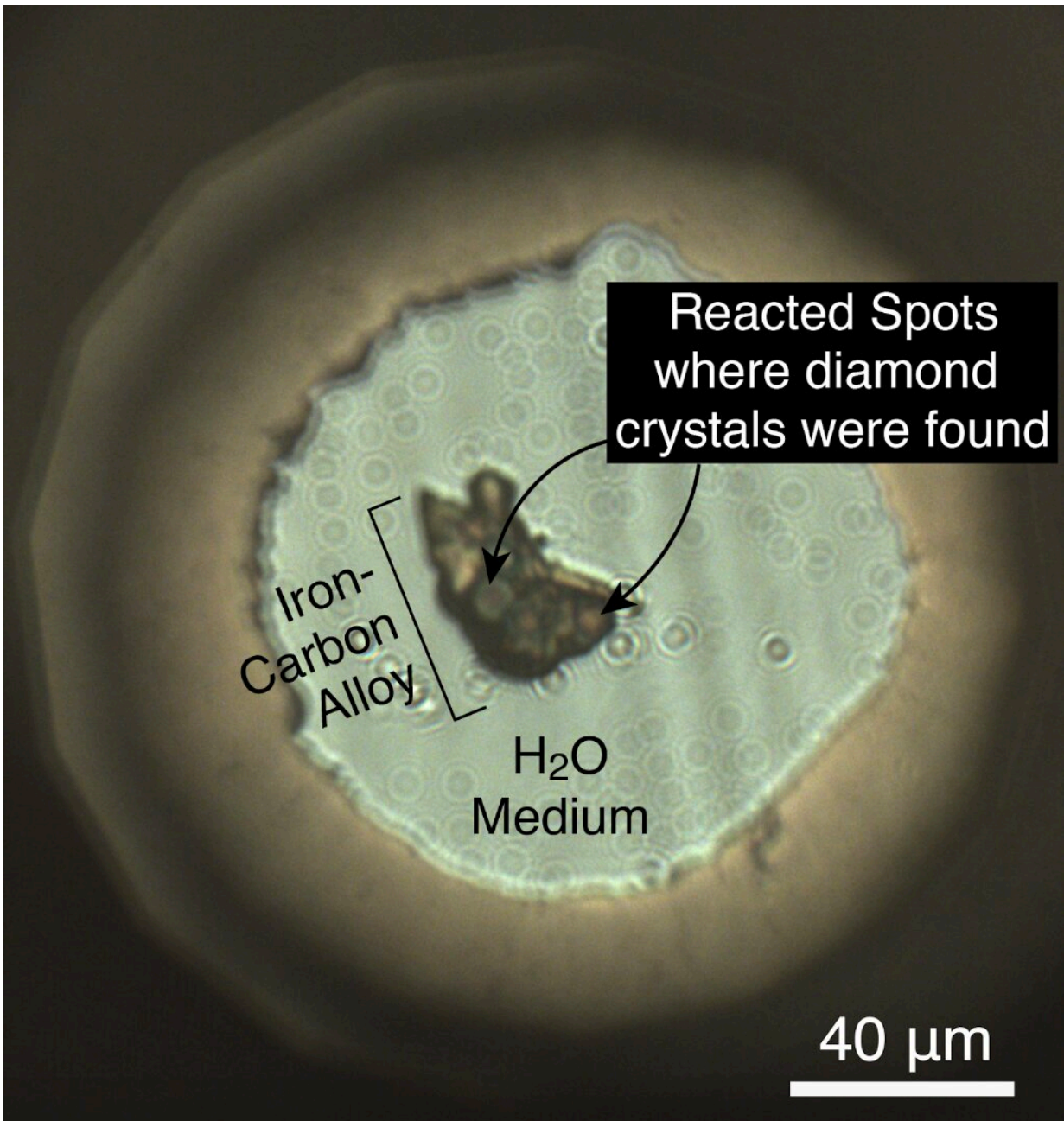


Diamonds and rust at the Earth's core-mantle boundary

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The iron-carbon alloy reacted with water at high pressure and high temperature conditions related to the Earth's deep mantle in a diamond-anvil cell. Credit: Arizona State University

Steel rusts by water and air on the Earth's surface. But what about deep inside the Earth's interior?

The Earth's core is the largest [carbon](#) storage on Earth—roughly 90% is buried there. Scientists have shown that the [oceanic crust](#) that sits on top of tectonic plates and falls into the interior, through subduction, contains hydrous minerals and can sometimes descend all the way to the core-[mantle](#) boundary. The temperature at the core-mantle boundary is at least twice as hot as lava, and high enough that water can be released from the hydrous minerals. Therefore, a chemical reaction similar to rusting steel could occur at Earth's core-mantle boundary.

Byeongkwan Ko, a recent Arizona State University Ph.D. graduate, and his collaborators published their findings on the core-mantle boundary in *Geophysical Research Letters*. They conducted experiments at the Advanced Photon Source at Argonne National Laboratory, where they compressed iron-carbon alloy and water together to the pressure and temperature expected at the Earth's core-mantle boundary, melting the iron-carbon alloy.

The researchers found that water and metal react and make [iron oxides](#) and iron hydroxides, just like what happens with rusting at Earth's surface. However, they found that for the conditions of the core-mantle boundary carbon comes out of the liquid iron-metal alloy and forms diamond.

"Temperature at the boundary between the silicate mantle and the metallic core at 3,000 km depth reaches to roughly 7,000 F, which is sufficiently high for most minerals to lose H₂O captured in their atomic scale structures," said Dan Shim, professor at ASU's School of Earth and Space Exploration. "In fact, the temperature is high enough that some minerals should melt at such conditions."

Because carbon is an iron loving element, significant carbon is expected to exist in the core, while the mantle is thought to have relatively low carbon. However, scientists have found that much more carbon exists in the mantle than expected.

"At the pressures expected for the Earth's core-mantle boundary, hydrogen alloying with iron metal liquid appears to reduce solubility of other light elements in the core," said Shim. "Therefore, solubility of carbon, which likely exists in the Earth's core, decreases locally where hydrogen enters into the core from the mantle (through dehydration). The stable form of carbon at the pressure-temperature conditions of Earth's core-mantle boundary is diamond. So the carbon escaping from the liquid outer core would become diamond when it enters into the mantle."

"Carbon is an essential element for life and plays an important role in many [geological processes](#)," said Ko. "The new discovery of a carbon transfer mechanism from the core to the mantle will shed light on the understanding of the carbon cycle in the Earth's deep interior. This is even more exciting given that the diamond formation at the core-mantle boundary might have been going on for billions of years since the initiation of subduction on the planet."

Ko's new study shows that carbon leaking from the core into the mantle by this diamond formation process may supply enough carbon to explain the elevated carbon amounts in the mantle. Ko and his collaborators also

predicted that diamond rich structures can exist at the core-mantle boundary and that [seismic studies](#) might detect the structures because seismic waves should travel unusually fast for the structures.

"The reason that seismic waves should propagate exceptionally fast through diamond-rich structures at the core-mantle boundary is because diamond is extremely incompressible and less dense than other materials at the [core-mantle boundary](#)," said Shim.

Ko and team will continue investigating how the reaction can also change the concentration of other light elements in the core, such as silicon, sulfur and oxygen, and how such changes can impact the mineralogy of the deep mantle.

More information: Byeongkwan Ko et al, Water-Induced Diamond Formation at Earth's Core-Mantle Boundary, *Geophysical Research Letters* (2022). [DOI: 10.1029/2022GL098271](https://doi.org/10.1029/2022GL098271)

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