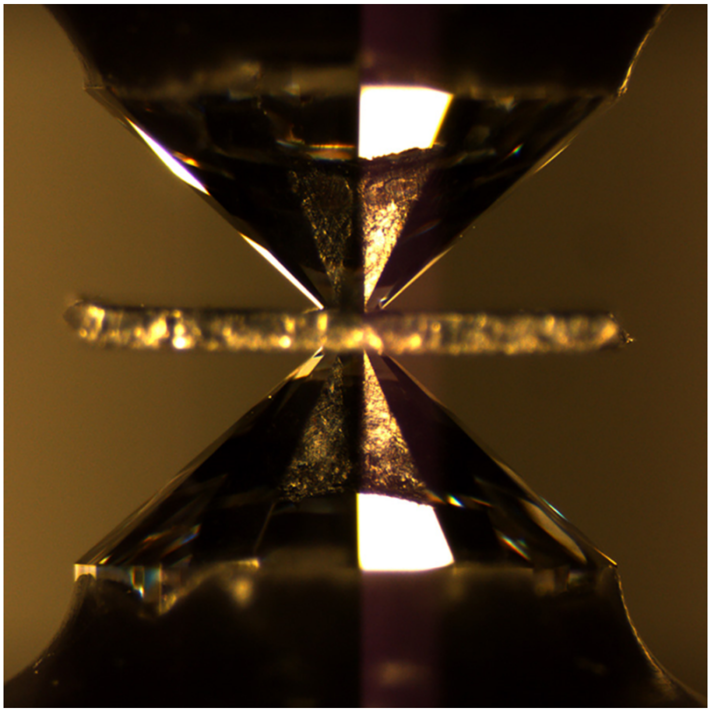
Superconductivity Experts Speak Up for Hydride Research

An independent analysis of data on the hotly debated superconductivity of certain hydrogen-rich compounds, or hydrides, concludes that the phenomenon is likely genuine.

By **Matteo Rini**

The search for superconductivity in hydrogen-rich compounds known as hydrides has been an emotional rollercoaster ride for the scientific community. Excitement mounted a few years ago, as hydride experiments had physicists imagining that a Holy Grail, room-temperature superconductivity, might be within reach. But the field was shocked in 2023 by allegations of malpractice and fraud. Now a group of physicists—leading superconductivity experts who aren't involved in hydride research—has offered an independent assessment of the available body of work on these materials [1]. They conclude that there is overwhelming evidence for superconductivity in hydrides.



A diamond anvil, like the one shown here, can exert extremely high pressures on material samples. Researchers have used diamond anvils to explore hints of superconductivity in hydrides.
Credit: S. Jacobsen/Northwestern University

"The more I read the foundational literature, and the more I learned about the way that results were being repeated, the more it became clear to me that hydride superconductivity is completely genuine," says Andrew Mackenzie of the Max Planck Institute for Chemical Physics of Solids in Germany and the University of St Andrews in the UK.

Mackenzie was one of the initiators of the group's work. "At conferences last spring, guys my age were having lots of young people coming up to ask: What's going on in hydrides?" he says. After a communal discussion at a superconductivity meeting in Berlin in August, he and other researchers thought that something needed to be done to address young researchers' concerns. They organized a group that would review available data with the goal of delivering an objective evaluation of hydride superconductivity claims, says Jörg Schmalian of the Karlsruhe Institute of Technology in Germany, who is one of the article's cosigners.

The group of 15 scientists includes some of today's most prolific superconductivity researchers working in the US, UK, Canada, Germany, and Japan. To ensure an impartial examination of the scientific facts, only people who had never worked directly on hydrides were consulted, Schmalian says. "I initially didn't know what my judgment would be." But after a few weeks of reviewing the literature, he concluded that the superconductivity finding looked genuine. "I assume other members of the group had similar experiences," he says. The researchers examined the data independently, with some subgroups formed to assess specific technical aspects. All the consulted experts supported the report's conclusion, Mackenzie and Schmalian say.

