IRON NANO-PARTICLES IN OLIVINE FROM THE NWA 1950 SHERGOTTITE: ADDITIONAL COMPLEXITY. T. Mikouchi, A. Takenouchi, S. Inoue, T. Kogure and T. Kurihara, Department of Earth and Planetary Science, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan (mikouchi@eps.s.u-tokyo.ac.jp).

Introduction: The dark color of olivine found in Martian meteorites is due to the presence of Fe-rich nano-particles possibly formed during strong shock metamorphism [1,2]. In these samples the nano-particles are present as either Fe metal or magnetite [3], but their formation has not been fully understood. Especially, olivine in NWA 1950 is the most complicated example. Van de Moortèle et al. [1] reported nano-particles of Fe metal, while Kurihara et al. [3] reported magnetite. Furthermore, our previous work even reported hematite although it is interpreted to be an artifact product during sample preparation by focused ion beam (FIB) for transmission electron microscope (TEM) observation. The different Fe-rich mineral species in a single meteorite nevertheless appears truly present because a magnetic study showed the presence of both Fe metal and magnetite in a 0.2-0.3 g sample [1]. In order to further understand the formation of Fe-rich nano-particles in olivine of Martian meteorites, we are further studying NWA 1950 because of reports on different Fe-rich mineral species. In this abstract we report new observations of nano-particles in this particular sample.

Analytical Methods: We prepared a powder sample of NWA 1950 by crashing a small rock chip (1~2 mm in size) with high abundance of dark olivine. The TEM observation was performed by JEOL JEM-2010 (Dept. of Earth and Planet. Sci., University of Tokyo) with 200 kV accelerating voltage. Energy dispersive spectroscopy (EDS) was used to estimate qualitative chemical compositions of analyzed phases.

Results: We found abundant nano-particles in NWA 1950 olivine with a diameter of mainly 10-20 nm. However, we also found a larger particles exceeding 100 nm in size. Usually these particles are not rounded in shape, but rather irregularly-shaped, sometimes elongated platy-shaped (Fig. 1). In fact, most large nano-particles in our NWA 1950 olivine sample are not rounded. This is consistent with our earlier observation [4]. We also found particles showing a two-layer texture that the core of the particles is surrounded with the outer rim (Fig. 2).

In order to identify the mineral species, we performed EDS and the selected area electron diffraction (SAED) analyses. All nano-particles are Fe-enriched, and thus consistent with previous studies [1,3,4]. The obtained SAED patterns show that many grains are Fe metal with a body-centered cubic (*bcc*) crystal structure. However, in the same sample we also found nano-particles whose EDS data show both Fe and O enrichment (Fig. 3). Their SAED patterns could be indexed either by magnetite or hematite, and we have not been able to distinguish these two Fe oxides in our sample yet. The core of the composite grains is Fe metal, but the rim is Fe oxide.

The olivine grains around the nano-particles often show mottled appearance and the domain sizes are <100 nm, suggesting recrystallization of olivine. Where nano-particles are abundantly present, the surrounding phase shows enrichment of Si. The obtained EDS spectra indicate that it is not olivine (Fig. 4). Probably, Si-enriched phases such as silica (or pyroxene) have been formed by precipitation of Fe-rich nano-particles as expected from the redox reaction of olivine.

Discussion and Conclusion: In this study we found more variation in the mineralogy of nano-particles in NWA 1950 olivine than before. Especially, the important new finding is the co-existence of Fe metal and Fe oxide on TEM scale for the first time although we have not been able to distinguish magnetite and hematite. The formation of hematite during FIB sample preparation as observed in [4] is ruled out this time because we analyzed powder samples. If the Fe oxide is hematite, it was formed by terrestrial weathering or it may be a Martian product. However, we consider that it is not hematite because the color of olivine is “black” rather than “red”. Olivine in a lunar meteorite including hematite nano-particles shows red color [5]. If the Fe oxide is magnetite, it is likely that it was formed on Mars rather than by terrestrial weathering because terrestrial weathering usually forms hematite or Fe hydroxides instead of magnetite.

The presence of the composite nano-particles showing rimming by Fe oxide is important. If the rim is magnetite, it could be formed after post-shock temperature decrease. In our previous study we experimentally showed that either magnetite or Fe metal could be produced only by the difference of increasing temperature at the same shock pressure [6]. Therefore, at high temperature Fe metal was first formed and upon cooling magnetite became stable and rimmed the Fe metal core. Thus, we found the coexistence of Fe metal and magnetite as suggested by the magnetic susceptibility of NWA 1950 [1] although their TEM analysis detected only Fe metal.

The finding of platy nano-particles is also important because they are likely to have crystallized from melt.

If this is the case, olivine was once melted by shock and recrystallized to minute domains with the formation of Fe-rich nano-particles. The presence of small olivine domains is consistent with this hypothesis. However, we cannot rule out the possibility of solid-state formation of nano-particles by olivine reduction or oxidation. The larger size of nano-particles found in NWA 1950 suggests that high temperature by shock lasted longer than other Martian meteorites.

