days. Furthermore, signs global partnership agreement with **Wienerberger AG** to develop clay blocks optimized for **Hadrian X®**.

2019

- **2019**
- **FBR's Hadrian X®** achieves significant milestones, including completing its first outdoor home structure with precision, launching Building Pilot Programs with local and international clients, starting construction of a second **Hadrian X®** and earns a **Gold Edison Award** for excellence.

2020

- **2020**
- **FBR's Hadrian X®** achieves a significant milestone with a commercial lay speed of over 200 blocks per hour. The company completes the walls of the first display home using **Hadrian X®** and the Pilot Program stage with **GP Vivienda**, building two home structures side by side. Additionally, **FBR** builds a commercial and community center in Western Australia, completing the final stage of the Building Pilot Program Agreement with **Archistruct**, and **Hadrian X®** finishes construction on its first two-

story structure. **FBR** wins the 2020 **Australian Institute of Health & Safety** - Health & Safety Innovation (Small - Medium Enterprise) award.

2021

- **2021**
- **FBR** partners with **Xella** for a Building Pilot Program, using autoclaved aerated concrete blocks and calcium silicate blocks. **Hadrian X®** constructs its largest project to date, an entire Childcare Centre, and builds five homes in the southern suburbs of Western Australia. **FBR** secures contracts for multi-home and **Wall as a Service®** supply and signs a term sheet for up to 5,000 homes in Mexico. **FBR** undertakes its largest project yet, constructing 16 homes with **Inspired Homes**. The company also signs a **Memorandum of Understanding** with **United Arab Emirates Ministry of Energy & Infrastructure** to bring the **Hadrian X®** to UAE.

2022

- **2022**
- **Liebherr-Mischtechnik GmbH** and **FBR** sign a **Memorandum of Understanding** to industrialise and commercialise **Hadrian X®**. **Hadrian X®** completes a structure with virtually zero on-site waste, and mechanical assembly of the first **next-generation Hadrian** is completed. **FBR** commences testing with **Xella** blocks and completes a house using **Wienerberger** Porotherm blocks. The construction on the fifth and final home in the **FBR** Wellard portfolio is completed, and preliminary testing of **DST®** for 3D printing applications on the existing **Hadrian X®** platform is finished. **Fastbrick Americas LLC** US operating entity is established, and **FBR** is featured in a showcase of West Australian innovation at **Expo 2020 Dubai**.

2023

- **2023**
- **FBR** achieves **ICC** certification for **Fastbrick® Adhesive** in masonry construction, while the next-gen **Hadrian X®** robot autonomously lays its inaugural blocks. Strengthening its endeavors, **FBR** collaborates with **M & G Investment Management** to finance three additional **Hadrian X®** robots, tailored for expedited use in the USA. Notably, the next-gen **Hadrian X®** sets a remarkable pace, surpassing **300 blocks per hour** with US format cement blocks, showcasing substantial advancements in automated construction technology.

2024

- **2024**
- **FBR** executes binding US agreement with **CRH Ventures Americas**. [Read More](#)
- **FBR** successfully completes Factory Acceptance Test for **CRH Ventures** ahead of **Hadrian X®** deployment to United States. [Read More](#)
- **FBR** completes work on a 16-townhouse development, the largest project ever undertaken. [Read More](#)
- First next-generation **Hadrian X®** arrives in the United States ahead of Demonstration Program. [Read More](#)

- **FBR** receives confirmation from **CRH Ventures** that first next-generation **Hadrian X®** successfully completes Site Acceptance Testing at Fort Myers facility in Florida. [Read More](#)
 - **Hadrian X®** completes the walls of the first home in US Demonstration Program with **CRH Ventures**, representing the first home ever built using the **Hadrian X®** construction robot outside of Australia. [Read More](#)
-
- **Next 12 months for FBR**
 - Introduce next-generation **Hadrian X®** into suburban building environments.
 - Complete construction at St. James.
 - Progress manufacture of U.S. spec next-generation **Hadrian X®** robots for deployment to U.S.
 - Establish European entity and complete certification of **Fastbrick Wall System®**.
 - Obtain binding orders for further next-generation **Hadrian X®** robots to be positioned into operating entities in Australia, U.S. and Europe.
 - Work to establish U.S. operational base in readiness for the arrival of next-generation **Hadrian X®** robots.

Award winning innovation

How We Solved The Home Wind Turbine Problem

I have solar on my home, but it's obviously only producing significant amounts of electricity on sunnier days. Being able to augment that with wind power is incredibly appealing. That's one of the reasons why companies like Aeromine and Harmony Turbines have been catching my eye, but I'll get to them in a minute. Chances are that if you're interested in renewable energy, you already know that residential wind is nowhere near the commonality and accessibility of residential solar...for now. Why? Well, I've previously discussed the practicality (or maybe more accurately, the lack of it) of [home wind generation](#) in depth. But for those who aren't up to speed, here's a recap.

What's the challenge?

First of all, just like with any kind of home renewable energy generation, wind requires installation space. However, what makes it different from solar is the amount of space needed. While solar allows for somebody to make use of the roof they already have, wind is generally much more demanding. This isn't only a function of the height needed to make the best use of winds found far off the ground, but the distance needed to keep turbines away from obstacles that cause turbulence. Otherwise, you risk not only undercutting energy production, but reducing the lifespan of the turbine.¹

So, with those factors in mind, the U.S. Office of Energy Efficiency & Renewable Energy recommends you should have at least 1 acre of land for the proper placement of a wind turbine.² For an idea of just how much that is, keep in mind that the average square footage of a US single family home is 2,273 square feet or 211 square meters on less than a tenth of an acre of land (or 43,560 square feet or 4,046 square meters).³ However, it's worth noting that about 19% of the U.S. population lives in rural areas, and this typically goes hand-in-hand with having enough room to support home wind systems.² Sorry, city slickers.

That's not to say that urban areas are completely out of luck forever, though. There are other companies, like [O-Wind](#) and [Alpha 311](#), that are focusing on integrating wind turbines directly into existing city infrastructure. I can dive into these companies in future videos if you're interested.

That brings us right to the next barrier to wind energy. It might seem obvious at first, but to take advantage of wind power on your home turf, you need...wind. If your local weather doesn't promote strong and consistent gusts that keep those blades turning, then wind simply isn't worth your time. And not all wind is the kind that you want. So what separates "good" wind from bad? What are acceptable wind speed ranges, and where can you find them? It depends heavily on where you live.

In a 2022 study on distributed wind setups conducted by the U.S. government's National Renewable Energy Laboratory, its authors identify California, Minnesota, and the Northeast region as areas of interest. These places tick all three of the boxes that allow for profitability: enough wind supply, high retail electricity prices, and favorable political policies. On a state-by-state basis, New York, Minnesota, Kentucky, Texas, Oklahoma, and South Dakota stand out for holding the "largest economic potential" for residential zones. The researchers also spotlight my own personal stomping grounds, the region of New England, as a solid contender because of its particularly pricey electricity.⁴ It's very expensive here.

When it comes to capturing wind energy in residential, suburban or urban settings, you're talking about wind speeds at roughly 10 meters (~30 feet) above surface level in most cases. And if you look at this map from NREL⁵ on those average wind speeds, you'll notice one major trend: most places have a speed of 3 to 5 meters per second (or roughly 6 to 12 mph). That's not nearly fast enough for wind energy to be cost effective ... yet. However, a bunch of companies are trying to address that shortcoming by creating cheaper, more effective turbine designs that can make the most of what little wind resources are available.

That slower, more chaotic wind is usually a big problem ... for traditional horizontal wind turbines at least. But not so for Savonius turbines — a type of vertical axis wind turbine that historically hasn't fared too well as a mass market option. However, this is where creative engineering can truly shine. I spoke to Chris and Cheryl Moore from Harmony Turbines, a small startup developing a really interesting Savonius turbine, about that exact point.

"Generally, wind in the rural and even urban areas is not very good, so it's dirty wind. It's disrupted wind, and Savonius turbines are the king of low wind speed power production. Now, it's not magic. This isn't like zero point energy or, you know, getting more out of a system than

you're putting in. It's not magic. It does need wind to make power. But if the majority of the United States, and the world at large, doesn't have good wind, shouldn't we try and make a wind turbine that can at least capitalize on that poor wind condition." — Chris Moore, CEO Harmony Turbines

Clever Approaches to VAWTs for residential

That brings me straight into possible solutions for the more residential market. There are multiple companies, like Harmony Turbines, trying to tap into that niche with a cheaper, smarter approach.

Harmony Turbines

As I mentioned before, Harmony Turbines' design is a type of Savonius wind turbine, which was invented by Sigurd Johannes Savonius in 1922. They typically consist of two or more half-cylindrical blades that are mounted on a vertical shaft in an 'S' shape.⁶ If you've seen an anemometer, which measures wind speeds, it works in the same basic way. They're designed to spin, even at low wind speed and regardless of wind direction. The turbine captures wind energy through a simple mechanism known as "differential drag." As wind interacts with the concave and convex sides of the blades, the difference in drag force causes the rotor to spin.⁷ That differential drag allows it to operate effectively in turbulent wind.⁸

While it's known for its simplicity and ease of construction, the Savonius turbine typically has a lower efficiency, which is often reported to be around 15% compared to traditional propeller designs at around 50-60%. But that's disputed by Chris Moore, the CEO of Harmony Turbines.⁹

"If you really dig into it and look, you're gonna see the Savonius Turbine is like the lowest crappiest out of all of them, out of like 10 or 12 pictures, and then you'll see one that suddenly it's like up in the 30, and you're like, well wait, what's that one? It's the same graph, just the arrows are reversed. Yeah, so, the bad data, because the internet is just a copy and paste society, it was just making it a thousand times worse, and just putting all this bad data out there. Um, in working with the universities, Penn State especially, like, the professor slapped her hands down on the table, she goes, 'Yes, yes, yes, I've been trying to teach this for the past five years in my classes, that the data's wrong.'

So they were excited to work with us on this project because they wanted to help debunk this bad data.” — Chris Moore, CEO Harmony Turbines

What sets their approach apart from a typical Savonius design is that the scoops can articulate to control the spin.

“So the way we approach that problem is we have our furling mechanism, where our scoops (or fins or whatever you want to call them) at a certain RPM or when the turbine reaches its max RPM, they’ll close in towards each other a little bit. And the purpose of this is twofold: one, it’ll control the spin, so we’re not spinning out of control. But the second thing that it does is it allows us to continue generating power. Even though we have strong winds, even though we’re partially closed, we’re still generating power. The other ones, they stop.” — Cheryl Moore, COO

When wind speeds exceed a turbine’s rated spin speed, they have to shut off to protect themselves ... or they’ll literally tear themselves apart. Harmony’s approach allows it to close itself off a little bit to slow the rotation, but not stop. The idea is to allow the device to keep going even under the kind of wild conditions that would typically grind production to a halt. The ability to reduce the exposure area and slow the rotational speed gives them some advantages over their larger HAWT cousins.

Aeromine

Then there’s Aeromine, [which I covered in a previous video](#). I’ll link to it in the description if you want a deeper dive, but in a nutshell, they’re using airfoils to concentrate and amplify the wind.

The purpose of an airfoil is to make physics work for you and to take advantage of the Bernoulli Effect. This refers to how gasses and liquids flow around an object at different speeds. Just like an airplane wing, air moves faster over the top section of the wing than the bottom, creating lift.

Looking at their turbine from the exterior, there’s no exposed moving parts. Instead, two vertically mounted, hollow foils stand opposite each other with a space between them. This creates a low-pressure zone and as wind flows through the space a short pipe then leads the captured wind to a fully enclosed turbine located at ground level.

The fact that Aeromine’s approach is to place their devices along the front edge of a building’s flat roof isn’t by accident. Have you ever walked between tall buildings and felt like you’re walking into a

wind tunnel? I used to work in the center of Boston, and it sometimes felt like I was one of those meteorologists trying to stand upright in hurricane force winds while talking about the ongoing storm. That wind tunnel effect is caused by the wind slamming into the surface of the building and getting compressed and funneled around it. It amplifies the speed of the wind, and Aeromine is capitalizing on that effect.

“One of the things that’s novel about Aeromine is we’re leveraging two fluid streams. What happens is the free wind hits the face of a building. It creates an amplification that goes into our generator, and at the same time, as the free wind hits the airfoils that creates a pressure, which pulls the wind up. So instead of kind of fighting the environment that it’s on, it’s actually helping it’s using the building structure itself to help. We’re leveraging the inherent aerodynamics of a building and those flow streams to effectively amplify the wind resources.” — David Asarnow, CEO

Basically, Aeromine is taking what would normally be a negative to a traditional horizontal wind turbine and making it an advantage. They’ve also been busy since I talked about them last time and have some interesting updates, which I’ll get to in just a minute.

The potential market for homes/urban/suburban wind

If one or more of these companies is successful at driving down the cost per watt of small wind turbines for more residential and suburban settings, there’s a huge market they can tap into.

“The traditional thinking in the wind industry, which is totally valid, is bigger is better because the bigger the swept area, the more power you can put out ... which makes all the sense in the world. You know, that’s a lot of physics, but at the same time it does create a limited market to some level as far as applications ... We think there’s a lot of behind the meter opportunity by leveraging these large rooftops to create power. You’re not as beholden to, you know, transmission requirements and you can get the power to where it’s needed.” — David Asarnow, CEO

“But it’s virtually an untapped market right now, so it’s not like ... 90 percent of residential areas already have wind turbines, and so then you’re trying to convince them to get rid of that and get a new one. People are looking for them ... People are waiting for the right solution to come out, and so we hope that we are the ones that fill that gap. People are looking for it, they’re not necessarily moving on the bad solutions, or the inferior solutions, I shouldn’t say that, the inferior solutions. You know, they’re just kind of waiting because they don’t know what to do.” — Cheryl Moore, COO

David said something very similar.

“If you think about onsite generation, what are folks really trying to achieve? They’re trying to maximize their on site generation. And so, I think that’s what really resonates with folks that we talk to every day all around the world, is that this technology allows Uh, an operator or owner of a building, um, were suitable to create this incremental generation, uh, which can really move the needle and be quite meaningful.” — David Asarnow, CEO

If a homeowner or building owner crunches the numbers and sees a path to maximizing their energy generation and savings by layering in wind turbines along with solar, small scale, distributed wind generation could finally see its...day in the sun.

When will they get here

This is where it gets interesting. Since I last covered Aeromine, there’s been some updates on what they’re doing. The company has had a pilot project running on top of a BASF building for about a year and a half with great results, and it’s planning to expand in 2024.

“We have a series of approximately 10 pilot projects that are actually in production right now and are starting to roll out in the next two quarters. So you’ll see a lot more Aeromines on the rooftops, both the US and Europe, in the next six months. And then we are in the final stages of what we call “design for manufacturing” of our mass market

product, which should be introduced late in 2024.” — David Asarnow, CEO

Meanwhile, Harmony Turbines is collaborating with two universities in the company’s home state of Pennsylvania: It just finished a study that involved receiving feedback from Bucknell University, and it also has additional work being done with Penn State University. Harmony is also making a splash across the pond at Northumbria University in the UK.

Bucknell’s study helped the Harmony team do full scale testing of its current design, and Penn State has been doing water tank testing for clustering effects. That’s basically determining how to group turbines together to maximize production. In horizontal axis wind turbines, that usually means having to space them far apart, as the wake created by the turbines upwind can dramatically impact those behind it. What’s interesting is that for vertical axis wind turbines, that’s not the case. In fact, studies are showing that grouping them closer together can actually amplify their production.¹⁰ Again, this is about turning the disadvantage of dirty, chaotic wind into a positive.

Chris and Cheryl spoke to me at length about how they’re continuing iteration on their scoop design and will be starting to gather a lot of data next year. Like I said, they’ve got a really interesting approach that I’m keen to see play out, but they’re very early days. One thing I LOVE about Harmony Turbines as a company is how they’re sharing their journey of development out in the open. Most companies don’t do this. They have a website and a YouTube channel with videos they’re publishing on a regular basis. So, if you’d like to see what it’s like to develop this technology, and why it takes more time than you think it should, be sure to follow them. It’s awesome stuff. And let me know if you’d like me to do a deeper dive on their approach (or any other companies in this area).

While smaller scale wind technology still isn’t here for homes just yet, there’s a lot of interesting developments in the works. It doesn’t seem like we’ll have to wait much longer to find out which way the wind is blowing.

1. [Small Wind Guidebook: How Do I Choose the Best Site for My Wind Turbine? ↵](#)
2. [Small Wind Guidebook: Intro ↵](#)
3. [Average size of floor area in new single-family houses built for sale in the United States from 1975 to 2022 ↵](#)
4. [NREL 2022: Distributed Wind Energy Futures Study ↵](#)
5. [NREL: Annual Average Wind Speed at 10 Meters Above Surface Level ↵](#)
6. [Savonius Wind Turbine ↵](#)
7. [Savonius Rotor ↵](#)
8. [REUK.co.uk – Savonius Wind Turbines ↵](#)
9. [FAQ: Everyone says that Savonius turbines have terrible efficiency compared to other designs. Why are you wasting time and money on this? ↵](#)
10. [Numerical modelling and optimization of Vertical Axis Wind Turbine pairs: a scale up approach ↵](#)

Solving waste plastic processing with heat circulation: Researchers develop large-scale pyrolysis process



The research team is collecting pyrolysis oil produced from the developed process. Credit: Korea Institute Of Energy Research

Dr. Byungwook Hwang's research team from the CCS Research Department at the Korea Institute of Energy Research (KIER) has successfully developed a process that applies the circulating fluidized bed technology, commonly used in coal-fired power plant boilers, to recycle waste plastics and produce pyrolysis oil on a large scale.

Their research is [published](#) in the *Chemical Engineering Journal*.

The COVID-19 pandemic has led to a sharp increase in household plastic waste worldwide. In response, countries around the globe are focusing on recycling technologies, such as pyrolysis, for eco-friendly waste plastic management. Recently, the Korean government announced plans to expand the annual volume of plastic waste processed via pyrolysis from 10,000 tons to 900,000 tons by 2030.

Currently, the kiln method is used in the Republic of Korea for the pyrolysis of waste plastics. This process involves placing waste plastics inside a cylindrical chamber, applying heat externally, and condensing the resulting vapor to produce pyrolysis oil. While the process design is relatively simple, it faces scalability limitations, as heat transfer from the exterior to the center of the cylinder becomes increasingly difficult as the size of the chamber increases.

The kiln method can process only up to 20 tons of plastic per day, which falls far short of the 900,000 tons per year target set by the government for pyrolysis processing. Additionally, the kiln method requires continuous external heat supply and cannot operate continuously, as the process must be paused to handle residual waste before restarting. These limitations make it inefficient for large-scale applications.

The research team developed a technology to recycle waste plastics using a circulating fluidized bed (CFB) process, overcoming the limitations of conventional methods. The CFB process is a technology in which heat carriers, such as high-temperature sand, circulate to enable continuous heat transfer during reactions. For the first time globally, the team successfully applied the CFB process to the pyrolysis of waste plastics, enabling both continuous operation and scalability—key challenges of existing processes.

The core of the developed process lies in heat circulation. In this system, catalyst particles heated in the combustion reactor are circulated to the pyrolysis reactor, where they transfer heat to facilitate the pyrolysis of waste plastics. After transferring heat, the catalyst, now at a lower temperature, returns to the combustion reactor along with the residual waste. The residual waste is incinerated, generating heat to reheat the catalyst. The reheated catalyst is then recirculated back to the pyrolysis reactor, maintaining a continuous process of heat transfer and pyrolysis.

By utilizing this process, a continuous operation is achievable as the cycle of raw material input, heat supply, and residual waste treatment is seamlessly

maintained. Additionally, since the catalyst moves freely within the reactor, heat can be effectively transferred from the center to the edges of the reactor, enabling scalability and the development of larger systems.

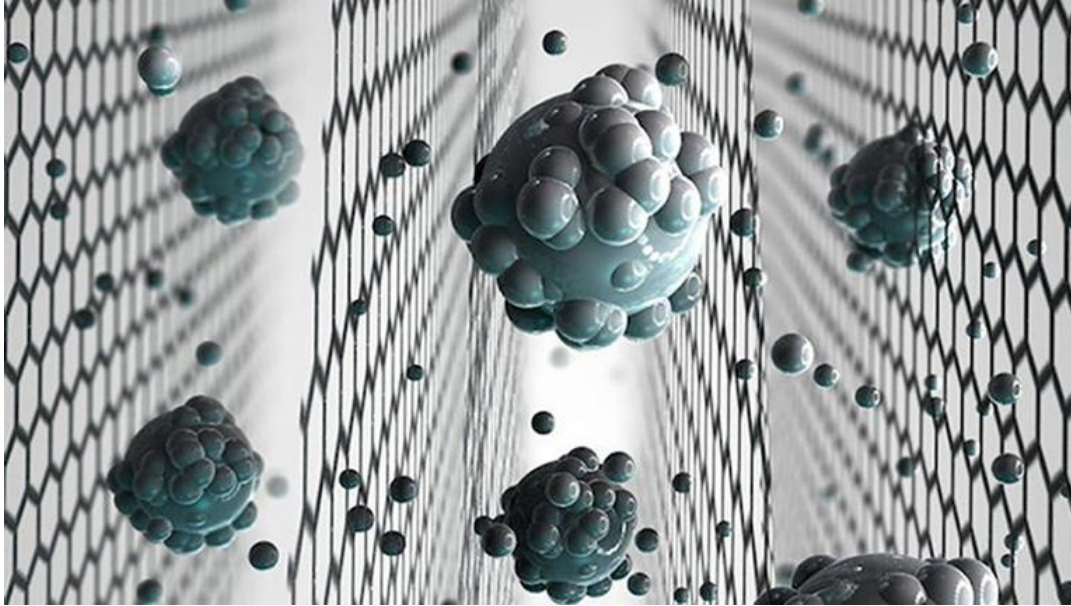
The research team conducted pyrolysis experiments on waste plastics using their process, handling up to 100 kilograms per day. They confirmed that the process can pyrolyze not only plastics but also solid recovered fuel (SRF) made from household waste. When SRF was processed, the yield was approximately 37%, which is 1.2 times higher than conventional methods. Additionally, the produced pyrolysis oil showed a significant improvement in quality, with a 45% content of light fractions, nearly doubling the quality compared to existing processes.

Dr. Byungwook Hwang, the lead researcher, stated, "The most significant achievement of this study is the design and development of a technology capable of continuously processing waste, including plastic waste, through pyrolysis. This core pyrolysis technology is highly suitable for achieving Korea's waste plastic pyrolysis targets, as it enables the processing of large volumes of waste plastics while producing high-quality pyrolysis oil."

More information: Daewook Kim et al, Development of a circulating fluidized bed for a 100 kg/day waste plastic pyrolysis-combustion system, *Chemical Engineering Journal* (2024). DOI: [10.1016/j.cej.2024.156257](https://doi.org/10.1016/j.cej.2024.156257)

Provided by National Research Council of Science and Technology

UK-Saudi deal to make 'miracle material' at scale



Graphene has been described as the world's first two-dimensional material.

A deal has been struck for the world's first commercial production of carbon fibre enriched with graphene in a new project led by a UK company in Saudi Arabia.

Manchester firm Graphene Innovations Manchester (GIM) has agreed to construct a factory in the Gulf state to manufacture the advanced "wonder" material for use in the kingdom's huge [plans to build futurist eco-cities in the desert](#).

About £250m could be invested in building a research and innovation hub in Greater Manchester as part of the deal and more than 1,000 jobs could be created.

Dr Vivek Koncherry, GIM chief executive, said producing the material at scale had the potential "to change every aspect of our lives".



The factory will be built in Saudi Arabia with the backing of investors© BBC

Scientists describe graphene as a nanomaterial that is effectively two-dimensional, because the hexagonal lattice structure that makes it up is only one atom thick.

About 200 times stronger than steel, it has been praised for its "amazing properties" and excitement built over its future use when it was discovered by scientists at the University of Manchester in 2004.

- [Graphene: 20 years of a 'miracle' made in Manchester](#)

The deal between GIM and Saudi-based investors Organized Chaos to build the factory and see investment return to the UK was heralded by UK Prime Minister Sir Kier Starmer on a trip to the Gulf State on Sunday.



Dr Vivek Koncherry said the advanced material would be produced at scale© GIM

The first machine constructing the material is already operational, with the factory expected to be up and running by the end of 2025, Dr Koncherry said.

He studied graphene as a student at the University of Manchester and was supported to set up his company by the university's National Graphene Institute.

Dr Koncherry said the material could "change the world" by enabling new building techniques, lighter materials for aviation and space explorations.

"My idea is to rapidly develop products that can solve global problems like climate change, water shortage, plastic pollution, because the world is facing so many challenges, we can't wait anymore."

His company plans to build the first factory producing graphene enriched carbon fibre in the UK by 2026, he said.

Professor James Baker at the university's Graphene Engineering Innovation Centre, said the deal was a "significant development".

He said the commercialisation of the material was evidence of a "tipping of new products and applications being developed for the market".

Scientists engineer bacteria to make two valuable products from plant fiber

We often look to the smallest lifeforms for help solving the biggest problems: Microbes help make foods and beverages, cure diseases, treat waste and even clean up pollution. Yeast and bacteria can also convert plant sugars into biofuels and chemicals traditionally derived from fossil fuels—a key component of most plans to slow climate change.

Now University of Wisconsin–Madison researchers have engineered bacteria that can produce two chemical products at the same time from underutilized plant fiber. And unlike humans, these multitasking microbes can do both things equally well.

"To my knowledge, it's one of the first times you can make two valuable products simultaneously in one microbe," says Tim Donohue, UW–Madison professor of bacteriology and director of the Great Lakes Bioenergy Research Center.

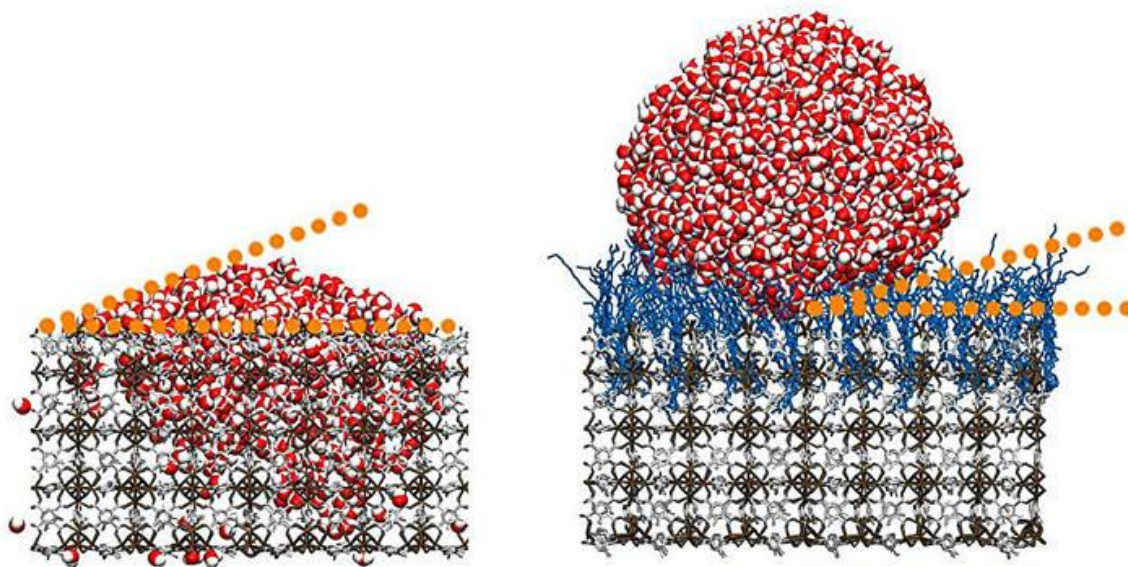
The discovery, [detailed in a paper](#) in the journal *Applied and Environmental Microbiology*, could help make biofuels more sustainable and commercially viable.

"In principle, the strategy lowers the net greenhouse gas emissions and improves the economics," Donohue says. "The amount of energy and greenhouse gas that you need to make two products in one pot is going to be less than running two pots to make one product in each pot." **Every molecule counts**

The quest to replace fossil fuels with sustainable alternatives hinges on extracting the most possible value from renewable biomass. Just as with petrochemicals, every molecule counts: Low-volume, high-value products help keep fuel more affordable.

One of the biggest barriers is a part of the plant cell wall called lignin. Lignin is the world's most abundant source of renewable aromatic carbons, but its irregular structure makes it notoriously difficult to break apart into useful components.

Scientists develop material with almost perfect water repellency



Porous substrate with a small water contact angle: The surface absorbs a lot of liquid. Right: The new material features a large water contact angle and is thus nearly completely hydrophobic. Credit: KIT

Scientists from Karlsruhe Institute of Technology (KIT) and the Indian Institute of Technology Guwahati (IITG) have developed a surface material that repels water droplets almost completely. Using an entirely innovative process, they changed metal-organic frameworks (MOFs)—artificially designed materials with novel properties—by grafting hydrocarbon chains.

The resulting superhydrophobic (extremely water-repellent) properties are interesting for use as self-cleaning surfaces that need to be robust against environmental influences, such as on automobiles or in architecture. The study was [published](#) in the journal *Materials Horizons*.

MOFs (metal-organic frameworks) are composed of metals and organic linkers that form a network with empty pores resembling a sponge. Their volumetric properties—unfolding two grams of this material would yield the area of a

football pitch—make them an interesting material in applications such as gas storage, carbon dioxide separation, or novel medical technologies.

The outer surfaces exposed by these crystalline materials also offer unique characteristics, which the research team took advantage of by grafting hydrocarbon chains onto thin MOF films. They observed a water contact angle of more than 160 degrees—the larger the angle formed by the surface of a water drop with the substrate, the better the hydrophobic properties of the material.

"With our method, we are able to achieve superhydrophobic surfaces with contact angles that are significantly higher than those of other smooth surfaces and coatings," states Professor Christof Wöll from KIT's Institute of Functional Interfaces. "Although the wetting properties of MOF powder particles have been explored before, the use of monolithic MOF thin films for this purpose is a groundbreaking concept."

Next-generation 'superhydrophobic' materials

The team attributes these results to the brush-like arrangement (polymer brushes) of the hydrocarbon chains on the MOFs. After being grafted to the MOF materials, they tend to form "coils"—a state of disorder that scientists call "high-entropy state," which is essential for its hydrophobic properties. The scientists asserted that this state of the grafted hydrocarbon chains could not be observed on other materials.

