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X-ray Imaging of Melts and its Application to Earth and Planetary Interior

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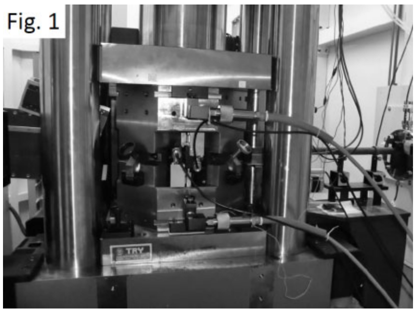
Introduction

Silicate melts and metallic melts have essential roles in the Earth's interior. Silicate melts play essential roles to produces the stratification and differentiation of the crust and mantle. The outer core is considered to be composed of metallic melts. Seismic observations suggest that the outer core may be composed of the metallic iron melt containing volatile elements, such as silicon and sulfur. Thus, we developed procedures for X-ray imaging to clarify the physical properties, such as density, viscosity, and rheology of melts under conditions of the Earth's interior.

Experimental procedure

The experiments were conducted at the beam lines, BL14C2, of the Photon Factory (PF), and BL-NE7at Accumulation Ring (AR). High pressure and temperature are generated by the 700 ton KAWAI-type multi-anvil apparatus (MAX-III). At the beamline BL14C2, we used monochromatized X-ray of 40-43 keV optimized for the best absorption image contrast. An imaging plate (IP) was used to collect X-ray diffractions. Transmitted X-ray from the sample was converted to a visible light by YAG scintillator and then detected using the cooled CCD camera (Bitran BS-40, or PIXIS2048F, Roper Co Ltd.) as X-ray radiography image. We introduced a deformation cubic anvil apparatus (D-CAP) for uniaxial deformation experiments (Figure 1). It enabled us to make in situ X-ray deformation experiments. The sample cell assembly for the melt density measurement is composed of magnesia pressure medium, $BN+TiB_2$ or graphite heater, and a single crystal cylindrical sapphire capsule. Pressure was calculated from the volume of the unit cell based on the equation of state of NaCl [1] or platinum [2] (Figure 2).



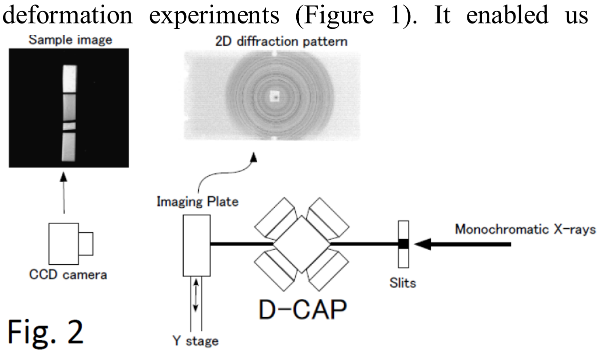
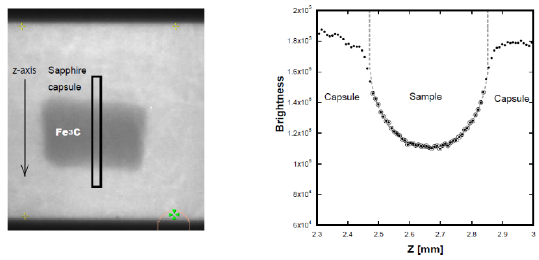


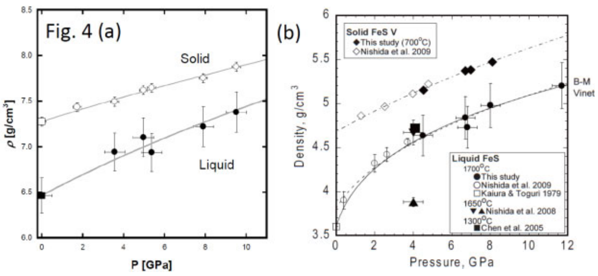
Fig. 2

Results and discussion

Density of the sample was measured using X-ray absorption image. The relation between absorption and density can be expressed by the Beer-Lambert law. Figure 3 shows an example of the X-ray absorption image of the molten sample Fe_3C at 9.5 GPa and 1973 K. Figures 4(a) and (b) indicate the densities of Fe_3C and FeS melts at pressures to 12 GPa. This is the highest pressure conditions for the density measurements of the molten metallic melts. Density of FeS melt was fitted by the Vinet equation of state using $\rho_0 = 3.60$ g/cm^3 [3], $K_T = 5 \pm 1$ GPa and K' = 11 ± 1. Density of liquid Fe_3C is expressed by K_T=54±3GPa, K'= 4 at 1973 K.. The density of the metallic alloy is useful to discuss the nature of the cores of terrestrial planets and Moon.

Fig. 3





References

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