Development of resistance-heated diamond anvil cell using boron-doped diamond heater

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Laser-heated diamond anvil cell is the most successful method for reproducing the pressures and temperatures of the Earth’s deep interior entirely in a laboratory (e.g. Tateno et al., 2010 Science). However, it is well known that laser-heating results in steep temperature gradients within a sample (e.g. Rainey et al., 2013). Such steep temperature gradients cause the solid-state chemical segregation called as ‘Soret diffusion’. This effect is well known in gas chemistry such that heavier elements or elements with larger ionic radii migrate from hot to cold regions, while the lighter elements move in the opposite direction (Grew and Ibbs, 1952). The Soret diffusion takes place not only in gas but also in liquid and solid. Therefore, Soret diffusion makes it difficult to perform chemical equilibrium experiments using laser-heated diamond anvil cell (Sinmyo et al., 2008 JGR).
The technique for homogeneous heating has been developed, that is internally-heated diamond anvil cell. In this method, the heater is put into a sample chamber and compressed together with the sample. Because the diamond has a high thermal conductivity, diamond anvils do not become a high temperature and the heated zone is limited to near the sample chamber. Therefore, internally-heated diamond anvil cell has a potential to generate temperature more than 2000 K because the diamond anvils do not transform to the graphite. A sample was used also as a heater in previous studies (e.g. Liu and Bassett, 1975; Boehler et al., 1986). Therefore, only electric conductor can be used as a sample for the experiment. Zha and Bassett (2003) overcame this situation by making a small hole in a Re heater and filled the hole with sample. Both metal and nonmetal can be used as the sample in this method. The study showed that temperature gradients of Re heater near sample room were gentler than that of laser-heating studies. However, its temperature gradients were still steeper than multi-anvil’s temperature gradients (Canil, 1994).
On the other hand, the boron-doped semiconductor diamond heater is known to be able to have a much smaller temperature gradient than that of metallic heater (Yoneda et al., 2014). In multi-anvil experiments, Yoneda et al. (2014) successfully generate high temperature more than 3000 K, which Re and $LaCrO_3$ heaters cannot generate.
In this study, I developed the internally-heated diamond anvil cell technique using boron-doped diamond heater. The results showed that temperature gradients of boron-doped diamond heater in diamond anvil cell were smaller than that of metallic heater used in previous study (Zha and Bassett, 2003). In addition, its temperature gradients are as steep as multi-anvil’s temperature gradients. In this presentation, we will show our recent progress on this study.

Keywords: Diamond anvil cell, Boron-doped diamond, Internal resistive heating

