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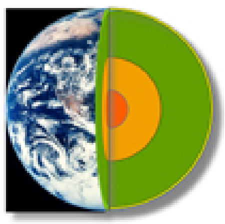
A new kind of metal in the deep Earth

December 19 2011



(PhysOrg.com) -- The crushing pressures and intense temperatures in Earth's deep interior squeeze atoms and electrons so closely together that they interact very differently. With depth materials change. New experiments and supercomputer computations discovered that iron oxide undergoes a new kind of transition under deep Earth conditions. Iron oxide, FeO, is a component of the second most abundant mineral at Earth's lower mantle, ferropericlase.

The finding, published in an upcoming issue of Physical Review Letters, could alter our understanding of deep Earth dynamics and the behavior of the protective magnetic field, which shields our planet from harmful cosmic rays.

Ferropericlase contains both magnesium and iron oxide. To imitate the extreme conditions in the lab, the team including coauthor Ronald Cohen of Carnegie's Geophysical Laboratory, studied the electrical conductivity of iron oxide to pressures and temperatures up to 1.4 million times atmospheric pressure and 4000°F—on par with conditions at the core-mantle boundary. They also used a new computational method that uses only fundamental physics to model the complex many-body interactions among electrons. The theory and experiments both predict a new kind of metallization in FeO.

Compounds typically undergo structural, chemical, electronic, and other changes under these extremes. Contrary to previous thought, the iron oxide went from an insulating (non-electrical conducting) state to become a highly conducting metal at 690,000 atmospheres and 3000°F, but without a change to its structure. Previous studies had assumed that metallization in FeO was associated with a change in its crystal structure. This result means that iron oxide can be both an insulator and a metal depending on temperature and pressure conditions.

"At high temperatures, the atoms in iron oxide crystals are arranged with the same structure as common table salt, NaCl," explained Cohen. "Just like table salt, FeO at ambient conditions is a good insulator—it does not conduct electricity. Older measurements showed metallization in FeO at high pressures and temperatures, but it was thought that a new crystal structure formed. Our new results show, instead, that FeO metallizes without any change in structure and that combined temperature and pressure are required. Furthermore, our theory shows that the way the electrons behave to make it metallic is different from other materials that become metallic."

"The results imply that iron oxide is conducting in the whole range of its stability in Earth's lower mantle." Cohen continues, "The metallic phase will enhance the electromagnetic interaction between the liquid core and lower mantle. This has implications for Earth's magnetic field, which is generated in the outer core. It will change the way the magnetic field is propagated to Earth's surface, because it provides magnetomechanical coupling between the Earth's mantle and core."

"The fact that one mineral has properties that differ so completely—depending on its composition and where it is within the Earth—is a major discovery," concluded Geophysical Laboratory director Russell Hemley.

Provided by Carnegie Institution

Citation: A new kind of metal in the deep Earth (2011, December 19) retrieved 17 May 2024 from https://phys.org/news/2011-12-kind-metal-deep-earth.html