It is remarkable that the water contact angle did not increase even when they used perfluorinated hydrocarbon chains for grafting, i.e., substituting hydrogen atoms with fluorine. In materials such as Teflon, perfluorination brings about superhydrophobic properties. In the newly developed material, however, it decreased the water contact angle significantly, as the team found out.

Further analyses in computer simulations confirmed that the perfluorinated molecules—in contrast to hydrocarbon chains—could not assume the energetically favorable high-entropy state.

In addition, the scientists varied the surface roughness of their SAM@SURMOF systems in the nanometer range, thereby further reducing the water adhesion

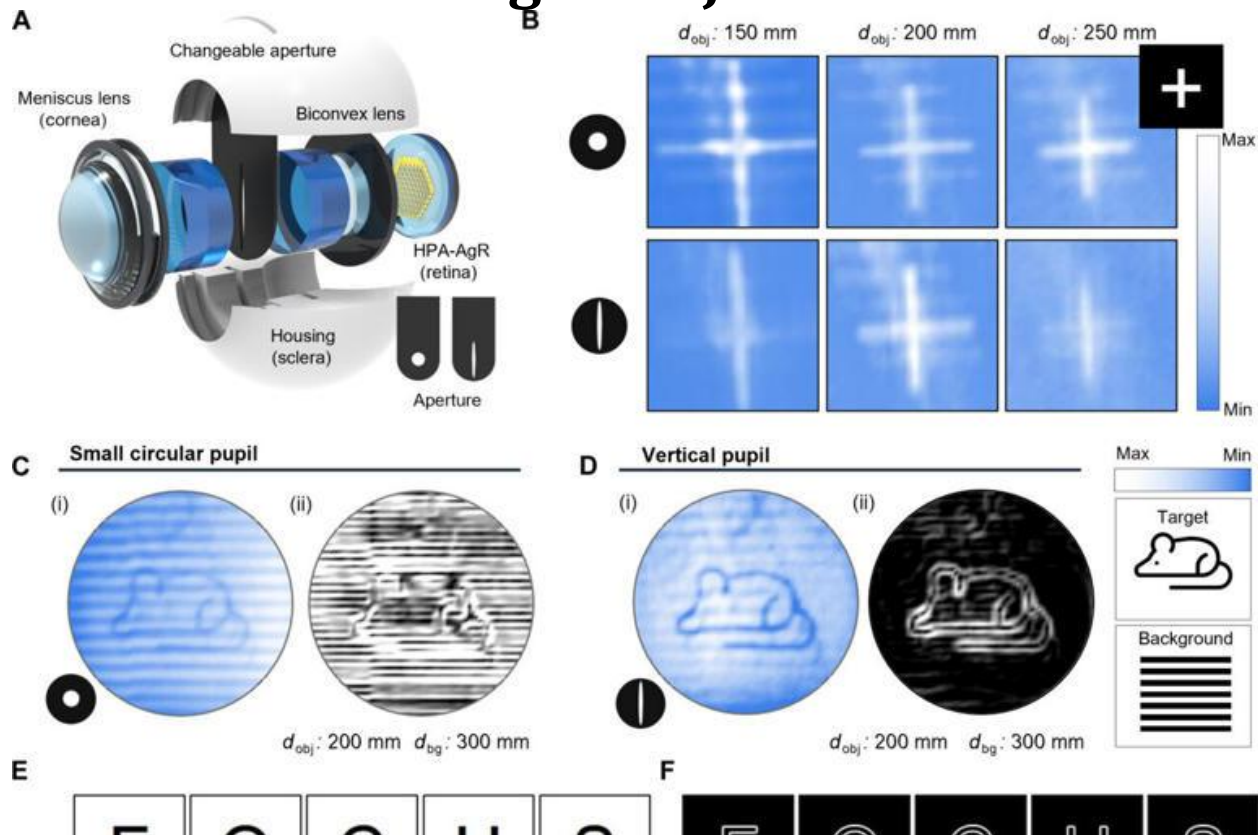
strength. Even with extremely small inclination angles, water droplets started rolling off, and their hydrophobic and self-cleaning properties were significantly improved.

"Our work also includes a detailed theoretical analysis, which links the unexpected behavior shown in experiments to the high-entropy state of the molecules grafted to the MOF films," says Professor Uttam Manna from IITG's Chemistry department. "This study will change the design and production of next-generation materials with optimum hydrophobic properties."

More information: Evgenia Bogdanova et al, Functionalization of monolithic MOF thin films with hydrocarbon chains to achieve superhydrophobic surfaces with tunable water adhesion strength, *Materials Horizons* (2024). DOI: [10.1039/D4MH00899E](https://doi.org/10.1039/D4MH00899E)

Provided by Karlsruhe Institute of Technology

Scientists mimic cat eyes to create artificial eye that sees better in the dark, detects camouflaged objects

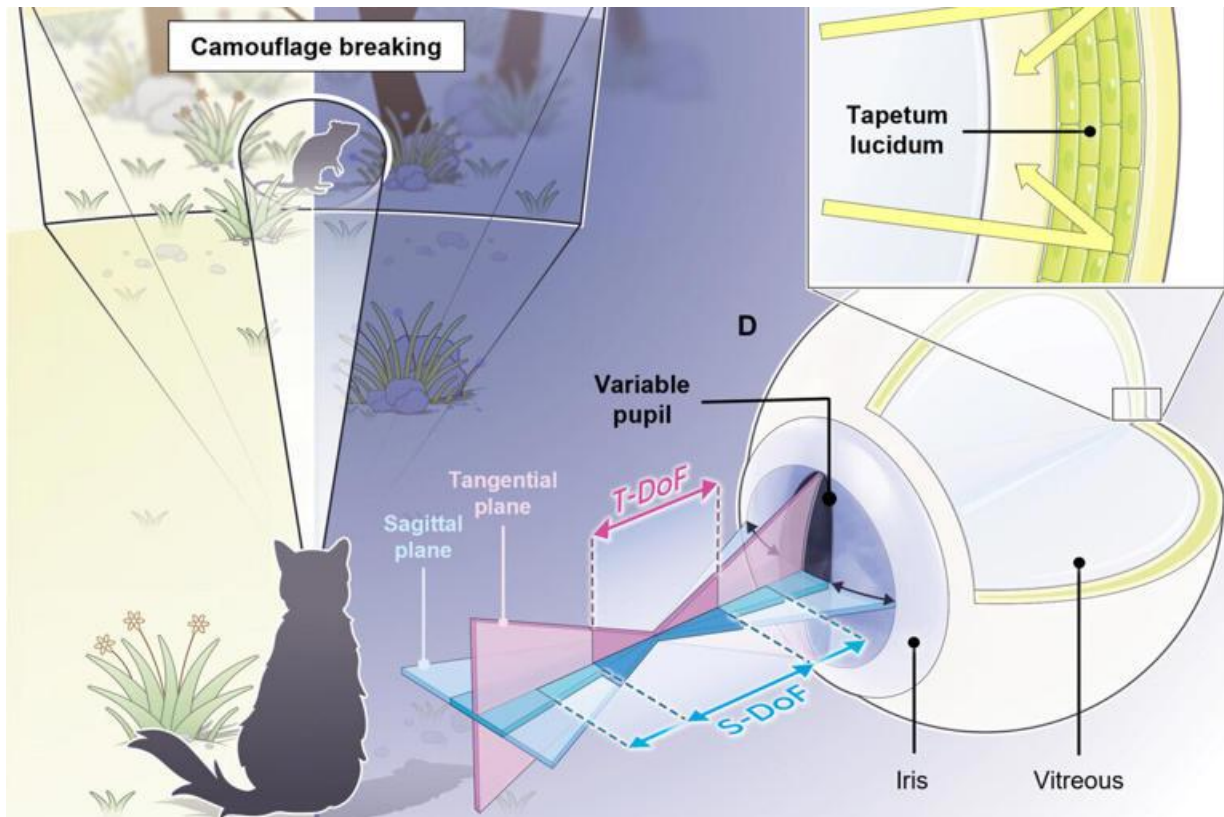


Imaging demonstration of the feline eye-inspired vision system. Credit: Science Advances (2024). DOI: 10.1126/sciadv.adp2809

A team of engineers from the Center for Nanoparticle Research, Seoul National University, the Gwangju Institute of Science and Technology and the Korea Institute of Science and Technology, all in Korea, has developed a new type of artificial eye based on natural cat eyes.

In their study [published](#) in the journal *Science Advances*, the group copied two features of cat eyes that give them unique abilities to see in the dark and to detect camouflaged objects.

As the researchers note, cameras installed on drones and robots are based on circular apertures that mimic the human eye, an approach that results in imagery with both a foreground subject and the background kept in focus. This approach sometimes makes it difficult for the camera to keep track of the target object.



Structural and functional features of feline eyes. (A and B) Schematic illustration showing the camouflage-breaking ability of a feline under diverse light condition. (C) Magnified schematic illustration of the tapetum lucidum in the retina. (D) Schematic illustration of the feline eye's anatomy. (E and F) Schematic illustrations showing the visual ecology of feline and conventional vision during the daytime (E) and nighttime (F). Credit: Science Advances (2024). DOI: 10.1126/sciadv.adp2809

Animals, such as cats, use a different approach: They have vertically slitted eyes to capture an asymmetric depth of field. Because of that, the researchers chose to use the cat eye architecture as a means for developing a new type of artificial eye.

Using animal eyes as a template for designing new types of artificial eyes is nothing new, of course—last year, another team of researchers in Korea [used the cuttlefish eye](#) as inspiration for the design of a robot eye that could see better in murky, underwater conditions.

For the new approach, the research team designed a vertical aperture, allowing the camera to keep a target in focus while the field behind it remained blurry, allowing for better tracking of target objects during the day.

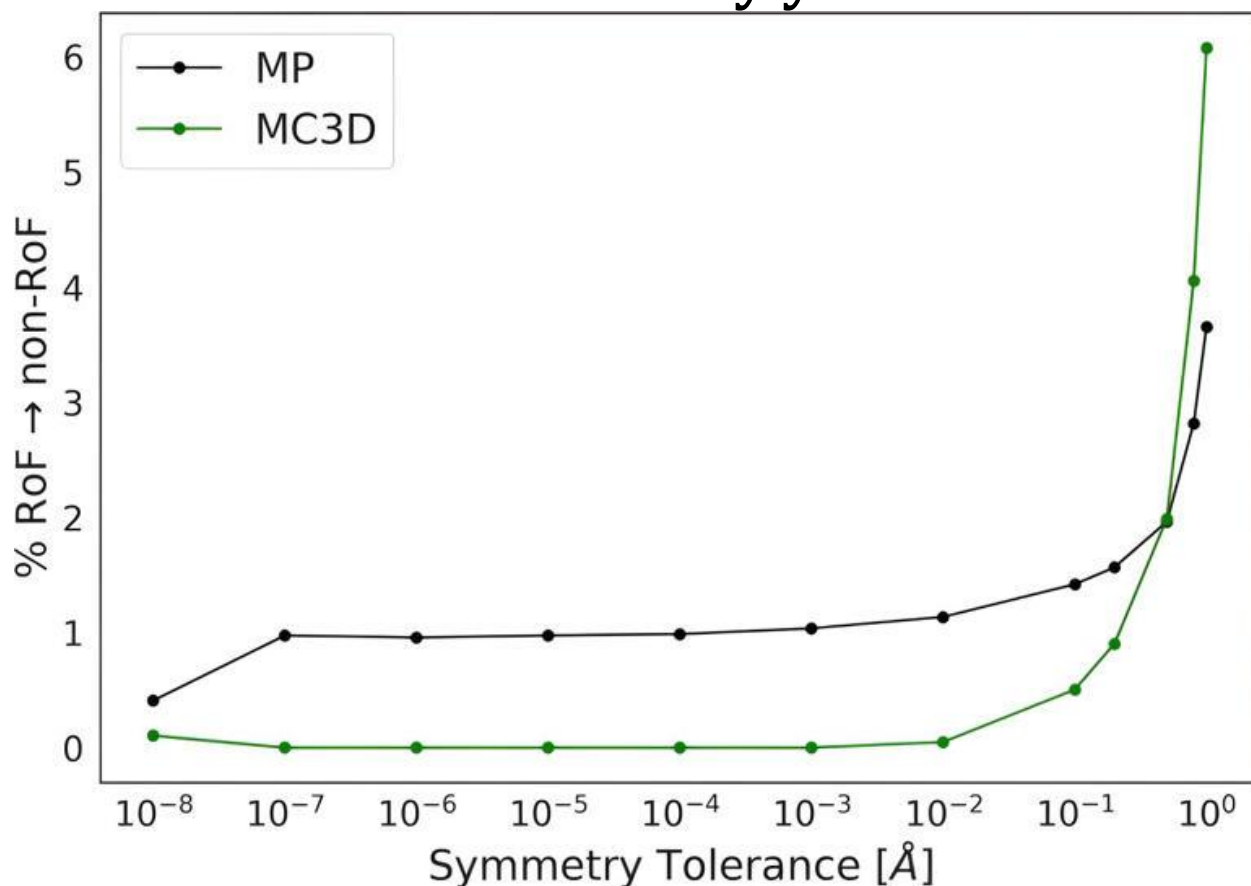
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Together, the two features give the new camera the ability to see better in the dark and to keep track of target objects, even if they are hidden by camouflage.

More information: Min Su Kim et al, Feline eye–inspired artificial vision for enhanced camouflage breaking under diverse light conditions, *Science Advances* (2024). DOI: [10.1126/sciadv.adp2809](https://doi.org/10.1126/sciadv.adp2809)

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Materials follow the 'Rule of Four,' but scientists don't know why yet



Percentage of RoF structures that become labeled non-RoF as a function of the symmetry tolerance parameter used for reduction to the primitive cell. The black and green lines correspond to structures in the MP and MC3D-source datasets, respectively. At typical symmetrization parameters, there is little to no change in the number of RoF structures (roughly 1% of RoF structures go to non-RoF). At larger symmetrization parameters (≈ 1 Å), this increases to roughly 6% based upon the large deviations allowed in considering sites as symmetrically equivalent. Credit: npj Computational Materials (2024). DOI: 10.1038/s41524-024-01248-z© Provided by Phys.org

Scientists are normally happy to find regularities and correlations in their data—but only if they can explain them. Otherwise, they worry that those patterns might just be revealing some flaw in the data itself, so-called experimental artifacts.

That's what scientists in Nicola Marzari's group at the Swiss Federal Institute for Technology in Lausanne (EPFL) worried about when they noticed an unexpected pattern in two widely used databases of electronic structures, the [Materials Project \(MP\) database](#) and the [Materials Cloud 3-dimensional crystal structures 'source' database \(MC3Dsource\)](#).

The two collections include over 80,000 electronic structures of experimental as well as predicted materials, and in principle, all types of structures should be equally represented. However, scientists noticed that around 60 percent of structures in both databases have primitive unit cells (the smallest possible cell in a crystal structure) made out of a multiple of 4 atoms. The scientists named this recurrence the "Rule of Four" and started looking for an explanation.

"A first intuitive reason could come from the fact that when a conventional unit cell (a larger cell than the primitive one, representing the full symmetry of the crystal) is transformed into a primitive cell, the number of atoms is typically reduced by four times," says Elena Gazzarini, a former INSPIRE Potentials fellow in the Laboratory of Theory and Simulation of Materials (THEOS) at EPFL and now at CERN in Geneva.

"The first question we asked was whether the software used to 'primitivize' the unit cell had done it correctly, and the answer was yes."

From a chemical point of view, another possible suspect was the coordination number of silicon (the number of atoms that can bind to its atom), which is four. "We could expect to find that all the materials following this Rule of Four included silicon," says Gazzarini. "But again, they did not."

The formation energies of the compounds could not explain the Rule of Four either. "The materials that are most abundant in nature should be the most energetically favored, which means the most stable ones, those with negative formation energy," says Gazzarini. "But what we saw with classic computational methods was that there was no correlation between the Rule of Four and negative formation energies."

Because the materials space covered by the two databases is huge, going from small units to very large cells with dozens of different chemical species, there was still a chance that a more refined analysis looking for a correlation between formation energies and chemical properties may provide an explanation.

So, the team involved Rose Cernosky, a machine-learning expert at the University of Wisconsin, who developed an algorithm to group structures according to their atomic properties and look at formation energies within classes of materials sharing some chemical similarities. But again, this method did not provide a way to distinguish the Rule-of-Four compliant materials from the non-compliant ones.

Similarly, the abundance of multiple of fours does not even correlate with highly symmetric structures but rather with low symmetries and loosely packed arrangements.

In the end, the resulting [article in *npj Computational Materials*](#) is the rare example of a scientific paper describing a negative result: the researchers could only describe the phenomenon and rule out several possible causes, without finding one.

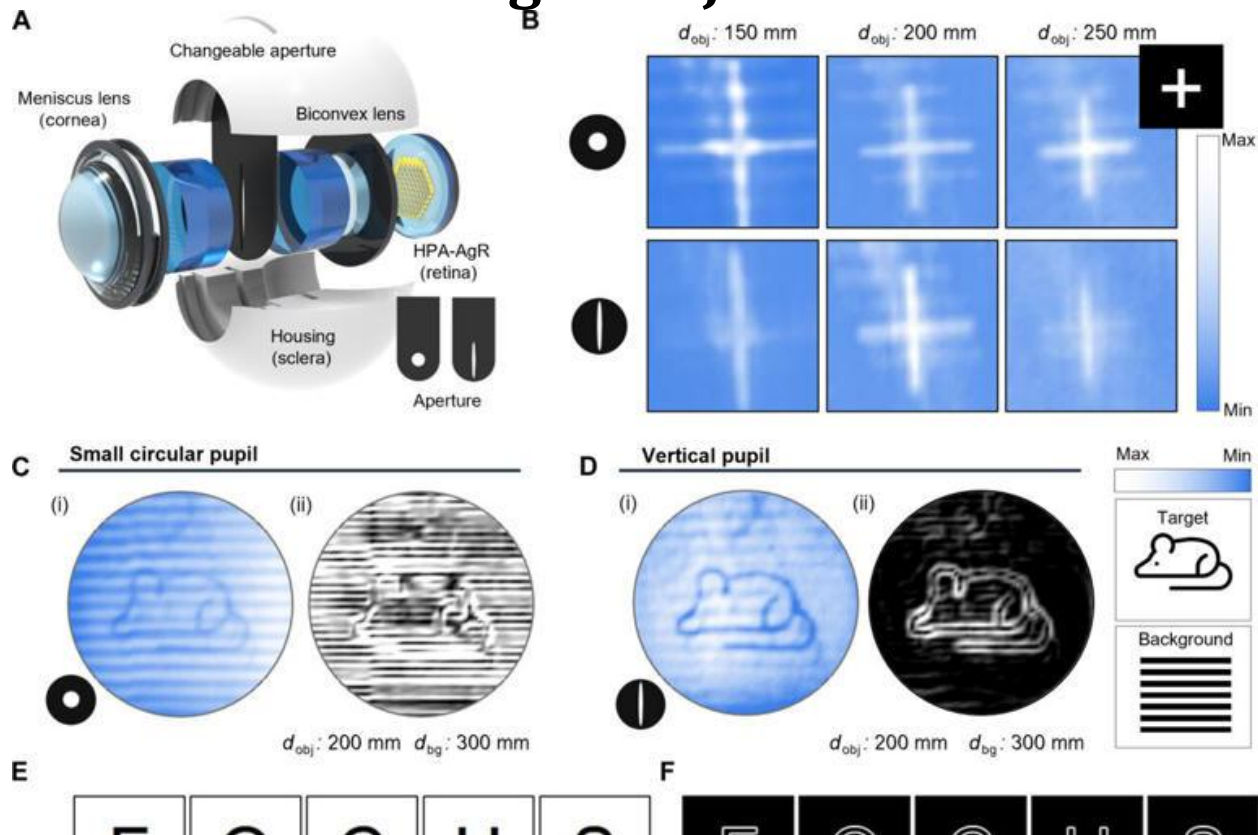
But negative results can be just as important as positive ones for scientific advancement, because they point to difficult problems—which is why scientists often complain that journals should publish more such studies.

The failure to find a compelling explanation did not prevent the group from predicting, through a Random Forest algorithm, with an accuracy of 87% whether a given compound will follow the Rule of Four or not. "This is interesting because the algorithm uses only local rather than global symmetry descriptors, which suggests that there may be small chemical groups in the cells (still to be found) that may explain the Rule of Four," says Gazzarini.

More information: Elena Gazzarrini et al, The rule of four: anomalous distributions in the stoichiometries of inorganic compounds, *npj Computational Materials* (2024). DOI: [10.1038/s41524-024-01248-z](https://doi.org/10.1038/s41524-024-01248-z)

Provided by National Centre of Competence in Research (NCCR) MARVEL

Scientists mimic cat eyes to create artificial eye that sees better in the dark, detects camouflaged objects

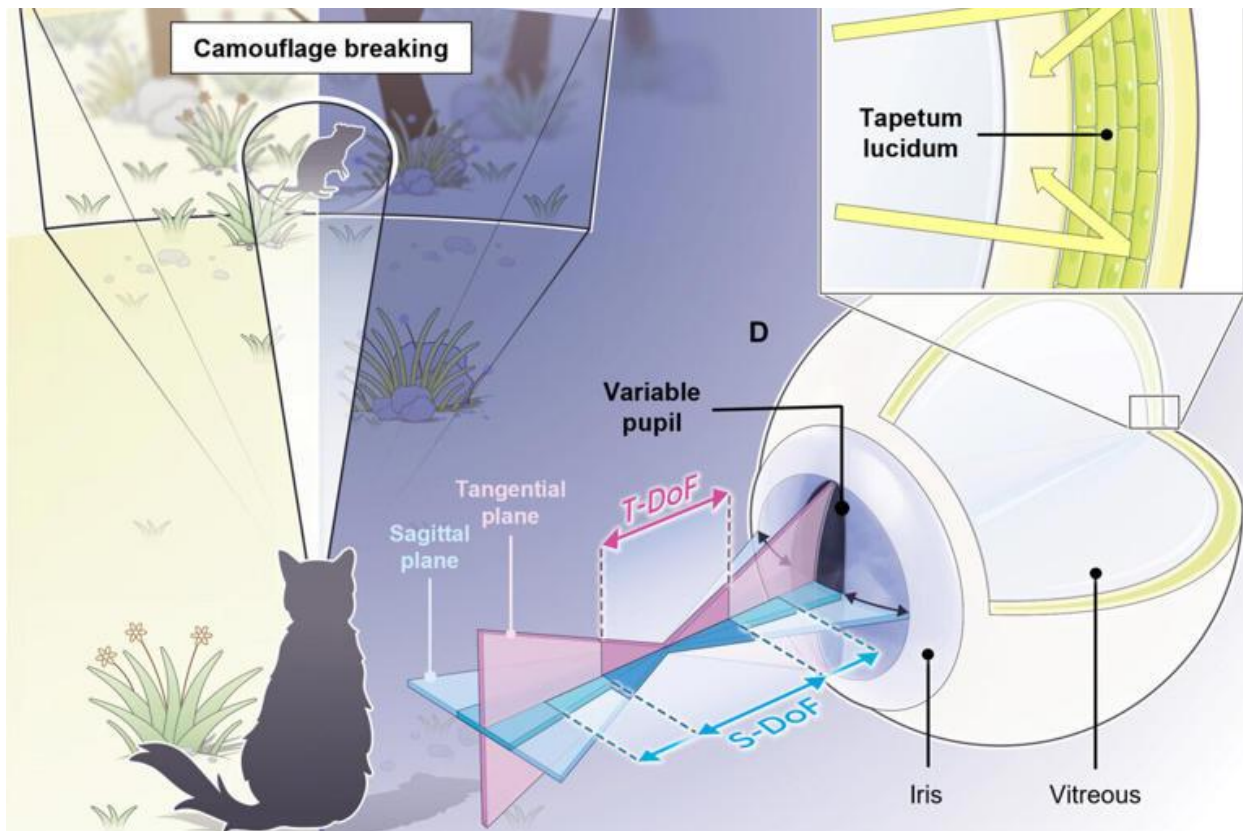


Imaging demonstration of the feline eye-inspired vision system. Credit: Science Advances (2024). DOI: 10.1126/sciadv.adp2809

A team of engineers from the Center for Nanoparticle Research, Seoul National University, the Gwangju Institute of Science and Technology and the Korea Institute of Science and Technology, all in Korea, has developed a new type of artificial eye based on natural cat eyes.

In their study [published](#) in the journal *Science Advances*, the group copied two features of cat eyes that give them unique abilities to see in the dark and to detect camouflaged objects.

As the researchers note, cameras installed on drones and robots are based on circular apertures that mimic the human eye, an approach that results in imagery with both a foreground subject and the background kept in focus. This approach sometimes makes it difficult for the camera to keep track of the target object.



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US creates strongest-ever armor material with 100 trillion bonds per cm²

A research team led by scientists at Northwestern University has developed the first-ever two-dimensional mechanically interlocked material with high flexibility and strength. In the future, this could be used to develop lightweight yet high-performance body armor and other such tough materials, a press release said.

It was in the 1980s that Fraser Stoddart, then a chemist at Northwestern University, first introduced the concept of mechanical bonds. Stoddart then expanded the role of these bonds into molecular machines by enabling functions like switching, rotating, contracting, and expanding in multiple ways and using them to develop interlocked structures, which also won him the Nobel Prize in 2016.

Researchers have been working on developing mechanically interlocked molecules with polymers for decades but have failed. "In organic chemistry, it is pretty straightforward to form so-called "medium-sized rings" that are 5-8 atoms around. But such rings are too small to thread another molecule through them," explained William Dichtel, a professor of chemistry at Northwestern University in an email to *Interesting Engineering*.

"In our paper, there are new rings formed at each repeat unit of the 2D structure, which are 40 atoms around," added Dichtel. This was achieved using an innovative and novel approach that even questioned assumptions about how molecules react.

A novel process

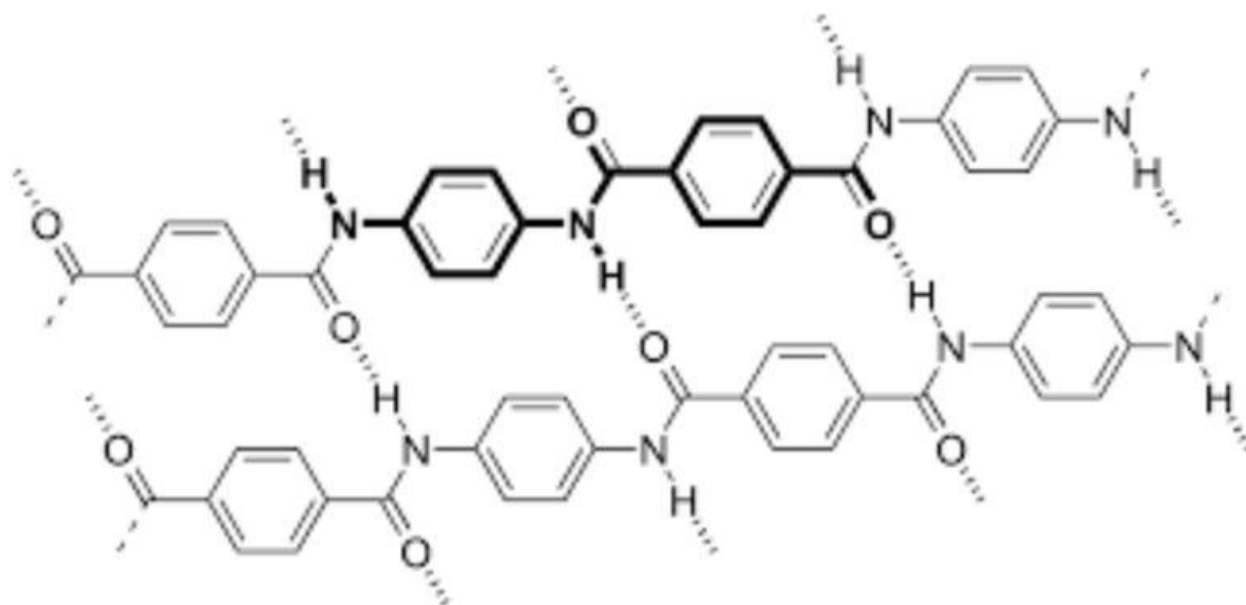
Madison Bardot, a Ph.D candidate in Dichtel's lab, developed a novel process using X-shaped monomers as building blocks and arranging them into highly ordered crystalline structures. They then used another molecule to create bonds between molecules of the crystal.

The resulting material consists of layers of two-dimensional (2D) polymer sheets where ends of X-shaped monomers are interlocked with ends of other X-shaped monomers, and more monomers are threaded through the gaps in between.

Together, the material consists of 100 trillion mechanical bonds per square centimeter, the highest density ever achieved.

Interestingly, the team also found that dissolving the polymer in the solution allowed the interlocked monomers to peel off each other, enabling the manipulation of individual sheets.

“Many highly crystalline substances are brittle, but our polymer has a regular, ordered structure yet is highly flexible because each mechanical bond has a little bit of space to move around,” explained Dichtel in the email to *IE*.



Chemical structure of Kevlar. Image credit: Wikimedia Commons

“When one applies a light force to the polymer, it is extremely flexible, but if more force is applied the material becomes more rigid as the mechanical bonds are stretched locally to their limits. This property is called “strain hardening” and is of great interest for ductile and mechanically tough materials.”

Beyond mechanical properties, the polymer architecture has interesting properties that can be explored for new applications.

