E221-034 Room: 303 Time: May 18 16:00-16:15

High pressure complex magnetic susceptibility measurements under low temperature of magnetite: implication for shocked rock

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Magnetite is the most abundant magnetic mineral in the Earth's crust and possibly on Mars, and its magnetic properties under various conditions provide essential ingredients for paleomagnetic studies. In this presentation, we show a high pressure complex magnetic susceptibility measuring system and provide a low temperature magnetic diagnostic of high pressure history of magnetite in association with a possible application for shocked rocks. Impact shock stress introduces a large strain and defects in crystals as well as magnetite in shocked rocks. Previous shock and static high pressure experiments suggest that these strain and defects lead to permanent change of magnetic properties of the minerals such as remanence, coercivity, saturation magnetization, and magnetic susceptibility. As a natural example, Carporzen [1] have found unusual low-temperature behavior of remanence in shocked granite at Vredefort, which shows two distinct Verwey-like transitions. They also reported that annealing of the shocked samples at 973 K modified the two transitions into a single Verwey transition [2]. Pressure effect on low temperature transition in magnetite was studied experimentally by Mossbauer spectroscopy [3]. The spectra showed a coordination crossover from inverse to normal spinel at slightly higher temperature than the Verwey transition under high pressures, implying magnetite would exhibit two distinct low temperature transitions under pressure. However, the magnetic consequence of the proposed coordination crossover has not been investigated, and it is not clear if magnetite would exhibit two distinct low temperature magnetic transitions under pressure. Therefore, we conducted low temperature complex magnetic susceptibility measurements of a natural magnetite sample in a diamond anvil cell down to 100 K. The in-phase component of complex susceptibility is considered to be almost equal to the direct current susceptibility, and the out-of-phase component is the measure of energy loss during magnetization. Up to 0.7 GPa, we observed a normal single Verwey transition as a sharp drop of in-phase magnetic susceptibility and a maximum of out-of-phase magnetic susceptibility. Under pressure larger than 1.6 GPa, the drop of in-phase susceptibility at the Verwey transition was suppressed, whereas out-of-phase component still clearly indicates the transition. At pressures of 1.6 GPa and 4.5 GPa, we newly observed another drop of in-phase magnetic susceptibility and a rise of out-of-phase susceptibility at slightly higher temperature than the Verwey transition. This new observation indicates that the Verwey transition apparently splits into two distinct transitions under pressure. The transition at higher temperature may be explained by pressure-induced coordination crossover in magnetite under low temperature, found by Mossbauer study under similar condition [3]. The decompression from 4.5 GPa to 0.5 GPa did not erase the splitting of low temperature transition, suggesting the transition is a permanent property. This result is interpreted as due to permanent change in magnetic domain wall structure, resulting from internal stress by compression. The presence of splitting under ambient pressure explains the natural observation of the Vredefort rocks [1, 2]. Therefore, the splitting of low temperature transition could be a high pressure memory of magnetite, being included within some meteorites (Allende) and impact crater rocks.

Reference:
[1] Carporzen, IRM Quarterly, 14(1): 3, 2004.
[2] Carporzen et al., AGU fall meeting 2005, abstract GP13A-0042, 2005.
[3] Pasternak et al., J. Magn. Magn. Mater.,265: L101, 2003.