Fe-Ni METAL AND MAGNETITE NANO-PARTICLES IN "BROWN" COLOR OLIVINES FROM MARTIAN METEORITES. T. Kurihara, T. Mikouchi, K. Saruwatari, J. Kameda, and M. Miyamoto, Dept. of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, JAPAN (E-mail: kurihar@eps.s.u-tokyo.ac.jp).

Introduction: Recent TEM studies revealed that Fe-Ni metal nano-particles are responsible for the dark "brown" color of olivine in the NWA2737 chassignite, which is interpreted to have formed by reduction of olivine due to heavy shock events [1,2]. Color change of olivine is important to understand the remote sensing data as is the case for space weathering [3,4]. Furthermore, nano-phase Fe particles can be a magnetic carrier of the meteorites, and is significant for their magnetic studies [5]. Similar brown color olivine is fairly common among Martian meteorites, especially in shergottites, and thus Fe-rich nano-particles may be widely present in these olivine grains. Indeed, at the last LPSC we reported that olivines in ALH77005 and Y000097 lherzolitic shergottites included Fe-Ni metal nano-particles, corresponding to their brown color [6]. At the same time, we also found that the LEW88516 lherzolitic shergottite, which has brown olivine, contains magnetite nano-particles instead of Fe-Ni metal nano-particles. The presence of magnetite nano-particles is also probably responsible for darkening of their host olivine grains, similar to Fe-Ni metal nano-particles. Because magnetite nano-particles can be formed during strong shock under oxidizing conditions [7], we expect that magnetite nano-particles can be more widely present in other Martian meteorites instead of Fe nano-particles. In this study we selected three shergottites (Dhofar 019, LAR06319 and NWA1950) including brown olivine grains to examine what kind of nano-particles they contain in olivine.

Analytical methods: We selected the above three samples because their thin sections contain brown olivines although the strength of the color is on many levels. In general, both colorless and brown areas are present in a common single crystal, but we found that there was no clear compositional difference when analyzed by electron microprobe. We prepared TEM samples by crashing small rock chips of each sample into powder by hand. The TEM observation was performed by JEOL JEM 2010 TEM equipped with EDS.

Results: TEM revealed the presence of nano-particles in olivines from all samples. Typical sizes of these particles were 5 to 20 nm in diameter. EDS shows that these particles are enriched in Fe, but do not contain Ni. The electron diffraction patterns show that they are magnetite rather than Fe metal.

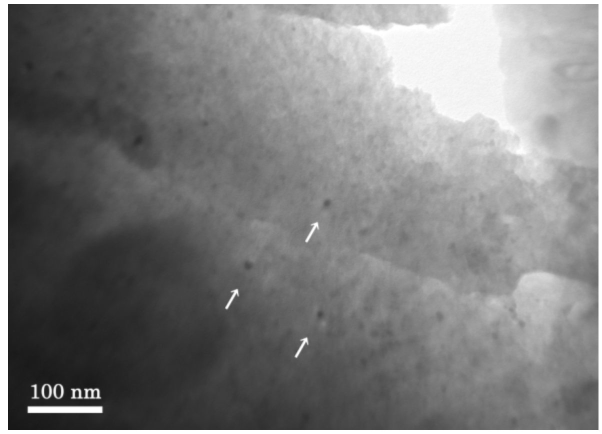

Fig. 1 TEM image of NWA1950 nano-particles (indicated by arrows).

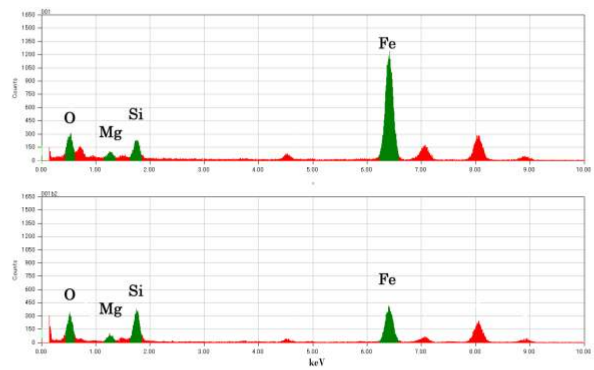

Fig. 2 EDS data of the Dhofar 019 nano-particle (above) and its host olivine (below).

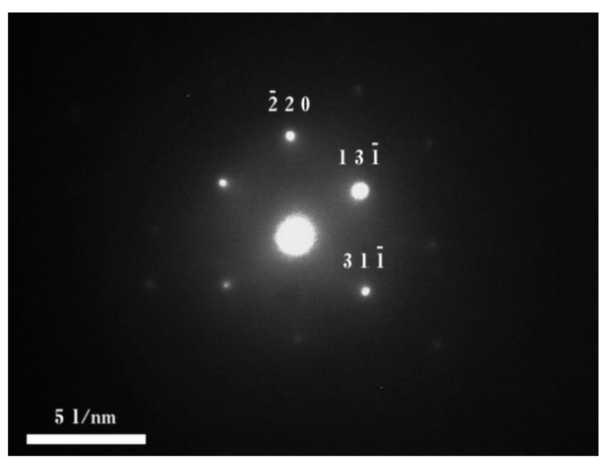

Fig. 3 Electron diffraction pattern of the NWA1950 nano-particle which shows that it is a magnetite.