Strength to strength

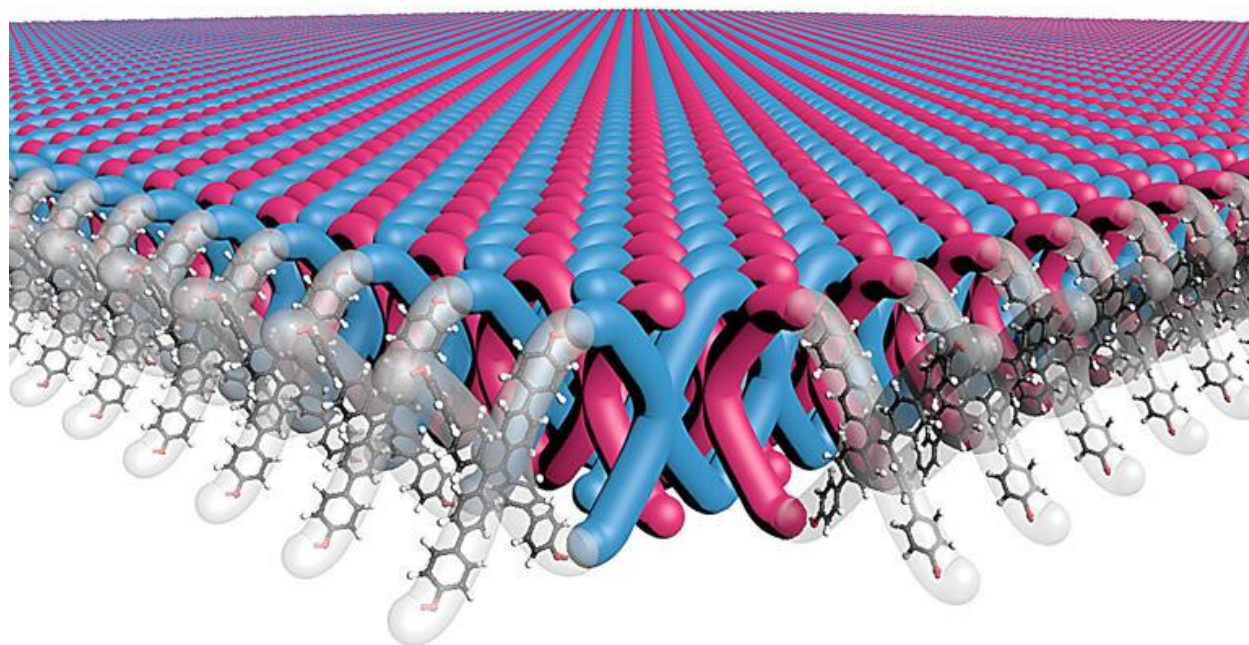
Dichtel's collaborators at Duke University added this newly developed polymer to Ultem, a fiber in the same family as [Kevlar](#) but which can withstand extreme temperatures and chemical exposure. Using just 2.5 percent of the polymer dramatically increased its strength and toughness. This could be used for making [armor](#) or ballistics protection.

While polymers containing mechanical bonds have previously been synthesized at a small scale, this approach helped Dichtel's team easily make almost a pound (half a kilogram) of the material. This also shows that the approach is highly scalable as well.

"Perhaps the most challenging aspect was proving to ourselves that we indeed had the proposed mechanically interlocked structure – it took a team of diverse expertise – synthetic chemists, electron microscopists, polymer engineers – to figure out how to make the materials and then how to actually study them," added Dichtel in the email.

The research findings were published in the journal [Science](#).

New chainmail-like material could be the future of armor



This illustration shows how X-shaped monomers are interlinked to create the first 2D mechanically interlocked polymer. Similar to chainmail, the material exhibits exceptional strength. Credit: Mark Seniw, Center for Regenerative Nanomedicine, Northwestern University

In a remarkable feat of chemistry, a Northwestern University-led research team has developed the first two-dimensional (2D) mechanically interlocked material.

Resembling the interlocking links in chainmail, the nanoscale material exhibits exceptional flexibility and strength. With further work, it holds promise for use in high-performance, lightweight body armor and other uses that demand lightweight, flexible and tough materials.

Publishing on Jan. 17 in the journal *Science*, [the study](#) marks several firsts for the field. Not only is it the first 2D mechanically interlocked polymer, but the novel material also contains 100 trillion mechanical bonds per 1 square centimeter—the highest density of mechanical bonds ever achieved.

The researchers produced this material using a new, highly efficient and scalable polymerization process.

"We made a completely new polymer structure," said Northwestern's William Dichtel, the study's corresponding author.

"It's similar to chainmail in that it cannot easily rip because each of the mechanical bonds has a bit of freedom to slide around. If you pull it, it can dissipate the applied force in multiple directions. And if you want to rip it apart, you would have to break it in many, many different places. We are continuing to explore its properties and will probably be studying it for years."

Dichtel is the Robert L. Letsinger Professor of Chemistry at the Weinberg College of Arts and Sciences and a member of the International Institute of Nanotechnology (IIN) and the Paula M. Trienens Institute for Sustainability and Energy. Madison Bardot, a Ph.D. candidate in Dichtel's laboratory and IIN Ryan Fellow, is the study's first author.

Inventing a new process

For years, researchers have attempted to develop mechanically interlocked molecules with polymers but found it near impossible to coax polymers to form mechanical bonds.

To overcome this challenge, Dichtel's team took a whole new approach. They started with X-shaped monomers—which are the building blocks of polymers—and arranged them into a specific, highly ordered crystalline structure. Then, they reacted these crystals with another molecule to create bonds between the molecules within the crystal.

"I give a lot of credit to Madison because she came up with this concept for forming the mechanically interlocked polymer," Dichtel said. "It was a high-risk, high-reward idea where we had to question our assumptions about what types of reactions are possible in molecular crystals."

The resulting crystals comprise layers and layers of 2D interlocked polymer sheets. Within the polymer sheets, the ends of the X-shaped monomers are bonded to the ends of other X-shaped monomers. Then, more monomers are

threaded through the gaps in between. Despite its rigid structure, the polymer is surprisingly flexible.

Dichtel's team also found that dissolving the polymer in solution caused the layers of interlocked monomers to peel off each other.

"After the polymer is formed, there's not a whole lot holding the structure together," Dichtel said. "So, when we put it in solvent, the crystal dissolves, but each 2D layer holds together. We can manipulate those individual sheets."

To examine the structure at the nanoscale, collaborators at Cornell University, led by Professor David Muller, used cutting-edge electron microscopy techniques. The images revealed the polymer's high degree of crystallinity, confirmed its interlocked structure and indicated its high flexibility.

Dichtel's team also found the new material can be produced in large quantities. Previous polymers containing mechanical bonds typically have been prepared in very small quantities using methods that are unlikely to be scalable. Dichtel's team, on the other hand, made half a kilogram of their new material and assume even larger amounts are possible as their most promising applications emerge.

Adding strength to tough polymers

Inspired by the material's inherent strength, Dichtel's collaborators at Duke University, led by Professor Matthew Becker, added it to Ultem. In the same family as Kevlar, Ultem is an incredibly strong material that can withstand extreme temperatures as well as acidic and caustic chemicals.

The researchers developed a composite material of 97.5% Ultem fiber and just 2.5% of the 2D polymer. That small percentage dramatically increased Ultem's overall strength and toughness.

Dichtel envisions his group's new polymer might have a future as a specialty material for light-weight body armor and ballistic fabrics.

"We have a lot more analysis to do, but we can tell that it improves the strength of these composite materials," Dichtel said. "Almost every property we have measured has been exceptional in some way."

Steeped in history

The authors dedicated the paper to the memory of former Northwestern chemist Sir Fraser Stoddart, who introduced the concept of mechanical bonds in the 1980s. Ultimately, he elaborated these bonds into molecular machines that switch, rotate, contract and expand in controllable ways.

Stoddart, [who passed away last month](#), received the [2016 Nobel Prize in Chemistry](#) for this work.

"Molecules don't just thread themselves through each other on their own, so Fraser developed ingenious ways to template interlocked structures," said Dichtel, who was a postdoctoral researcher in Stoddart's lab at UCLA.

"But even these methods have stopped short of being practical enough to use in big molecules like polymers. In our present work, the molecules are held firmly in place in a crystal, which templates the formation of a mechanical bond around each one.

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Provided by Northwestern University

Researchers design mind-blowing construction material to replace steel: 'This technology holds a lot of promise'

Researchers at the University of Maine have managed to 3D print an organic building material with the strength of steel.

The SM2ART Nfloor is printed as a single piece in about 30 hours, which is a third faster than building something comparable by hand according to [TechXplore](#).

The nice thing about this set-up is that these panels can be printed in bulk off-site and get shipped to the construction area. Since there are already channels in the floor for electrical and plumbing, the only other thing that needs to be applied by hand is soundproofing and floor covering.

The Nfloor's material is a bioplastic made of roughly 20% bamboo and 80% polylactic acid (PLA). PLA is a common material in 3D printing and fully biodegradable as it is made of corn residue and wood flour from lumber processing. PLA can also be effectively [recycled](#) to be used again when needed.

Acoustic Pinot Norde For many people, installing sound dampening panels

 Smart Tech

Smart Inventions Transforming Construction

The Nfloor has the dual benefits of a graceful end of life and highly scalable production. When affordable housing is a real challenge across the world, it's important to be able to provide solutions that speed up construction. Work on the Nfloor is ongoing, including fire retardant improvements.

"The next steps will be to make the manufacturing process faster, more efficient and cost-effective with additional functionality," said Scott Tomlinson, structural engineer with the University of Maine's Advanced Structures and Composites Center, per [TechXplore](#). "This [technology](#) holds a lot of promise for the future of sustainable buildings."

Watch now: This 'win-win-win' app offers up to 50% savings on food

The researchers had previously put together [a demo home](#) using similar 3D printing techniques.

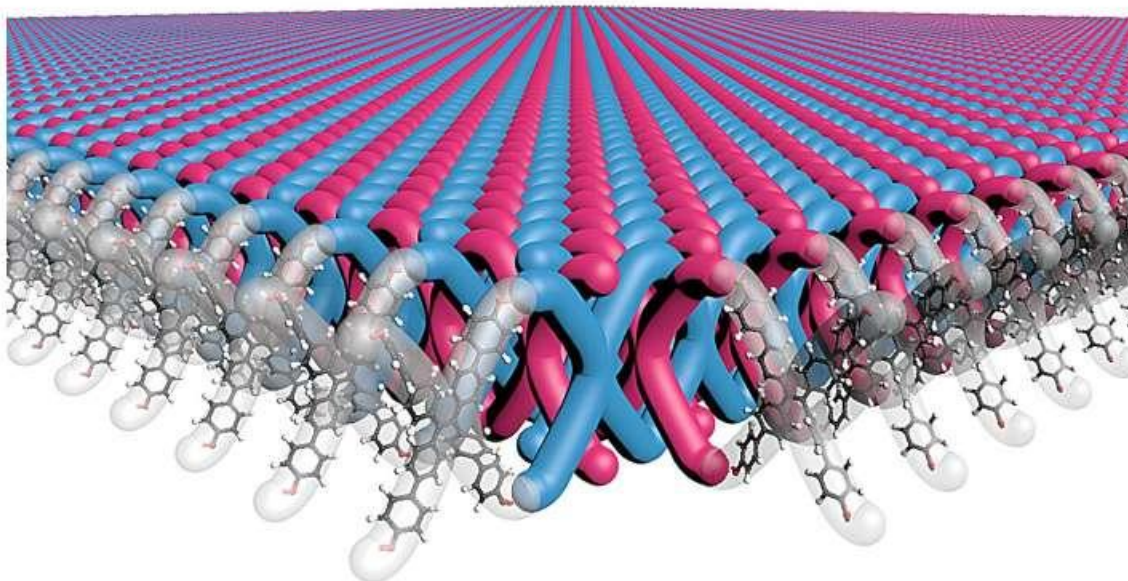
While 3D printing is gradually getting [more use in construction](#), we've seen loads of exciting developments using the technology. A new resin type is showing promise for [improved recyclability](#), new 3D-printed metal can provide [improvements in aviation](#), and 3D-printed monoliths can [extract toxins](#)

from water.

JANUARY 16, 2025

New chainmail-like material could be the future of armor

by [Northwestern University](#)



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Journal information: [Science](#)

Provided by [Northwestern University](#)

Superman-like alloy defies laws of heat, withstands 400 Kelvin with zero expansion

The pyrochlore magnet's exceptional performance is due to its non-uniform structure.

Updated: Feb 04, 2025



Metal usually expands when heated

Things are known to expand when they get hot. Bridges, roads, and even the Eiffel Tower grow a little taller in the summer.

The Eiffel Tower's height changes by 10 to 15 centimeters between summer and winter due to thermal expansion. It's taller in the summer when the metal is warmer and expands.

However, this expansion can be a real problem for many technologies like precision instruments or spacecraft. That's why scientists have been searching for a material that maintains a constant size regardless of temperature changes. One potential candidate is

Invar — an iron-nickel alloy famous for its incredibly low thermal expansion. But the science behind Invar’s magic remained a mystery, until now

Researchers at TU Wien in Vienna teamed up with experimentalists at the University of Science and Technology Beijing to unravel Invar’s secret using computer simulations.

Interestingly, this new understanding led to the development of a new superman-like strong alloy called a pyrochlore magnet.

“The higher the temperature in a material, the more the atoms tend to move – and when the atoms move more, they need more space. The average distance between them increases,” explained Sergii Khmelevskiy from the Vienna Scientific Cluster (VSC) Research Centre at TU Wien.

“This effect is the basis of thermal expansion and cannot be prevented. But it is possible to produce materials in which it is almost exactly balanced out by another, compensating effect,” Khmelevskiy added.

Pyrochlore magnet’s less thermal expansion

The research began with an investigation into Invar’s unusual property of low thermal expansion. They found that its magnetic properties are the key to its stability.

“The effect is due to certain electrons changing their state as the temperature rises. The magnetic order in the material decreases, causing the material to contract. This effect almost exactly cancels the usual thermal expansion,” said Khmelevskiy.

This new theoretical framework based on simulations allowed scientists to predict and design materials that exhibit almost no change in size with temperature.

With this new understanding, the team set out to create an even better material. And they succeeded.

Researchers developed a new alloy, the pyrochlore magnet, which exhibits even less thermal expansion than Invar.

The pyrochlore magnet exhibits incredibly stable dimensions across a wide temperature range of over 400 Kelvins (126.8 degrees Celsius). Interestingly, it changes by only “one ten-thousandth of one percent per Kelvin.”

Composed of four metals

The Invar is made of two metals, but the pyrochlore magnet is composed of four: zirconium, niobium, iron, and cobalt. This more complex composition gives it an unprecedented ability to resist thermal expansion.

“It is a material with an extremely low coefficient of thermal expansion over an unprecedentedly wide temperature range,” said Yili Cao from the Institute of the Solid State Chemistry of the University of Science and Technology Beijing, in a [press release](#).

This new [alloy](#)’s exceptional thermal stability is due to its irregular, heterogeneous structure.

Its composition varies throughout, with differing concentrations of elements like cobalt. This influences how different regions of the material respond to temperature changes. Moreover, it balances the material’s properties at each point to achieve near-zero overall thermal expansion.

Navy HELIOS Laser Aboard USS Preble Zaps Drone In Latest Test

Service brass have clamored to get shipboard laser weapons operational, as other similar systems have suffered delays and cancellations

83



(DOD)

The Navy has disclosed that the *Arleigh Burke* class destroyer USS *Preble* successfully test-fired its High-Energy Laser with Integrated Optical Dazzler and Surveillance (HELIOS) system to take out an aerial target drone in Fiscal Year 2024. It was the latest major demonstration of the surface fleet's shipboard laser ambitions, even as other U.S. military laser efforts have faced [a reality check](#) in recent years.

Preble's drone zapping was “to verify and validate the functionality, performance and capability” of HELIOS, and this latest step toward moving shipboard lasers into a fully operational state was revealed in the Pentagon's annual [Director, Operational Test and Evaluation \(DOTE\) report](#) that was released Friday night.

Little else was disclosed in the DOTE report regarding where and when *Preble*, a Flight IIA *Arleigh Burke* subvariant, fired its laser. The warship [shifted homeports](#) from San Diego to Japan in September, just a few days before the end of FY24. *TWZ* has reached out to the Navy for more information on the test and where HELIOS currently stands, and this report will be updated when that information comes in.



A rendering of the HELIOS system in action aboard a Navy destroyer. (Lockheed Martin)

Either way, it's a capability that Navy brass has been [increasingly clamoring for](#), especially in the past year, as Navy warships shoot down an at-times daily barrage of drones and missiles fired by [Iran-backed Houthi rebels](#) over the Red Sea and Gulf of Aden. Those battles and other global flashpoints [have raised continued concerns](#) about the Navy draining its finite missile stocks, as the pacing threat of China looms on the horizon. *TWZ* has reported on several aspects of the Navy's battle against the Houthis, including [a tally of ordnance expended](#) during more than 400 engagements against [the Houthi arsenal](#) of aerial drones, anti-ship cruise missiles, and anti-ship ballistic missiles.

“When I was in Bahrain as [the Destroyer Squadron 50 commanding officer] 10 years ago, the afloat staging base [USS Ponce had a laser on it](#),” Naval Surface Forces Commander Vice Adm. Brendan McLane told reporters in early 2024, before the Surface Navy Association conference. “We’re 10 years down the road, and we still don’t have something we can field?”

Indeed, the 60-kilowatt HELIOS and other long-promised directed-energy weapons have been a long time coming for the surface fleet. As [TWZ previously reported](#), it was first spotted aboard [Preble](#) in 2022. Its debut predates the Houthi fight, but is the type of system that would seem primed to help, at least to a limited degree, ease missile expenditures during similar operations.



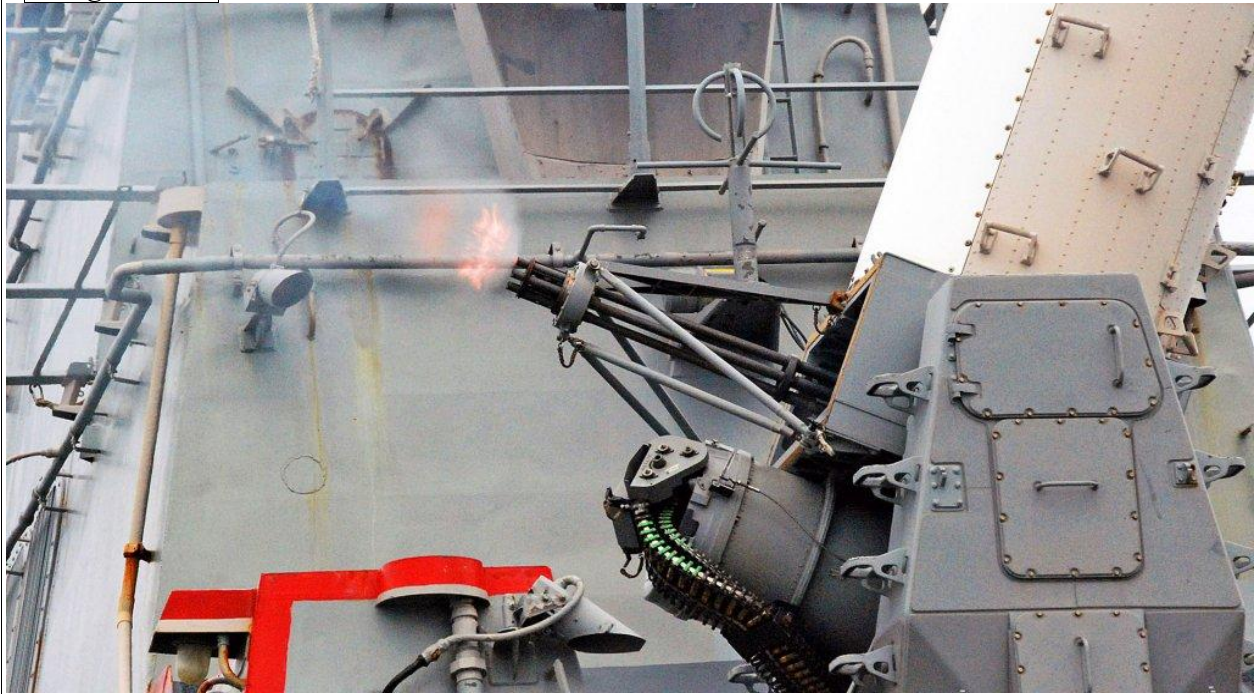
The High-Energy Laser with Integrated Optical Dazzler and Surveillance (HELIOS) laser directed energy weapon installed on the Navy destroyer USS [Preble](#), with an inset showing a rendering of the system. (U.S. Navy/Lockheed Martin)

[TWZ’s past reporting](#) on HELIOS points to why it would be so useful for taking out drone attacks and disabling or destroying [small boats](#), both manned and unmanned, with nefarious intent.

It can also [serve as a “dazzler” to blind or confuse](#) optical seekers on incoming missiles and drones. The dazzler can limit an opponent’s general situational awareness by denying their sensors the ability to surveil the ship. HELIOS also sports its own optical sensors, which can serve a secondary intelligence, surveillance, and reconnaissance (ISR) role.

On [Preble](#), HELIOS sits on the warship’s main forward pedestal that hosted the [Mk 15 Phalanx Close-In Weapons System](#) (CIWS) on earlier [Arleigh Burke](#) class destroyer variants. Flight IIA destroyers [currently have only one CIWS installed](#) above the hangar bay. Outside of the handful of destroyers [modified to the ‘Rota configuration,’ which feature](#) SeaRAM and Phalanx, Flight

I [Arleigh Burkes](#) feature two CIWS, front and rear.



The Phalanx Close-In Weapons System (CIWS). (U.S. Navy)

Lockheed Martin received its first contract from the Navy for work on HELIOS in 2018, but the system builds on [a much longer history](#) of directed energy research and [development at the company](#).

The system is particularly powerful when paired with [the Aegis Combat System](#). Rich Calabrese, director of Surface Navy Mission Systems for Lockheed Martin, expounded on HELIOS and Aegis during a broader interview [with The War Zone](#) in 2021:

“We’re continuously upgrading the multi-source integration infusion capability of the Aegis weapon system and looking to bring in new weapons and sensors and do coordinated hard kill and soft kill. Directed energy weapons ... We’re really already integrating the HELIOS Laser Weapon System with the Aegis Weapon System CSL [Common Source Library] in our lab here in New Jersey. In fact, we’ve ... The guy who’s now managing the laser program ... He let me know the other day that we recently fired a laser here under the control of the Aegis Weapon System computer program. So, we’re building in the capability to do that weapon coordination and to do the hard kill, soft kill coordination in an automated fashion working with the HELIOS Weapon System.”



The HELIOS laser system sits on a pedestal in front of the USS *Preble's* bridge. (U.S. Navy) Petty Officer 2nd Class Malcolm KelleyLockheed Martin is contracted to [deliver at least one more](#) HELIOS system for an *Arleigh Burke*. Company officials said they designed the system with future capability growth in mind as well, including increasing the system's maximum power [up to 150 kilowatts](#).

Such a power level would allow HELIOS to more rapidly down smaller drones at longer ranges and take on bigger and more complex threats, such as anti-ship cruise missiles and even enemy aircraft, albeit still at relatively shorter distances.

The Navy and Lockheed Martin demonstrated the ability of a solid-state laser directed energy weapon [to successfully shoot down](#) a target drone acting as a surrogate for a subsonic cruise missile in 2022, using a weapon called the [Laser Layered Defense](#) (LLD) system, during a test at the U.S. Army's White Sands Missile Range in New Mexico.

HELIOS constitutes one facet of the Navy's directed energy ambitions, which are now set to eventually include [high-power microwave-based systems](#) as well. Fellow destroyers, including the *USS Dewey* and *USS Stockdale*, are now equipped with the less powerful [Optical Dazzling Interdictor, Navy](#) (ODIN). Unlike HELIOS, ODIN's laser can only be used as a dazzler, but it also has secondary surveillance capabilities.

In late 2021, the year before HELIOS debuted aboard the *Preble*, the *San Antonio* class amphibious transport dock ship *USS Portland* engaged a static surface target with [its laser directed energy weapon](#) in the Gulf of Aden. That system, known as the [Laser Weapon System Demonstrator](#) Mk 2 Mod 0, was placed aboard *Portland* in late 2019, which *The War Zone was first to report*, and subsequently used to [knock down a small drone](#) in a demonstration in the Pacific Ocean in 2020.

All told, the Pentagon is spending an average of \$1 billion annually to develop such weapons for ships, aircraft and ground vehicles, [Navy Times reported](#) last year.

But figuring out how to develop, procure and field such technology has proven challenging, according to [a 2023 Government Accountability Office](#) (GAO) report.



The Navy amphibious transport dock USS [Portland](#) uses a laser to strike a static surface target in 2021. (U.S. Navy)

The Defense Department has struggled to get “these technologies out of the lab and into the field” for a number of reasons, including difficulty in determining how the force would use them during missions, according to the federal watchdog. “Without early transition planning and drafting transition agreements, the Navy risks developing technology that is misaligned with operational needs,” the report warned.

The realities of actually deploying and sustaining advanced laser weapons in the field, and just how effective they can be at this time, [are also becoming clearer](#). These revelations have led to the DoD [stepping back from some key](#), long-touted, laser weapons programs recently.



The U.S. Air Force scrapped plans to flight test a laser directed energy weapon on an AC-130J Ghost Rider gunship. (U.S. Air Force)

Generally, laser weapon systems are chronically over-hyped, especially in the mainstream media, compared to what they can realistically achieve. Laser weapons can only engage one target at a time and they need to dwell on that target steadily for a prolonged period to have an effect, especially lower power-class examples that are fielded today. They also have power and thermal limitations that impact how many shots they can fire back-to-back.

Their range is limited and impacted by atmospheric conditions and their components are delicate and hardening them for hash military use is an ongoing process. So, even in a naval sense, while they still are a very attractive capability, they are for low-volume point defense cases against very limited target sets for the foreseeable future.



The Navy destroyer USS [Preble](#) arrives at its new homeport in Yokosuka, Japan, in October. (U.S. Navy)

Those realities haven't stopped Navy brass from continuing to hammer the need for shipboard lasers. U.S. Fleet Forces Command head Adm. Daryl Caudle lamented the glacial pace of laser development at last month's Surface Navy Association annual symposium, [Breaking Defense's](#) Justin Katz reported.

"There's been many a thesis and dissertation written on building lasers on ships, but we've not transitioned that into a place where that's an acceptable way to actually take out missile systems," Katz quoted Caudle as saying.

"These things are based on renewable energy, so I can recharge the system ... I don't have to worry about payload [or] volume with directed energy. All those things are appealing to a navy, [but] we just haven't really matriculated that into a place ... that's ready for prime time," Caudle continued.

Even as the Navy proceeds with shipboard laser programs like HELIOS, the timing as to when they will actually become a widespread and robust capability remains unclear. Still, recent events are likely to only increase pressure to make shipboard laser weapons a commonplace reality within the U.S. Navy.

FEBRUARY 20, 2025

France's parliament votes to ban some uses of 'forever chemicals'

by Stephanie Lerouge



Ski wax containing the chemicals has been found to pollute remote mountain slopes. France's parliament on Thursday voted to limit the production and sale of some items containing polluting and health-threatening "forever chemicals" including cosmetics, most clothing and ski wax in the Alpine nation.

The lower-house National Assembly adopted the bill put forward by the Greens 231 votes to 51, after the upper-house Senate gave it a green light last year.

President Emmanuel Macron still needs to sign it into law.

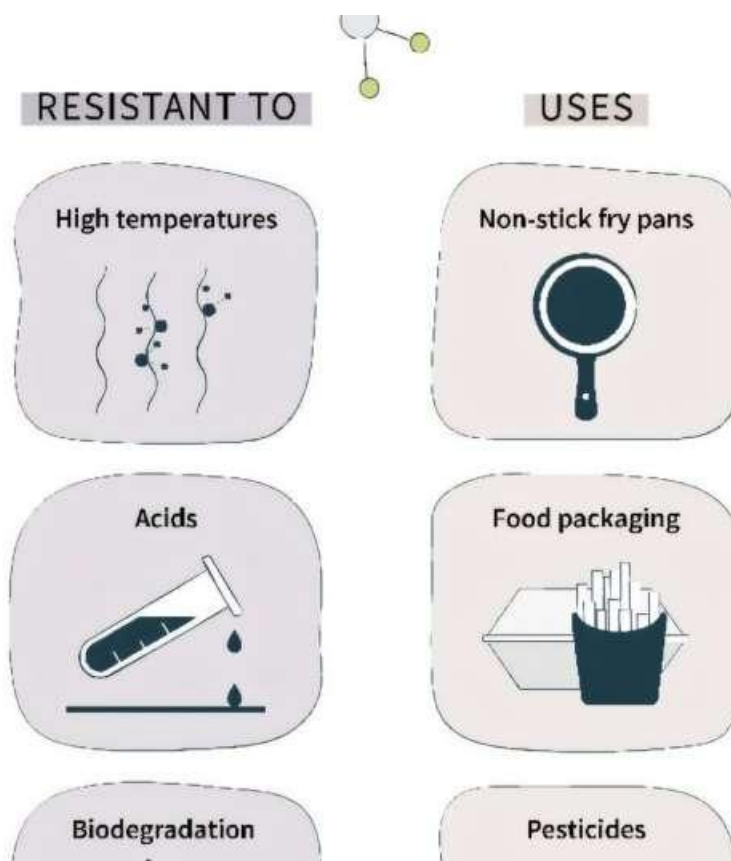
Per- and [polyfluoroalkyl substances](#) (PFAS) are human-made chemicals used since the late 1940s to mass produce the non-stick, waterproof and stain-resistant treatments that coat everything from frying pans to umbrellas, carpets, dental floss and ski wax.

Because PFAS take an extremely long time to break down—earning them their "forever" nickname—they have seeped into the soil and groundwater, and from there into the food chain and drinking [water](#).

These chemicals have been detected virtually everywhere on Earth, from the top of Mount Everest to inside human blood and brains.

Chronic exposure to even low levels of the chemicals has been linked to [liver damage](#), [high cholesterol](#), reduced immune responses, low birthweights and several kinds of cancer.

The French bill aims to prevent the production, import or sale from January 2026 of any product for which an alternative to PFAS already exists.



Graphic showing properties and some product uses of a group of synthetic chemicals, Per- and Polyfluoroalkyl Substances (PFAS), also known as "forever" chemicals" which contaminate food and drinking water, posing serious risks to human health. These include cosmetics and ski wax, as well as clothing containing the chemicals, except certain "essential" industrial textiles.

A ban on non-stick saucepans was originally included in the draft law, but removed after intense lobbying from the group that owns French manufacturer Tefal.

It will also make French authorities regularly test drinking water for all kinds of PFAS.

There are thousands of different PFAS.

Under new EU regulations from next year, member states will have to test their water for 20 types.

But the French law could allow analysis to check for further types in water if needed.

In January, a study found that a type of "forever chemical" linked to health problems and [birth defects](#) has been found in the tap water of many French cities and towns including Paris.

A 2023 study of snow and [soil samples](#) in Austria found that skiers using ski wax containing PFAS to glide faster down the slopes were contaminating runways and soil in remote Alpine areas.



