What Makes Up Earth's Core?

Challenge

Scientists have long believed that Earth's core is made up primarily of iron (Fe). As one of the most abundant elements in the solar system, Fe also has the necessary conductivity at high pressures and temperatures for the generation of Earth's magnetic field. However, seismic data suggest that the density of Earth's core is less than that of pure iron. Theories abound as to which other elements might help to make up the core — the more popular candidates being silicon, sulfur, oxygen, hydrogen, and carbon. Since it is not possible to "journey to the center of the earth," how can scientists solve the mystery about which elements make up our planet's core?

Argonne's Role

Researchers at The University of Chicago used Argonne National Laboratory's Advanced Photon Source (APS) to help answer the question of "what lies beneath." Employing a device known as a laser-heated diamond anvil cell (LHDAC) (Figure 1), the researchers were able to simulate a core-like combination of extremely high pressure (approximately 840,000 atmospheres) and intense heat (approximately 4,200°F).

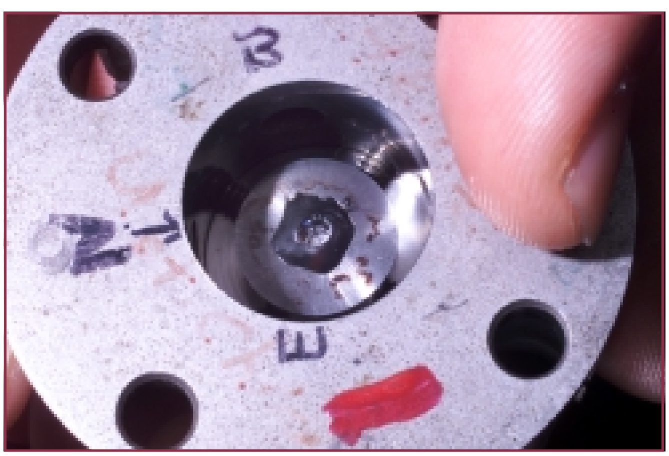

Figure 1. The LHDAC device is small and relatively simple, yet it affords scientists the capability to subject samples to intense pressures and temperatures that simulate those found at Earth's core.

Background

The diamond anvil cell (DAC) was developed during the 1950s by the late John Jamieson of The University of Chicago and simultaneously by scientists at the National Bureau of Standards. It consists of two gem-quality diamonds mounted between screws in a press. In the central gap is placed a very small sample, which is compressed between the diamonds by tightening the screws, then heated using a laser (Figure 2). As the screws are tightened and temperatures are increased, material changes occur within the sample.

Double-Sided Laser Heating in a Diamond Anvil Cell

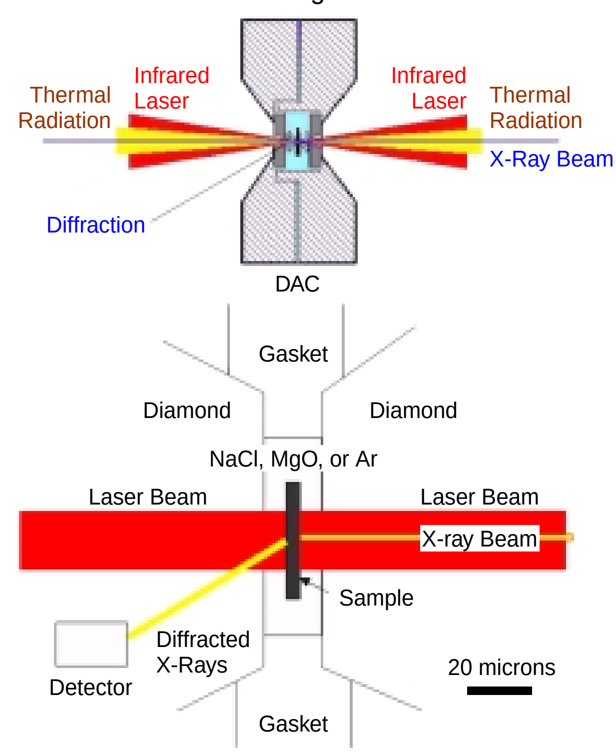

Figure 2. The laser-heated diamond anvil cell consists of a press that holds a sample between two diamonds, which are compressed using screws and then subjected to heating by a laser. The material changes that result from the intense pressure and temperature allow scientists to learn more about the chemical and physical behavior of elements at conditions similar to those in the Earth's interior.

Approach

Alloys of iron-silicon (Fe-Si) were compressed and heated in the LHDAC while x-ray diffraction patterns were collected using a synchrotron x-ray beam at the APS. As the world's most powerful source of x-rays, the APS provided an unparalleled environment in which to examine the atomic structure of the alloys (Figure 3). Results were compared with seismic data to determine whether the materials showed traits suggested by seismic observations.

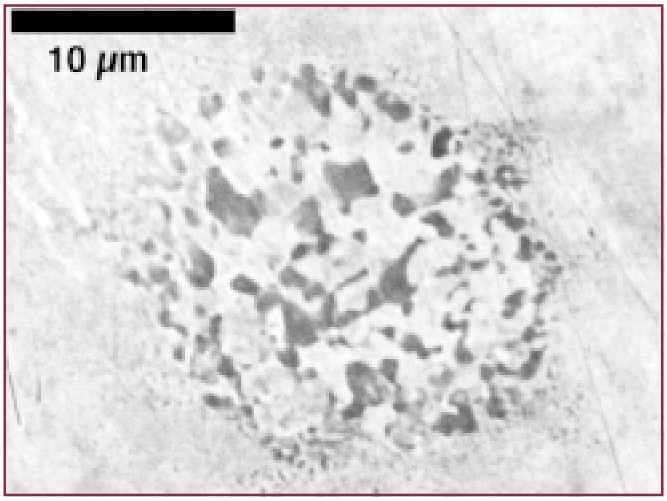

Figure 3. A back-scattered electron image of an Fe-Si alloy examined with the LHDAC. The dark areas represent a silicon concentration of just over 11% by weight, and the bright areas represent a silicon concentration of approximately 7% by weight.

Accomplishments

The researchers discovered that at high pressures and high temperatures, when small amounts of silicon (approximately 7% by weight) were alloyed with iron, the high-pressure phase of Fe broke down into two phases: one identical in structure with the low-pressure phase of Fe and the other with the high-pressure structure of Fe. Samples of Fe-Si examined with a scanning electron microscope (SEM) showed that two different alloys of Fe-Si had different amounts of Si present.

Comparison of seismic data with findings from the LHDAC studies have led the project team to conclude that Earth's inner core may be made up of close-packed, hexagonal iron crystals alloyed with up to 7% silicon by weight, but it is also conceivable that the inner core could be a mixture of an Si-rich, body-centered cubic phase and an Si-poor close-packed, hexagonal phase. The big surprise is that a small amount of a lighter element can change the phase diagram of iron; thus, the effect of small amounts of other possible light elements needs to be examined in light of the current findings.

Collaborators

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Sponsor

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