RETRACTED ARTICLE: Researchers synthesize room temperature superconducting material

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The goal of new research led by Ranga Dias, assistant professor of mechanical engineering and of physics and astronomy, is to develop superconducting materials at room temperatures. Currently, extreme cold is required to achieve superconductivity, as demonstrated in this photo from Dias's lab, in which a magnet floats above a superconductor cooled with liquid nitrogen. Credit: University of Rochester / J. Adam Fenster

Compressing simple molecular solids with hydrogen at extremely high pressures, University of Rochester engineers and physicists have, for the first time, created material that is superconducting at room temperature.

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phys.org/news/2022-09-paper-te … oom-temperature.html

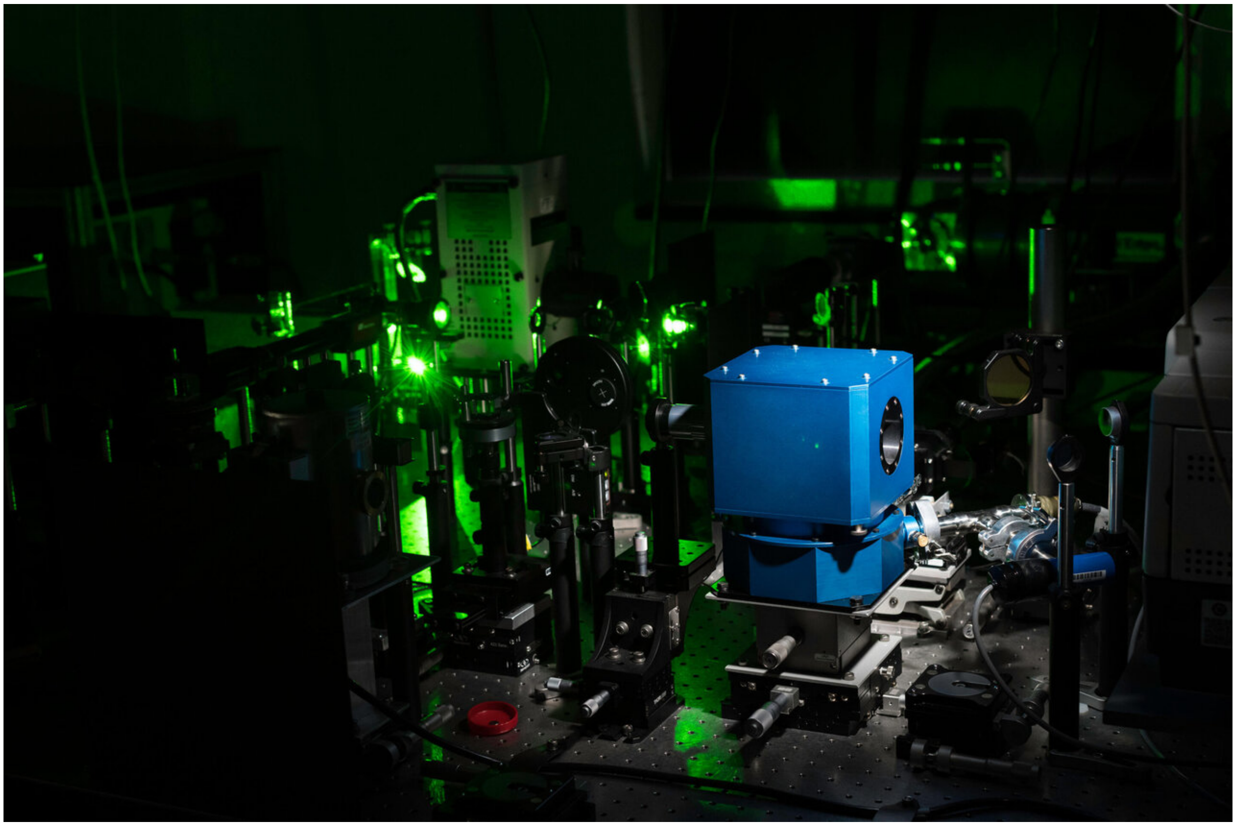
Featured as the cover story in the journal *Nature*, the work was conducted by the lab of Ranga Dias, an assistant professor of physics and mechanical engineering.

Dias says developing materials that are superconducting—without electrical resistance and expulsion of magnetic field at room temperature—is the "holy grail" of condensed matter physics. Sought for more than a century, such materials "can definitely change the world as we know it," Dias says.

