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Hydrostaticity and Equation of states of NaCl, KCl, KBr up to 70 GPa at room temperature

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Recently, the high pressures and temperatures corresponding to the inner Earth's core have been achieved due to the progress of the experimental techniques (e.g., Tateno et al., 2010). To understand the physical properties of the Earth's core, it is essential to perform high pressure and temperature experiments. Fiquet et al. (2001) reported first results on sound velocities of Fe by an inelastic X-ray measurement over 100 GPa. Antonangeli et al. (2004) and Ohtani et al. (2013) also reported sound velocities of Fe over 100 GPa. Fiquet et al. (2001) reported slow sound velocities above 100 GPa due to preferred orientation of iron. They concluded the preferred orientation was caused by a uniaxial compression using a diamond anvil cell and slow sound velocities propagated along c-axis were observed. Therefore, hydrostatical compression is essential to avoid texturing of the samples and understand physical properties under high pressure.

To produce hydrostatic condition under high pressures, some liquid pressure media have been used, such as 4:1 (in volume ratio) Methanol Ethanol mixture (ME), 16:3:1 (in volume ratio) Methanol Ethanol Water mixture (MEW). Those materials are solidify at around 10 GPa. Therefore, the hydrostatic conditions are limited up to 10 GPa. Noble gases are also used as pressure media. He is solidified at 12 GPa and Ne is solidified at 5 GPa. They show hydrostatic behavior up to 40 and 20 GPa, respectively. Although they are good material to produce hydrostatic compressions, ME and MEW are reactive under high temperature and the noble gases require a special equipment to load them into a sample chamber. In this study, we employed alkali halides (NaCl, KCl, KBr) as pressure media, which are relatively soft and are expected to produce pseudo hydrostatic condition.

A foil made from powdered Au was used as a pressure scale (Fei et al., 2007) and a laser absorber. The foil was embedded between alkali halides pellets which served as pressure media and thermal insulators. A symmetric diamond anvil cell was used to generate high pressure. A double-sided laser heating method using fiber lasers was used for annealing the Au foil under high pressures for 10 min. Experimental pressure was imposed to the sample every a few GPa step and its X-ray diffraction (XRD) patterns were taken at room temperature. At 50 GPa and 70 GPa, the sample was annealed in order to reduce stress in the chamber. XRD patterns were taken before and after annealing. All XRD patterns were taken at BL10XU of SPring-8, Japan (Ohishi et al. 2008). The diameter of the X-ray beam was collimated to be 20 μm. The volume of Au at ambient pressure was measured to be 67.69(5) $\AA^3$ (a=4.0755(9) $\AA$) at the BL10XU, SPring-8. The gold volume obtained here was used for V_0 in the equation of state for Au to calculate experimental pressures.

We have obtained XRD patterns from the samples between 1 and 70 GPa and annealed the samples at 2000 K at 50 and 70 GPa. KCl, KBr, and NaCl transformed from B1 to B2 phase at 2.6, 2.8, and 32.6 GPa, respectively. The standard deviations of the pressure distributions in the chamber decreased slightly due to the transformations. The pressure standard deviations increased from 0.1 GPa at 1 GPa to 0.2 GPa at 20 GPa. After further compressions, the pressure distributions of Au in NaCl was almost constant but those in KCl and KBr increased up to 0.8 GPa and 1.2 GPa, respectively. After annealing at 50 GPa, the pressure distributions slightly reduced in KCl and KBr but they increased in NaCl. The compression behaviors of KCl and KBr are in good agreement with Dewaele et al. (2012) and those of NaCl are consistent with Dorfman et al. (2012).

Keywords: equation of state, hydrostatic compression, alkali halides, high pressure