PFAS have seeped into the soil and groundwater, and from there into the food chain and drinking water.

It however added that a much smaller quantity could also be deposited from the atmosphere.

The European Union has been studying a possible ban on the use of PFAS in consumer products, but has not yet implemented such regulation.

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Scientists develop space-age metal that doesn't expand when heated



(CREDIT: CC BY-SA 4.0)© The Brighter Side of News

The Eiffel Tower grows taller in summer due to thermal expansion. While this effect is common in most metals, it poses challenges in precision engineering. Certain applications demand materials that maintain a stable size regardless of temperature. The search for such materials has led to discoveries in [zero thermal expansion](#) (ZTE) materials.

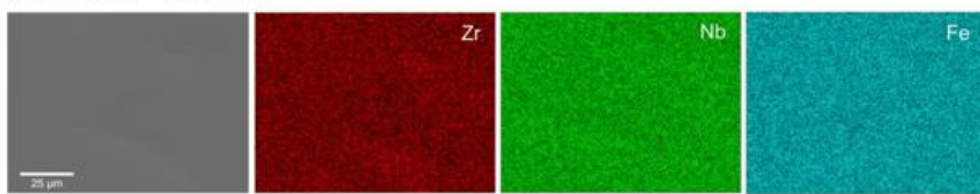
Atoms vibrate more as temperature rises, increasing the average space between them. This leads to expansion in most materials. However, some materials counteract this effect through compensating mechanisms. Magnetic materials, for instance, can contract when their magnetic order weakens with rising temperatures. This balance between expansion and contraction results in a stable material size.

One well-known example is Invar, an iron-nickel alloy with extremely low thermal expansion. However, the underlying physics behind its stability remained unclear. Recent advancements in [computer simulations](#) have provided a deeper understanding of this phenomenon, paving the way for new ZTE materials.

A Breakthrough in Zero Thermal Expansion

A collaboration between researchers at [TU Wien](#) and the [University of Science and Technology Beijing](#) led to the development of a new ZTE material. Using advanced computer models, scientists analyzed atomic-level interactions in magnetic materials. Their simulations revealed how specific electron behaviors influence thermal expansion.

(a) $\text{Zr}_{0.75}\text{Nb}_{0.25}\text{Fe}_2$



(b) $\text{Zr}_{0.75}\text{Nb}_{0.25}\text{Fe}_2\text{Co}_{0.1}$



(c) $\text{Zr}_{0.75}\text{Nb}_{0.25}\text{Fe}_2\text{Co}_{0.3}$



SEM images and EDS elemental maps of $\text{Zr}_{0.75}\text{Nb}_{0.25}\text{Fe}_2\text{Co}_y$ ($y = 0$ (a), 0.1 (b) and 0.3 (c)) samples of Zr, Nb, Fe or Co, which show uniform elemental distribution. (CREDIT: National Science Review)© The Brighter Side of News

Dr. Sergii Khmelevskiy from TU Wien explains, "The effect is due to certain electrons changing their state as the temperature rises. The magnetic order in the material decreases, causing it to contract. This effect almost exactly cancels out the usual thermal expansion."

With this knowledge, researchers predicted new materials with similar properties. Their predictions were tested in collaboration with an experimental team led by Prof. Xianran Xing and Assoc. Prof. Yili Cao. The result was a new alloy with even better thermal stability than Invar: the pyrochlore magnet. The research findings were published in the journal [National Science Review](#).

Pyrochlore Magnets: A New Class of ZTE Materials

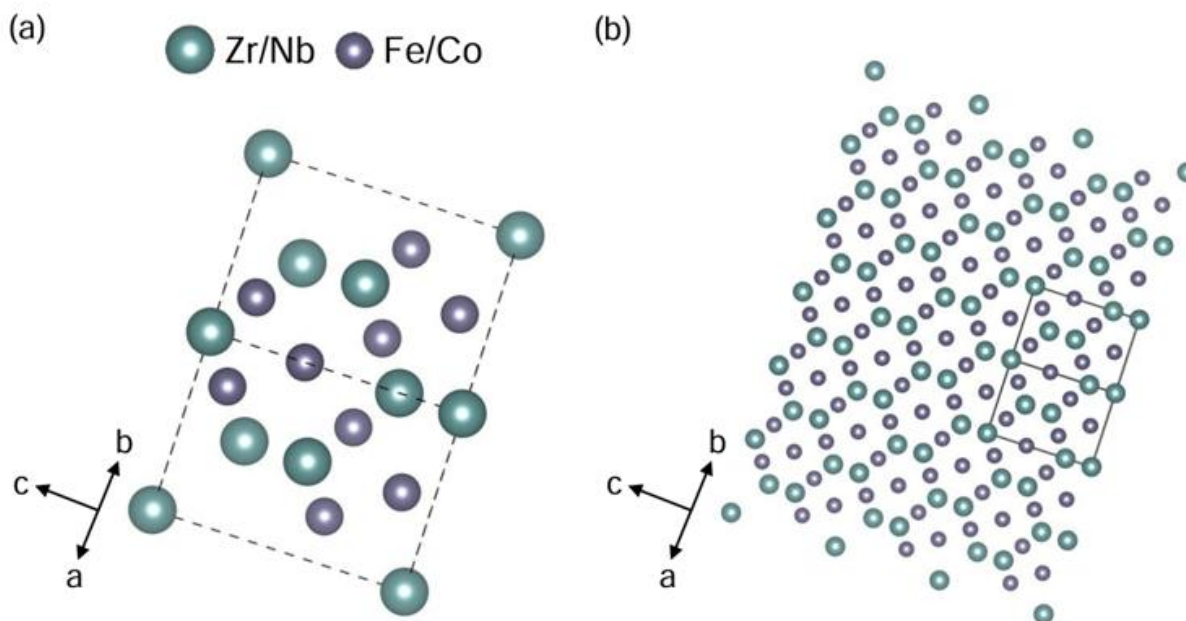
Unlike traditional invar alloys made from two metals, the new pyrochlore magnet consists of four elements: zirconium, niobium, iron, and cobalt. This combination results in an exceptionally low thermal expansion coefficient over a wide temperature range—approximately 3 to 440 K.

The material's unique behavior stems from its heterogeneous composition. Unlike a perfect crystalline lattice, its structure contains localized variations in element concentration. This non-uniformity allows different regions to respond to [temperature changes](#) in complementary ways, achieving near-zero overall expansion.

"The material has an extremely low coefficient of thermal expansion over an unprecedentedly wide temperature range," says Yili Cao. Its stability makes it highly desirable for precision applications, including aerospace engineering, semiconductor manufacturing, and scientific instruments.

The Role of Magnetic Order in ZTE

Magnetism plays a crucial role in achieving zero thermal expansion. The new pyrochlore magnet is a cubic lattice composed of corner-sharing tetrahedra. This unique arrangement fosters strong interactions between atomic spins, affecting thermal expansion behavior.



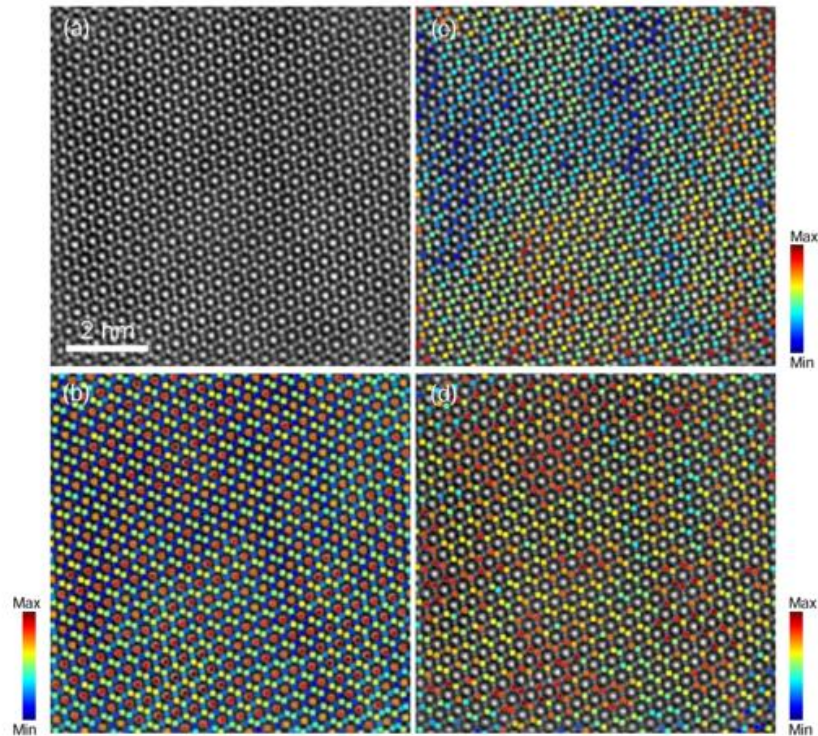
The cubic crystal structure of $(\text{Zr,Nb})\text{Fe}_2\text{Co}$ in a pyrochlore lattice. (CREDIT: National Science Review)© The Brighter Side of News

Researchers have long studied materials with negative thermal expansion (NTE), where substances shrink as they heat up. These materials, found in oxides, [fluorides](#), and certain metal alloys, have been used to engineer ZTE materials. However, past attempts were limited by narrow temperature ranges and structural impurities.

To enhance ZTE properties, scientists explored different approaches, including element substitution and lattice modifications. In one study, adding germanium altered the distortions in cubic $\text{Mn}_3\text{Cu}_{0.5}\text{Ge}_{0.5}\text{N}$, influencing its NTE characteristics. Similarly, controlled doping in ScF_3 -based materials improved their structural stability.

The new pyrochlore magnet achieves its stability through a nonstoichiometric approach. Excess [cobalt atoms](#) alter the lattice's magnetic interactions, stabilizing the material across a wide temperature range. Experimental techniques like neutron diffraction, Mössbauer spectroscopy, and synchrotron X-ray analysis confirmed these findings.

Beyond thermal stability, this new material exhibits excellent corrosion resistance in both acidic and alkaline environments. This makes it highly promising for real-world applications requiring durability in extreme conditions.



(a) HAADF-STEM image along the [110] zone axis of $\text{Zr}_{0.75}\text{Nb}_{0.25}\text{Fe}_2\text{Co}_y$ ($y = 0.1$); (b-d) The integrated intensity profile of the column of Zr/Nb or Fe/Co atoms. (CREDIT: National Science Review)© The Brighter Side of News

Future Applications of ZTE Materials

ZTE materials have broad applications in industries where thermal stability is critical. In aerospace engineering, components must endure drastic temperature fluctuations without deforming. [Satellite systems](#), for instance, experience temperature swings from -150°C to 150°C in space. A ZTE material prevents structural changes that could affect performance.

In semiconductor manufacturing, even minute expansions can disrupt microscopic circuits. The new pyrochlore magnet could lead to more stable electronic components, enhancing device reliability. High-precision optical instruments also benefit from ZTE materials, ensuring accurate measurements in varying temperatures.

The discovery of this new alloy marks a significant step forward in [material science](#). By understanding atomic-scale interactions, researchers can now design

materials with tailored thermal properties. This opens the door to future innovations in engineering and technology.

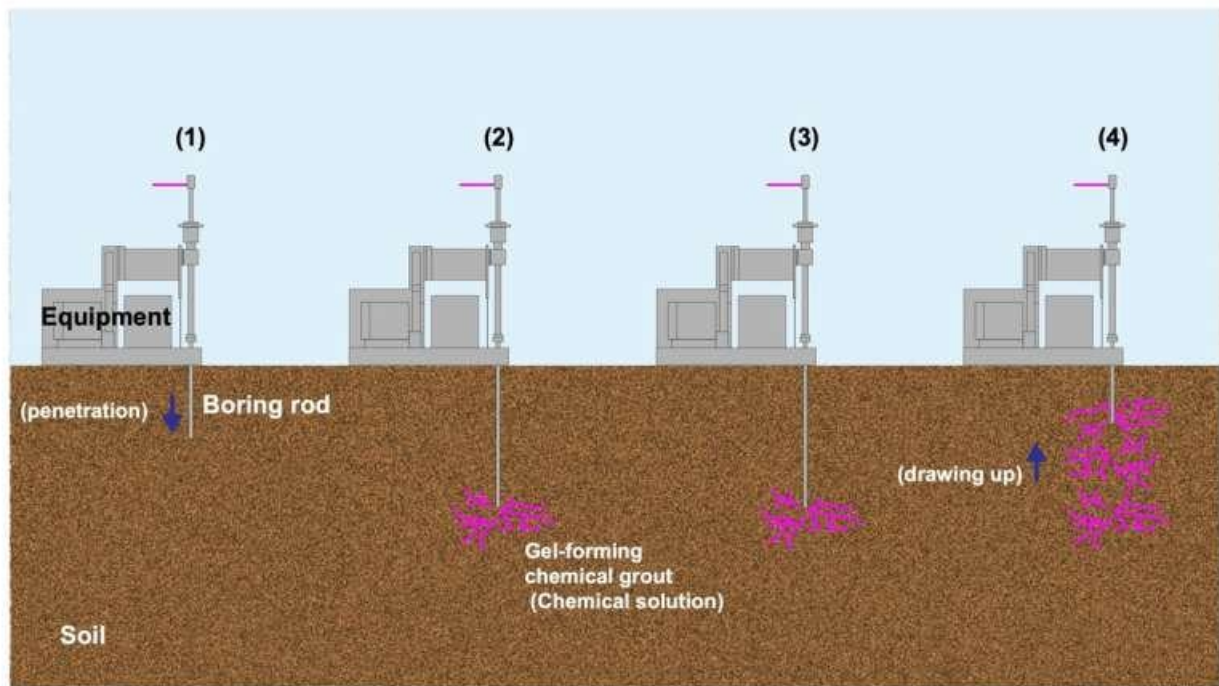
As research progresses, further refinements may enhance the performance and scalability of ZTE materials. Scientists continue to explore new element combinations and structural modifications to optimize stability. The ability to manipulate atomic interactions offers exciting possibilities for next-generation materials.

The breakthrough in pyrochlore magnets demonstrates how advanced simulations and experimental techniques can transform material science. With practical applications spanning multiple industries, this innovation may soon become a cornerstone of precision engineering.

FEBRUARY 25, 2025

From waste to wonder: Green grout developed for sustainable construction practices

by [Shibaura Institute of Technology](#)



This schematic diagram illustrates the typical components of a chemical grouting system, where gel-forming chemicals are applied to the soil to prevent erosion and liquefaction that could threaten the structural integrity. Researchers developed a new type of grout made from a byproduct of geothermal energy harvesting, minimizing carbon emissions linked to grouting. Credit: Shinya Inazumi from Shibaura Institute of Technology, Japan

In modern construction projects, ground improvement through grouting is commonly used to ensure structural stability and safety. This technique, which involves injecting stabilizing materials into the soil, is essential for buildings in earthquake-prone regions and areas with adverse ground conditions. From securing foundations and preventing soil erosion to strengthening underground structures, grouting plays a vital role in creating a resilient infrastructure capable of withstanding environmental stresses and geological challenges.

However, traditional grouting methods have long posed significant environmental challenges. The construction industry's heavy reliance on silica-based chemical grouts, produced through energy-intensive processes, contributes substantially to global carbon dioxide (CO₂) emissions. With growing pressure to reduce its environmental impact,

developing sustainable alternatives to conventional grouting materials has become a critical priority for scientists and engineers worldwide.

Against this backdrop, a research team from the Shibaura Institute of Technology, Japan, has developed an innovative solution that could revolutionize ground improvement through grouting. Led by Professor Shinya Inazumi of the College of Engineering, the research team developed a novel carbon-neutral grout called Colloidal Silica Recovered from Geothermal Fluids (CSRGF) that enhances soil stabilization while simultaneously reducing the [environmental impact](#) of construction and geothermal energy harvesting. Their study is published in the journal [Case Studies in Construction Materials](#).

"Geothermal energy production generates large amounts of silica-rich waste fluids, which traditionally pose maintenance and disposal challenges," explains Inazumi. "By repurposing this waste into a high-performance CSRGF grout, we aimed to establish a circular economy approach, transforming an industrial byproduct into a valuable construction material."

In doing so, the newly developed grout addresses two major issues—preventing high-silica-content waste fluids from damaging [geothermal energy](#) harvesting equipment and minimizing the carbon footprint of conventional grout production.

Extensive laboratory tests demonstrated the grout's remarkable performance, showing a 50% increase in liquefaction resistance compared to existing materials. Its low viscosity and controlled gelling time allow deep soil penetration while meeting environmental safety standards. These properties make CSRGF grout particularly valuable in earthquake-prone regions, where soil stabilization is crucial for preventing structural damage during seismic events.

Notably, the applications for CSRGF grout extend beyond earthquake protection. Its superior water-sealing properties make it ideal for underground construction projects, including tunnels, subways, and basements, where water infiltration threatens structural integrity. Additionally, in coastal and flood-prone areas, CSRGF grout can reinforce soil to combat erosion and mitigate risks associated with rising sea levels.

The development of CSRGF grout marks a significant milestone in the construction industry's journey toward carbon neutrality. By repurposing industrial byproducts and reducing waste, this innovation demonstrates how circular economy principles can drive more sustainable construction practices.

Moreover, its cost-effective and scalable production reduces CO₂ emissions in construction. Its adoption aligns with international sustainability initiatives, setting new industry standards for environmentally responsible soil stabilization.

"By replacing traditional silica-based grouts with our sustainable alternative, the construction industry can advance toward a greener infrastructure development, supporting global efforts to achieve carbon neutrality by 2050," says Inazumi.

The research team's next steps include scaling up production and conducting field trials to further validate the material's performance under real-world conditions. As the [construction](#)

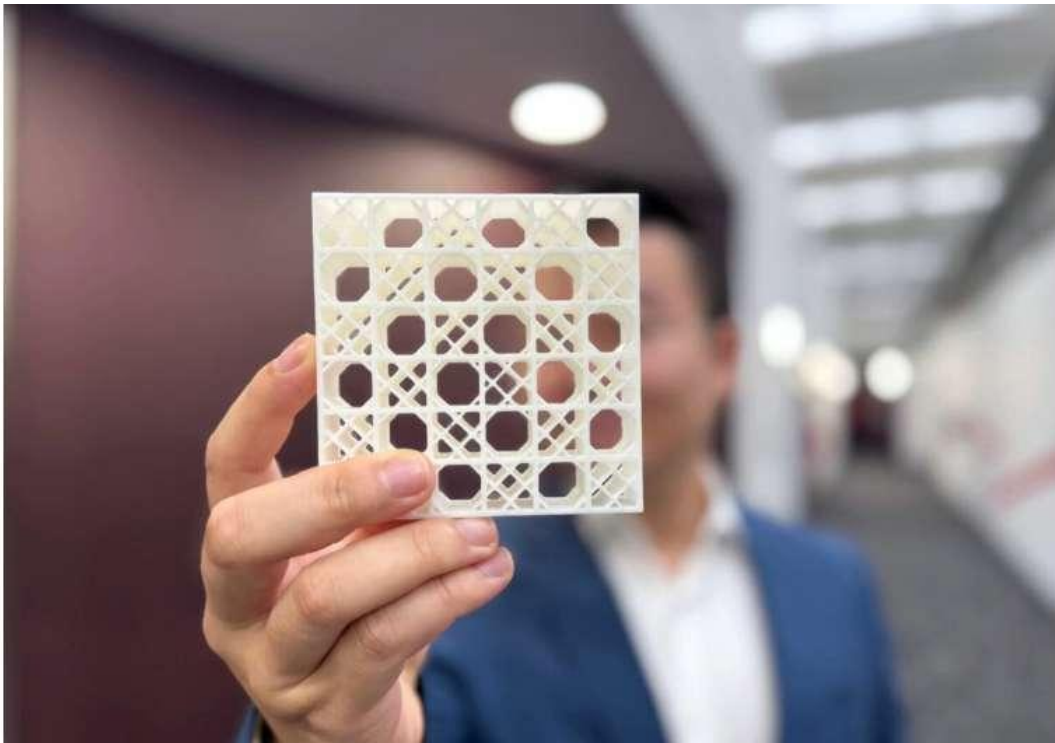
[sector](#) strives to balance sustainability with high performance, this innovation showcases the power of innovative thinking in solving engineering challenges sustainably.

More information: Taichi Terui et al, Development and application of geothermally derived silica grout for carbon-neutral soil stabilization, *Case Studies in Construction Materials* (2025). DOI: [10.1016/j.cscm.2025.e04297](https://doi.org/10.1016/j.cscm.2025.e04297)
Provided by [Shibaura Institute of Technology](#)

FEBRUARY 26, 2025

Bioinspired lattice design offers new possibilities for construction and safety

by [RMIT University](#)



Dr. Jiaming Ma holds a 3D-printed model of the team's double lattice design. Credit: RMIT University.

Inspired by the humble deep-sea sponge, RMIT University engineers have developed a new material with remarkable compressive strength and stiffness that could improve architectural and product designs.

The double lattice design was inspired by the intricate skeleton of a deep-sea sponge known as 'Venus' flower basket, which lives in the Pacific Ocean.

Lead author of the latest RMIT study into the structure, Dr. Jiaming Ma, said extensive testing and optimization revealed the pattern's impressive combination of stiffness and strength, mixed with an ability to contract when compressed.

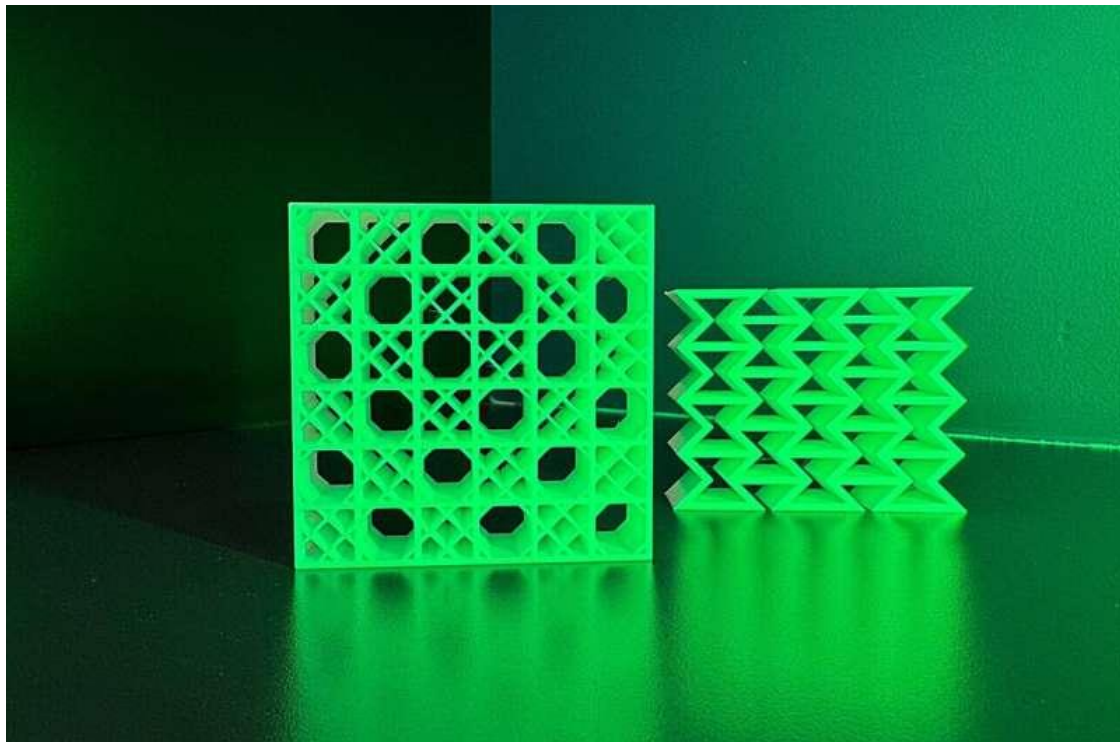
It's this last aspect—known as auxetic behavior—that opens a whole range of possibilities to apply the design across structural engineering and other applications.

"While most materials get thinner when stretched or fatter when squashed, like rubber, auxetics do the opposite," Ma said. "Auxetics can absorb and distribute [impact energy](#) effectively, making them extremely useful."

Natural auxetic materials include tendons and cat skin, while synthetic ones are used to make heart and vascular stents that expand and contract as required.

But while auxetic materials have useful properties, their low stiffness and limited energy absorption capacity limit their applications. The team's nature-inspired double lattice design is significant because it overcomes these main drawbacks.

"Each lattice on its own has traditional deformation behavior, but if you combine them as nature does in the deep-sea sponge, then it regulates itself and holds its form and outperforms similar materials by quite a significant margin," Ma said.



The team's double lattice structure (left) outperforms the standard re-entrant honeycomb design (right). Credit: RMIT University.

Results [published](#) in *Composite Structures* show that with the same amount of material usage, the lattice is 13 times stiffer than existing [auxetic materials](#), which are based on re-entrant honeycomb designs.

It can also absorb 10% more energy while maintaining its auxetic behavior with a 60% greater strain range compared to existing designs.

Dr. Ngoc San Ha said the unique combination of these properties opened several exciting applications for their new material.

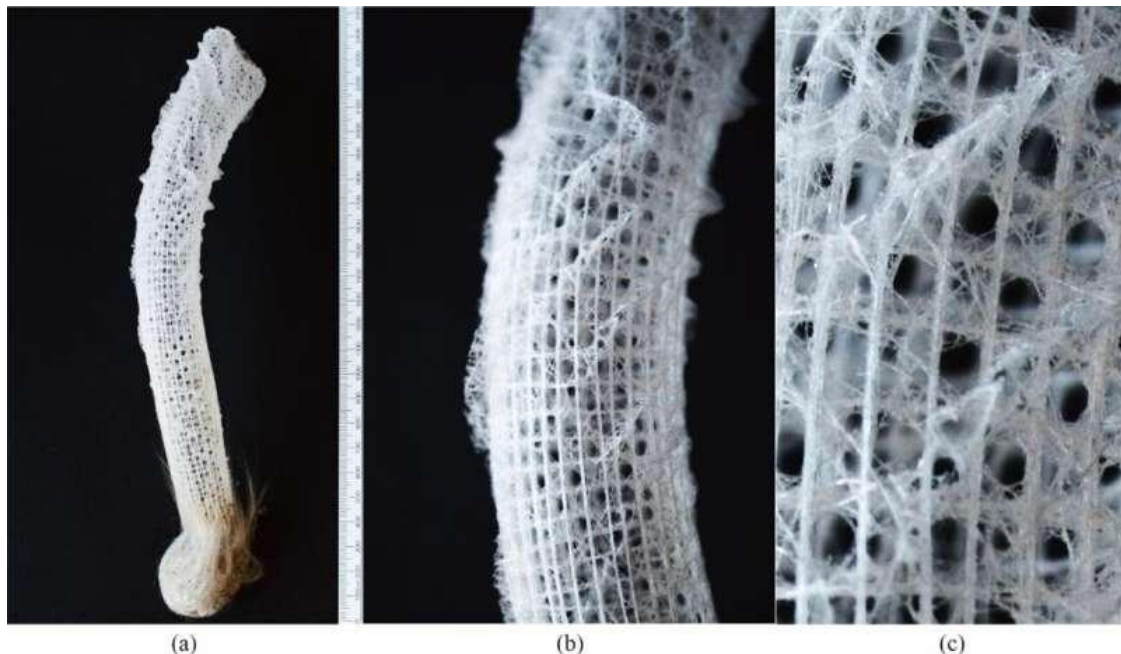
"This bioinspired auxetic lattice provides the most solid foundation yet for us to develop next-generation sustainable building," he said.

"Our auxetic metamaterial with high stiffness and energy absorption could offer significant benefits across multiple sectors, from construction materials to protective equipment and sports gear or medical applications."

The bioinspired lattice structure could work as a steel building frame, for example, allowing less steel and concrete to be used to achieve similar results to a traditional frame.

The structure could also form the basis of lightweight sports [protective equipment](#), bulletproof vests or medical implants.

Honorary Professor Mike Xie said the project highlighted the value of taking inspiration from nature. "Not only does biomimicry create beautiful and elegant designs like this one, but it also creates smart designs that have been optimized through millions of years of evolution that we can learn from," Xie said.



The skeletal system of the *Euplectella aspergillum*, showing: (a) the entire skeletal tube, (b) a magnified view highlighting its regular lattice-like structure, and (c) the detailed pattern of alternating open and closed cells. Credit: *Composite Structures* (2024). DOI: 10.1016/j.compstruct.2024.118835

Next steps

The team at RMIT's Centre for Innovative Structures and Materials tested the design using [computer simulations](#) and lab testing on a 3D printed sample made from thermoplastic polyurethane.

They now plan to produce steel versions of the design to use along with concrete and rammed earth structures—a construction technique using compacted natural raw materials.

"While this design could have promising applications in sports equipment, PPE and medical applications, our main focus is on the building and construction aspect," Ma said.

"We're developing a more sustainable building material by using our design's unique combination of outstanding auxeticity, stiffness, and energy absorption to reduce steel and cement usage in construction.

"Its auxetic and energy-absorbing features could also help dampen vibrations during earthquakes."

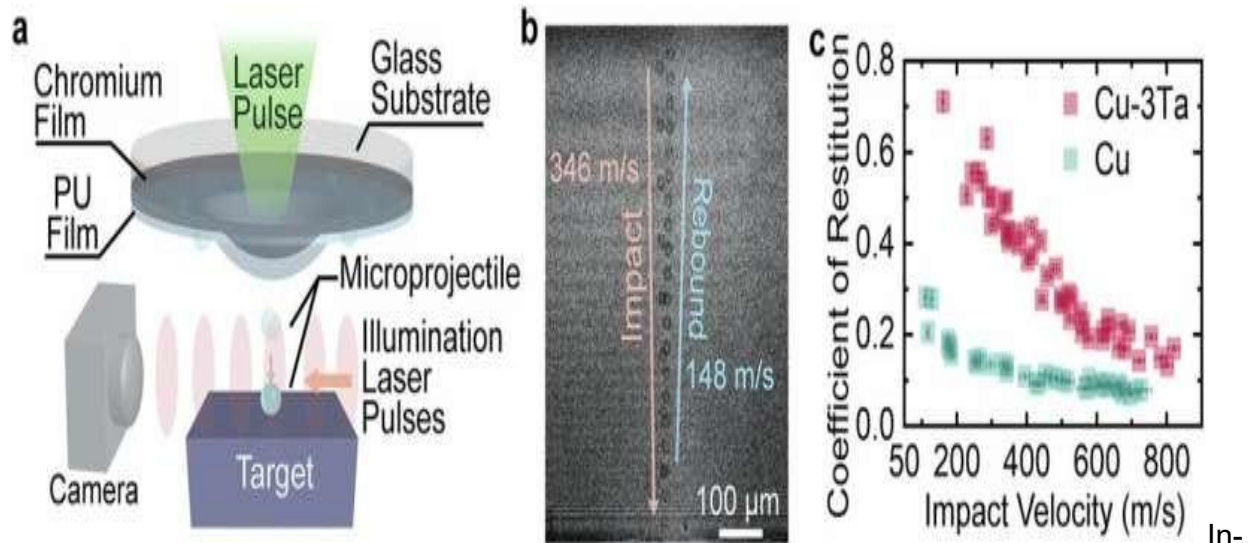
The team is also planning to integrate this design with machine learning algorithms for further optimization and to create programmable materials.

