A new material to unearth mysteries of magnetic fields

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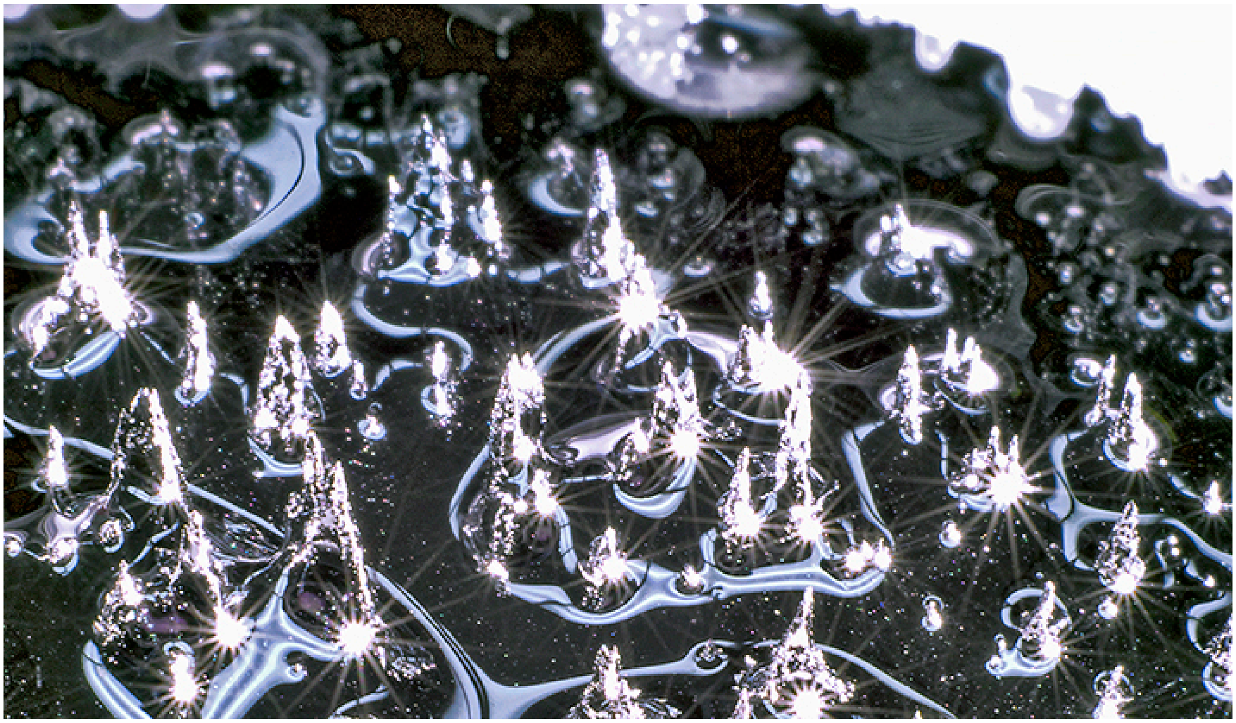

Credit: Yale University

Journeying to the center of the Earth, a la Jules Verne, won't be happening anytime soon. A new material made from a liquid metal and magnetic particles, however, could make it much easier for researchers to recreate the powerful forces at the planet's core.

"We can potentially reproduce some of the phenomena seen in planets and stars with this material," said Eric Brown, assistant professor of mechanical engineering and materials science at Yale and senior author of a study published Jan. 30 in the journal *Physical Review Fluids*.

The new material is made from an alloy of indium and gallium (eGaIn) with various particles suspended within it. When flowing, its ability to generate or modify magnetic fields is up to five times greater than that of pure liquid metal. That, along with a significant increase in electrical conductivity, means researchers can use the material to study the effects of magnetohydrodynamics (MHD)—the magnetic properties of conductive fluids usually only observable in the cores of planets and stars.

One challenge of suspending particles in liquid metals is that the air oxidizes the skin of the metals, keeping particles on the surface. The researchers got around this by submerging the liquid metal in an acid solution, which removes and prevents oxidation.

"We managed to suspend almost anything we wanted—steel, zinc, nickel, iron—basically anything with a conductivity higher than that of the eGaIn," said Florian Carle, a postdoctoral associate in Yale's Department of Mechanical Engineering & Materials Science, and lead author of the paper.

The discovery could hold benefits for geophysics, astrophysics, and other fields that explore the dynamics of the Earth's magnetic field, which is generated by the liquid metal flowing in the core. This magnetic field creates an electrical current inside the Earth and blocks radiation from space. Considering the wide range of the material's potential applications, the researchers developed a detailed protocol to ensure that other labs could reproduce their results.

One potential use of the material is studying magnetic pole flips, when the Earth's north and south poles reverse. It doesn't happen often—on average, flips occur once every few hundred thousand years—but the effects of the geomagnetic switch can be devastating by temporarily lifting the barrier that shields radiation from space. Some scientists believe these flips have caused a number of species extinctions on Earth.

With the material, Carle said, researchers can "create a smaller Earth" and explore these phenomena and potentially make better predictions about pole reversals and other effects of the magnetic field. Attempts to recreate the Earth's magnetic field have been attempted in other labs, but with limited success. Most involve the use of highly explosive liquid sodium, which requires very large models.

"People have tried these big flow chambers as large as three meters across, filled with liquid sodium and spinning around like a miniature Earth," said Brown.

With the material that the Yale researchers have developed, scientists can potentially create models as small as 20 square centimeters to recreate the phenomena of magnetic fields. Besides being much easier to work with, the material allows users to tune its viscosity and levels of magnetism to better fit their own research and applications.

"So they might see results that you couldn't get with liquid sodium, or even observe completely different MHD phenomena," said Carle.

Because these effects can be created on such a small scale, the material could also lead to the creation of new devices. "You can imagine people coming up with applications that use these MHD phenomena in lab and industrial settings," Brown said.

Provided by Yale University

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