In-situ magnetic hysteresis measurement of magnetite under high-pressure up to 1 GPa

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Recent explorations of the terrestrial planets have revealed that there are many magnetic anomalies, which probably recorded their ancient environment of the magnetic field (Maus et al., 2009; Acuna et al., 1999; Tsunakawa et al., 2010). Based on their results, studies of the paleomagnetism (Kikawa and Ozawa, 1992), the magnetic anomaly pattern (Nimmo and Gilmore, 2001; Langlais et al., 2004) and thermal models (Dunlop and Arkani-Hamed, 2005) suggest that depth of the magnetic sources are several tens of kilometer from the surface. Therefore it is important to investigate pressure and temperature effect on the magnetic properties of magnetic minerals. Modern techniques of high-pressure experiments enable us to measure sample magnetizations under high-pressure (Gilder et al., 2002; Kodama and Nishioka, 2005; Sadykov et al., 2008). In the present study, we focus on the magnetite, since main magnetic mineral of terrestrial rocks is magnetite and its associates. We have conducted in-situ magnetic hysteresis measurement on magnetite under pressure up to 1 GPa using the high-pressure cell specially designed for a Quantum Design Magnetic Property Measurement System (MPMS).

Natural magnetite of large crystal (Brazil, KOMURO MINERALS) was crushed by hand and ground into powder under ethanol in an agate mortar. For relaxation of internal stress, powder samples were annealed in vacuum at 700 C with carbon buffer for several hours. The magnetite powders were dispersed in the cement and it was then placed in a Teflon capsule with an inner diameter of 2.4 mm and a length of 10 mm. We used a 1:1 mixture of Fluorinert No. FC70 and No. FC77 as a pressure transmitting fluid. For the pressure calibration, a small chip of indium was placed together, since its transformation temperature has been known to vary with pressure (Jennings and Swenson, 1958). The Teflon capsule was inserted in the high-pressure cell of piston-cylinder type, which was made of copper beryllium alloy and zirconium oxide (Kodama and Nishioka, 2005). The high-pressure cell was connected with the end of the sample rod of MPMS and measured in a regular manner.

All magnetic measurements were carried out using an MPMS-XL5 instrument at Center for Advanced Marine Core Research, Kochi University. Keeping a constant pressure, the magnetic measurements were performed at various temperatures: magnetic hysteresis loops and DC field demagnetization behavior of saturation isothermal remanent magnetization imparted in a magnetic field of 1 T. After completion of an experimental sequence at the pressure, temperature was set back to the room temperature and then we changed an induced pressure for a subsequent experiment. The maximal field of the hysteresis loop measurements was 1 T, while a field increments was taken to be 4 mT when application field was close to zero and to be a coarser step in other fields.

Based on the hysteresis parameters (saturation magnetization, Ms; saturation remanence, Mrs; coercivity, Hc; coercivity of remanence, Hcr) obtained from the experimental results, we will show pressure dependence of the hysteresis parameters of magnetite and discuss possible rock magnetic behaviors in the deep part of the planetary crusts.