More information: Jiaming Ma et al, Auxetic behavior and energy absorption characteristics of a lattice structure inspired by deep-sea sponge, *Composite Structures* (2024). DOI: [10.1016/j.compstruct.2024.118835](https://doi.org/10.1016/j.compstruct.2024.118835)
Provided by [RMIT University](#)

MARCH 5, 2025

Nanoscale tweaks help alloy withstand high-speed impacts

by David Nutt, [Cornell University](#)



in situ measurements of microprojectile impact data of NC Cu-3Ta. Credit: *Communications Materials* (2025). DOI: 10.1038/s43246-025-00757-8

A Cornell-led collaboration devised a new method for designing metals and alloys that can withstand extreme impacts: introducing nanometer-scale speed bumps that suppress a fundamental transition that controls how metallic materials deform.

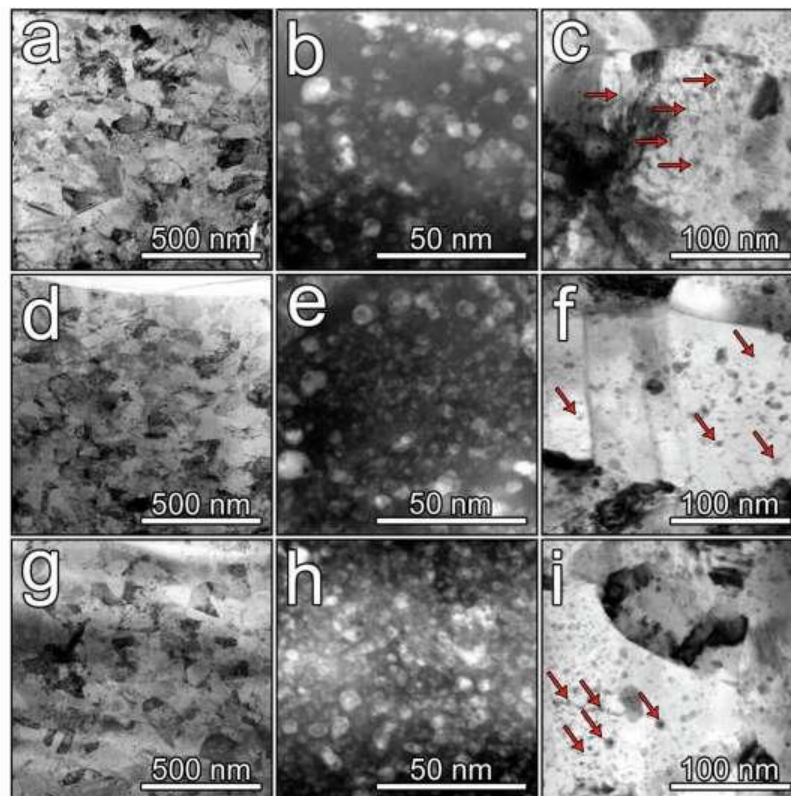
The findings, [published](#) March 5 in *Communications Materials*, could lead to the development of automobiles, aircraft and armor that can better endure high-speed impacts, extreme heat and stress.

The project was led by Mostafa Hassani, assistant professor in the Sibley School of Mechanical and Aerospace Engineering and in the Department of Materials Science and Engineering in Cornell Engineering, in collaboration with researchers from the Army Research Laboratory (ARL). The paper's co-lead authors were doctoral candidate Qi Tang and postdoctoral researcher Jianxiong Li.

When a metallic material is struck at an extremely high speed—think highway collisions and ballistic impacts—the material immediately ruptures and fails. The reason for that failure is embrittlement—the material loses ductility (the ability to bend without breaking) when deformed rapidly. However, embrittlement is a fickle process: If you take the same material and bend it slowly, it will deform but not break right away.

That malleable quality in metals is the result of tiny defects, or dislocations, that move through the crystalline grain until they encounter a barrier. During rapid, extreme strains, the dislocations accelerate—at speeds of kilometers per second—and begin interacting with

lattice vibrations, or phonons, which create a substantial resistance. This is where a fundamental transition occurs—from a so-called thermally activated glide to a ballistic transport—leading to significant drag and, ultimately, embrittlement.



As-

processed and post-deformed microstructures beneath the surface of a representative nanoindentation impression and a microprojectile impact impression in NC Cu 3-Ta alloys. Credit: *Communications Materials* (2025). DOI: 10.1038/s43246-025-00757-8

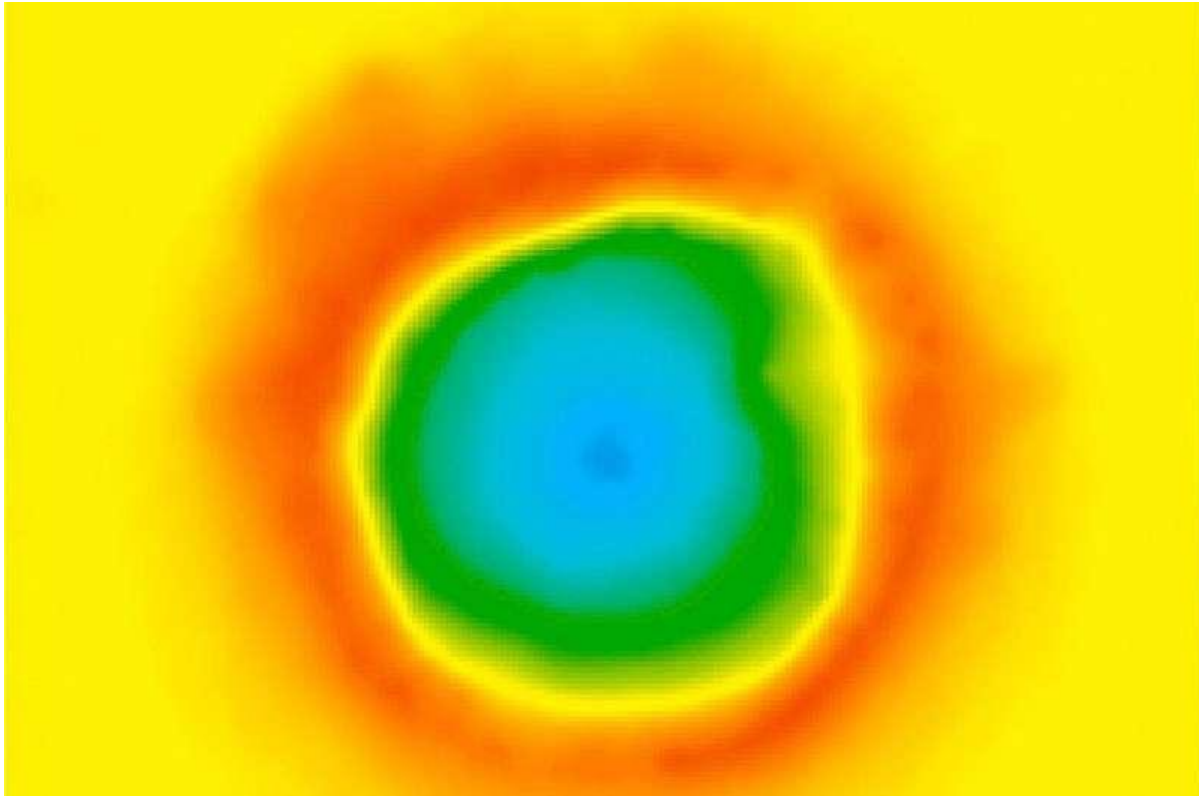
"What you really want in a metallic material is the ability to absorb energy. So one mechanism to absorb energy would be deformation or ductility. In this case, we hope that by suppressing the ballistic transport of dislocations, and, in turn, by preventing the embrittlement, we let the alloy deform, even under a very high rate of deformation, such as those that happen under impact or shock conditions," Hassani said. "To suppress ballistic dislocation transport and the resulting phonon drag, we use the concept of confining dislocations' motion, their glide, to nanometer scale."

Hassani's team worked with the ARL researchers to create a nanocrystalline alloy, copper-tantalum (Cu-3Ta). Nanocrystalline copper grains are so small, the dislocations' movement would be inherently limited, and that movement was further confined by the inclusion of nanometer clusters of tantalum inside the grains.

To test the material, Hassani's lab used a custom-built tabletop platform that launches, via laser pulse, spherical microprojectiles that are 10 microns in size and reach speeds of up to 1 kilometer per second—faster than an airplane. The microprojectiles strike a target material, and the impact is recorded by a high-speed camera. The researchers ran the experiment with pure copper, then with copper-tantalum. They also repeated the experiment

at a slower rate with a spherical tip that was gradually pushed into the substrate, indenting it.

The biggest challenge, however, was parsing the data. The key was to track the amount of energy used in each impact and indentation. Tang and Li developed a theoretical framework to separate the contributions of the two mechanisms—thermal activation at the low rate, and ballistic transport at the high rate.



This laser confocal microscopy reconstruction shows the impression of a spherical microprojectile impact. Credit: Cornell University

"While we are measuring things at high rates—the impact and rebound velocities and particle size—how can we treat the data so that we can really isolate the contribution of dislocation-phonon drag and systematically suppress that contribution?" Hassani said.

In a conventional metal or alloy, dislocations can travel several dozen microns without any barriers. But in nanocrystalline copper-tantalum, the dislocations could barely move more than a few nanometers, which are 1,000 times smaller than a micron, before they were stopped in their tracks. Embrittlement was effectively suppressed.

"This is the first time we see a behavior like this at such a high rate. And this is just one microstructure, one composition that we have studied," Hassani said. "Can we tune the composition and microstructure to control dislocation-phonon drag? Can we predict the extent of dislocation-phonon interactions?"

Co-authors include Billy Hornbuckle, Anit Giri and Kristopher Darling with ARL.

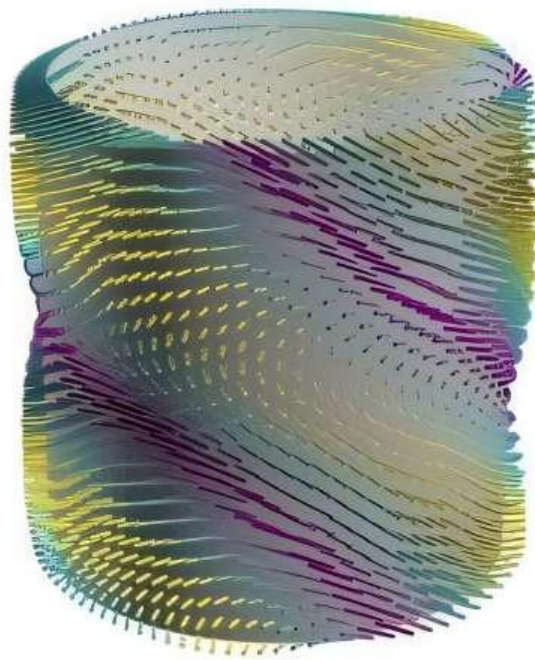
More information: Qi Tang et al, Suppressed ballistic transport of dislocations at strain rates up to 10^9 s^{-1} in a stable nanocrystalline alloy, *Communications Materials* (2025). DOI: [10.1038/s43246-025-00757-8](https://doi.org/10.1038/s43246-025-00757-8)

Journal information: [Communications Materials](#)
Provided by [Cornell University](#)

MARCH 5, 2025

Open-source software that models soft materials expands engineering solutions

by Mike Silver, [Tufts University](#)



"Many things that are interesting in science and engineering are shape optimization problems," said Tim Atherton. Here, a chiral liquid crystal membrane simulated with Morpho software is shown. Credit: Chaitanya Joshi and Tim Atherton

When mechanical and structural engineers design machines, bridges, and buildings, they calculate loads, stresses, and deformation of metal, steel, concrete, glass, wood, and plastic to find the optimal geometry that bears loads with the minimum cost of material.

Designs for relatively hard materials that do not deform too much are commonly handled by software that calculates and optimizes structures using mathematical models that are well understood and easily applied.

But there is an expanding class of design challenges for things that incorporate soft materials—[biological materials](#), engineered tissues, membranes, and even shape-shifting fluids that respond to electromagnetic fields. Predicting how these soft and fluidic materials respond to forces is more challenging than predicting the behavior of hard materials. Real world applications can include design of artificial hearts and heart valves or robot materials that mimic flesh and soft tissue.

To meet this challenge, a team of Tufts researchers led by Tim Atherton, professor of physics, created Morpho, an [open-source programmable environment](#) that enables researchers and engineers to solve shape optimization problems for soft materials.

The software, recently [described](#) in *Nature Computational Science*, is meant to be easy to use, free to use, and applicable to a broad range of scenarios. Among the team developing the software were James Adler, professor of mathematics, and Chaitanya Joshi, postdoctoral scholar in physics.

"Many things that are interesting in science and engineering are shape optimization problems," said Atherton. That might mean coming up with the best possible contours for a city to accommodate traffic and pedestrians, or the shape of a riverbed with water flowing over it. The question then is, how to make flexible materials that respond in different ways to forces, light, temperature.

"Traditional modeling packages are used for geometric optimization of rigid structures, and are not usually designed to solve shape optimization problems for soft materials," he said. "Engineers typically have to come up with their own mathematical formulations for soft materials, which can be challenging. Morpho provides a set of tools to help anyone conveniently solve these problems."

Soft materials have an inherent complexity in their response to their environment. Membranes, for example, can be susceptible to compression, liquid flows, pressure, and vibrations. Particulate material can experience random turbulence when in motion. Their final shape can be very different than their starting point, and less predictable relative to rigid structures.

The Morpho program models the soft materials with a process known as finite elements, mathematically dividing them into small, simple shapes (2D or 3D shapes like triangles or tetrahedrons), while equations modeling [material properties](#), forces, and boundary constraints are generated for each node around the shapes. Then the whole system of equations is solved to predict the optimal shape of the system.

In addition to [soft materials](#), the program can model packing problems as well, whether it's the flow of granular particles in pharmaceutical manufacturing, coffee, or wine (yes, their properties are due mostly to the particles in these fluids) or how companies can optimally pack and ship products to minimize use of space and packing materials.

Morpho can also model heterogeneous systems, which include both hard and soft components. For example, a cardiovascular stent is a metal mesh surrounded by the soft tissue of the heart and arteries. Researchers can get a better idea of a stent's expected performance using the Morpho modeling software.

"You don't really need a lot of training on the program to tackle complex problems," said Atherton. "I've seen undergrads within a couple of weeks of learning Morpho use the package to solve research grade problems, which is amazing."

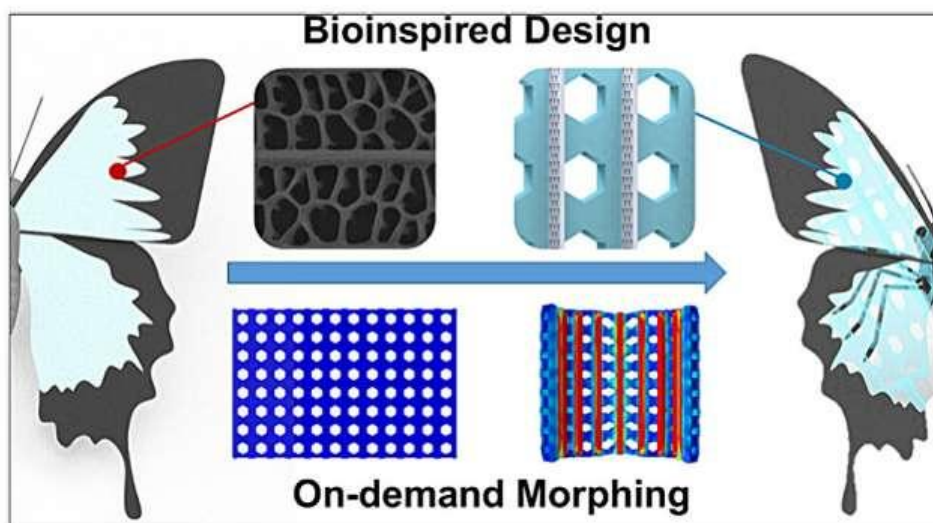
More information: Chaitanya Joshi et al, A programmable environment for shape optimization and shapeshifting problems, *Nature Computational Science* (2024). DOI: [10.1038/s43588-024-00749-7](https://doi.org/10.1038/s43588-024-00749-7)

Journal information: *Nature Computational Science*
Provided by [Tufts University](#)

MARCH 5, 2025

Butterfly-inspired 4D printing of smart hydrogels enables precise micro-nano deformation

by Zhang Nannan, [Chinese Academy of Sciences](#)



Credit: *ACS Materials Letters* (2025). DOI: [10.1021/acsmaterialslett.4c02589](https://doi.org/10.1021/acsmaterialslett.4c02589)

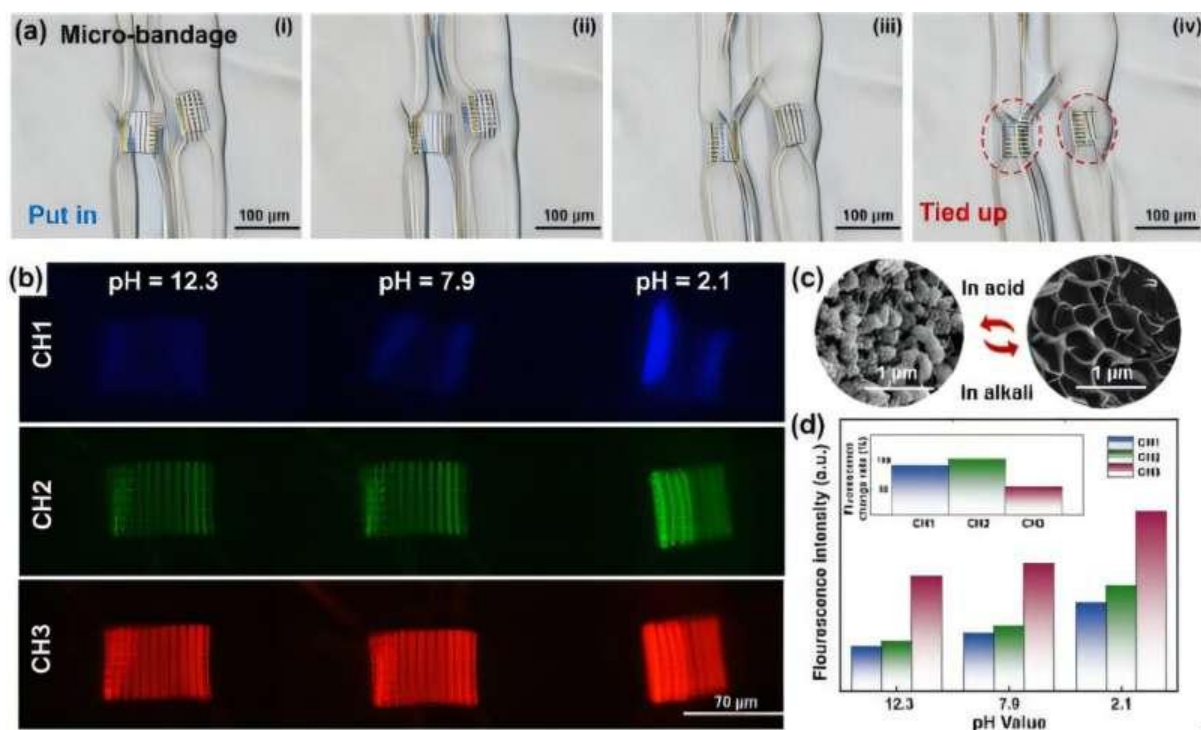
A Chinese research team has developed a single-step femtosecond laser 4D printing technology that enables rapid and precise micro-scale deformation of smart hydrogels. This innovation, inspired by the hierarchical structure of butterfly wings, holds significant promise for applications in flexible electronics and minimally invasive medicine.

The findings were [published](#) online in *ACS Materials Letters* on February 17.

Led by Prof. Liu Lianqing from the Shenyang Institute of Automation of the Chinese Academy of Sciences and Prof. Li Wenjung from the City University of Hong Kong, the researchers drew inspiration from the wing structure of *Papilio maackii*, a [butterfly species](#) known for its remarkable balance of lightness and toughness.

They discovered that the honeycomb-like pores and reinforced textures of butterfly wings work synergistically to dissipate [mechanical stress](#) during flight. Mimicking this natural design, the researchers employed femtosecond laser technology to sculpt pH-responsive hydrogel structures with a pre-programmed mechanical gradient.

By adjusting laser scanning modes, they encoded alternating soft and rigid regions into the material, effectively embedding a "deformation code." Experimental results and [finite element analysis](#) demonstrated that when exposed to an acidic environment, the hydrogel automatically folds within one second, shrinking to just 25% of its original volume.



Two potential applications based on 4D printed customized hydrogels design of microstructures. Credit: The research group

The key breakthrough lies in its single-step fabrication. Unlike traditional methods that require layering multiple materials to achieve deformability, this approach directly encodes mechanical heterogeneity during printing. As a result, the hydrogel exhibits dual functionality—sensing [environmental changes](#) and actuating structural responses.

In medical demonstrations, smart hydrogel dressings were shown to autonomously enwrap biomembranes with micron-level precision in response to pH shifts. For sensing applications, the material's fluorescence intensity fluctuated by up to 110% during acid-base transitions, highlighting its potential as an adaptive sensor.

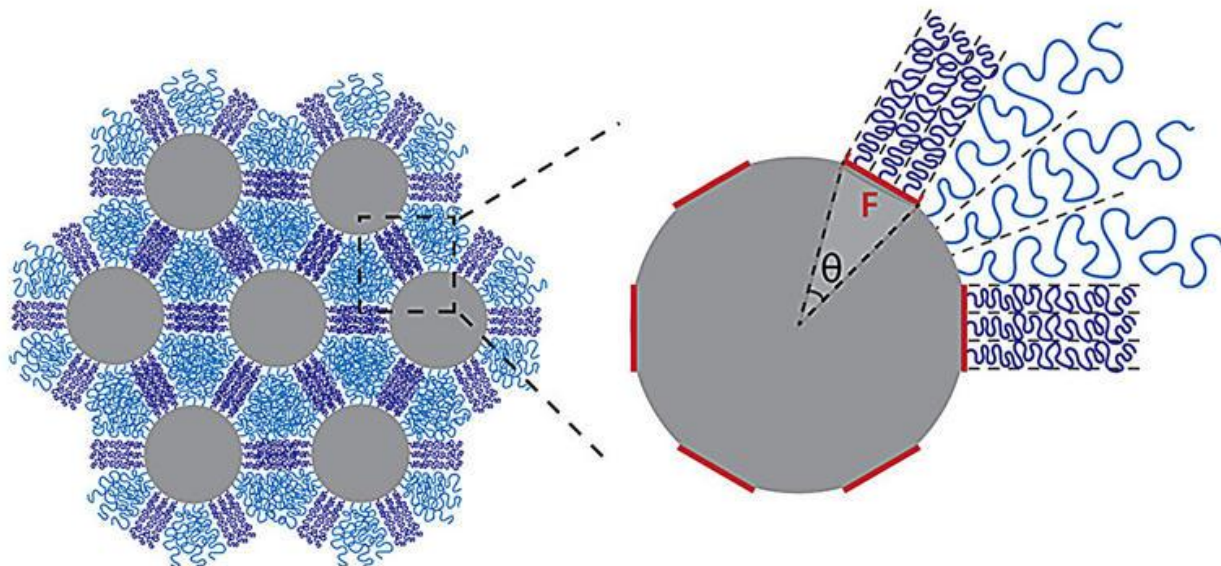
This streamlined 4D printing approach marks a significant advance in micro/nanoscale manufacturing, unlocking novel applications for responsive [hydrogel](#) systems—from adaptive medical devices to eco-friendly flexible electronics.

More information: Jianchen Zheng et al, 4D Printed Butterfly-Inspired Hydrogel Structures: Simple Strategies for Multifunctional Morphing, *ACS Materials Letters* (2025). DOI:

[10.1021/acsmaterialslett.4c02589](https://doi.org/10.1021/acsmaterialslett.4c02589)

Provided by [Chinese Academy of Sciences](#)

A new way to engineer composite materials: Polymer design combines strength with reversibility



Silica nanoparticles affixed with a distribution of polystyrene chains (purple) self-assemble into hexagonal lattices. Depending on how the chains are organized on the particle surface, they tangle together (purple) or unravel (blue) when compressed. Credit: Tiffany Chen; Ting Xu

Composite adhesives like epoxy resins are excellent tools for joining and filling materials including wood, metal, and concrete. But there's one problem: once a composite sets, it's there forever. Now there's a better way. Researchers have developed a simple polymer that serves as a strong and stable filler that can later be dissolved. It works like a tangled ball of yarn that, when pulled, unravels into separate fibers.

A new study led by researchers at the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) outlines a way to engineer pseudo-bonds in materials. Instead of forming chemical bonds, which is what makes epoxies and other composites so tough, the chains of molecules entangle in a way that is fully reversible. The research is [published](#) in the journal *Advanced Materials*.

"This is a brand new way of solidifying materials. We opened a new path to composites that doesn't go with the traditional ways," said Ting Xu, a faculty senior scientist at Berkeley Lab and one of the lead authors for the study.

Traditionally, there are two ways to make polymer materials strong and tough. In the first, adding a setting agent creates a crosslinked network of polymer molecules held together by permanent chemical bonds. In the second, increasing the length of polymer molecule chains causes them to get more and more entangled, so they can't come apart.

The latter, Xu proposed, offers the possibility of a reversible design. She likened the concept to folded proteins that interact without chemical bonds to create sturdy structures in nature, and can later unfold into their constituent strands.

Xu along with her colleagues in Berkeley Lab's Materials Sciences Division wanted to build on this concept and start with a collection of simple polystyrene chains, tangle them together into a tough and stable structure, and then take the material back to its starting point. "Let's say you have a ball of yarn, and it's a mess. You can't untangle it," said Xu. "But if you play with the yarn, maybe you can trick it to untangle."

With this in mind, the researchers attached polystyrene chains to hundred-nanometers-diameter silica particles, to create what Xu dubbed "hairy particles."

By forming nanocomposites, these hairy particles self-assembled into a crystal-like structure, providing different spaces between each unit for the hairy polymers to fill. The space available to each polystyrene chain depended on its position in the structure—and, therefore, determined how much it tangled together with its neighbors.

By confining the polymer chains into these tiny spaces with different geometries, Xu reduced the freedom with which any cluster of polystyrene chains could move—thus exercising control over how entangled they became. Or, as it turns out, how not entangled: for certain arrangements, the response to squeezing was that a specific cluster of polystyrene chains loosened up in response to an applied force.

"How much entanglement happens with the particles determines their response to an external force," said Xu, who is also a professor in UC Berkeley's College of Engineering and College of Chemistry. By adjusting the polystyrene chain size, as well as precisely where and how many chains were affixed to each facet of the silica particle, she could tweak how the structure responded to dissipate external stresses. Ultimately, these parameters provided the key to engineering entanglement-based "pseudo bonds."

Microscopy studies revealed that while some chains became rigid under confinement, others ultimately disentangled and stretched to dissipate the external stress. The result was a strong, tough, thin-film material, held firmly together by pseudo bonds of tangled polystyrene chains. Adding small amounts of polystyrene chains themselves to the nanoparticle assemblies increased the final load-bearing properties by another 50%.

"We were really excited that now we can maneuver amorphous polymer organization using nanoconfinement," said Xu. Until now, amorphous polymers are often randomly entangled, whereas proteins fold nicely. The variations in polystyrene chain arrangement now hits a sweet spot that can be used to engineer composites in a smart way. Moreover, adding a drop of solvent and stirring dissolved the nanocomposite back into its constituent particles suspended: there were no chemical bonds to break, allowing the materials to be reprocessed.

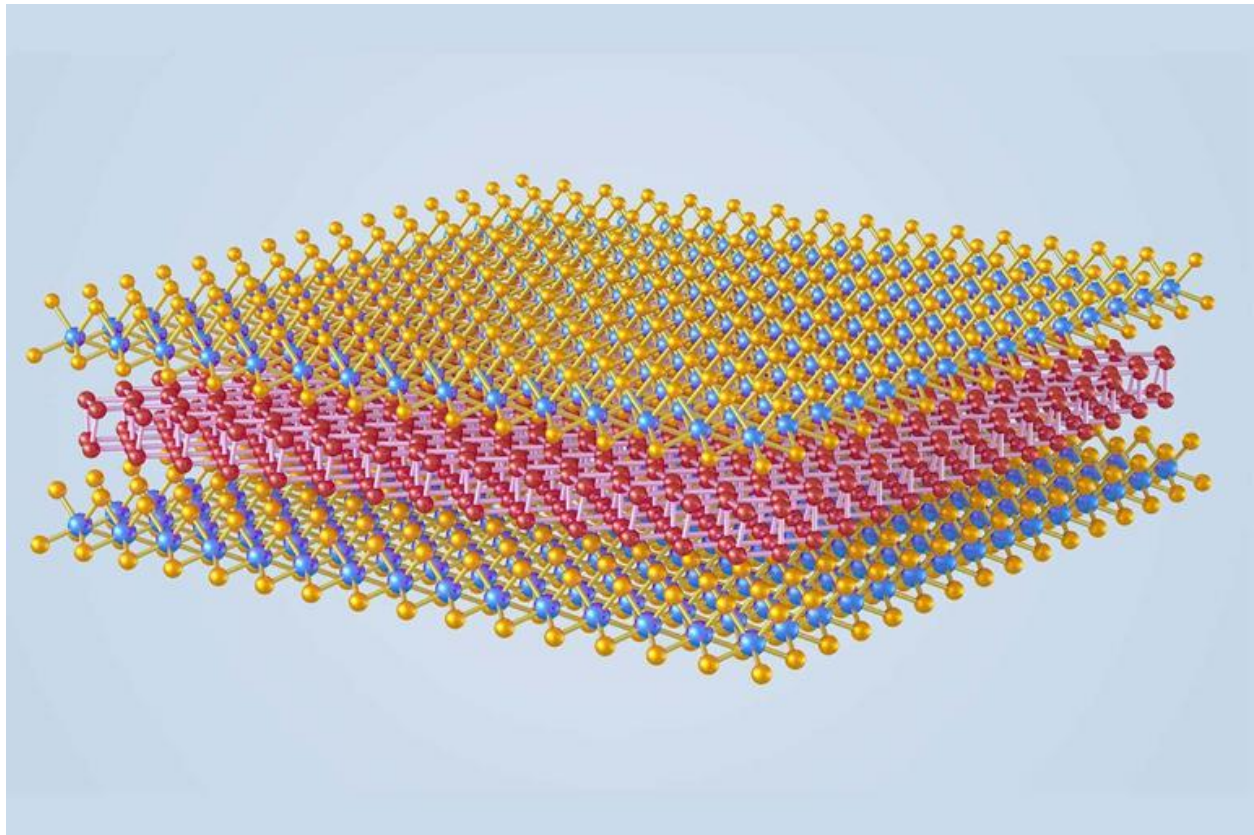
According to Xu, the Berkeley Lab study can readily be extended to other polymers and fillers. Polystyrene is one of the most common polymers and silica

is a cheap nanoparticle; nonetheless, Xu hypothesizes that the results will apply to other composites as well. She imagines a future with particles that have other optical or magnetic properties, for example, to create composites for optoelectronic devices. "We can have both strength and toughness, just by modulating how the polymers are distributed," said Xu.

