IMAGING PERCOLATION DURING CORE FORMATION BY HIGH-RESOLUTION 3D TOMOGRAPHY. Yingwei Fei[1], and Chi Zhang[1], [1]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, N.W., Washington, DC 20015 (fei@gl.ciw.edu)

Introduction: Planetary accretion is a fast process and small planetary bodies were differentiated during the early history of the solar system. The internal core-mantle differentiation could proceed through efficient liquid-liquid separation or by percolation of liquid metal in solid silicate matrix, depending on the heat sources and the size of the planetary bodies. The percolation of liquid metal in solid silicate matrix is likely a dominant process in the initial differentiation when the temperature is not high enough to melt the entire planetary body. It could also be an important process in the deep mantle if solidification of the deep mantle occurred before the completion of metal-silicate separation. The efficiency of percolation depends on the dihedral angle, determined by the interfacial energies of the solid-solid and solid-liquid interfaces. Recent studies [e.g., 1-4] have investigated the wetting ability of liquid iron alloys in a solid silicate matrix at high pressure and temperature. They measured the relative frequency distributions of apparent dihedral angles between the quenched liquid metal and silicate grains on polished cross-sections to determine the true dihedral angle. In this study, we present a new imaging technique to visualize the distribution of liquid metal in silicate matrix in 3D by combination of focus ion beam (FIB) milling and high-resolution field-emission SEM imaging, and provide precise determination of the dihedral angle and quantitative measure of the volume fraction and connectivity.

Experimental Data and Results: We have conducted a series of experiments using mixtures of San Carlos olivine and Fe-FeS metal alloys with different metal-silicate ratios, as the starting materials. The S content of the metals ranges from 5 to 16 weight % S. The high-pressure experiments were performed up to 25 GPa and 1800 ˚C, using well-calibrated multi-anvil assemblies with either graphite or rhenium heater [5]. For each experiment, we used Al_2O_3 capsule with three sample chambers. At 6 GPa and 1800 ˚C, Fe-FeS melt evenly distributes in the olivine matrix without forming interconnected melt network, consistent with the previous experimental results [e.g., 6, 7]. High-quality 3D volume renderings were reconstructed from FIB serial sectioning and imaging with 10-nm slice thickness and 14-nm image resolution. Figure 1 shows 3D reconstruction of the sample quenched from 6 GPa and 1800 ˚C. The metallic melt pockets were trapped at olivine grain corners. The calculated melt percentage is about 3.3 volume%.

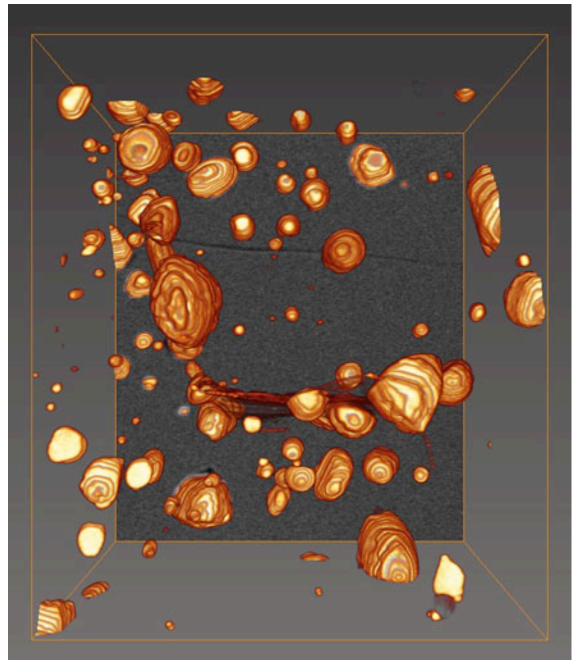

Fig. 1. 3D reconstruction of Fe-FeS melt in an olivine matrix. The size of the bounding box is 5x6.1x7.2µm.

At 25 GPa and 1800 ˚C, olivine transforms into silicate perovskite and ferropericlase. The metallic melts form the isolated pockets at the grain corners of the crystalline phases (Fig. 2). The grain sizes of the perovskite phase are less than 2µm, whereas some of the ferropericlase grains are substantially larger than 2µm. With a multi-phase matrix, the melts may be trapped at the corners of the same phase or of different phases, resulting different dihedral angles. The result shows different wetting ability of the melt with perovskite and ferropericlase.

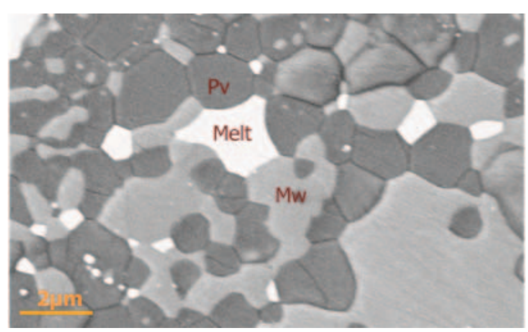

Fig. 2. Backscattered electron image of the sample quenched from 25 GPa and 1800 ˚C. Pv-silicate perovskite and Mw-ferropericlase.

We reconstructed the melt distribution in a lower mantle mineral assemblage in 3D (Fig. 3). The calculated melt percentage is about 4.9 volume% for this experiment. The unprecedented spatial resolution at nano scale allows detailed examination of textural features and precise determination of the dihedral angles.

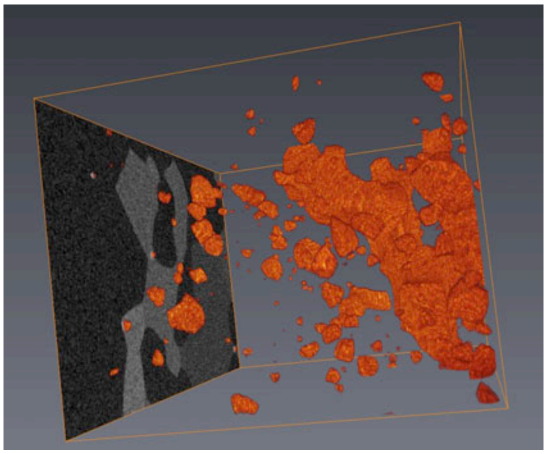

Fig. 3. 3D reconstruction of Fe-FeS melt in a lower mantle mineral assemblage. The size of the bounding box is 7x7.5x8μm.

Discussion: The efficiency of removal of liquid metal alloys from a solid silicate matrix strongly influence the timing of core formation and the composition of the core through mantle-core interaction. It depends on the percolation threshold and the dihedral angle. This study along with previous studies [e.g., 6-7] showed that the dihedral angle for Fe-FeS melts in an olivine matrix is above 60˚ which requires a minimum interconnection threshold for efficient melt removal. The minimum percolation threshold derived from electrical conductivity measurements and static annealing experiments differs significantly, ranging from 5 vol.% to 17.5 vol.% [8-11]. Using high-resolution 3D nano tomography, we directly assess the interconnection threshold in a multi-phase matrix, providing a new way to investigate the efficiency of metal percolation in a real silicate mantle.

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