Nano-particles are directly contacted with olivine and no other phases were observed between them. The electron diffraction patterns of olivine adjacent to the nano-particles show sharp crystalline spots.

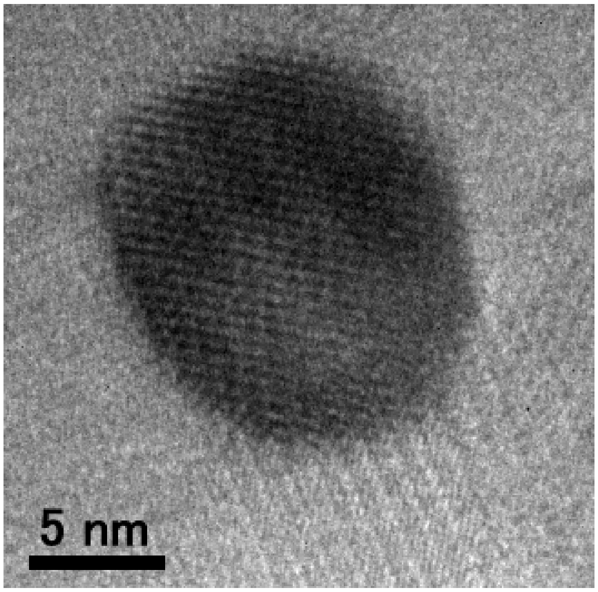

Fig. 4 High resolution TEM image of a magnetite nano-particle in LAR06319.

Discussion and Conclusion: In our previous study, only LEW88516 contained magnetite nano-particles although Fe-Ni metal nano-particles were observed in several Martian meteorites (NWA2737, ALH77005 and Y000097) [6]. In this study we found that LEW88516 is not an exception as three other shergottites contain magnetite nano-particles. Thus, probably magnetite nano-particles are widely present among Martian meteorites.

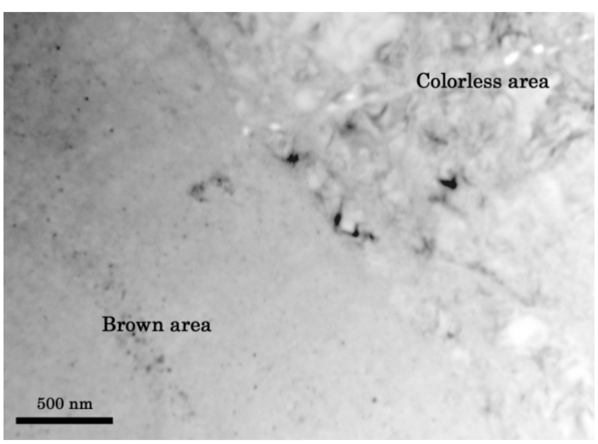

Fig. 5 TEM image of NWA2737 olivine. Fe-Ni nano-particles are represented as black dots spread in the brown area.

Although there is no doubt that Fe-Ni nano-particles have a significant effect of darkening of their host crystals as Fig. 5 clearly illustrates, there has shown no clear evidence for darkening effect of magnetite nano-particles. Darkening of olivine may be caused by other factors, mainly by terrestrial oxidation. However, this is probably unlikely for the samples studied here and our previous study [6] since distribution of dark parts in olivines (color of olivine grains are heterogeneous) is not along grain surfaces or cracks. As there is no other reasonable explanation, it is likely that magnetite nano-particles have a darkening effect similar to Fe-Ni metal.

There has been suggested that Fe-Ni nano-particles have formed by reduction of Fe^{2+} in olivine crystal during heavy shock [1,2]. Although the formation of magnetite requires oxidation of Fe^{2+} in olivine crystal in contrast to the formation of Fe-Ni metal, our shock experiments indicate that both Fe-Ni metal and magnetite nano-particles could be produced by heavy shock, whose maximum shock pressure is above 40 GPa [7]. Redox state during shock affects the formation of Fe-rich particles. Fe-Ni metal nano-particles were formed under relatively reducing condition and magnetite nano-particles were formed under relatively oxidizing condition [7]. If this is the case for Martian meteorites, it is necessary to assume different redox state during shock on (or near) the Martian surface to explain the coexistence of magnetite and Fe-Ni metal. Atmospheric composition could be a major factor which can directly control the redox state. However, it is unlikely to suppose drastic change of Martian atmosphere among these samples because they crystallized under similar conditions (e.g., burial depth, crystallization age). Then, temperature difference during shock could be another possible factor. The iron-wüstite (IW) buffer curve is a function of temperature. Magnetite nano-particles would be formed when temperature increased moderately. When temperature increase was significant and fO_2 during the shock was below the IW buffer, Fe-Ni nano-particles would be formed.

References: [1] Van de Moortele B. et al. (2007) *Earth Planet. Sci. Lett., 262,* 37-49. [2] Treiman A. H. (2007) *Jour. Geophys. Res., 112, E4,* E04002. [3] Pieters C. M. et al. (2007) *Meteoritics & Planet. Sci., 42,* 5062. [4] Noble S. et al. (2007) *Icarus*, 192, 629-642. [5] Hoffmann V. et al. (2008) *LPS XXXIX*, Abstract #1703. [6] Kurihara T. et al. (2008) *LPS XXXIX*, Abstract #2478. [7] Kurihara T. et al. (2008) *LPS XXXIX*, Abstract #2505.