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The study of Fe-H2O reaction by diamond anvil cell with externally heating method

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It is widely accepted that the density of the Earth's outer core is about 10 percent less than that of pure iron under the relevant conditions. This density deficit can be explained by the dissolution of light elements. Recent studies have demonstrated that the solubility of hydrogen in iron increases under high pressure. But these experiments were conducted at limited conditions. The high pressure and high temperature experiments with laser heating method combined with the synchrotron radiation at KEK were done, and results at 33 GPa and moderate temperature below 1300K showed that Fe and H2O react into FeO and FeH. We have also developed the externally-heating diamond anvil cell. The reaction was not observed up to 800K in the pressure range of 11-20GPa.

It is widely accepted that the density of the Earth's outer core is approximately 10 percent less than that of pure iron under the relevant pressure and temperature conditions (Birch et al., 1952; Jeanloz, 1990). This density deficit can be explained by the dissolution of light elements such as sulfur, oxygen, silicon, and carbon (Boehler, 1992, 1993; Ohtani et al., 1984; Ringwood and Hibberson, 1990; Urakawa et al., 1987). Stevenson (1977) proposed dissolution of hydrogen, although the solubility of hydrogen into iron is very limited at atmospheric pressure. However, experimental studies on the Fe-H system have demonstrated that the solubility of hydrogen in iron increases substantially under high pressure (Antonov, et al., 1980; Fukai et al., 1982; Badding et al., 1991; Yagi and Hishinuma, 1995). Dissolution of hydrogen was inferred from the observation that the iron melts at a temperature of several hundred degrees below the melting point of pure iron. Based on these experimental results, it was proposed that the Fe-H2O reaction should have played a crucial role in the evolution of the Earth (Fukai, 1984, 1992; Fukai and Suzuki, 1986). But these experimental conditions were made at very limited pressure and temperature conditions. The highest-pressure investigated is 62 GPa at room temperature in the case of Fe-H system (Badding et al., 1991), and the high temperature experiments were performed only at below 10 GPa (Fukai et al., 1986; Yamakata et al., 1992; Hishinuma et al., 1995; Okuchi, 1997).

In the present study, experiments were carried out at high temperature and high pressure above 10 GPa using a diamond anvil cell with two different heating methods of laser heating and external heating. The starting materials of fine iron powder (99.9 percent), ruby (Al2O3) and distilled water were put into sample room. The high pressure and high temperature experiments with laser heating method combined with the synchrotron radiation at the National Laboratory for High Energy Physics (KEK) were done at 33 GPa and the room temperature and high temperature around 1300K. These experimental results at 33 GPa and moderate temperature below 1300K showed that Fe and H2O react into FeO and FeH. However, the estimation of temperature was difficult in laser heating method below 1300K because of the weak intensity of radiation from the hot spot. To determine the accurate reaction boundary of Fe-H2O system we have developed the externally-heating diamond anvil cell which is suitable for the experiments up to about 1300K. For generating high temperature above 800K, the cooling attachment is desirable to prevent the piston and cylinder from thermal damage. So, we designed the water cooling system with the reducing gas (Ar-10%H2) flow unit. The heating device to generate high temperature was made of the Pt-Rh wire. The high pressure and high temperature experiments were carried out using these devices. The reaction between Fe and H2O was not observed up to 800K in the pressure range of 11-20GPa. The present result is consistent with the previous report (Yamakata et al., 1992).

Compared with the previous studies on the thermal history of the accreting earth (Sasaki et al., 1986), Fe in a high-temperature component and H2O in a low temperature component may have reacted to form FeO and FeH during the accretional stage of the Earth. Thus the reaction between Fe and H2O may have played a key role in the evolution of the Earth.