In setting the new record, Dias and his research team combined hydrogen with carbon and sulfur to photochemically synthesize simple organic-derived carbonaceous sulfur hydride in a diamond anvil cell, a research device used to examine miniscule amounts of materials under extraordinarily high pressure.

The carbonaceous sulfur hydride exhibited superconductivity at about 58 degrees Fahrenheit and a pressure of about 39 million psi. This is the first time that superconducting material has been observed at room temperatures.

"Because of the limits of low temperature, materials with such extraordinary properties have not quite transformed the world in the way that many might have imagined. However, our discovery will break down these barriers and open the door to many potential applications," says Dias, who is also affiliated with the University's Materials Science and High Energy Density Physics programs.



Applications include:

- Power grids that transmit electricity without the loss of up to 200 million megawatt hours (MWh) of the energy that now occurs due to resistance in the wires.
- A new way to propel levitated trains and other forms of transportation.
- Medical imaging and scanning techniques such as MRI and

magnetocardiography
- Faster, more efficient electronics for digital logic and memory device technology.

"We live in a semiconductor society, and with this kind of technology, you can take society into a superconducting society where you'll never need things like batteries again," says Ashkan Salamat of the University of Nevada Las Vegas, a coauthor of the discovery.

The amount of superconducting material created by the diamond anvil cells is measured in picoliters—about the size of a single inkjet particle.

The next challenge, Dias says, is finding ways to create the room temperature superconducting materials at lower pressures, so they will be economical to produce in greater volume. In comparison to the millions of pounds of pressure created in diamond anvil cells, the atmospheric pressure of Earth at sea level is about 15 PSI.

Why room temperature matters

First discovered in 1911, superconductivity gives materials two key properties. Electrical resistance vanishes. And any semblance of a magnetic field is expelled, due to a phenomenon called the Meissner effect. The magnetic field lines have to pass around the superconducting material, making it possible to levitate such materials, something that could be used for frictionless high-speed trains, known as maglev trains.

Powerful superconducting electromagnets are already critical components of maglav trains, magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) machines, particle accelerators and other advanced technologies, including early quantum supercomputers.

But the superconducting materials used in the devices usually work only at extremely low temperatures—lower than any natural temperatures on Earth. This restriction makes them costly to maintain—and too costly to extend to other potential applications. "The cost to keep these materials at cryogenic temperatures is so high you can't really get the full benefit of them," Dias says.

Previously, the highest temperature for a superconducting material was achieved last year in the lab of Mikhail Eremets at the Max Planck Institute for Chemistry in Mainz, Germany, and the Russell Hemley group at the University of Illinois at Chicago. That team reported superconductivity at -10 to 8 degrees Fahrenheit using lanthanum superhydride.

Researchers have also explored copper oxides and iron-based chemicals as potential candidates for high temperature superconductors in recent years. However, hydrogen—the most abundant element in the universe—also offers a promising building block.

"To have a high temperature superconductor, you want stronger bonds and light elements. Those are the two very basic criteria," Dias says. "Hydrogen is the lightest material, and the hydrogen bond is one of the strongest.

"Solid metallic hydrogen is theorized to have high Debye temperature and strong electron-phonon coupling that is necessary for room temperature superconductivity," Dias says.

However, extraordinarily high pressures are needed just to get pure hydrogen into a metallic state, which was first achieved in a lab in 2017 by Harvard University professor Isaac Silvera and Dias, then a postdoc in Silvera's lab.

A 'paradigm shift'

And so, Dias's lab at Rochester has pursued a "paradigm shift" in its approach, using as an alternative, hydrogen-rich materials that mimic the elusive superconducting phase of pure hydrogen, and can be metalized at much lower pressures.

First the lab combined yttrium and hydrogen. The resulting yttrium superhydride exhibited superconductivity at what was then a record high temperature of about 12 degrees Fahrenheit and a pressure of about 26 million pounds per square inch.

Next the lab explored covalent hydrogen-rich organic-derived materials.

This work resulted in the carbonaceous sulfur hydride. "This presence of carbon is of tantamount importance here," the researchers report. Further "compositional tuning" of this combination of elements may be the key to achieving superconductivity at even higher temperatures, they add.

More information: Room-temperature superconductivity in a carbonaceous sulfur hydride , *Nature* (2020). DOI: 10.1038/s41586-020-2801-z

Provided by University of Rochester