Iron-Water and iron-hydrogen reactions in the accretional stage of the Earth

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Reaction between metallic iron and water may be of fundamental importance for core formation process in the accretion stage of the terrestrial planets. Metallic iron existing in the high temperature component and water contained in the low temperature component could extract and react to form FeO and hydrogen during Earth's accretion. The reaction may also control the oxidation state of the proto-Earth and the composition of the proto atmosphere (e.g., Ringwood,1979; Abe and Matsui,1985). Even if hydrogen atmosphere might be formed by oxidation of metallic iron in the surface of the proto-planet, once metallic iron and hydrogen was buried deep in the proto-Earth by some mechanisms, iron hydrides FeHx become stable due to dissolution of hydrogen into metallic iron at high pressure (Fukai,1984). Therefore, formation of FeHx at high pressure may imply a possibility of hydrogen as a candidate for the light elements in the core (e.g., Stevenson,1981).

In-situ X-ray diffraction experiments made at pressures from 8.9 GPa to 84 GPa after laser heating in diamond anvil cell revealed occurrence of the following reaction; 3Fe+H2O=FeO+2FeHx.The reaction between metallic iron and water at high pressure and high temperature potentially plays an important role for water (or hydrogen) transport from the surface to the core-mantle boundary region in the accretion stage of the Earth. The earth is considered to be formed from the components with various temperature conditions, which may be simplified to the two component model,comprising a low temperature component such as the chondritic meteorite and a high temperature and reduced component (A and B components; e.g., Ringwood,1979). Metallic iron is likely to be in a high temperature and reduced component, whereas various hydrous phases are expected to exist in the low temperature component, as is observed in the matrix of the chondritic meteorites. Thus, both metallic iron and water could have coexisted in the proto-Earth. According to the temperature profile in the accretional stage of the earth and the present experimental results, metallic iron and water react to form FeHx and FeO even under the low temperature conditions of the early stage of the Earth's accretion. FeO of the reaction product reacts further to the surrounding mantle silicates, whereas FeHx is transported to the core-mantle boundary region during the gravitational separation of metallic iron and silicates in the early Earth. According to Hirao et al.(2004) incorporation of only a small amount of hydrogen in iron-nickel core readily accounts for the density of the earth's core.