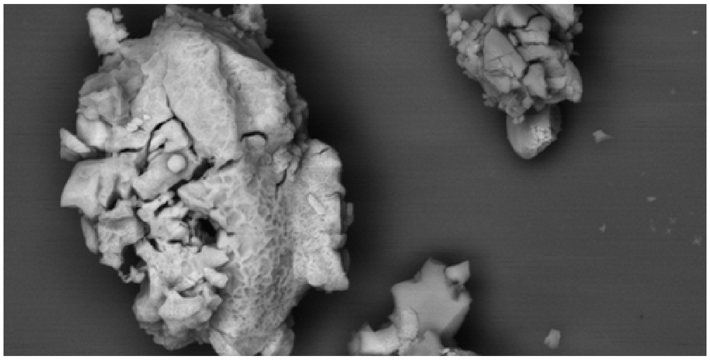
Hot Measure of Spin States Under Pressure

Researchers heat iron carbonate samples under high pressure without destroying the sample enclosure, a feat that enables lab-based studies of the spin properties of materials deep inside Earth and other planets.

By **Sarah Wells**

Inside Earth, elements such as iron and aluminum experience such extreme temperatures and pressures that the materials ooze through Earth's interior—on geological timescales—like sap moves through a tree. Scientists can use high-pressure diamond-anvil cells for laboratory-based studies of the macroscopic structural behavior of these elements at the relevant conditions. To gain a full picture of what happens inside Earth, scientists also need to capture subatomic information, such as how electron spin states change in this environment. But doing so is tricky because diamond-anvils can deteriorate under the conditions required for these measurements. Now, Johannes Kaa of the Technical University of Dortmund, Germany, and colleagues have demonstrated a way to heat samples to temperatures of up to 3000 K without destroying the diamond-anvils in the process [**1**].

Previously, researchers have combined diamond-anvil cells with heat pulses from x-ray free-electron lasers (XFELs) and with x-ray diffraction to study compounds at the conditions found deep inside Earth. But in those experiments they only measured structural properties of the compounds and not quantum ones, which can require that the sample be exposed to high pressures and temperatures for tens of minutes.



Credit: J. Kaa *et al*. [**1**]

In their setup, Kaa and colleagues expanded on previous work by adding to the setup an x-ray emission spectroscope (XES). They used femtosecond bursts of the XFEL to raise the sample's temperature and the XES to analyze the sample's fluorescent-emissions signals to determine its spin state at each heating step. The team found they were able to heat the material without destroying the cell, allowing them to make the spin measurements.

Following the demonstration, the team has begun applying the process to materials found in the core of Mars, such as iron sulfate. They say that their method could provide insight into the current density and elasticity of a planet's core as well as information about a planet's evolutionary history.

Sarah Wells is an independent science journalist based in Boston.

REFERENCES

1. J. M. Kaa *et al.*, "Structural and electron spin state changes in an x-ray heated iron carbonate system at the Earth's lower mantle pressures," **Phys. Rev. Research 4, 033042 (2022).**