More information: Tiffany Chen et al, Reversible Nanocomposite by Programming Amorphous Polymer Conformation Under Nanoconfinement, *Advanced Materials* (2025). DOI: [10.1002/adma.202415352](https://doi.org/10.1002/adma.202415352)

Provided by Lawrence Berkeley National Laboratory

Metals can be squeezed into sheets just a few atoms thick



A two-atom-thick layer of bismuth sandwiched between two layers of molybdenum disulphide LuoJun Du

Sheets of metal just two atoms thick can be produced by squashing molten droplets at great pressure between two sapphires. The researchers who developed the process say the unusual materials could have applications in industrial chemistry, optics and computers.

Last year, scientists created a gold sheet that was a [single atom thick](#), which they dubbed "goldene" after graphene, a material made of a single layer of carbon atoms. Such materials have been described as two-dimensional, as they are as thin as chemically possible.

Toughest material ever is an alloy of chromium, cobalt and nickel

But making other 2D metals hadn't been possible until now. The new technique, developed by [Luojun Du](#) at the Chinese Academy of Sciences and his colleagues, can create 2D sheets of bismuth, gallium, indium, tin and lead that are as thin as their atomic bonds allow.

To squeeze the metal, the researchers used two extremely flat sapphire crystals with a thin layer of molybdenum disulfide (MoS_2) as the jaws of a vice. They placed powdered metal between these jaws, heated it up to 400°C until it formed a droplet, then crushed it at an enormous pressure of up to 200 megapascals. The metal was compressed until it was a few atoms thick – or, in the case of bismuth, just two – then allowed to cool. When the pressure was removed, the 2D metal was sandwiched between the MoS_2 sheets, which then slipped away from the sapphires.

Du says the process was conceived eight years ago, but only recently bore fruit when the team discovered that the MoS_2 layers kept the thin metal sheets stable. "A single layer of free-standing metal atoms is simply unstable from a thermodynamic point of view. Therefore, we [had to] develop entirely new techniques," says Du. "The process seems simple, but it works."

As well as making extremely thin layers of atoms, the researchers were able to fine-tune the squeezing pressure and make metal plates three, four or more atoms thick with precision.

2D metals could have unusual properties that help scientists explore macroscopic quantum phenomena and superconductivity, says Du, and may lead to ultra-low

power transistors, transparent displays for computers and extremely efficient catalysts for chemical reactions.

One issue is that the MoS₂ encapsulating the metal sheet can't be easily removed. Du says this may be problematic for some applications, but experiments suggest they don't affect electrical conductivity, so they wouldn't prevent the 2D metal being used in electronic devices.

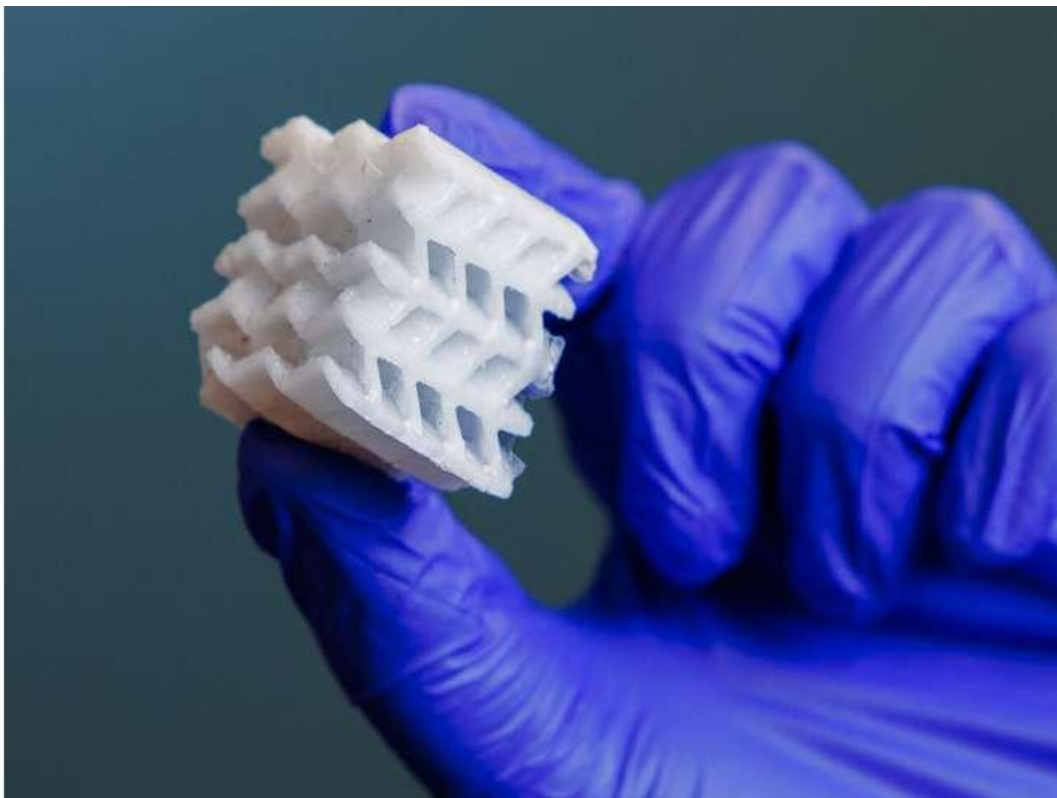
Journal reference

Nature DOI: [10.1038/s41586-025-08711-x](https://doi.org/10.1038/s41586-025-08711-x)

APRIL 23, 2025

Engineer reinvents ceramics with origami-inspired 3D printing

by [University of Houston](#)



Bendable ceramic origami material created in the UH lab of Maksud Rahman, assistant professor of mechanical and aerospace engineering. The new material could power next-gen prosthetics and aerospace technology. Credit: University of Houston

In a breakthrough that blends ancient design with modern materials science, researchers at the University of Houston have developed a new class of ceramic structures that can bend under pressure—without breaking.

Potential applications for this technology range from medical prosthetics to impact-resistant components in aerospace and robotics, where lightweight—but tough—materials are in high demand.

Traditionally known for their brittleness, ceramics often shatter under stress, making them difficult to use in high-impact or adaptive applications. But that may soon change as a team of UH researchers, led by Maksud Rahman, assistant professor of mechanical and [aerospace engineering](#), and Md Shajedul Hoque Thakur, postdoctoral fellow, has shown that origami-inspired shapes with a soft polymer coating can transform fragile ceramic materials into tough, flexible structures. Their work was recently [published](#) in *Advanced Composites and Hybrid Materials*.

"Ceramics are incredibly useful—biocompatible, lightweight and durable in the right conditions—but they fail catastrophically," said Rahman. "Our goal was to engineer that failure into something more graceful and safer."

To do that, the team 3D printed a ceramic structure based on the Miura-ori origami pattern—which is a way to fold something flat, like paper, so it takes up less space but stays flat overall—and then coated it with a stretchable, biocompatible polymer.

The resulting structures can handle stress in ways ordinary ceramics cannot. When compressed in different directions, the coated structures flexed and recovered, while their uncoated counterparts cracked or broke.

"The origami geometry gave us mechanical adaptability," said Thakur. "And the polymer coating introduced just enough flexibility to prevent sudden breakage."

The researchers tested the structures under both static and cyclic compression and backed up their experiments with computer simulations. The coated versions consistently showed greater toughness—especially in directions where the original ceramic was weakest.

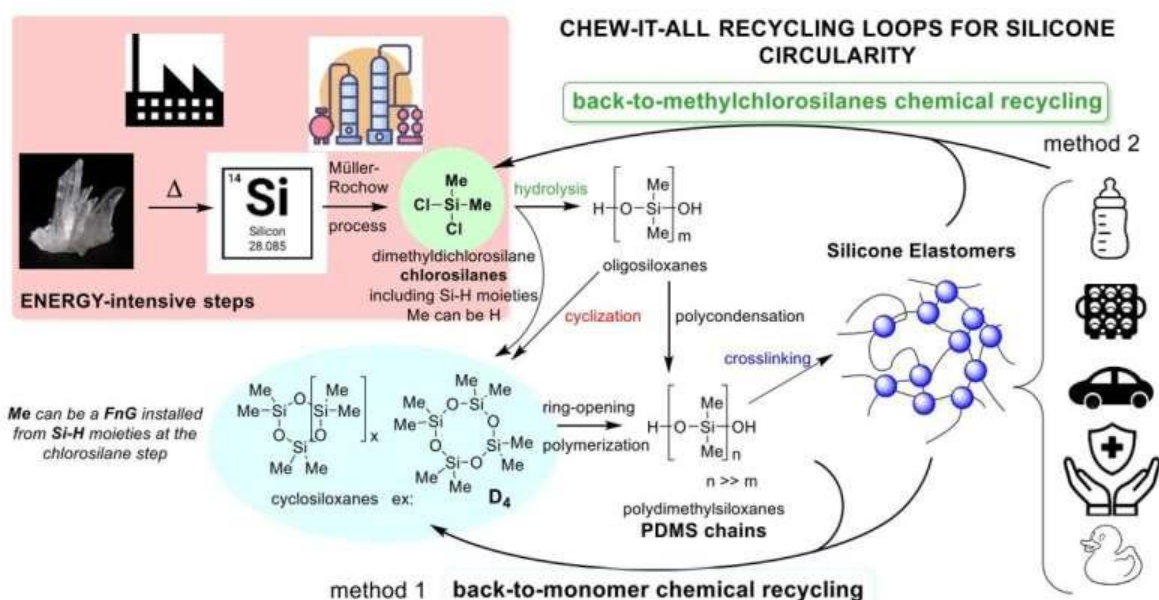
"Origami is more than an art—it's a powerful design tool that can reshape how we approach challenges in both biomedical and engineering fields," said Rahman. "This work demonstrates how folding patterns can unlock new functionalities in even the most fragile materials."

More information: Md Shajedul Hoque Thakur et al, Macroscale ceramic origami structures with hyper-elastic coating, *Advanced Composites and Hybrid Materials* (2025). DOI: [10.1007/s42114-025-01284-3](https://doi.org/10.1007/s42114-025-01284-3)
Provided by [University of Houston](#)

APRIL 24, 2025

Chemical recycling turns used silicones into pure building blocks, promising infinite reuse

by [CNRS](#)



General strategies for the chemical recycling of silicone polymers. Credit: Nam Đức Vũ et al. A study conducted by CNRS researchers describes a new method of recycling silicone waste (caulk, sealants, gels, adhesives, cosmetics, etc.). It has the potential to significantly reduce the sector's environmental impacts.

This is the first universal recycling process that brings any type of used silicone material back to an earlier state in its [life cycle](#) where each molecule has only one silicon atom. And there is no need for the [raw materials](#) currently used to design new silicones. Moreover, since it is chemical and not mechanical recycling, the reuse of the material can be carried out infinitely.

The associated study is [published](#) in *Science*.

The raw material used to make silicones is naturally occurring quartz. Its constituents are decomposed using metallurgy at high temperature to obtain pure silicon. That then reacts with methyl chloride to form chlorosilanes, molecules essential to all silicone-based polymers.

These first two transformations are very energy intensive and emit CO₂, the main greenhouse gas causing [climate change](#).

Consequently, this new recycling technique would make it possible to circumvent one of the most harmful impacts of the silicone sector. Moreover, as this chemical recycling process gives [direct access](#) to (methyl)chlorosilanes, which can be separated and purified industrially, it guarantees the quality of silicone materials from recycling, and can do that infinitely without loss of properties.

At a time when key chemical elements—and the associated mineral resources—are increasingly sought after, a recycling process like this also opens up a path to easing potential tensions around the crucial [quartz](#) resource, and the resulting silicon that is one of the key components used by the [electronics industry](#).

Together with their scientific and industrial partners, the authors continue their research, both on improving this process to make it industrially applicable, and by proposing recycling methods for other stages of silicone processing. Finally, they are also working on recycling other materials to make their use more sustainable.

More information: Nam Đức Vũ et al, Gallium-catalyzed recycling of silicone waste with boron trichloride to yield chlorosilanes, *Science* (2025). DOI: [10.1126/science.adv0919](https://doi.org/10.1126/science.adv0919). www.science.org/doi/10.1126/science.adv0919

Koushik Ghosh, Reimagining silicone's life cycle, *Science* (2025). DOI: [10.1126/science.adx1728](https://doi.org/10.1126/science.adx1728) , www.science.org/doi/10.1126/science.adx1728

Journal information: [Science](#)

APRIL 24, 2025

Researcher investigates hydrogel-infused additive manufacturing of ceramics

by Ashley Piccone , [Lawrence Livermore National Laboratory](#)



Summer intern Natalie Yaw (left) created an artistic image (right) for the inside front cover of *Inorganic Chemistry Frontiers*, where her research was published. Credit: Natalie Yaw, Maryline Kerlin

Doctoral student Natalie Yaw came to Lawrence Livermore National Laboratory (LLNL) as a summer intern. But when her time at the Laboratory ended, her work did not. She took the lead to write a paper based on her findings, and the result was [published](#) in *Inorganic Chemistry Frontiers*.

As a Department of Energy Nuclear Energy University Program fellow, Yaw chose to intern at LLNL because of its materials research capabilities. Her publication explores hydrogel-infused [additive manufacturing](#) (HIAM) of ceramics, which are essential materials in industries like aerospace because of their high thermal stability, chemical resistance and mechanical strength. In particular, 3D-printed ceramics offer design flexibility, reduce material waste, accelerate production and support tailored applications.

To address challenges associated with traditional ceramic manufacturing, HIAM separates the printing step from the ceramic material. The process starts with a viscous orange resin,

which is used to 3D print an initial gel. That gel is converted into a hydrogel via a few processes, including infusion with a metal salt solution. From there, much like the firing of traditional ceramics, the hydrogel is heated to burn off organic components and convert the metal salts into [metal oxides](#).

The study shows that the hydrogel formulation and the type of metal salts both play key roles in determining the ceramic's quality, density, porosity and strength. By evaluating the impacts of these precursors, the work provides valuable insights for optimizing ceramic quality and shape, creates a foundation for expanding HIAM to new materials and applications, and addresses a knowledge gap in the HIAM space.

Throughout this research, Yaw found the collaborative environment and wide-ranging expertise at LLNL to be an asset.

"I had several 'aha' moments when talking to people in different disciplines who had completely different perspectives on my work and ideas I would never have considered," she said. "It really highlighted the importance of interdisciplinary collaboration."

Yaw worked closely with LLNL research scientist Maryline Kerlin on the project.

"This was Natalie's first experience as a lead author, and together we navigated the challenges of writing, revising and addressing feedback, including conducting additional experiments to strengthen the paper," said Kerlin. "I believe her story reflects the incredible opportunities LLNL provides for young scientists."

Yaw will soon start the final year of her Ph.D. program and is interested in pursuing science policy. She advises anyone curious about an internship at LLNL to reach out directly to the scientists in their field of interest.

More information: Natalie S. Yaw et al, Precursor design for additive manufacturing of ceramics through hydrogel infusion, *Inorganic Chemistry Frontiers* (2025). DOI:

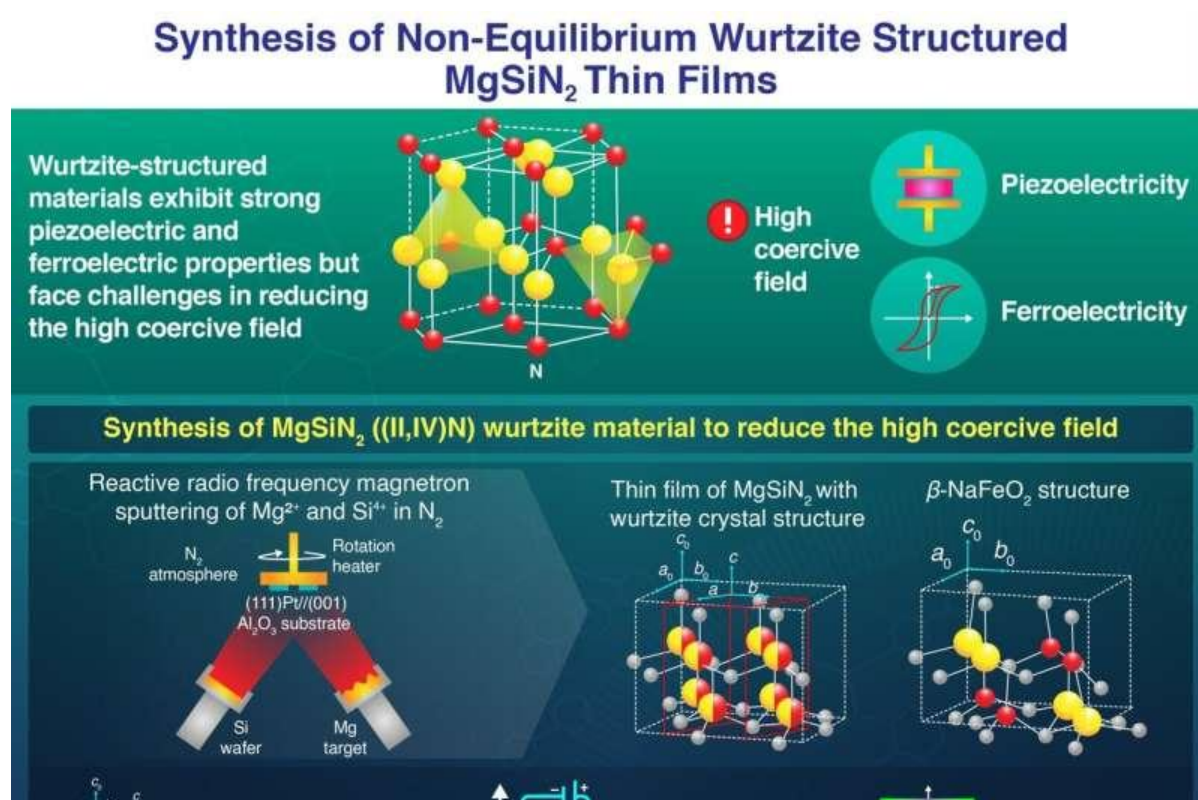
[10.1039/D5QI00139K](https://doi.org/10.1039/D5QI00139K)

Provided by [Lawrence Livermore National Laboratory](#)

APRIL 30, 2025

First wurtzite-structured MgSiN_2 thin film unlocks promising electronic properties

by [Institute of Science Tokyo](#)



The realization of MgSiN_2 with a wurtzite structure is expected to significantly broaden the composition of piezoelectric and ferroelectric materials with wurtzite structures. Credit: Institute of Science Tokyo

Wurtzite-structured crystals, characterized by their hexagonal symmetry, are widely valued for their unique electronic and piezoelectric properties—their ability to generate an electric charge when subjected to mechanical stress. Among these, gallium nitride (GaN), a key material in blue light-emitting diodes, and aluminum nitride (AlN), used in high-frequency radio frequency (RF) filters in smartphones, are prominent examples. These materials play a crucial role in advanced semiconductors, sensors, and actuators.

Scientists at the Institute of Science Tokyo (Science Tokyo), Japan, have made a significant breakthrough in expanding the wurtzite structure to include heterovalent ternary nitrides, specifically for potential piezoelectric and ferroelectric applications. Their [paper](#), which was made available on February 6, 2025, in *Advanced Electronic Materials*, describes the fabrication of the first-ever magnesium silicon nitride (MgSiN_2) heterovalent nitride in a wurtzite structure with piezoelectric properties.

This pioneering study was led by Professor Hiroshi Funakubo from MDX Research Center for Element Strategy, Science Tokyo, in collaboration with Mr. Sotaro Kageyama, a second-year Master's student, Assistant Professor Kazuki Okamoto, and Professor Hiroko Yokota from the School of Materials Science and Engineering, Science Tokyo. The research team also included Professor Venkatraman Gopalan from Pennsylvania State University, Associate Professor Yoshiomi Hiranaga from Tohoku University, Professor Hiroshi Uchida from Sophia University, and others.

Wurtzite structures, such as AlN and GaN, are usually made of trivalent cations. However, these materials face challenges due to high coercive electric fields—the energy required to switch polarization for piezoelectric charge generation and ferroelectric properties.

Incorporating heterovalent cations with valencies of II/IV alters the structural rigidity due to differences in cation radii. This alteration has been shown to facilitate polarization and lower the coercive field. To explore this effect, the researchers selected the heterovalent ternary nitride MgSiN_2 , composed of Mg^{2+} and Si^{4+} .

MgSiN_2 typically crystallizes in the orthorhombic $\beta\text{-NaFeO}_2$ structure. However, the research team successfully stabilized it in a wurtzite phase using reactive RF magnetron sputtering of Mg and Si ions at 600 °C in a nitrogen-rich atmosphere. This structural transformation introduced a random cationic ordering.

"The ability to synthesize MgSiN_2 in a new wurtzite phase is a major advancement in the field of piezoelectric materials," explains Funakubo. "Our findings could open new avenues for developing high-performance materials with tailored electronic properties."

The results confirmed the piezoelectric nature of wurtzite- MgSiN_2 using advanced characterization techniques, including X-ray diffraction, [transmission electron microscopy](#), and piezoresponse force microscopy.

The fabricated material exhibited a converse piezoelectric coefficient ($d_{33,f} = 2.3 \text{ pm/V}$) comparable to those of conventional simple nitrides, indicating its ability to effectively convert mechanical stress into electric charge. This breakthrough creates potential applications in ultrasonic transducers, nanoelectromechanical systems, and energy harvesters.

The piezoelectric MgSiN_2 exhibited a wide bandgap of approximately 5.9 eV (direct) and 5.1 eV (indirect), comparable to traditional piezoelectric wurtzite AlN. This suggests that the material provides excellent insulation by restricting electron movement between the [valence band](#) (where electrons are bound to atoms) and the [conduction band](#) (where electrons are free to move and conduct electricity).

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A wider bandgap indicates strong resistance to electrical conduction under normal conditions, confirming the material's durability and stability. These properties make MgSiN_2 a promising candidate for next-generation electronics.

"Our research lays the foundation for further exploration of heterovalent ternary nitrides with [piezoelectric properties](#). Fine-tuning the deposition parameters could lead to greater improvements in polarization switching and further validate the material's ferroelectric properties," concludes Funakubo.

As the researchers continue to investigate new material phases for piezoelectric applications, the wurtzite-structured MgSiN_2 emerges as a promising candidate for next-generation piezoelectric and ferroelectric technologies, paving the way for advancements in electronic materials.

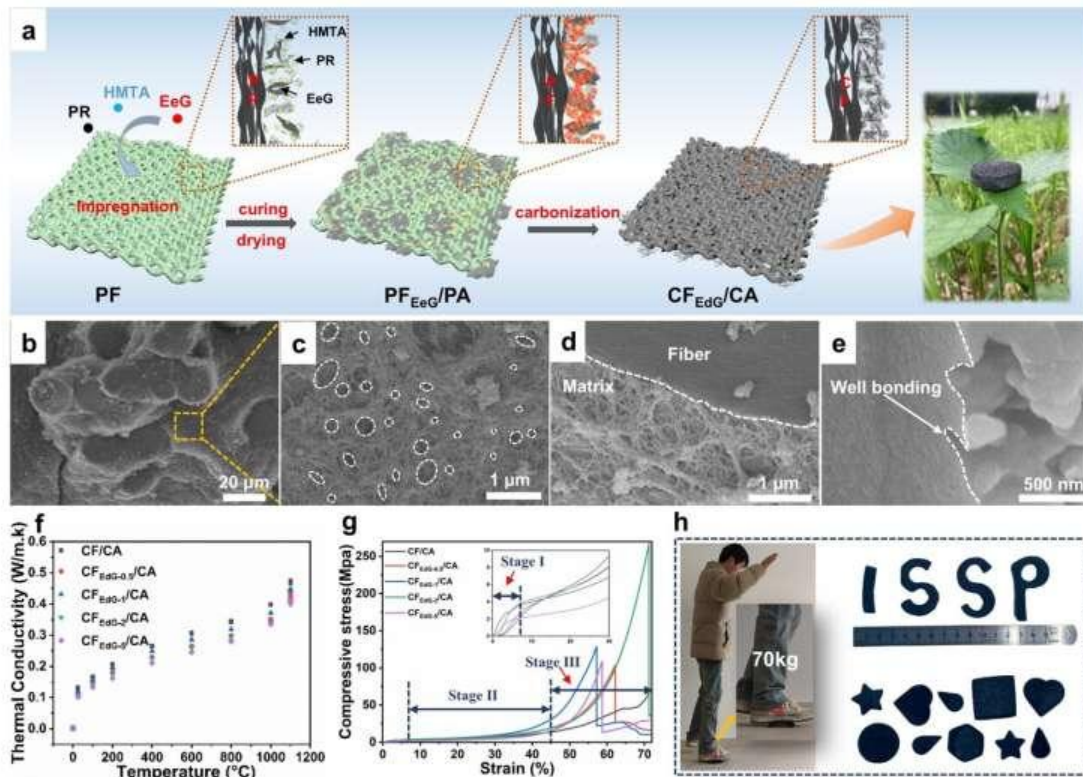
More information: Sotaro Kageyama et al. Realization of Non-Equilibrium Wurtzite Structure in Heterovalent Ternary MgSiN_2 Film Grown by Reactive Sputtering, *Advanced Electronic Materials* (2025). DOI: [10.1002/aelm.202400880](https://doi.org/10.1002/aelm.202400880), advanced.onlinelibrary.wiley.com/doi/10.1002/aelm.202400880

Provided by [Institute of Science Tokyo](#)

APRIL 30, 2025

Advanced aerogel composite developed for extreme thermal environments

by Zhang Nannan , [Chinese Academy of Sciences](#)



The synthesis schematic (a), microstructure characterization (b–e), thermal conductivities at different temperatures (f), stress-strain curves (g) and molding performance (h) of the carbon-based aerogel composites. Credit: Yu Jie

A research team from the Hefei Institutes of Physical Science of the Chinese Academy of Sciences has developed advanced aerogel composites that integrate high-temperature insulation with mechanical load-bearing capabilities, while also achieving controllable fabrication of large-size samples.

The findings were published in [Materials Today Energy](#) and the [Journal of Materials Research and Technology](#).

As high-performance systems are increasingly deployed in [extreme conditions](#), there is a growing need for insulation materials that are not only lightweight and thermally efficient but also mechanically strong and stable at elevated temperatures.

Traditional aerogels, known for their ultra-low density and excellent insulating properties, often suffer from poor mechanical integrity, limited [thermal stability](#), and challenges in large-scale manufacturing—hindering their practical application in demanding environments.

To address these challenges, the researchers built upon their previous work and developed a carbon fiber reinforcement strategy to create high-performance aerogel composites. By introducing expandable graphite as an interfacial bonding agent, they constructed a robust multi-scale framework that significantly enhanced [structural integrity](#) and resistance to thermal deformation.

The resulting composites maintained [mechanical strength](#) under load while providing efficient thermal insulation across a wide temperature range.

In parallel, for ceramic-based aerogel composites, the researchers proposed a novel precursor impregnation and in-situ dual-morphology growth technique. This approach enabled the simultaneous formation of dense silicon carbide coatings and a network of nanowires within the carbon fiber structure, greatly improving oxidation resistance and ablation performance.

Even after exposure to extremely [high temperatures](#), the composites retained their lightweight structure, mechanical strength, and excellent thermal insulation properties, demonstrating strong potential for future thermal protection applications.

Importantly, both types of composites demonstrated the feasibility of large-size fabrication, with samples successfully prepared and capable of being cut and processed as needed.

These advancements provide new technical pathways for the engineering applications of aerogel composites.

More information: Ningning Zhou et al, Expandable graphite optimized carbon-fiber/carbon-aerogel composites with enhanced mechanical property for thermal insulation under extreme environments, *Materials Today Energy* (2025). DOI: [10.1016/j.mtener.2025.101852](https://doi.org/10.1016/j.mtener.2025.101852)

Chunxue Zheng et al, Synthesis of carbon fiber reinforced SiC aerogel composites with enhanced mechanical and antioxidant properties for high temperature insulation, *Journal of Materials Research and Technology* (2025). DOI: [10.1016/j.jmrt.2025.04.131](https://doi.org/10.1016/j.jmrt.2025.04.131)
Provided by [Chinese Academy of Sciences](#)

MAY 6, 2025

Researchers explore how AI tools can improve manufacturing worker safety, product quality

by Josh Stowe , [University of Notre Dame](#)



Credit: Unsplash/CC0 Public Domain

Recent artificial intelligence advances have largely focused on text, but AI increasingly shows promise in other contexts, including manufacturing and the service industry. In these sectors, targeted AI improvements can improve product quality and worker safety, according to a new study co-authored by an interdisciplinary team of experts from the University of Notre Dame.

