Electronic heat trap grips deep Earth

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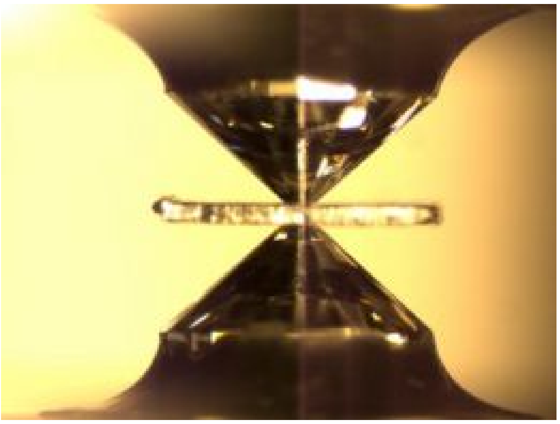

The diamond anvil cell squeezes samples to inner-Earth pressures, between two diamond tips. Image courtesy Alex Goncharov, Carnegie Institution

(PhysOrg.com) -- The key to understanding Earth's evolution, including how our atmosphere gained oxygen and how volcanoes and earthquakes form, is to look deep, really deep, into the lower mantle—a region some 400 to 1,800 miles (660 to 2,900 kilometers) below the surface.

Researchers at the Carnegie Institution's Geophysical Laboratory simulated conditions at these depths and recently discovered that the concentration of highly oxidized (ferric) iron (Fe^{3+}) in the two major mantle minerals is key to moving heat in that region. Such heat transfer affects material movement throughout the planet. They also discovered that less oxidized (ferrous) iron (Fe^{2+}) has much smaller effect than expected. The results, reported in the November 13, issue of *Nature*, call into question current models of mantle dynamics.

Lead author of the study Alexander Goncharov explains: "The lower mantle sits on top of the core where pressures range from 230,000 to 1.3 million times the pressure at sea level. Temperatures are unimaginable -- from about 2,800 to 6,700 °F. About 80% of the mantle is made of iron-containing silicate perovskite, while the mineral ferropericlase makes up the rest. The iron in both of these minerals strongly influences many properties of matter.

Goncharov and team developed a new optical spectroscopy system to reveal how matter absorbs heat from infrared through ultraviolet wavelengths; in addition they measured how energy is dissipated. They subjected the minerals to mantle pressures—up to 1.3 million atmospheres at room temperature and to 590,000 atmospheres at temperatures up to 1160°F.

The scientists, including a co-author who was an NSF-sponsored summer college intern Benjamin Haugen, found that heat absorption is governed by the concentration of ferric (Fe^{3+}) iron in silicate perovskite and ferropericlase. Their results for silicate perovskite in the visible and near infrared showed that heat absorption is dominated by the transfer of electron charges during oxidation—the process of electron loss—in the oxide O-Fe^{3+}.

"Our results show that the conductivity of heat in this part of the lower Earth is driven by the amount of ferric iron in the mantle and the process of losing and gaining electrons," said co-author Viktor Struzhkin. "We'll need to use this new collection of information to reexamine how mantle plumes and other dynamic features of this remote realm are affected."

Steven Jacobsen, a co-author from Northwestern University, formerly a postdoctoral fellow at Carnegie, and a member of the Carnegie DOE

Alliance Center (CDAC), remarked, "The amount of light we are able to see through these mantle materials under extreme pressures and temperatures is telling us a lot about how effectively heat is transported out of the core and through the mantle."

Provided by Carnegie Institution

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