Hydrogen in Iron at High Pressure

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Introduction

Seismic data indicate that both inner and outer cores are less dense than pure iron at core pressures and temperatures [Jephcoat and Olson, 1987; Mao et al., 1990]. This suggests that one or more light elements as iron compounds are contained in the inner and outer cores. The preferred candidates for the light element are sulfur, oxygen, carbon, silicon, and hydrogen [Poirier, 1994; Hillgren et al., 2000]. However, the identity and abundance of the light elements are unknown.

It is suggested that hydrogen could be a major light element of the Earth's core [Stevenson, 1977; Okuchi, 1997]. Badding et al. (1991) formed solid iron hydride (FeH0.94) in the diamond anvil cell (DAC) and showed it was stable up to 62 GPa. They estimated that, by extrapolation of the equation of state of iron hydride, it should be stable to pressures above 100 GPa and proposed that iron hydride could be a component to account for decreasing the core density. Other experimental works show that iron hydride forms, reacting iron with water [e.g., Suzuki et al., 1984]. To constrain the abundance of hydrogen in the Earth's core, it is essential to determine the stability, composition, and equation of state of iron hydride at core pressures and temperatures.

Experimental Procedure

High pressures were generated in a DAC using type I diamond with 0.45 mm diameter culets. Iron (99.99% purity) was loaded to a DAC with hydrogen [Takemura et al., 2001]. Rhenium was used as a gasket material, with a 0.2 mm hole and 0.064 mm thickness. The iron sample was compacted from a powder into a shiny foil (0.07 mm in diameter and by 0.01 mm thickness). Pressures were determined using the ruby fluoresencence method with the accuracy of 0.02 GPa. Since solid hydrogen filled the sample chamber, these run were quasi-hydrostatic and the R1-R2 ruby line splitting was well resolved. Powder x-ray diffraction experiments at high pressure and room temperature were carried out by the angle dispersive method using an imaging plate detector. Powder patterns were obtained at BL13A beamline of the Photon Factory, National Laboratory for High Energy Physics (KEK). The synchrotron radiation beam was monochromatized to the wavelength 0.4258 A. In order to describe the compression curve with accuracy, diffraction patterns were obtained up to 25 GPa with pressure interval of1-2 GPa at the room temperature.

Results and Discussion

Iron hydride decomposes at the ambient pressure and temperature. Badding et al. (1991) showed that hydrogen reacted with iron to form iron hydride at pressures above 3.5 GPa, and the body-centered cubic (bcc) phase of iron is present with iron hydride below 14.7 GPa. We observed that iron hydride forms at 3.6 GPa coexisting with the bcc iron, and only diffraction lines from iron hydride were detected at pressures above 3.6 GPa. We determined the lattice parameters and the unit cell volume as a function of pressure of iron hydride using the four diffraction lines (100), (101), (004), and (102). The detail analysis of the equation of state of the iron hydride are now in progress.