Report:

We have measured phonon dispersion curves in Pu-bearing material *for the first time* using the high resolution inelastic x-ray scattering capabilities at ID28. In particular, we have determined the longitudinal acoustic phonons in an fcc δ Pu-Ga alloy and their frequency/wave vector dispersions for the symmetry directions [00ξ], [0ξξ] and [ξξξ] in the fcc lattice at ambient temperature.

A strain-enhanced re-crystallization technique [1] was employed to fabricate a large-grain polycrystalline bulk sample of a Pu-Ga alloy containing ~0.6 wt % of Ga. The Ga stabilizes the otherwise high temperature (329 – 451 ^{o}C) pure fcc δ-phase Pu to room temperature [2]. The specimen was 2.8 mm in diameter, ~ 10 micron thick with a grain size ranges from 75 to over 100 μm. A 30 μm x 60 μm focused undulator beam at 21747 eV was used to impinge on an oriented grain to record the phonon energy as a function of scattering angle (q-vector).

The results are summarized in Figure 1 which shows the LA branches along the main symmetry directions [00ξ], [0ξξ] and [ξξξ] in the Pu-Ga fcc lattice. The following observations are made.

1. From the slope of the [00ξ] dispersion curve and known density of this alloy (15.8 gm /cc), the elastic modulus C_{11} was determined to be 39.8 GPa in good agreement with that determined for a similar alloy by Ledbetter and Moment [3] from sound velocity measurements.

2. The [00ξ] dispersion exhibits a large linearity range - over half way across the Γ–X zone, (resulting no representation of any fitting procedure for this dispersion). Furthermore, in contrast with Pb which shows a Kohn anomaly at the X boundary [4], the [00ξ] LA branch of the Pu-Ga alloy does not exhibit a dip at the zone boundary

3. At the respective zone boundaries, the phonon frequencies of both [00ξ] and [ξξξ] LA branches for the Pu-Ga alloy are much higher that those of Pb [4], which is unexpected from reduced mass considerations.

4. The experimental LA dispersions for the fcc Pu-Ga alloy are very different (in shape and magnitude) than those calculated for fcc Pu [5] using generalized Morse potentials as have been applied by Mohammed et al [6] with quantitative success for several fcc metals: Ni, Cu Ag, Pd, Au, and Pb.

Our future experiments are aimed at extending the IXS investigations to obtain the transverse branches in this fcc Pu-Ga alloy and the dependence on Ga concentration of selected phonon dispersions to shed light on the fcc stabilization effects of Ga in this binary alloy system.

References

[1] J. Lashley, et al., Scripta Mater. 44, 2815 (2001)
[2] S.S. Hecker, Los Alamos Science, No. 26, Vol. 2 (2000), p.292
[3] Ledbetter and R.L. Moment, Acta Metallurgica, 24, 891 (1976).
[4] Brockhouse, et al., Phys. Rev., 128, 1099 (1962).

[5] Joe Wong, et al., PRL (2003) submitted
[6] K. Mohammed, et al., Phys. Rev. B29, 3117 (1984).

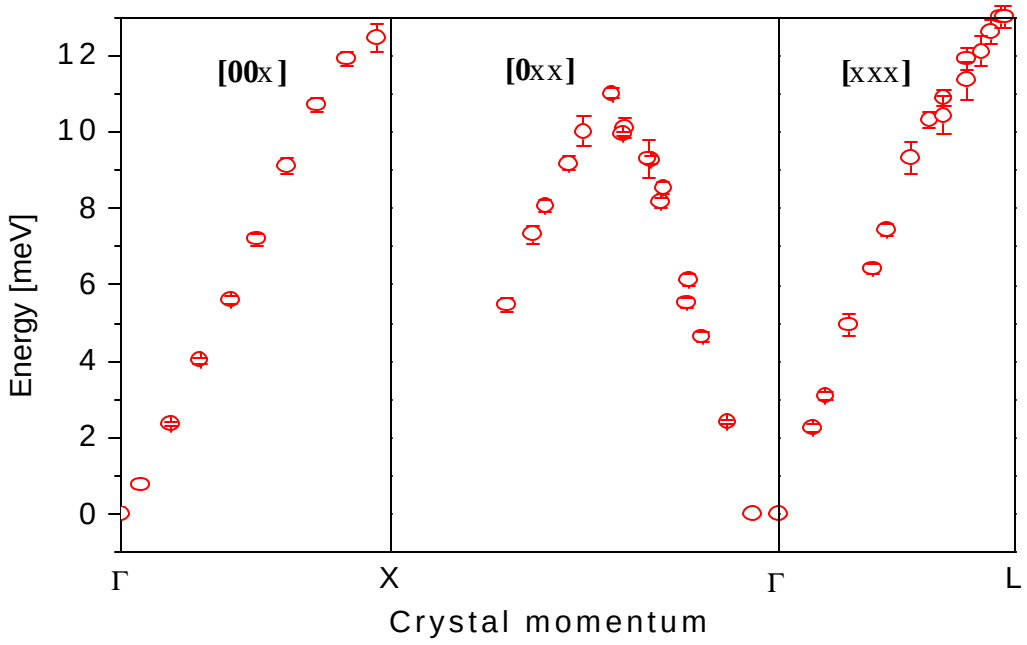

Figure 1. Experimental longitudinal acoustic phonon dispersion curves for a Pu-Ga 0.6 wt % alloy along the three major symmetry directions in the fcc lattice at room temperature.