A NEW ALLOTROPIC PHASE OF CERIUM ABOVE 122 KBAR

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INTRODUCTION

It is well known that cerium metal appears in many different allotropic phases. The existence of two fcc phases, \( \gamma \) and \( \alpha \), has been the subject of extensive study particularly relative to the behavior of the 4f electrons in this transition. At pressures higher than 50 kbar, \( \alpha \)-Ce transforms to a superconducting \( \alpha' \) phase [1]. Conflicting results have been reported on the crystal structure of \( \alpha' \)-Ce [2-6]. During the course of an x-ray diffraction study to clarify this situation, we found another allotropic phase around 120 kbar pressure. This paper deals with the crystal structure of the new phase and the resistance change associated with the transition from the \( \alpha' \) phase to the new phase.

EXPERIMENTAL

X-ray Diffraction

A high pressure x-ray diffraction apparatus originally designed for liquid helium temperature [7] was used to obtain diffraction patterns at room temperature. This apparatus is based on the Guinier focusing geometry which permits high-resolution patterns with sharp lines in low background. The available range of 20 is limited within \( \pm 45° \). The Mo-K\( \alpha \) radiation was used, and the lattice parameter was determined within an accuracy of \( \pm 0.01\text{Å} \). A powdered
Ce sample filed from an ingot of nominal 99.95% purity was packed into a hole in a boron-epoxy cell and pressed between Bridgman anvils.

Calibration of pressure was made using aluminum as the marker. The pressure-volume relation for aluminum was measured [8] with reference to the equation of state for NaCl [9].

Resistance Measurement

The cerium metal ingot was rolled down to 0.03 mm thickness. A polished foil with 0.60 mm width and 2.00 mm length was placed in a semi-sintered magnesia cell [10] in the shape of an octahedron (Fig. 1). A multi-anvil apparatus modified from the "6-8 type" [11] was used for the high pressure resistance measurement. The eight anvils were forced together by means of a hydraulic press. The pressure in the cell was calibrated by observing the press forces required to produce the \( \gamma - \alpha \) and \( \alpha - \alpha' \) transitions in Ce (7 kbar and 51 kbar [4], respectively), the I-II transition in Sn (100 kbar), and the semiconductor-metal transitions in ZnTe (120 kbar), ZnS (150 kbar), GaAs (180 kbar) and GaP (220 kbar) [12]. The pressure was increased up to 220 kbar at a rate of about 0.5 kbar/min. A four-lead measurement was adopted to measure the resistance of a cerium foil.

RESULTS AND DISCUSSION

Figure 2 shows diffraction patterns of Ce, taken as a function of increasing pressure. Gradual structural transitions are observed. After releasing the pressure from 175 kbar to ambient pressure, the sample was again examined with x-ray diffraction. As shown in the bottom pattern of Fig. 2, no measurable change in the diffraction pattern of the \( \gamma \) phase is observed as seen in comparison with the initial state in the top pattern of Fig. 2. Thus it is apparent that the Ce sample was not subjected to oxidation and/or contamination during the high pressure experiment.