

Synchrotron Mössbauer spectroscopy on Fe₃S, FeO and natural almandine

KAMADA, Seiji^{1*}; HIRAO, Naohisa²; HAMADA, Maki³; SUZUKI, Nanami¹; OHTANI, Eiji¹; OHISHI, Yasuo²; MASUDA, Ryo⁴; MITSUI, Takaya⁵

¹Tohoku Univ., ²JASRI, ³School of Nature system, College of Science and Engineering, Kanazawa University, ⁴Research Reactor Institute, Kyoto Univ., ⁵JAEA

The Earth's core is considered to be composed of an iron alloy with light elements since its density is smaller than that of pure iron under core conditions (e.g., Birch, 1964; Dubrovinsky et al., 2000). Although there are many candidates for these elements, such as H, C, O, Si, and S, sulfur in particular has been considered as one of the most plausible candidates. This is because it is depleted in the mantle, suggesting that it exists in the Earth's core (Murthy and Hall, 1970), and iron sulfides are found universally in iron meteorites, i.e., analogues of the Earth's core. Although the content of sulfur in the Earth's core is not known precisely, the sulfur content in the core is estimated to be at least a few wt% based on cosmic element abundances (McDonough, 2003) and high pressure partitioning experiments (e.g., Hillgren et al., 2000).

Since sulfur is one of the most plausible light elements, a compressibility and phase diagram in the Fe-FeS system has been studied (e.g., Campbell et al., 2007; Chen et al., 2007; Fei et al., 2000; Kamada et al., 2010; Li et al., 2001; Seagle et al., 2006). According to previous studies, Fe₃S is stable from 21 GPa and at least up to 200 GPa. Therefore, Fe₃S can be one of a candidate of the inner core materials. In addition, a synchrotron Mössbauer spectroscopy (SMS) and X-ray emission spectroscopic studies on Fe₃S revealed a spin transition and magnetic transition between 20 and 25 GPa (Lin et al., 2004; Shen et al., 2003). It also showed an abnormal evolution of a and c axes with increasing pressure (Chen et al., 2007).

Synchrotron Mössbauer spectroscopy is a good probe of a small sample under high pressure to investigate magnetic properties and electronic states of Fe of core and mantle minerals. An energy domain Mössbauer spectroscopic system has been recently developed at the BL10XU, SPring-8. We have measured Mössbauer spectra from Fe₃S and FeO under high pressure and a natural almandine at ambient pressure.

A powder mixture was made from ⁵⁷Fe (96.63%, ISOFLEX) and FeS (99.9%, RAREMETALLIC co., LTD.) with a ratio of Fe:S=75.0:25.0 (in at%). A foil was made from the mixture by a cold compression using a diamond anvil cell (DAC) and loaded into a sample chamber. ⁵⁷Fe enriched Fe₃S was synthesized from the powder mixture in a DAC at 30 GPa and 1350 K. The synthesis of Fe₃S was confirmed by X-ray diffraction patterns at BL10XU, SPring-8. ⁵⁷FeO was made by reducing from ⁵⁷Fe₂O₃ (ISOFLEX) at ambient pressure and high temperature. A pellet was made from ⁵⁷FeO powder and loaded into a sample chamber of a DAC. We also measured Mössbauer spectra of a natural almandine (Py_{15.7}Alm_{78.6}Gros_{4.4}Sp_{1.3}, Idaho, USA). The energy of used X-ray for Mössbauer spectroscopy was 14.4125 keV.

We have measured Mössbauer spectra of Fe₃S during decompression at 5, 15, 20, 25, and 30 GPa and room temperature at BL10XU and BL11XU. At BL10XU, those of FeO and the almandine were obtained at 200 GPa and ambient pressure, respectively. The magnetic transition in Fe₃S was observed between 20 and 25 GPa, which is consistent with Lin et al. (2004). We observed doublet peaks from FeO. An evidence of Fe³⁺ in the almandine was not detected in this study. We will report the results of the Mössbauer spectra based on the newly developed system at BL10XU, SPring-8.

Keywords: Earth's core, Mantle, Mössbauer, Fe₃S, FeO