Comparison of shock induced lamellar texture in olivine between Martian meteorites and experimentally shocked basalt

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Introduction: Collisional events, which are fundamental but important processes in the solar system, are often recorded in meteorites. Olivine is one of the most abundant minerals in meteorites and a good indicator for estimating shock degrees [1]. Therefore, studying a behavior of olivine under high pressure is essential in order to reveal such collisional events [e.g., 2]. In order to estimate shock degrees of meteorites we have observed both naturally and experimentally shocked olivine by scanning electron microscopy (SEM) and transmitted electron microscopy (TEM). Since we have found characteristic shock-induced lamellar textures in olivine from experimentally shocked olivine-phyric basalt (reported in [3]), we sought a similar lamellar texture in naturally shocked olivine in Martian meteorites by SEM. In this study, we describe shock-induced lamellar textures in olivine and propose their formation conditions, which are related to different shock conditions of meteorites.

Samples and Methods: We studied two shergottites (Northwest Africa (NWA) 1950 and Roberts Massif (RBT) 04261). NWA 1950 characteristically contains brown colored olivine while RBT 04261 does not [4-5]. The lamellar textures of olivine were found using SEM (JEOL JSM-7100F at NIPR). Thin film sections were cut off by focused ion beam (FIB; Hitachi FB-2100) and observed by TEM (JEOL JEM 2010 at The University of Tokyo).

Results: By SEM observation, lamellar textures similar to those in shock recovered samples as reported in [3] were found in olivine from NWA 1950 and RBT 04261. The abundance of lamellae is higher in NWA 1950 compared to RBT 04261 (olivine lamellae in RBT 04261 are rare). The distribution of lamellae is heterogeneous even in NWA 1950. The maximum widths of each lamella were about 1.1 μm and 0.5 μm in NWA 1950 and RBT 04261, respectively. The lamellae have darker contrast in BSE images compared to the surrounding olivine crystal and the lamellae are parallel to a few crystallographic orientations of olivine. The FIB sections were cut off from olivine to be normal to the lamella elongation. By TEM observation, the lamellae are easily recognized in the FIB section of NWA 1950 (Fig. 1). The lamellae show no diffraction patterns indicating that they are composed of glassy material. Compositions of lamellae are almost the same as that of surrounding olivine. There are abundant dislocations throughout the FIB section although the dislocations are rare around lamellae (Fig. 1). On the other hand, such glassy lamellae were not found in the FIB section of RBT 04261. Instead, high dislocation density areas seem to correspond to the lamellae in BSE images similar to the result of shock recovery experiment [3].

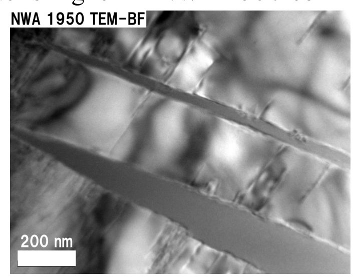

Fig. 1 TEM-Bright field image of glassy lamellae in olivine from NWA 1950

Discussion and Conclusion: The lamellae in RBT 04261 are composed of dislocations similar to those in shock-recovered samples. This indicates that the lamellar areas in RBT 04261 have experienced a similar shock condition to those of the experiments. According to [3], the lamellae became wider as the shock pressure became higher (~0.25 and ~1 μm at 39.5 and 48.5 GPa, respectively). Therefore, the olivine showing lamellae with ~0.5 μm in width may have experienced shock pressure between 39.5 and 48.5 GPa although the conditions of shock recovery experiments and natural shock events are not completely the same. On the other hand, lamellae in NWA 1950 composed of glass. Its identical chemical composition to that of surrounding olivine and its topotaxial texture indicate that the glass is of solid-state origin. In previous experimental studies, olivine diaplectic glass formed over 41 GPa and over 50-55 GPa under hydrostatic and shock compression, respectively [6-7]. Therefore, NWA 1950 may have experienced high pressure such as over 50-55 GPa (at least over 41 GPa). However, the lamellae in NWA 1950 are surrounded by less abundant defects compared to the shock recovered sample in [7]. This may be induced by a difference of post shock temperature between shock recovery experiments and natural shock event. In natural samples, dislocations are likely to have disappeared due to high post shock temperature. Such high post shock temperature is also supported by the presence of brown colored olivine because brown olivine may form under high-pressure and high-temperature inducing high post shock temperature [5].

This study demonstrated that TEM observation of lamellar texture in shocked olivine has a potential to provide a good indicator for estimating shock pressures and post shock temperature throughout meteorites.

References: [1] Stöffler D. et al. (1991) *Geochimica et Cosmochimica Acta* 55:3845–3867. [2] Gillet P. and El Goresy A. (2013) *Annu. Rev. Earth Planet. Sci*. 41:257–85. [3] Takenouchi A. et al. (2017) *LPS XLVIII*, Abstract #1897. [4] Van de Moortèle et al. (2007) *Earth & Planet. Sci. Letter* 262:37-49. [5] Takenouchi et al. (2015) *LPS XLVI,* Abstract #1650. [6] Santamaria-Perez D. et al. (2016) *American Mineralogist* 101:1642-1650 [7] Jeanloz R. et al. (1977) *Science* 197:457-459.