TRANSMISSION ELECTRON MICROSCOPY OF EXPERIMENTALLY SHOCKED SAN CARLOS OLIVINE. T. Kurihara[1] , T. Mikouchi[1], A. Yamaguchi[2], and T. Sekine[3], Dept. of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, JAPAN[1], Antarct. Meteorite Res. Center, National Inst. of Polar Res., Itabashi-ku, Tokyo 173-8515, JAPAN, [3]Natiolal Inst. for Materials Sci., Tsukuba, Ibaraki 305-0044, JAPAN (E-mail: maequalsf@hotmail.com).

Introduction: Nanometer-sized Fe-Ni metal particles were recently reported in olivine from the NWA2737 chassignite [1]. These particles are assumed to affect color of their host olivine grains, that are brown in thin sections and black in hand specimen [2], thus important for interpretations of remote sensing data [3]. Van de Moortele et al. [1] proposed that these particles were formed as reduction of olivine due to extensive shock metamorphism. We also found similar Fe-Ni metal particles in some lherzolitic shergottites, but some of them are present as magnetite rather than metal [4]. In this abstract, we report transmission electron microscopy of experimentally shocked San Carlos olivine powders by paying attention to the formation of nanometer-sized Fe particles.

Experimental Methods: The shock-recovery experiments were performed using a single stage 30 mm-bore propellant gun to generate shock waves by hypervelocity impact at the National Institute for Materials Science, Tsukuba. We prepared powder (100-200 µm) of San Carlos (Fo_{89}) olivine for starting material. The olivine powder was set into a Cu container and shocked by a 2-4 mm-thick Cu plate, bedded at the front of a polyethylene sabot. The peak pressure was estimated by the impedance match method using the measured impact velocity. Details of shock experimental procedures are similar to [5]. Shock pressure was set at 20, 30, 40, and 46 GPa. The recovered samples were observed by TEM (JEOL JEM2010) with EDS. For comparison, we also performed shock experiments on powdered olivine mixed with graphite powder (100-200 µm) with the wt% ratio of 1 : 1 to achieve more reducing conditions. The peak shock pressures were the same as those for olivine powder. The sample chamber was evacuated to 200 Pa before each shot.

Results: No nano-phase particle was observed in the samples recovered from the 20 and 30 GPa experiments. Fe-rich nano particles were observed in the sample shocked at 40 GPa (Fig. 1). These particles were usually 5 to 30 nm in diameter and identified as magnetite by electron diffraction patterns. Magnetite particles were also observed in the 46 GPa experiment. However, it is not clear about the abundance of magnetite particles between 40 and 46 GPa experiments, since their densities were at very low level in both samples. Magnetite particles were present in the host olivine, and we did not find any secondary phases between magnetite and olivine, similar to natural olivines in LEW88516 [4]. EDS analysis shows that these particles are free in Ni.

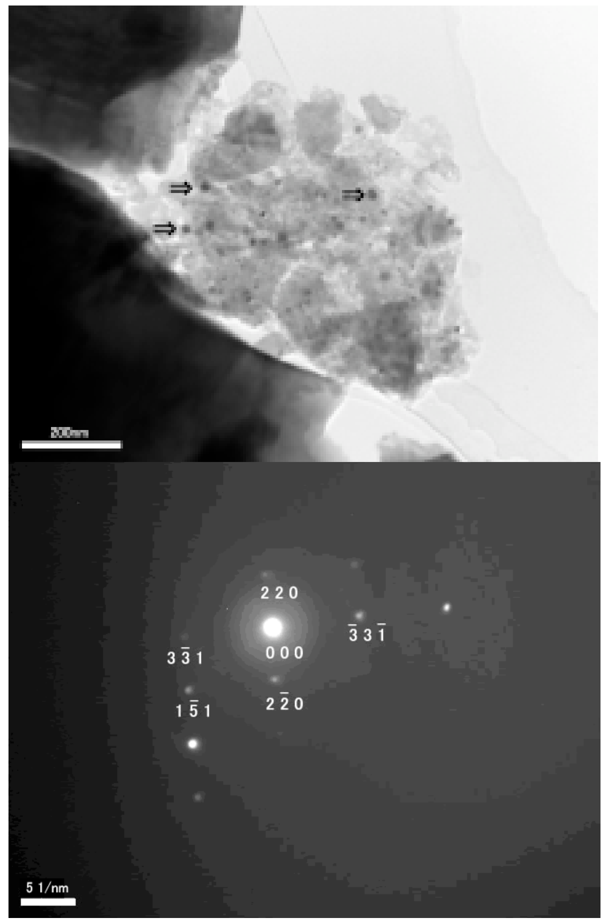

Fig. 1 TEM image of olivine powder shocked at 40 GPa, showing the formation of nano-particles (above). The scale bar is 200 nm. The electron diffraction pattern of the particle shows that it is magnetite (perpendicular to [1 -1 -6]) (below).