The study, [published](#) in *Information Fusion*, explores how a class of AI tools capable of processing multiple types of inputs and reasoning can affect the future of work. These tools, which include ChatGPT, are known as multimodal large language models. And while most studies on AI and work have focused on office work, this new research examined production work settings, where the benefits of AI may seem less apparent.

Notre Dame researchers collaborated with Indiana welding experts at the Elkhart Area Career Center, Plymouth High School, Career Academy South Bend, Plumbers & Pipefitters Local Union 172 and Ivy Tech Community College to gather images for the study, leveraging relationships cultivated through the work of the University's iNDustry Labs. Northern Indiana has one of the highest concentrations of manufacturing jobs in the United States and iNDustry Labs has collaborated with more than 80 companies in the region on more than 200 projects.

Research focused on welding across several industries: RV and marine, aeronautical and farming. The study examined how accurately large language models assessed weld images to determine whether the welds shown would work for different products. Researchers found that while these AI tools showed promise in assessing weld quality, they performed significantly better analyzing curated online images compared to actual welds.

"This discrepancy underscores the need to incorporate real-world welding data when training these AI models, and to use more advanced knowledge distillation strategies when interacting with AI," said co-author Nitesh Chawla, the Frank M. Freimann Professor of Computer Science and Engineering at the University of Notre Dame and the founding director of the University's Lucy Family Institute for Data and Society. "That will help AI systems ensure that welds work as they should. Ultimately, this will help improve worker safety, [product quality](#) and economic opportunity."

Researchers discovered that context-specific prompts may enhance the performance of AI models in some cases, and noted that the size or complexity of the models did not necessarily lead to better performance. Ultimately, the study's co-authors recommended that future studies focus on improving models' ability to reason in unfamiliar domains.

"Our study shows the need to fine-tune AI to be more effective in manufacturing and to provide more robust reasoning and responses in [industrial applications](#)," said Grigorii Khvatski, a doctoral student in Notre Dame's Department of Computer Science and Engineering and a Lucy Family Institute Scholar.

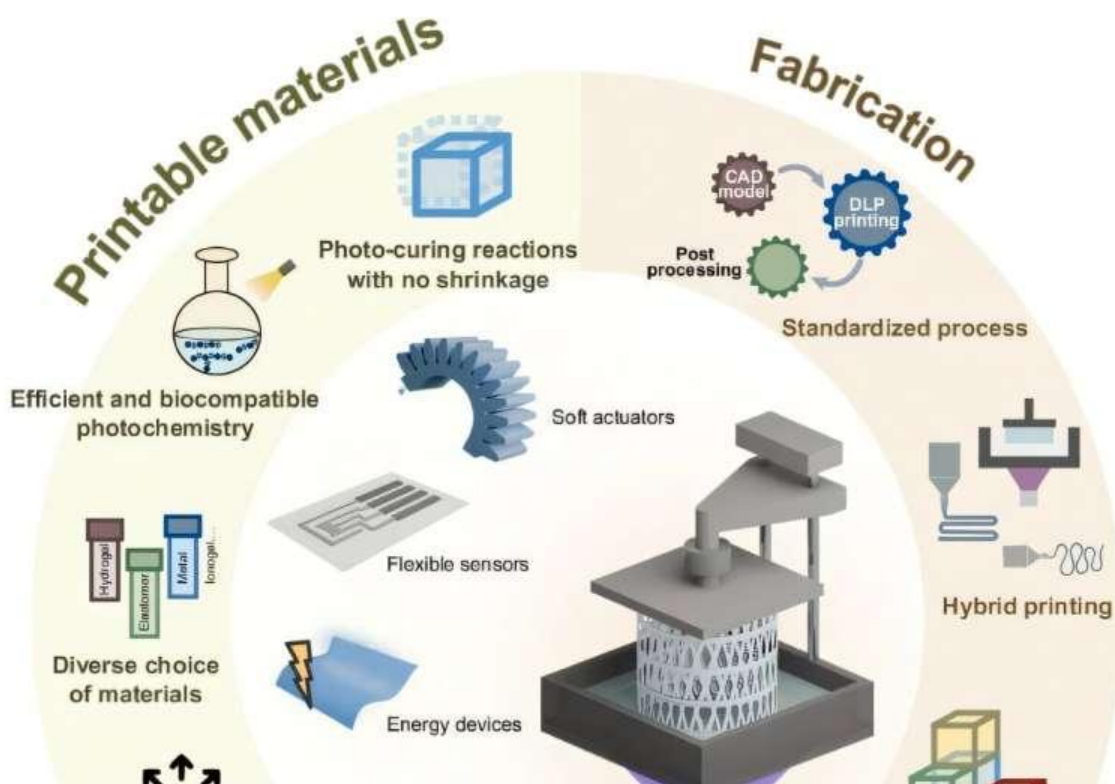
Yong Suk Lee, associate professor of technology, economy and global affairs in Notre Dame's Keough School of Global Affairs and program chair for technology ethics at Notre Dame's Institute for Ethics and the Common Good, said the study's findings have important implications for the future of work.

"As AI adoption in industrial contexts grows, practitioners will need to balance the trade-offs between using complex, expensive general-purpose models and opting for fine-tuned models that better meet industry needs," Lee said. "Integrating explainable AI into these decision-making frameworks will be critical to ensuring that AI systems are not only effective but also transparent and accountable."

More information: Grigorii Khvatskii et al, Do multimodal large language models understand welding?, *Information Fusion* (2025). DOI: [10.1016/j.inffus.2025.103121](https://doi.org/10.1016/j.inffus.2025.103121)
Provided by [University of Notre Dame](#)

Smart, stretchable and sustainable: The future of DLP-printed flexible devices

by [Chinese Academy of Sciences](#)



Perspective on DLP printing of flexible devices. Credit: *Microsystems & Nanoengineering* (2025). DOI: 10.1038/s41378-025-00885-8

Flexible devices play a central role in next-generation technologies, from health monitoring to soft robotics. However, conventional manufacturing methods such as casting and lithography often fall short—they are costly, time-consuming, and struggle with design complexity and multifunctionality. Moreover, traditional materials like rigid polymers and non-stretchable conductors compromise both comfort and durability.

As demands rise for smarter, adaptable electronics, the need for a more scalable and environmentally responsible fabrication method becomes urgent. In response, researchers are increasingly turning to advanced 3D [printing technologies](#) like digital light processing (DLP), which offer high precision, material versatility, and speed, making them ideal for producing flexible, high-performance devices tailored for dynamic applications.

In a compelling [review](#) featured in *Microsystems & Nanoengineering*, scientists from the University of Macau and Hong Kong University of Science and Technology (Guangzhou) explore the cutting-edge role of DLP 3D printing in the field of [flexible devices](#).

Highlighting innovations in soft actuators, sensors, and [energy systems](#), the study delves into how this technology—enabled by grayscale control, multi-material printing, and new printable materials—allows engineers to fine-tune the mechanical and conductive properties of printed devices. Their findings underscore DLP's transformative potential for wearables, implants, and sustainable smart systems.

The review outlines how DLP 3D printing achieves unprecedented capabilities in flexible devices by addressing core challenges in resolution, speed, and material integration. With printing resolutions reaching down to 1 μm , DLP enables intricate geometries such as porous sensor arrays and compact energy-harvesting structures—faster and more precisely than traditional methods.

Material breakthroughs include self-healing hydrogels, conductive liquid metals, and biodegradable elastomers, dramatically enhancing flexibility and environmental compatibility.

The integration of DLP with other techniques has led to the creation of complex devices like liquid crystal elastomer actuators, capable of programmable deformation and load-bearing functions. Grayscale DLP printing further allows for spatially tunable stiffness within a single structure, enabling pneumatic actuators that twist or bend as needed.

In sensing, the review features dome-shaped ionogel capacitive sensors with ultra-high sensitivity (15.1 kPa^{-1}) and fatigue-resistant rotaxane hydrogel-based strain sensors. For energy applications, innovations include biomimetic triboelectric nanogenerators that harvest [kinetic energy](#) with improved efficiency and supercapacitors with 3D-customized internal architectures for better storage.

Collectively, these advances showcase DLP's ability to seamlessly integrate materials science and [structural engineering](#), offering a new design paradigm for multifunctional, miniaturized electronics.

According to senior author Dr. Iek Man Lei, "DLP is no longer just a prototyping tool—it's becoming a foundational platform for next-generation electronics and flexible devices. Its ability to print with both structural precision and material diversity allows us to rethink how devices are designed and deployed."

Co-author Dr. Liang Yue adds, "By pushing the boundaries of what's possible in soft device fabrication, DLP offers an efficient path forward for personalized medical technologies and sustainable smart systems."

Looking ahead, DLP-printed flexible devices are expected to revolutionize sectors from health care to robotics. In medicine, they could enable skin-conforming sensors for continuous health tracking or soft actuators for delicate surgical interventions. Robotics will

benefit from integrated sensor-actuator systems that mimic biological movements and respond intelligently to stimuli.

Energy innovations, like personalized supercapacitors or motion-powered generators, promise to enhance mobile and wearable tech. Importantly, the use of recyclable hydrogels and biodegradable materials supports greener electronics and reduces waste.

While scaling up production and material standardization remain ongoing challenges, DLP's flexibility and accessibility make it a vital tool for accelerating innovation in both academic and industrial R&D environments.

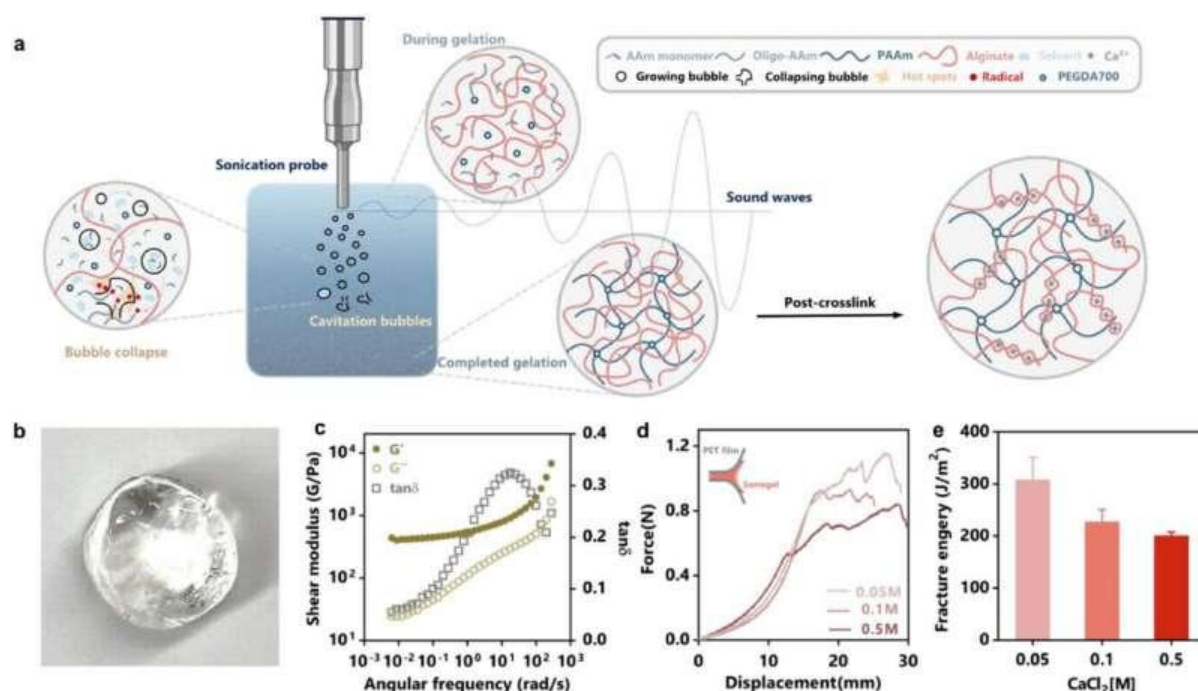
More information: Jiahong Yi et al, Digital light processing 3D printing of flexible devices: actuators, sensors and energy devices, *Microsystems & Nanoengineering* (2025). DOI: [10.1038/s41378-025-00885-8](https://doi.org/10.1038/s41378-025-00885-8)

Journal information: [Microsystems and Nanoengineering](#)
Provided by [Chinese Academy of Sciences](#)

MAY 8, 2025

Ultrasound unlocks a safer, greener way to make hydrogels

by Claire Loewen, [McGill University](#)



Initiator-free and oxygen-tolerant sono-synthesis of tough hydrogels. Credit: *Advanced Science* (2025). DOI: 10.1002/advs.202416844

Researchers at McGill University, in collaboration with Polytechnique Montréal, pioneered a new way to create hydrogels using ultrasound, eliminating the need for toxic chemical initiators. This breakthrough offers a faster, cleaner and more sustainable approach to hydrogel fabrication, and produces hydrogels that are stronger, more flexible and highly resistant to freezing and dehydration.

Hydrogels are gels composed of polymers that can absorb and retain large amounts of water. They are widely used in wound dressings, [drug delivery](#), [tissue engineering](#), soft robotics, [soft contact lenses](#) and more.

The new method, now [published](#) in *Advanced Science*, also promises to facilitate advances in tissue engineering, bioadhesives and 3D bioprinting.

Gel formation within minutes

Traditional hydrogel manufacturing relies on chemical initiators, some of which can be harmful, particularly in medical applications. Initiators are the chemicals used to trigger chemical chain reactions.

The McGill research team, led by Mechanical Engineering Professor Jianyu Li, has developed an alternative method using ultrasound. When applied to a liquid precursor, [sound waves](#) create microscopic bubbles that collapse with immense energy, triggering gel formation within minutes.

"The problem we aimed to solve was the reliance on toxic chemical initiators," said Li. "Our method eliminates these substances, making the process safer for the body and better for the environment."

This ultrasound-driven technique is dubbed "sonogel."

"Typical hydrogel synthesis can take hours or even overnight under UV light," said Li. "With ultrasound, it happens in just five minutes."

Revolutionizing biomedical applications

One of the most exciting possibilities for this technology is in noninvasive medical treatments. Because ultrasound waves can penetrate deep into tissues, this method could enable in-body hydrogel formation without surgery.

"Imagine injecting a liquid precursor and using ultrasound to solidify it precisely where needed," said Li. "This could be a game-changer for treating [tissue damage](#) and regenerative medicine. With further refinement, we can unlock new possibilities for safer, greener material production."

The technique also opens the door to ultrasound-based 3D bioprinting. Instead of relying on light or heat, researchers could use sound waves to precisely "print" hydrogel structures.

"By leveraging high-intensity focused [ultrasound](#), we can shape and build hydrogels with remarkable precision," said Jean Provost, one of the co-authors of the study and assistant professor of engineering physics at Polytechnique Montréal.

More information: Yixun Cheng et al, Ultrasound Cavitation Enables Rapid, Initiator-Free Fabrication of Tough Anti-Freezing Hydrogels, *Advanced Science* (2025). DOI: [10.1002/advs.202416844](https://doi.org/10.1002/advs.202416844)

Journal information: [Advanced Science](#)

Provided by [McGill University](#)

MAY 9, 2025

The forest byproduct lignin can play a key role in new sustainable materials

by University of Borås



Lab sample of a lignin polymer product. Credit: University of Borås

Lignin, a by-product of the forest industry, can be used to produce sustainable materials that can replace traditional plastics. This has been revealed in a research project at the University of Borås in Sweden. Matilda Johansson, holder of a Ph.D. in Polymer Technology, has investigated how lignin can be chemically modified and used in fiber-reinforced biocomposites. The goal was to create materials that can not only replace oil-based products, but also reduce the weight of structures without compromising mechanical properties.

The project revolved around four key issues: How can the compatibility of [lignin](#) with other substances be improved? How can the modification process be made more efficient and environmentally friendly? How can the mechanical and thermal properties of the material be improved? And how can a fiber be incorporated to further strengthen the material?

"There are many unexplored possibilities for lignin. By chemically modifying lignin, it is possible to create a material that has great potential to replace oil-based materials," said Johansson.

The method involves extracting lignin from forest and agricultural waste and chemically modifying it using acetic anhydride and microwaves. This allows the lignin to bind with other polymers, such as PLA ([polylactic acid](#)). Then, methods such as extrusion, 3D printing and compression molding are used to create a composite reinforced with regenerated cellulose fibers.

Environmental benefits and resource efficiency

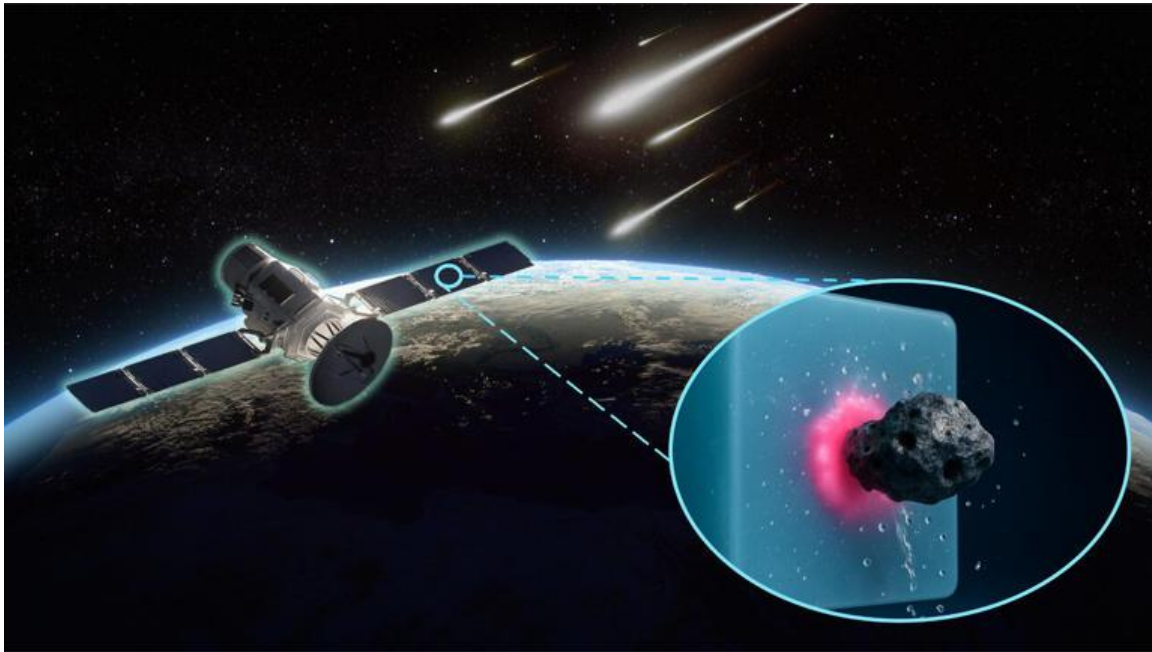
"The project contributes to minimizing the use of traditional plastics, i.e. oil-based materials. The material consists of natural components and no harmful chemicals are used during production. More and more industries are switching to bio-based alternatives and this material could be an option to reduce climate impact. The fact that it also consists of a material that is considered to be a byproduct from another industry, i.e. of low value, makes the whole process more resource-efficient," explained Johansson.

The project is an important contribution to research on [sustainable materials](#). This demonstrates the importance of developing environmentally friendly alternatives to today's materials.

"Today's high consumption means that there is an incredible amount of material, yet a very small proportion is recycled, resulting in accumulations of material that contribute to a lot of destruction in nature. If it is possible to choose a material that has had less impact on nature when it is produced as well as less impact on nature when it is used, that's a win-win," said Johansson.

More information: Matilda Johansson, [Valorising lignin: A pathway to sustainable and high-performance biocomposites](#) (2025)
Provided by University of Borås

New self-healing polymer possesses a quality never before seen at any scale



Credit: Texas A&M Engineering

What if there were a fabric that, like Superman, could take a bullet and self-heal? Such a super-dynamic, action-powered polymer might actually help protect real-life flyers in space.

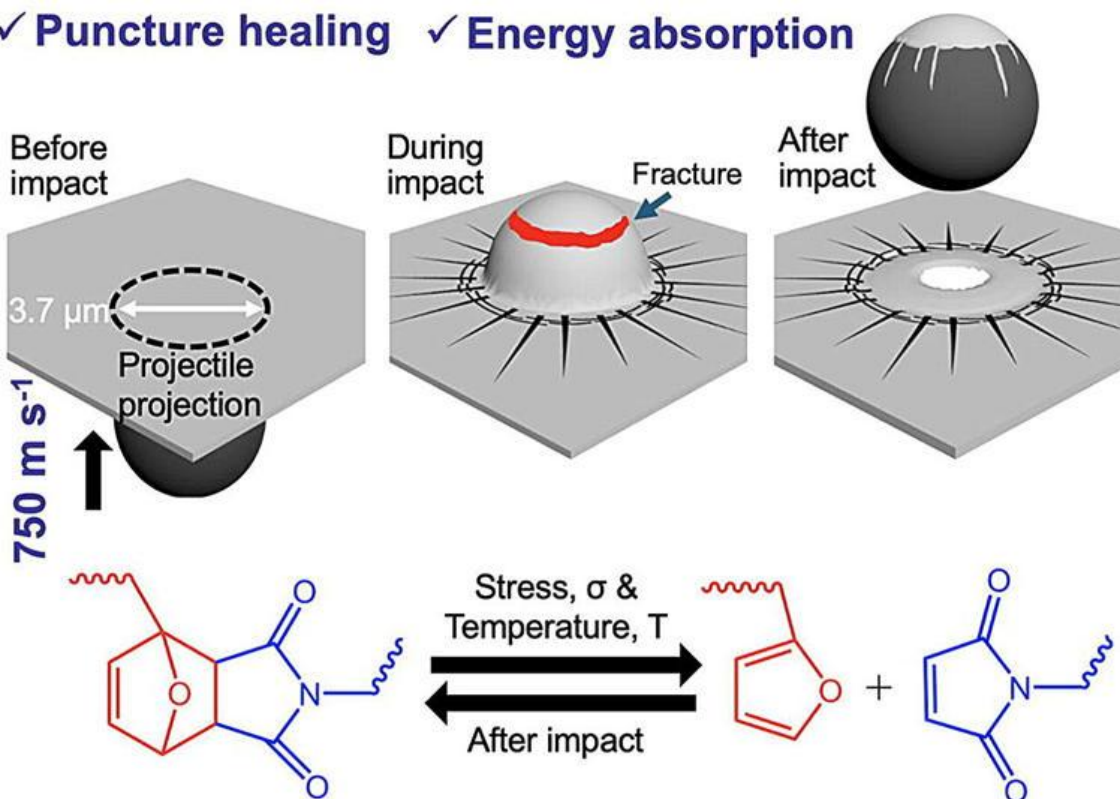
Material scientists at Texas A&M University have developed just such a polymer with a unique self-healing property never before seen at any scale. When struck by a projectile, this material stretches so much that when the projectile manages to pass through, it takes only a small amount of the polymer with it. As a result, the hole left behind is much smaller than the projectile itself.

However, for now, this effect has only been observed under extreme temperatures and at the nanoscale.

"This is the first time a material at any scale has displayed this behavior," said Dr. Svetlana Sukhishvili, a professor in the Department of Materials Science and Engineering, who has been working on development of this polymer film with materials science and engineering professor Dr. Edwin (Ned) Thomas, and then-

graduate student Dr. Zhen Sang. Their findings are [published](#) in the *Materials Today* journal.

✓ Puncture healing ✓ Energy absorption



Graphical abstract. Credit: Materials Today (2025). DOI: 10.1016/j.mattod.2024.12.006

"Besides being very cool, the new polymer will likely have many applications, including making the windows of space vehicles more resilient to the onslaught of micrometeoroids," Thomas said.

Space vehicles are frequently bombarded with micrometeoroids traveling at speeds of 10 kilometers per second. A micrometeoroid can create a hole in the window that, while small, is visible to the human eye. However, a window manufactured with a layer of this polymer could potentially sustain damage tinier than the meteoroid itself.

Thomas, who first suggested subjecting the polymer to ballistic testing, said a key goal of the research is to design a material that will protect structures such as orbiting satellites and vehicles in space, with applications for military equipment and body armor on Earth.

The phenomenal behavior occurs in the new solid polymer film as it melts when impacted by a laser-launched high-speed projectile, and snaps back to its original shape when cooled. The polymer does this by absorbing much of the kinetic energy generated by the projectile, causing the film to stretch and liquefy as the projectile continues its journey, finally piercing the film. Once pierced, the polymer quickly cools, its covalent bonds reform, and it returns to its original solid state, leaving a tiny hole.

"A major goal of our work was to see if we could simultaneously provide a material that would absorb a lot of kinetic energy per unit target mass from the high-speed projectile and be capable of very rapid healing of the punctured region," Thomas said.

"We wanted the post-impact material to still be capable of performing its intended function, such as carrying air or liquids and remaining sealed against the loss of such fluids across the material membrane."

The material is a Diels-Adler Polymer or DAP, so-named by the researchers for its dynamic covalent bond networks that can be broken and reformed. It belongs to a class of materials called Covalent Adaptative Networks or CANs. While other Diels-Adler networks have been reported in the scientific literature, DAP's specific chemistry, topology and self-healing quality are novel. The DAP acronym could also refer to their polymer as a Dynamic Action-Powered material for its ability to self-heal.

"When we were synthesizing DAPs, we aimed to do it in such a way that the polymers would turn to liquids upon temperature increase," Sukhishvili said.

"Although this feature was introduced to facilitate 3D printing, we thought that due to its ability to liquefy upon heating, our polymers could show improved ballistic healing characteristics."

"Polymers are amazing materials, especially DAP materials," Thomas explained.

"Because at low temperatures, they are stiff and strong; then at higher temperatures, they become elastic; and at still higher temperatures, they become an easily flowing liquid. That's a huge range of property behavior."

What's more, he said, the process reverses itself. "Nothing else on Earth can do that."

The DAP structure is of long polymer chains containing double carbon bonds that break when severe strain and heat are applied, but quickly reform when cooled, albeit not necessarily in the same configuration.

"Think of the long polymer chains in the fabric as being like a bowl of Ramen noodle soup," said Sang, who worked on this project for his doctoral research and is first author on the paper. "You can stir it with chopsticks, then freeze it. When you unfreeze it, you can stir it, then refreeze. It will have the same ingredients as before, just in a slightly different appearance."

Sang, who is now an engineer at Apple, Inc., said it wasn't easy to do ballistic testing at such a small scale until he came across a new research methodology called LIPIT (laser-induced projectile impact testing), recently developed by Thomas and colleagues at MIT.

Sang used LIPIT to laser-launch a tiny silica projectile 3.7 micrometers in diameter from a glass slide covered with a thin gold film resting on a one-square inch platform. His target consisted of a thin layer (75 to 435 nanometers) of the super DAP.

An ultrahigh-speed camera with a 3-nanosecond exposure time at 50 nanosecond intervals recorded the action. The research team then used scanning electron microscopy, laser scanning confocal microscopy and an infrared nano spectrometer to view the holes and assess the covalent bonding in the super polymer.

The results were puzzling at first, Sang said, because he could find no holes in the targeted polymer.

"Was I not aiming correctly? Were there no projectiles? What's wrong with my experiment, I asked myself," he said. However, when he placed the DAP sample under the infrared nano spectrometer, which combines chemical analysis with high-scale resolution, he was able to see the tiny perforations.

"This was actually a surprising, surprising finding," Sang said. "A very exciting finding."

He explained this behavior can't yet be recreated at the macro level because the strain rate during perforation of a very thin target material under impact is so much larger than at the nanoscale.

"If this strain rate is really high, materials often have unexpected behavior that people don't usually see under normal circumstances," Sang said. "With the LIPIT apparatus that we're using, we're talking about a strain rate many orders of magnitude higher than for conventional scale bullets and targets. At that perspective, materials behave very differently."

Other co-authors on the paper are materials science doctoral student Hongkyu Eoh; former postdoctoral researchers Drs. Kailu Xiao, Wenpeng Shan and Jinho Hyon; and Dr. Dmitry Kurouski, associate professor in the department of biochemistry and biophysics at Texas A&M.

Sukhishvili and Thomas plan to continue researching the super DAP using different polymer compositions, temperature- and stress-responses.

"One could even imagine designing DAPs with characteristics such that it would be possible to absorb kinetic energy by breaking DAP bonds, then some of these broken bonds could very rapidly reform—by perhaps having just the right 'bond reform catalyst' present in the material—whereby the projectile would have to break these bonds a second (or even multiple times) before the material ultimately heals itself, and is ready for the next ballistic event.

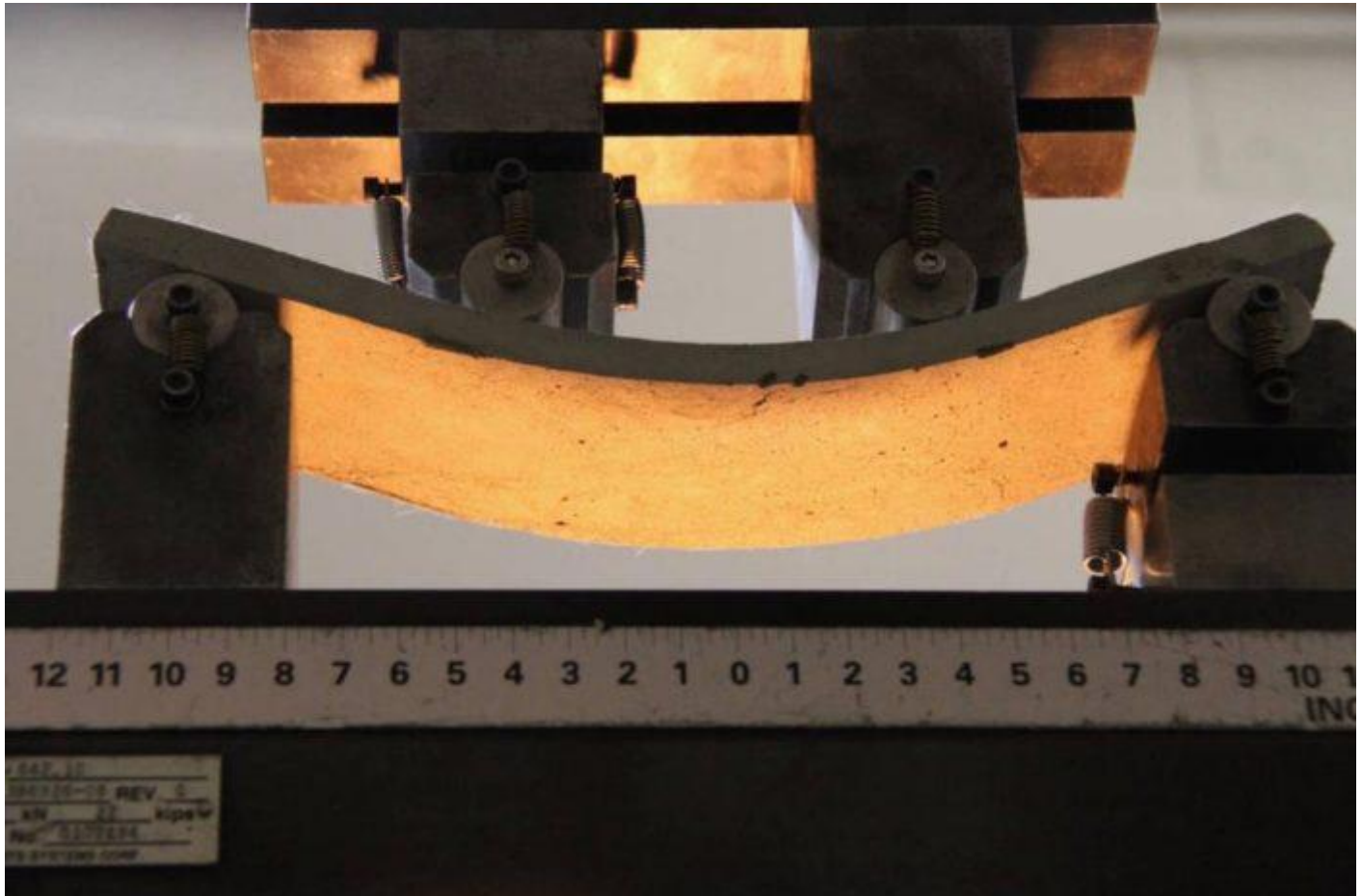
"To date, no material has the requisite time response to deform, break, reform; and then deform, break and reform again during the sub-microsecond interval of a ballistic event," Thomas said.

