Density and elastic properties of liquid gallium using externally heated diamond anvil cell

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It is important to measure density of liquid metals at high pressure and high temperature for understanding compression behavior and elastic properties of liquid metals. Since gallium (Ga) has a low melting temperature, Ga can become liquid state easily under high pressure. The densities of liquid Ga have been reported by X-ray tomography (Li et al. 2014), by sound velocity (Ayrinhac et al. 2015), by reverse Monte Carlo simulations combined with X-ray scattering data (Yu et al. 2012). However these densities were not consistent with each other. X-ray absorption method is effective to measure liquid density directly. In this study, the densities of liquid gallium were measured using X-ray absorption method combined with an externally heated diamond anvil cell (DAC).

In X-ray absorption method, density of liquid Ga was obtained from measured incident and transmitted X-ray intensities of the samples using Lambert-Beer law (Takubo et al. 2019). Ga sample and two reference materials (RbBr, KBr, or Fe) were loaded into each hole drilled on a pre-indented Re gasket. The Re gasket was coated with Al_2O_3 to avoid a reaction between the Ga sample and the gasket. High pressure was generated using a symmetric DAC with a lever-arm frame. High temperature was generated using external heaters composed of Pt-Rh wires with a ZrO_2 insulator. X-ray absorption measurements were conducted with monochromatic X-ray of 30 keV at BL10XU and BL22XU beamlines in SPring-8.

The density of liquid Ga were measured up to 10 GPa and 533 K. The elastic properties (bulk modulus (K_{T0}), its pressure derivative (K')) of liquid Ga were calculated by fitting the density data with equations of state (EOSs) and obtained 45.8(4) GPa, 6.1(2) from third-order Birch-Murnaghan EOS at 500 K, respectively. In lower pressure region, the compression curve is consistent with the density calculated from sound velocity data reported by Ayrinhac et al. (2015). However, our results show that density variation is smaller than Ayrinhac et al. (2015) in higher pressure (e.g. 1% smaller at 10 GPa).

Keywords: gallium, diamond anvil cell, X-ray absorption method

