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Compressibility of Ar

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1 Introduction

Rhenium (Re) is a group VII transition metal that crystallizes in a hexagonal close-packed (hcp) structure. The high-pressure behaviors of Re have been studied widely, as Re has a high bulk modulus value (~350 GPa) compared with other metals. It is known that Re has the second-highest bulk modulus value after Os. Since Re is used as gasket material in diamond anvil cell experiments, there is considerable interest in its high-pressure behavior. The equation of state (EOS) for Re has often been used as a pressure marker at extremely high pressures. An investigation of EOS could therefore improve the reliability of high-pressure experimental studies. Therefore, we performed high-pressure experiments to determine the room temperature EOS for Re.

2 Experiment

The high-pressure and high-temperature X-ray diffraction experiments were performed using a diamond anvil cell (DAC) high-pressure apparatus with a laser-annealing system. The culet size of the diamond anvil was 300 or 150 µm, and Re reagent powder (99.9% purity) was used as the starting material. Powdered sample was sandwiched between pellets of NaCl powder, which was used as the pressure-transmitting medium and the pressure reference. After annealing, we performed in situ measurements using the synchrotron X-rays 5–10 min. The sample was probed using angle-dispersive X-ray diffraction, employing the AR-NE1A synchrotron beamline at KEK, Japan. The angle-dispersive X-ray diffraction patterns were obtained on an image plate system (Rigaku R-AXIS, Japan).

3 Results and Discussion

Typical diffraction data are shown in Fig. 1. After compression to the desired pressure, stress broadening of each diffraction peak was observed, which decreased drastically after laser annealing. This indicates that the differential stress under compression was released on annealing. Diffraction data after annealing were used to determine the EOS, since the differential stress often causes bias in the relationship between volume and pressure. The room-temperature bulk modulus of Re was measured in the pressure range 0 to 115 GPa using a laser-annealing diamond anvil cell and the synchrotron X-ray diffraction method. A Vinet equation of state fitted to the 300 K data yielded a bulk modulus of K_{T0} = 384 GPa and a pressure derivative of K'_{T0} = 3.26 [1]. The value of the bulk modulus obtained in our experiments differs slightly from those reported from previous experiments without annealing, K_{T0} = 330~360 GPa. The difference between our experimental method and the approaches used in previous studies is related to the use of annealing before the acquisition of X-ray diffraction data. It is known that differential stress accumulates in the sample chamber during room-temperature compression, and this stress often has an influence on the measurement of the elastic properties of solids. In our study, laser-heated annealing was performed to minimize the influence of the differential stress at each pressure increment. The differences between our value and those reported in previous studies are therefore likely to be due to the differential stress in the sample chamber..

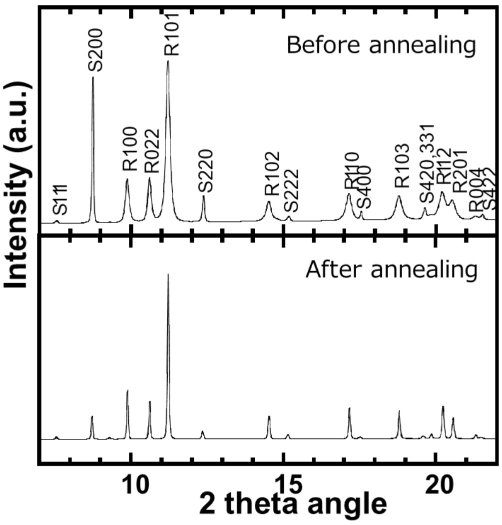

Fig. 1: Labels for the diffraction peaks are as follows: R – Re with hexagonal structure; S – B1-type NaCl. Numbers on the labels correspond to the indices of hexagonal or cubic symmetry. Monochromatic incident X-ray beam wavelength: λ = 0.4110 Å.

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References

[1] S. Ono, Equation of state determination for rhenium using first-principles molecular dynamics calculations and high-pressure experiments, Adv. Condens. Matter Phys., 2022, 7545777, doi.org/10.1155/2022/7545777

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