

COMPRESSIBILITY OF ORIENTED ALPHA PLUTONIUM*

J. F. ANDREW and J. R. MORGAN

University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, U.S.A.

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This note reports the compressibilities, in the pressure range to 7 kilobar of both randomly and preferentially oriented plutonium of much higher purity than was available when Bridgman¹ made the first compressibility measurements on plutonium in 1945.

A 10% volume contraction in plutonium during cooling through its $\beta \rightarrow \alpha$ transformation at about 115°C produces numerous small internal voids (microcracks). The purer the metal the more severe is the cracking. Effecting this transformation under a compressive load, as described by Bronisz and Tate², nearly eliminates the microporosity and at the same time induces a preferential alignment of the (020) perpendicular to the direction of applied stress. The (020) are the most densely populated planes in the monoclinic crystals of α plutonium.

All specimens used in this work were produced from arc-melted, vacuum cast, unalloyed plutonium of greater than 99.9 at % purity. The ingot from which the randomly oriented specimen was obtained was cooled through the $\beta \rightarrow \alpha$ transformation under negligible external restraint. Ingots with preferential (020) alignment and few microcracks were produced by subjecting them to a compressive load of 60 000 psi in a die in a hydraulic press while the temperature was raised into the β -phase range and then slowly reduced to room temperature. The density of the specimen with random orientation was 19.61 g/cm³ and that of each

preferentially oriented specimen was 19.79 g/cm³, as compared to the X-ray density of 19.86 g/cm³. The specimens were machined to cylindrical form, 1/4" in dia. by 1.9" long, and were compressed under hydrostatic pressure in an apparatus[†] similar to that which Bridgman used successfully to 30 kbar. The pressure transmitting fluid was an equal-volume mixture of pentane and 2-methylbutane (isopentane). The apparatus used in this study allowed measurement of the relative linear contraction between the specimen and a sleeve of Armco iron. This contraction was detected by a variable inductance displacement transducer (LVDT)^{††}, the coil of which was attached to the iron sleeve while the core, through a metal rod extension, followed the displacement of the free end of the specimen. The entire apparatus including the LVDT was immersed in the hydrostatic pressure medium. The LVDT was activated by 6 V-5kc power and its rectified output was recorded. The piezometer response for iron and aluminium calibration specimens was adjusted to agree with the values reported by Bridgman³). Appreciable non-linearity of the LVDT response was encountered at pressures greater than about 8 kbar but a sensitivity of about 1/2% was consistently realized at pressures up to this value. Pressure was measured and recorded to a sensitivity of 1/2% or better based

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upon the changing resistance of a manganin coil immersed in the pressure transmitting fluid. Overall accuracy of the compressibility data resulting from this work is estimated to be about 5%.

The parameter actually measured in these experiments was the linear decrement along the longitudinal axis of the specimen. The volume compressibility of preferentially oriented plutonium was therefore calculated as the sum of $2 \Delta l/l$ parallel to the (020) plus $\Delta l/l$ perpendicular to the (020). The equivalent value for a specimen with randomly oriented grains is $3 \Delta l/l$. A refining term, $1 - \Delta l/l$, contributed less than 0.7% for these specimens and was therefore omitted.

The results show a marked dependence of compressibility on the orientation of the (020). For the preferentially oriented specimens:

$$-\Delta l/l = 7.4 \times 10^{-7} p - 0.65 \times 10^{-11} p^2$$

perpendicular to the (020),

$$-\Delta l/l = 5.8 \times 10^{-7} p - 0.60 \times 10^{-11} p^2$$

parallel to the (020),

where p is in bar. Thus the linear compressibility in a direction parallel to the (020) is 22% lower than that in a direction perpendicular to the (020).

For the randomly oriented specimen:

$$-\Delta l/l = 7.3 \times 10^{-7} p - 0.77 \times 10^{-11} p^2.$$

The volume compressibilities, calculated as indicated above, are $19.0 \times 10^{-7}/\text{bar}$ for the preferentially oriented material and $21.9 \times 10^{-7}/\text{bar}$ for the randomly oriented specimen. The corresponding value reported by Bridgman¹⁾ in 1945 for less pure metal was $18.3 \times 10^{-7}/\text{bar}$. The 13% lower compressibility of the preferentially oriented plutonium as compared with that of the randomly oriented metal may be accounted for in part by the presence of relatively few microcracks in the preferentially oriented specimens, but the volume that can reasonably be attributed to microcracks in the randomly oriented specimen—on the basis of density measurements—seems too small to account for all the observed difference between the compressibilities.

References

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