The scientists examined two pieces of evidence for superconductivity based on measurements of electrical resistance and of magnetization. Specifically, a superconductor should both exhibit zero resistance and exclude a magnetic field from its interior.

In analyzing data, the group accounted for unique difficulties with fabricating and measuring hydride samples. "The uncertainties…are higher in the hydrides than in any previously studied materials class," the group writes. The materials' inhomogeneity, in particular, means that only some islands within a given sample may be superconducting, so the resistance measured between electrodes only vanishes if there is a connected superconducting path between them. The challenge for magnetization measurements is that minuscule amounts of material have to be measured in diamond-anvil cells that apply extreme pressures. The magnetization signal from the cell—many millions of times the mass of the sample—may thus mask the sample signal.

The group concludes that, despite the experimental challenges, the resistance measurements of several teams as well as the magnetization measurements by one team (led by the late Mikhail Eremets at the Max Planck Institute for Chemistry in Germany [**2**]) indicate that there is an overwhelmingly probability that hydrides indeed host superconductivity.

Some of the data analyzed by Mackenzie, Schmalian, and colleagues come from the group of Sven Friedemann at the University of Bristol, UK. "We faced strong doubts in the community," Friedemann says. "As a consequence, we struggled to secure funding and acknowledgment for our work. So, we are pleased to see the central message of this review article confirming the credibility of the research field."

"It is significant that a group of highly respected theorists and experimentalists, none of whom is directly linked to hydrides, made a strong effort to restore the reputation of the field, while highlighting the technical challenges connected with hydride experiments," says Lilia Boeri, a theorist at Sapienza University of Rome who has worked on delivering predictions for superconducting hydrides.

One researcher, however, takes issue with the analysis. Jorge Hirsch at the University of California, San Diego, has been a vocal skeptic of hydride superconductors, having flagged problems in results that are now discredited. "I was surprised and disappointed to see this [new paper]," he says. "I speculate [they wrote] it because hydrides being superconductors would establish the validity of BCS theory, in which they firmly believe." Hirsch disputes the widely accepted Bardeen-Cooper-Schriffer (BCS) theory for conventional superconductors [**3**]. And in regard to hydride magnetization measurements, he has recently raised concerns about the data from Eremets' group [**4**].

Settling all doubts over magnetization measurements may require new experimental methods. A promising technique uses nitrogen vacancies as sensors, Mackenzie says. The vacancies are implanted into the same diamond-anvil cell used to apply pressure to the hydride samples, thus overcoming the problem associated with probing magnetization at high pressure. Earlier this year, scientists using this approach claimed to have observed simultaneous electrical and magnetic signatures of superconductivity in a cerium hydride [**5**]. Mackenzie, Schmalian, and colleagues, however, didn't include these magnetization results in their analysis. "We wanted to be conservative, as it's a new technique," Mackenzie says. "But that class of experiments holds tremendous promise, and we encourage people to read the paper and follow up on that intriguing work."

Mackenzie and Schmalian stress that confirmation work has been—and will continue to be—crucial to the field. "The gold standard of judgment in any field of discovery is when your colleagues are interested enough to go and try to do the same things themselves, and they get the same answer," Mackenzie says. Schmalian says that researchers should reflect on the incentives, such as citations, for scientists who do the important work of checking previous results. "The community could be a bit more gracious to [them]," he says.

Both Mackenzie and Schmalian say the key issue for them is responding to the young people who approached them for advice on hydrides. “If you’re interested in high-pressure superconductivity and are wondering whether you should work on it, the objective facts say that you should be well advised to go and do it,” Mackenzie says. “I believe that the discoveries that have been made in hydrides are some of the most important [ones] that I’ve witnessed during my time as a researcher.”

Matteo Rini is the Editor of ***Physics Magazine***.

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