Behavior of Some Delta-Stabilized Plutonium Alloys at High Pressures*

R. O. ELLIOTT and K. A. GSCHNEIDNER, JR.

Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico

Abstract

Delta-phase, Pu-rich, binary alloys containing Al, Zn, In, and Ce were observed at pressures up to 11,000 atm at 24 ± 1°C. Some of these alloys transformed under compression, and their transformation pressures and volumes, densities, compressibilities, and hardnesses were determined as a function of composition. The natures of the observed high-pressure transformations are discussed and related to their respective binary alloy phase diagrams with plutonium.

Introduction

Bridgman[1] did the first work (in 1945) toward determining the effects of high pressures on pure plutonium and plutonium alloys. Recently, his data on pure plutonium were declassified and published in an unclassified journal.[2] Nothing more was done with plutonium in this field until 1956, when Hughes[3] made a study of two delta-stabilized plutonium alloys at high pressures. His results were incomplete, and so a number of additional delta-stabilized Pu-rich binary alloys were investigated at high pressures by the authors, and the results reported here.

The high-temperature, delta allotrope of plutonium can be easily retained to room temperature by the proper combination of alloying and heat treating. Alloys of this type are generally referred to as delta-stabilized alloys although the delta phase in many such alloys is actually metastable and will transform to a more stable state when the

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alloy is thermally treated or compressed. A number of delta-stabilized alloys containing Al, Zn, In, and Ce were observed at pressures up to 11,000 atm. Many of these alloys transformed under compression and their transformation pressures and volumes, compressibilities, densities, and hardnesses were determined as a function of composition. Other plutonium alloys containing Cu, Ge, Cd, and Sn were prepared, but no delta phase was found in any of these systems at room temperature.

The main objective of the present investigation was to examine the behavior of delta-phase alloys at high pressures in order to obtain new data to aid in the theoretical explanation of the anomalous properties of delta plutonium. A secondary objective was to determine the effects of these alloying elements on the stabilization of delta phase, and to correlate the results with the respective binary Pu-rich phase diagrams.

Experimental

Specimen Preparation

The alloys were made by melting and casting weighed amounts of the component metals *in vacuo* in an induction furnace to form ingots about 0.5 in. OD by 1.75 in. long. These ingots were homogenized at 450°C for at least 200 hr, air-quenched to room temperature, and, finally, machined to right cylinders 0.434 in. diam and 1.5 to 1.7 in. long. All alloy compositions given in this paper are nominal except those of the Pu-Zn alloys, which are analyzed compositions.

Procedure

The specimens were examined using metallographic and x-ray diffraction methods both before and after compression. The densities of these alloys were also measured before and after a run.† Several of the alloy specimens were found to be cored or inhomogeneous. These specimens were heat-treated for an additional 200–400 hr at 450°C.

The alloys were subjected to high pressures in the simple piston and cylinder device shown in Figure 1. The stationary piston is placed in one end of the high-pressure cylinder, and the specimen,

† Precision of density measurements is ±0.03 g/cu cm.