Development of a new internally-resistive heated diamond-anvil cell for planetary mineral physics

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For the past few decades, diamond-anvil cell (DAC) has been commonly used to reproduce simultaneous high-pressure (P) and temperature (T) conditions of deep planetary interiors. In particular, laser-heated DACs achieved ultrahigh P-T conditions corresponding to the centre of the Earth [1]. However, laser fluctuation and a steep temperature gradient across the sample induce large uncertainty (±10%) in temperature measurements. Precise experimental temperature determination is crucial to implications for planetary interior models. For example, the location of the phase transition is a key to understanding the origin of the seismic discontinuity; the melting temperatures of the planetary materials under high-pressure place important constraints on the temperature of a planet’s deep interior.

Here we present a new heating system for the DAC that offers stable and homogenous heating of a sample under high-pressure condition. The new system is based on the so-called internally-resistive heated DAC (IHDAC) [2]. In an existing IHDAC, a metallic foil heater, which is the sample at the same time, is heated by supplying electricity to the foil. Although it requires extremely delicate fabrication of the heater, the internal-heating benefits from smaller temperature uncertainty (<5%) due to more stable, uniform heating compared to laser-heating.

The very recent study on high-pressure melting temperature of iron has shown its capability of achieving 290 GPa and 5360 K, P-T conditions close to the inner core boundary of the Earth [3]. A drawback of this system, however, is that the sample must be metallic. To overcome this limitation, we have employed thin-film deposition technique to fabricate a thin-film heater together with an insulation layer on each of the opposing anvils, enabling double-sided heating of non-metallic samples including rocks and ices. This unique feature not only ensures the homogenous heat distributions in the non-metallic sample but also simplifies the heater instalment process for a liquid sample, which is particularly challenging with the existing IHDAC.

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