In contrast, many nano-phase particles were observed in the olivine-graphite mixed samples shocked at 40 and 46 GPa (Fig. 2). Their sizes were typically about 5 to 50 nm in diameter. These particles were identified as Fe metal by electron diffraction patterns, which is similar to nano-phase particles in NWA2737, ALH77005, and Y000097 olivines [4]. The EDS shows that they contain Ni.

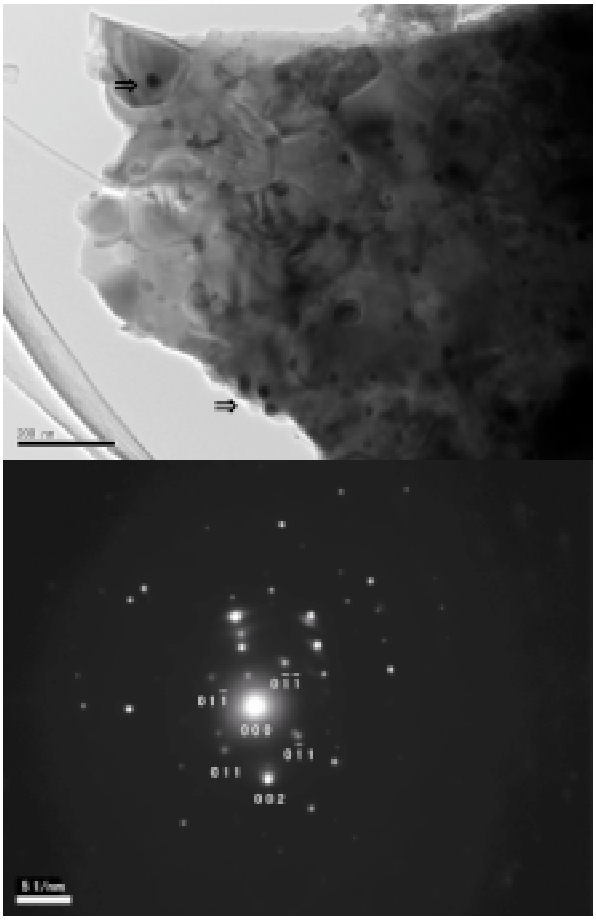

Fig. 2 TEM image of the olivine-graphite mixed sample shocked at 46 GPa (above). The scale bar is 200 nm. The diffraction pattern of the particle shows that it is iron metal (below).

Discussion and Conclusion: Our shock experiments of olivine powder could successfully produce nano-phase magnetite at the peak shock pressure higher than 40 GPa. This shock pressure range is equivalent to that for Martian meteorites containing brown color olivine [6]. Because magnetite is observed in LEW88516 [4], its formation process may be similar to the experimental condition of this study. However, Fe-Ni metal nano particles were observed in Y000097 and ALH77005 as well as in NWA2737. This difference probably originated in the difference of redox condition during shock events. In our shock experiment, we could produce Fe-Ni metal when olivine was mixed with graphite. Thus, reduction of olivine takes place in the presence of graphite when heavily shocked, suggesting that different oxidation state produces either magnetite or Fe-Ni metal during shock higher than 40 GPa. In fact, we found a magnetite particle in the carbon mixed sample shocked at 46 GPa. This particle was present away from graphite grains. EDS data does not show either C or Ni, which can be explained by heterogeneity of sample. Thus, Fe-Ni metal particles in the experiments are present only adjacent to graphite grains, and is not directly applicable for the formation of Fe-Ni metal particles in Martian meteorites, where graphite is absent. Shock experiment of olivine-graphite mixture is more comparable to analog shock history of ureilite.

In order to form an Fe-Ni metal particle in olivine, reduction of Fe^{2+} is a necessary process. The absence of silicate phases near the nano particles suggests that Fe reduction was achieved by volatilization of Si, rather than the following formula: $3Fe^{2+} \rightarrow Fe^0 + 2Fe^{3+}$. Our preliminary XANES analysis using synchrotron radiation shows no clear difference of $Fe^{3+}/\Sigma Fe$ between Fe-Ni particle-enriched and -poor areas in Martian meteorite olivines [4], supporting this hypothesis. In contrast, the formation of magnetite requires oxidation of Fe^{2+}, which may be caused by oxidizing atmosphere. As in the case of Fe-Ni metal particle, the absence of silica or pyroxene near the nano particles also suggests volatilization of Si.

References: [1] Van de Moortele B. et al. (2007) *Earth & Planet. Sci. Lett., 262,* 37-49. [2] Beck P. et al. (2006) *Geochim. Cosmochim. Acta, 70,* 2127-2139. [3] Pieters C. M. et al. (2007) *Meteoritics & Planet. Sci., 42,* 5062. [4] Kurihara T. et al. (2008) *LPS XXXIX* (in this volume). [5] Sekine T. et al. (1987) *Jour. Material Sci.*, 22, 3615-3619. [6] Fritz J. et al. (2005) *Meteoritics & Planet. Sci.*, 40, 1393-1411.