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Microscopic magnetic field distribution of chondrules: In-situ scanning magnetic microscope study of type-3 chondrites

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Petrologic type-3 chondrites have been provided many information of the early solar nebula because of an abundance of chondrules, resulting their low metamorphic temperatures. Because chondrules were thought to be formed through a high temperature process in the early solar nebula, the individual chondrule is expected to acquire a thermal remanent magnetization. Thus, a natural remanent magnetization (NRM) of the individual chondrule within type-3 chondrite gives an evidence for the presence of the ancient extraterrestrial magnetic field that is important for the astrophysical study of the early evolution of the solar system. However, even in type-3 chondrites, magnetic minerals show complex appearances within the chondrite due to a superimpose nature of thermochemical alterations during the long history of solar system, bundling information for each magnetic mineralogy within the chondrule.

Individual chondrules within type-3 carbonaceous and ordinary chondrite (e.g. Allende CV3, Chainpur LL3.5) show scattered and stable components of NRM (Sugiura et al., 1979; Sugiura and Strangway, 1982), which may give evidence of pre-accretional remanence. However, carriers of the stable NRM of Allende (CV3) were ferromagnetic iron sulphide, suggesting that the stable NRM were acquired during a post-accretional sulfidation event (Wasilewski and Saralker, 1981). In ordinary chondrites, the scattered and stable NRM components can be explained by abundant tetrataenite (ordered near equiatomic Fe-Ni alloy), whose stable direction is controlled by the crystallographic orientation (Sugiura and Strangway, 1988). However, tetrataenite has been formed during the slow cooling of the parent-body in space by Ni solid-state diffusion below 320 C, suggesting a post-accretional remanence. On the other hand, recent magnetic study of synthetic chondrules (Uehara and Nakamura, 2004) suggested that a 'dusty olivine' (i.e. olivine crystal enclosing submicron-sized Fe inclusions) in chondrules can hold a pre-accretional NRM that has been acquired during chondrule formation. Although type-3 chondrites are the most primitive meteorites and contain dusty olivines, we need to discriminate a pre-accretional NRM of dusty olivine from post-accretional magnetic sources in type-3 chondrites. We developed a scanning MI (magnetic impedance) magnetic microscope lately, which can observe a spatial distribution of magnetization in chondrites (Uehara et al., 2005). Here, we report an in-situ magnetic microscope study of type-3 chondrites in order to investigate the correlation between magnetic minerals and their NRMs.

A sample used in this study is a 3 mm thick slice of NWA1756 (LL3.0/3.2), which is a monomict chondritic breccia (Russell et al., 2004). Our BSE studies confirmed that this sample contains several dusty olivines within one chondrule. Images of sample perpendicular magnetic fields were obtained by a scanning MI magnetic microscope that has a resolution and sensitivity of 0.5 mm, 120 nT, respectively. The measurements were made in a three-layered mu-metal magnetic shield. Magnetic and BSE images of NWA1756 (LL3.0/3.2) reveal a spatially heterogeneous pattern of magnetization, which seems to be correlated to the distribution of breccias, dusty olivine, and possibly chondrules within the breccias. This preliminary result suggests that the scanning MI magnetic microscopy is able to decide the NRM carriers in the type-3 chondrites. We will also report results of other type-3 chondrites, e.g. Dho008 (LL3.3).