Temperature and time-dependence of the elastic moduli of Pu and Pu-Ga alloys

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INTRODUCTION

We measured the elastic moduli of Pu and Pu-Ga alloys with three goals. They are 1) Provide accurate elastic moduli, 2) provide accurate temperature dependence, and 3)Measure the relative changes with time. We summarize here results for the time dependences with conclusions and results important to LANL and LLNL programs.

Fig. 1shows an example of an RUS system for use with Pu and Pu-Ga alloys. A complete description of this system and a review of RUS are described by Migliori et al.[1] We have measured Pu, Pu-Ga alloys and an Accelerated-Aging Program (AAP) alloy at ambient and cryogenic temperatures. The AAP alloy "ages" at a rate 16.5 times that of normal ^{239}Pu and it was "made" on 15 May 2002. All measurements presented were performed on fine-grained polycrystal, accurately-polished RPR's of known composition. It is expected that some formation of mechanically-induced alpha-Pu has occurred in delta-Pu specimens, but because all samples are at least as large as a 2mm cube, minimal errors in absolute moduli are calculated from this effect.

TIME DEPENDENCE OF ELASTIC MODULI OF PU AND PU-GA ALLOYS

To understand the variation of the elastic moduli with time in Pu one must keep in mind several effects. These are: 1) Pu-Ga alloys are not thermodynamically stable at ambient temperature. 2) As ^{239}Pu decays radioactively, interstitial-dislocation pairs are produced, about 2200/decay. 3) Decay products include He and metals that are not Pu, and so can change physical properties. A few key referents include: 1) from radioactive decay, 3.16×10^{-9} of the Pu atoms present in a specimen decay per hour, 2) 6.9×10^{-6} Frenkel pairs/hour/atom are produced, 3) From measurements of 3.3 at. % Ga and the 3.9 at. % Ga samples, the maximum long term fractional rate of change of the bulk modulus is of order 9×10^{-7}/h, 4) The elastic moduli change at a rate much higher than that of e.g. the density or Frenkel pair retention rate. Thus from the raw Frenkel pair production rate, we can estimate that the elastic moduli change at a fractional rate of order 7×10^{-5}/h. These rates are limiting associated with radioactive decay and very low temperature . Any rate substantially different from these must be associated with other physical effects.

It is important to note that the effects seen are much smaller than the error bars for measurements presented above. This is because the precision of RUS for Pu specimens is of order 5 parts in 10^7, but absolute accuracy is limited by errors in the measured size of specimens, of order several tenths of a percent.

Measurements were made using a very-high-precision temperature control system that held temperatures to within a few mK over many days. Good temperature control is crucial because of the strong temperature dependence of the elastic moduli of all samples.