More information: Zhen Sang et al, Supersonic puncture-healable and impact resistant covalent adaptive networks, *Materials Today* (2025). DOI: [10.1016/j.mattod.2024.12.006](https://doi.org/10.1016/j.mattod.2024.12.006)

Provided by Texas A&M University College of Engineering

Making Bendable Concrete

With a design inspired by seashells, this reformulated concrete can make the U.S. infrastructure safer and more durable



Unlike conventional concrete, engineered cementitious composite (ECC) can bend under pressure without rupturing. (Photo: Victor Li)

More Guest Blogs

Spring construction season is underway, and many tons of concrete will be used in the coming months. Unfortunately, concrete is a brittle material: Placed under stress, it cannot bend very far before it fractures. Some pavements that are being poured now will crack within a few years and require expensive repairs. New concrete will be mixed, and the cycle will start again.

But a better solution is in view. [My laboratory](#) at the University of Michigan, along with many other laboratories around the world, has shown it is possible to make concrete more ductile — that is, bendable without fracturing. Bendable concrete makes infrastructure safer, extends its service life and reduces maintenance costs and resource use.

Civil infrastructure very rarely fails because it lacks compressive strength — the ability to bear loads that push it together, as when columns support the weight of a building. Most failures occur because structures do not have enough capacity to carry tensile load — the ability to deform or stretch without rupturing — even though steel reinforcements often are added to concrete to prevent catastrophic structural failure.

Many serious concerns about the woeful state of U.S. infrastructure can be traced back to concrete's brittleness. Cracks in concrete can reduce a structure's usable life. They also weaken it and make it less resilient against natural forces, such as earthquakes or tornadoes, or man-made forces, such as bomb blasts in terrorist attacks.

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For example, 52 people died in the 1989 Loma Prieta earthquake in Northern California due to building and freeway collapses. Major freeways also sustained heavy damage in the 1994 Northridge earthquake in Los Angeles, including one that had been rebuilt after a quake in 1971. If the quake had occurred during a weekday rush hour, rather than at 4:30 a.m. on a Monday holiday, the results could have been catastrophic.

Repeated infrastructure repairs and rebuilds use enormous quantities of materials and energy. Studies have shown that the carbon and energy footprints of frequent repair events, and the social and economic costs they generate, far exceed those associated with initial

construction. We all pay these costs in time stuck in traffic jams, higher taxes and polluted air.

Making concrete bend

To develop ductile concrete, our laboratory borrowed ideas from nacre, also known as mother of pearl — the iridescent material on the inside of abalone shells.

Mollusks make nacre from aragonite, a natural form of calcium carbonate, which by itself is extremely brittle. But nacre is ductile because of its architecture at the nanoscale, which looks like a brick wall. The “bricks” are thin layers of aragonite platelets, and the “mortar” between them is a natural polymer that is very elastic. The polymer holds the rigid aragonite layers together, but allows them to slip from side to side under stress. This structure makes nacre both strong and flexible.

Concrete is a composite mixture that normally consists of gravel and sand particles bound together with cement. To design ductile concrete, we imitated nacre’s “give” by dispersing tiny fibers inside the composite. When properly controlled, the interfaces between fibers and cement recreate the controlled slippages in nacre.



Nacre, the coating on the inside of abalone shells, is highly ductile, allowing the shell to resist impacts without fracturing. It protects abalone from sea otters that try to break shells open by banging them on rocks.

We call the resulting ductile concrete engineered cementitious composite (ECC) or strain-hardening cementitious composite. It can deform up to 3% to 5% in tension before it fails, which gives it 300 to

500 times more tensile strain capacity than normal concrete. This allows a slab of it to undergo a lot of bending without fracturing into pieces, earning it the nickname of flexible or bendable concrete.

ECC was invented at the University of Michigan, and it has now acquired a following of hundreds of universities and industrial entities conducting further engineering research and technology development.

Uses for bendable concrete

Making concrete bendable addresses several of conventional concrete's key flaws. First, suppressing brittle fracture prevents the formation of wide cracks that allow water and other aggressive agents like road salt to penetrate easily into concrete structures and attack their reinforcing steel.

Experimental evidence and our theoretical calculations show that it is possible to extend the time it takes for chloride from road salt on a bridge deck surface to reach and corrode reinforcing steel from years to tens of years. A number of projects, ranging from patch repair to link slabs on bridge decks that dramatically extend service life, have taken advantage of this fracture suppressing ability.

Bendable concrete also enables structural elements to absorb a lot of energy. For example, manufacturers have developed ECC dampers to retrofit the 28-kilometer Seisho Bypass viaduct along Japan's eastern seaboard and to help make new tall buildings more resilient during earthquakes, including several in Tokyo and Osaka. Flexible concrete has many other potential large-scale industrial applications, including water infrastructure and underground construction.

Widespread use of ECC will require a good supply chain and intelligent use of the material to optimize cost economics. The most significant obstacle is the fact that ECC is still relatively novel to structural engineers, who are trained to assume that concrete cannot withstand tension.

How bendable concrete can heal itself

Our concrete composite can also learn new tricks. For example, when it is damaged, the hairline cracks that form can undergo healing just through exposure to water and air. Self-generating reactions create healing products through continued hydration and carbon mineralization, binding crack surfaces together in much the same way that our skin heals from a paper cut. Self-healing concrete can make structures such as roads and bridges more durable.

Bendable concrete also can adjust its own thermal capacity, so that it stores more heat when the outside temperature is high, keeping building interiors cool. Encapsulated micron-sized wax-like materials within the concrete change from solid to liquid form, like tiny ice cubes melting into water, when temperatures reach levels that are uncomfortable for humans.

We are currently teaching ECC to neutralize pollutants, thereby helping to maintain clean air in urban environments. Embedded nano-titanium particles in the composite break down pollutants into harmless substance via reactions catalyzed by sunlight.

These autonomous and adaptive functional features can contribute to the development of future smart cities with infrastructure that responds to environmental changes. Our goal is to create a new generation of smart, bendable concrete that will help build and maintain a resilient, sustainable and healthy living environment.

Victor Li is a professor of engineering at the University of Michigan.



All about Flexible Concrete or Bendable Concrete | Engineered Cementitious Composite(ECC)

April 1, 2017 by [Ashutosh Gupta](#)

Engineered Cementitious Composite

This article will enlighten a unique construction material i.e. the flexible concrete also known as bendable concrete. This material can bring the revolution because of its some special quality such as flexibility, [self-healing](#), lighter weight, etc. In some countries such as Japan, Korea, U.S.A, etc the flexible concrete is used in many [structure](#). But in India it is still a new material and requires proper research for its use in India. Soon we may saw the use of flexible [concrete](#) in many structure.

Flexible concrete specimen made by Professor Victor Li

Concrete is widely used in today's construction industry. It has good load [bearing capacity](#). It can take the [compressive](#) load very effectively. But the main problem with the traditional concrete is that it cannot take much tensile stresses. It fails under the tensile load. The flexible concrete is a good substitute for this problem.

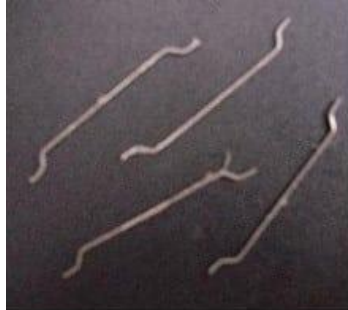
What is Flexible Concrete?

It is special type of concrete that can take the bending stresses. It consist of special type of materials that makes it flexible. It was developed by the Professor Victor Li at the University of Michigan. Its engineering name is Engineered Cementitious [Composite](#)(ECC). It exhibits the property of a ductile material instead of a brittle material which is shown by the conventional concrete.

Materials used in Bendable Concrete

Fibres reinforcement:

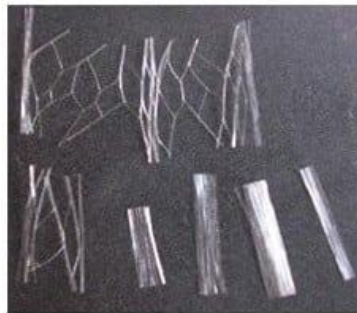
For giving the concrete flexibility we have to alter the material of the conventional concrete. In the flexible [concrete](#) we eliminate the coarse aggregate. Instead of that we use the fibres that are used in the fibre reinforced concrete such as silica [fibres](#), glass fibres, steel fibres, asbestos fibers, polyvinyl alcohol fibers, etc. The micro fibres provide the flexibility to the [concrete](#). It also act as a [reinforcement](#) material in the concrete.



Hooked steel



Glass



Polypropylene



Polyester

Different types of

reinforcement fibres used in Bendable Concrete

Slick coating (anti-friction coating):

Additionally the **slick coating** (anti-frictional coating) is provided so that the fibers particles can slide over one another and does not have the friction which may result into the cracks in concrete. This tendency of slipping of fibers over one another helps the concrete to minimize the crack and provide flexibility to the concrete. The normal cement can be used for the [concrete](#).

Fine sand:

The fine **silica sand** is suitable for the flexible concrete which is used in the water treatment plant but if it is not available the normal sand can be used but it may effects the strength and flexibility of concrete. We can also add fly ash, silica fume, blast furnace slag can also be used in the concrete.



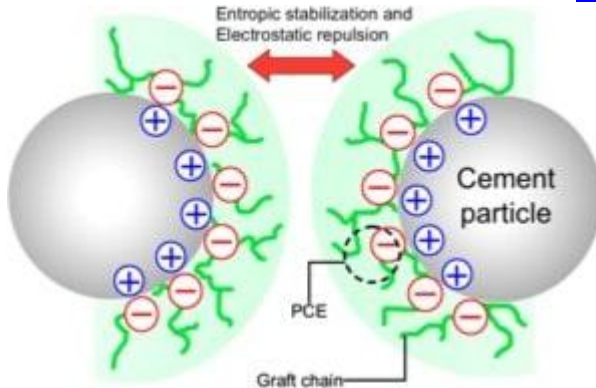
Silica sand & Silica

sand close-up

Superplasticizer:

Polycarboxylated ether, lignosulfonates, lignin, naphthalene or melamine formaldehyde sulphonate (any one) is used in the concrete for increasing the [workability](#) of the concrete.

Latex can also be used in the concrete for [improving](#) its flexibility.



Plasticizer



Superplasticizer

Effect of Plasticizers on cement

Advantages of flexible concrete

- The flexible concrete has the ability to bend like a metal
- It is more Stronger, more durable, and lasts longer than conventional concrete
- It has a self-healing property that is it can heal itself by using carbon dioxide and rainwater
- It is not brittle like a glass
- It is more resistant to [cracking](#)

- It does not emit that amount of harmful gases as compared to conventional concrete.
- The flexible concrete is approx. 20-40 percent lighter
- The use of [steel](#) reinforcement is reduces and can be eliminated
- It reduces the cost of the project
- It can be used as [precast](#) concrete.



Steel fibres used in

Bendable Concrete

Disadvantages of flexible concrete

- It has a high initial cost as compared to conventional concrete.
- It requires skilled labor for its construction.
- It needs some special type of materials which can be difficult to find in some areas.
- Its quality depend upon the material used and the condition under which it is made.
- Its compressive strength can be lesser than the conventional concrete.

Special features of Bendable concrete

- The bending strength or tensile capacity of flexible concrete is in the range of 10 to 15 MPa and compressive strength is upto 70 MPa.
- It has a self-healing property as the [cement](#) particles make reaction with the rain water and makes some complex product that expands and fill the [microcracks](#) that are developed in the flexible concrete.

- The flexible concrete is proved to be lighter and also proved to be 500 times more flexible than normal concrete.
- Its ultimate tensile strain capacity is 3 to 5 %.
- The strain capacity in flexible concrete is 300 times more than conventional concrete. Due to this the concrete is act like a flexible material such as metal.

Flexure test on Flexible concrete

beam

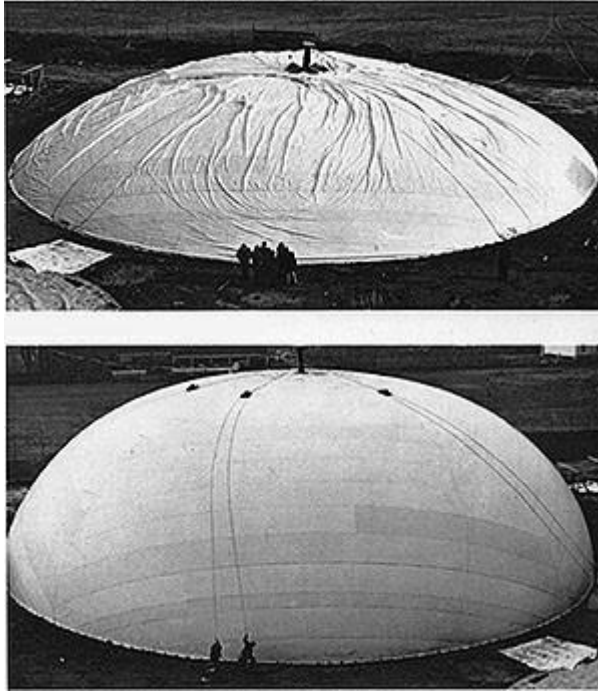
Uses of ECC or Bendable Concrete

Earthquake resistance building: The structure made with the flexible concrete can take more tensile stresses that it does not break down due to the vibration caused by the [earthquake](#). In Japan a 60 floor is under construction which uses this concrete.



Structure made with flexible concrete

Concrete canvas: The concrete canvas can also be made with the flexible concrete. The concrete canvas is stronger and durable than the normal canvas. It can be used in the military area.



Concrete canvas made by flexible concrete

For roads & bridges: It can be used in [roads](#) and bridges. With the use of flexible concrete in roads and [bridges](#) there is no need of [joints](#) such as expansion joint, contraction joint as the concrete is itself have the ability to change its shape. Moreover the bridges and roads are more durable and has low repair cost.

Comparison between Conventional Concrete & Bendable Concrete

Point of difference	Normal Concrete	Engineered Cementitious Composite(ECC)
Durability	The normal concrete structure are less durable.	The flexible concrete structure are more durable.
Earthquake resistance	The structure made with the original concrete are prone to earthquake. They generally forms cracks or may collapse during earthquake.	As the flexible concrete does not break easily by the earthquake motion. So the structure made with the flexible concrete are more earthquake resistance.

Self-healing property	The normal concrete has very low self-healing property as it has very low free cement concrete.	The flexible concrete has a very good self-healing property as it can heal the micro-cracks itself by the reaction of carbon dioxide and water.
Repair & maintenance	The repair & maintenance cost of concrete structure is high as it developed cracks and other defects.	The repair & maintenance cost of flexible concrete is less as it does not develop that much cracks.
Self-weight	The self-weight of conventional concrete is more	The flexible concrete is 30-40 % lighter than the conventional concrete
Reinforcement	The steel bar reinforcement is require for taking the tensile load.	The fibre reinforcement can provide the require tensile strength in the concrete so less or may be steel reinforcement is require.
Curing time	The concrete structure generally requires more curing time (around 28 days).	The flexible concrete requires less curing time (generally 7 days)
Labour	It requires less skilled labour	It requires more skilled labour
Cost	The cost of construction is less as it consist of common material	The initial cost of construction is more

Reference

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4. <http://www.concretcanvas.com/>

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Thermoelectric energy harvesting using cement-based composites: a review

Author links open overlay panelV.P. Singh, M. Kumar, R.S. Srivastava, [R. Vaish](#)

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Highlights

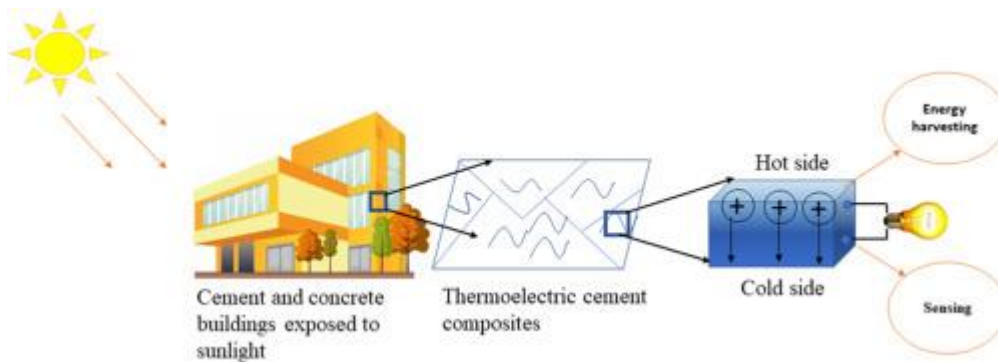
- •
The performance of cement-based [thermoelectric](#) composites has been characterized based on additives used.
- •
Carbon and steel fibers, metal oxides, graphene, and CNTs are found to alter the thermoelectric properties of cement.
- •
Most thermoelectric cement composites have ZT values below 10^{-3} .
- •
Challenges for more efficient and large-scale operation of thermoelectric-based cement composites are mentioned.

Abstract

In the modern era, cement and cement-based structures with additional functionalities are highly desirable. For example, the temperature difference induced between the outdoor and indoor surfaces of cement structures in buildings can be exploited for thermoelectric-based cement structures for [energy harvesting](#). This article reviews the application of thermoelectric-based [cement composites](#) for [energy harvesting](#) and thermal sensing. These properties could be exploited in structures such as buildings, roads, housing, dams, and bridges. The enormous exposure of solar energy over the area

of civil infrastructures is stored thermally within the construction materials, which is harvested when thermoelectric-based cement materials are used. First, the review describes the basic properties of [thermoelectric](#) materials and their applicability in [cement composites](#). Furthermore, a broad classification of admixtures that are added in the cement composites for the enhancement of [thermoelectric](#) properties is made. The hole conduction improved significantly with the addition of carbon fibers in cement and [thermoelectric](#) power was recorded to be $-17 \mu\text{V}/^{\circ}\text{C}$, which is much higher as compared to the pristine carbon fiber reinforced cement ($-0.8 \mu\text{V}/^{\circ}\text{C}$). Steel fiber [cement pastes](#) show higher volume electrical resistivity than carbon fiber [cement pastes](#) even when steel fiber content is raised to 1% by mass of cement. Hence, development in thermoelectric-based cement composites by the addition of different admixtures is summarized. Finally, the challenges for the more efficient and large-scale operation of thermoelectric-based cement composites are mentioned and discussed for further improvements.

Graphical abstract



Introduction

Cement, one of the major civil infrastructure constituents, covers the wide-ranging applicability of structure material. Owing to their remarkable mechanical properties, cement-based materials possess to be basic material as a binder in concrete for various construction, including building, roads, housing, dams, and bridges [[1], [2], [3], [4], [5]]. The cement-based structures in constructions are exposed to a large quantity of solar energy exposure. The amount of solar energy received over the exposed area is

stored as thermal energy [6,7]. Thus, for harvesting this stored energy, either certain additional technologies or multifunctional materials are contemplated. In recent years, the use of multifunctional structural materials while preserving their structural properties has been apprehended [[8], [9], [10]], [11], [12], [13]]. By adding various additives to the cement, its properties can be altered for suitable applications. Therefore, the temperature difference induced between the outdoor and indoor surfaces of cement structures in buildings triggers thermoelectric-based cement structures for energy harvesting. The thermoelectric-based cement materials dwell potentials to convert stored thermal energy from solar irradiation to electrical energy and reduce the surface temperature of the building [[14], [15], [16]]. Thus, decrease in building temperature servers for better indoor conditions and reduces the cooling load. Hence, eventually offers a reduction in electricity consumption for the air-conditioning cooling units in the building [17].

The use of multifunctional structural materials while preserving their structural properties has been seized in different ways [18]. Carbon-based structural composites hold budding capabilities for multifunctional applications, can act as an electrochemical energy storage device in parallel [19]. Likewise, structural capacitors developed by laminating glass-epoxy prepared with metalized film electrodes and based on laminates of activated structural carbon fiber (CF) fabric electrodes sandwiching a structural glass fiber separator filled with (structural) electrolyte [20,21]. However, it is still challenging to produce multifunctional-based composites for large-scale applications. The pavements and building roofs constituting the large surface are integrated with several technologies for directly serving in the reduction of temperature. There are quite a few techniques for pavement cooling, which are greatly affecting in reducing surface temperature, such as reflective cooling pavement, serpentine tubes under the road, and green roofs [22,23]. Conversely, these techniques store daytime solar energy and release it in the night time, which eventually results in a hotter night. Phase change materials encapsulated in building walls are also effective for reducing cooling loads and providing better indoor thermal comfort [24,25]. Although, the major portion of phase change material used is of non-use because of the low convective heat transfer coefficient.

Thermoelectric-based cement composites thus offer a reduction in surface temperature along with a better indoor thermal comfort level. In addition, the thermal energy stored is rather converted into electrical energy instead of just releasing it into the environment at night time. This proposes the strategy of the multifunctionality of the thermoelectric-based cement composites [26]. The thermoelectric modules are fabricated of conventional thermoelectric materials like Bi_2Te_3 positioned on walls and openings for cooling and heating indoor space [27]. However, proficient application dwelled when concrete walls themselves possessed thermoelectric characteristics. This offers a more efficient and convenient way for energy harvesting applications using the thermoelectric effect.

The research areas of multifunctional structural materials, cementitious-based multifunctional structures, and free cooling systems for buildings are extensively explored. There are several review articles also on nanoengineered multifunctional composites, phase change material-based building cooling, and carbon nanotubes/nanofibers on cement admixture particles [28]. Han et al. reviewed the recent progress made by introducing nanoparticles in cementitious materials [29]. Several other articles on the free cooling system of the building using phase change materials have been reported [30]. However, the potential of thermoelectric technology for civil structures has also been explored and there has been notable work performed on cement-based thermoelectric composites. Although, it is to be noted that no such review article exists describing the performance and status of cement-based thermoelectric composites. Therefore, the present article presents a summary of the thermoelectric properties of cement composites. The classification was done based on various admixtures mixed in the cement to induce thermoelectricity. Potential applications, challenges, and future scope of these composites are also discussed.

Thermoelectric materials and applications

Thermoelectric materials, which can be applied for proficient cooling/heating including refrigeration, energy harvesting, and sensing, and thermopower systems, provide significant contributions for green and clean energy operations [[31], [32], [33], [34]]. The thermoelectric material-based devices cause no such carbon dioxide emission while

its operation and have no moving parts, which make them very robust. The thermoelectric effect works based on the principle of Seebeck, Peltier, and

Cement-based thermoelectric composites

Generally, cement exhibits slight electron movements because of the presence of n-type conductivity. Therefore, with the addition of p-type conductive admixtures, hole movements are present, which eventually develops electron–hole distribution in cement composites [36]. Thus, a voltage difference is attained and TEP is generated. The conductivity of the cement-based matrix can be enhanced even when admixtures are added below the percolation threshold (Fig. 2). However, there has been notable

CF composites

An introduction of CFs in the cement earlier was intended to enhance the optimal mechanical properties of cement and concrete. However, Sun et al. discovered the hole conduction aspect in CF admixed cement in 1998 [37]. Based on their experimental studies, it was proposed that hole conduction also exists in CF cement composites along with ionic and electronic conduction. In this report, the author reported the Seebeck coefficient concerning copper as used commonly for thermoelectric

Steel fiber composites

The addition of short steel fibers was initially found attractive for enhancing structural properties. However, in the early 21st century, it was discovered that short steel fibers are also beneficial for enhancing the p-type Seebeck effect. The absolute TEP for all the steel fiber cement composites is found to be more positive than the CF-cement composites. Steel fiber content increment leads to an increase in linearity and reversibility of Seebeck voltage as there exists a difference in

Carbon nanotube composites

Carbon nanotubes (CNTs) have a very wide range of applications in the fields of batteries, sensors, and transistors. They are formed from rolled graphite sheets having hollow tubular structure and registers superb electrical conductivity. Considering their

microscopic length and nanoscopic diameter, the CNTs exhibit high strength nearly 100 times than steel because of their high strength to weight ratio. It is also expected that incorporating CNTs would increase the mechanical strength of

Graphite/graphene composites

Graphene is a two-dimensional form of carbon found abruptly in nature possesses excellent features such as high mechanical strength, electrical and thermal conductivity, lightweight, cheaper, and easily producible than CF and CNTs [55,56]. Graphene nanoplatelets (GNPs) can alter non-conductive material to be conductive material and improve the Seebeck coefficient, which makes it advantageous to enhance cement-based research. However, despite possessing excellent electrical and thermal

Metallic oxide composites

New thermoelectric materials such as Bi_2Te_3 , PbTe , SiGe , GaN , and their derivatives were discovered in the 19th century [61]. Transition metal oxides have attracted researchers in aid to their high Seebeck coefficients, temperature stability, minimal environmental effect, and advanced synthesis techniques. Manganese dioxide (MnO_2) determined for its structural flexibility and rich polymorphism is extensively used in electrodes, batteries, capacitors, and catalysis. MnO_2 shows excellent

Limitations and future scope

The cement-based thermoelectric materials seem quite promising for waste solar energy harvesting. Owing to major applicability in cement infrastructures, cement-based thermoelectric composites show effective potentials to recover waste heat present in abundance. The enhancement in the thermoelectric property of cement-based materials was attained by certain types of admixtures like carbon and steel fibers, carbon nanotubes, graphite, and metal oxides. Although there are more than 30 reports,

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Engineered composite materials offer broad-spectrum synergistic radiation shielding

by Zhang Nannan, Chinese Academy of Sciences, edited by [Lisa Lock](#), reviewed by [Robert Egan](#)

SEM images of micron spindle-shaped PbWO_4 -I (a), micron spherical PbWO_4 -II (b), rough micron spherical PbWO_4 -III (c), commercial PbWO_4 (d). Credit: Huo Zhipeng

In a recent breakthrough, Dr. Huo Zhipeng and his student Chen Zuoyang from the Hefei Institutes of Physical Science of the Chinese Academy of Sciences have developed a new class of PbWO_4 filler-reinforced $\text{B}_4\text{C}/\text{HDPE}$ composites with tunable microstructures.

By precisely regulating the microstructure of PbWO_4 fillers, they achieved enhanced synergistic radiation shielding performance against both neutron and gamma radiation, while elucidating the correlation mechanisms between the microstructure and thermal, mechanical, radiation shielding properties, and service durability of the shielding composites. The results were [published](#) in *Composites Part A: Applied Science and Manufacturing*.

The demand for advanced radiation shielding materials has surged with the growing applications in [nuclear energy](#), medical radiotherapy, and aerospace exploration. Neutron and [gamma radiation](#)—two prevalent and hazardous forms of ionizing radiation—pose significant risks to human health and sensitive equipment. Conventional shielding materials often fall short, offering limited protection against only one type of radiation or exhibiting poor mechanical integrity and aging resistance.

In this study, by synthesizing PbWO_4 fillers with varied microstructures through controlled [reaction conditions](#), the researchers achieved distinct microscopic morphologies such as micron spindle-shaped PbWO_4 -I, micron spherical PbWO_4 -II and rough micron spherical PbWO_4 -III. Among them, the micron-scale rough spherical PbWO_4 -III filler exhibited superior characteristics such as increased specific surface area, more uniform particle distribution, and better dispersion within the polymer matrix.

Schematic diagram of synergistic shielding mechanism of neutrons and gamma photons interacting with the PbWO_4 filler-reinforced composites. Credit: Huo Zhipeng

This microstructural refinement improved interfacial bonding, leading to enhanced [thermal stability](#), [mechanical properties](#), and ultraviolet aging resistance. Pb and W atoms in PbWO_4 fillers effectively absorb gamma photons and [fast neutrons](#), while B atoms in B_4C fillers provide high thermal neutron absorption. The resulting composite thus offers enhanced synergistic shielding across a broad neutron energy spectrum and gamma ray.

The optimized PbWO₄-III/B₄C/HDPE composite achieved a 97.32% shielding rate against ²⁵²Cf neutrons and 76.43% against ¹³⁷Cs gamma photons at a thickness of 15 cm. These results represent a significant improvement over conventional materials, which typically lack this combination of synergistic shielding and robust mechanical performance.

This work not only demonstrates the importance of microstructure control in composite design but also provides a promising strategy for next-generation, high-performance radiation protection materials, according to the team.

More information: Zhipeng Huo et al, Microstructure regulatable PbWO₄ fillers reinforced B₄C/HDPE composites for synergistic radiation shielding of neutron and gamma-ray, *Composites Part A: Applied Science and Manufacturing* (2025). DOI: [10.1016/j.compositesa.2025.109011](https://doi.org/10.1016/j.compositesa.2025.109011)
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