References: [1] Van de Moortèle B. et al. (2007) *EPSL*, *262*, 37-49. [2] Treiman A. H. (2007) *JGR*, *112*, *E4*, E04002. [3] Kurihara T. et al. (2009) *LPS XL*, Abstract #1049. [4] Mikouchi T. et al. (2011) *LPS XLII*, Abstract #1689. [5] Kurihara T. et al. (2008) *LPS XXXIX*, Abstract #2478. [6] Kurihara T. et al. (2010) *LPS XLI*, Abstract #1655.

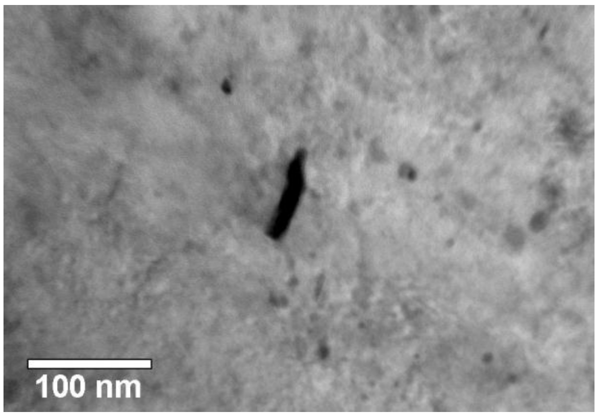

Fig. 1. Bright field TEM image of NWA 1950 olivine. A large platy nano-particle (near the center of the image) is present with other small rounded nano-particles of 10-20 nm in diameter.

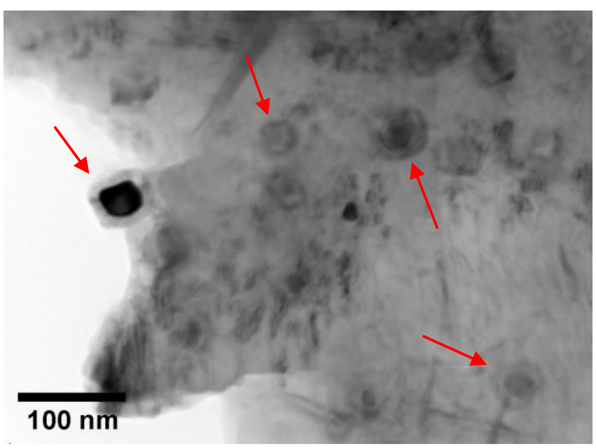

Fig. 2. Bright field TEM image of NWA 1950 olivine. Note the presence of composite nano-particles showing core-rim textures (indicated by arrows). The Fe metal cores are surrounded with the Fe oxide rims.

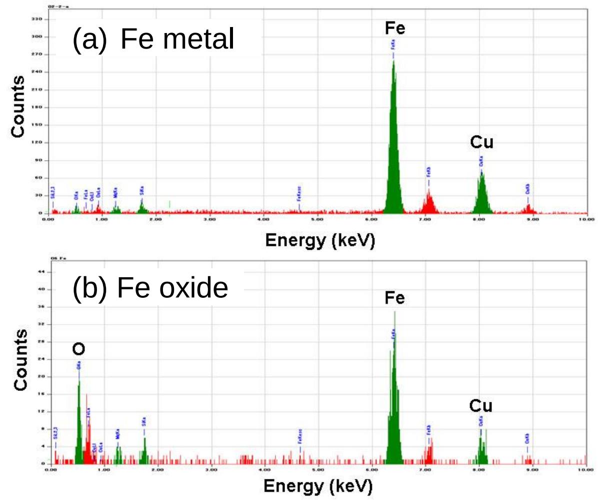

Fig. 3. EDS data of (a) Fe metal and (b) Fe oxide. These spectra are from large grains reaching 100 nm in size, and therefore are not influenced by olivine signal caused by beam overlapping.

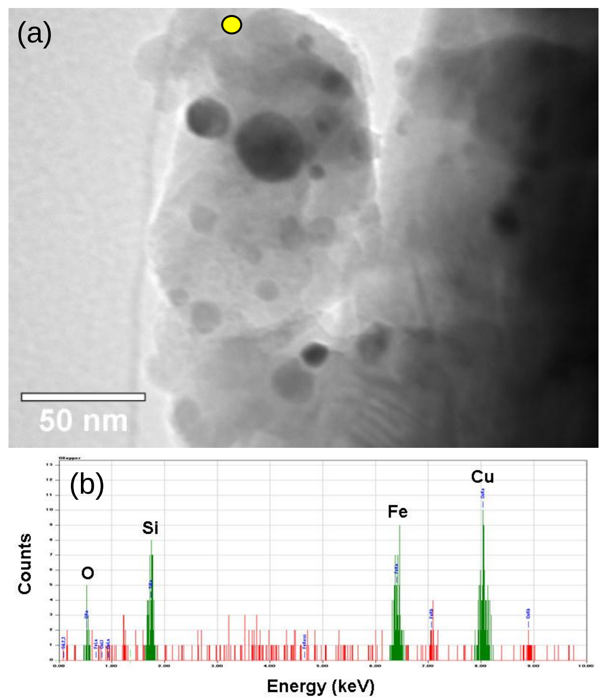

Fig. 4. (a) Bright field TEM image of NWA 1950 olivine where abundant nano-particles are present. (b) EDS shows enrichment of Si. Probably this is a silica mineral. The EDS was taken from the yellow spot shown in (a).