LA-UR- 99-1120

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Title: POLYCRYSTALLINE DEFORMATION IN ENGINEERING MATERIALS: INSIGHTS FROM NEUTRON DIFFRACTION DURING LOADING!

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Submitted to: American Nuclear Society, 1999 Annual Meeting
6-10 June 1999, Boston MA

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Form 836 (10/96)

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Polycrystalline deformation in engineering materials; insights from neutron diffraction during loading!

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Introduction.

In-situ **measurements using the non destructive penetration of neutrons are commonplace at neutron sources and permit investigations within environmental chambers at stress, pressure, or temperature. Many of these studies explore the microstructural performance of engineering materials under service conditions. For example, by measuring phase strains during the application of static loads, neutron diffraction provides insight into failure, relaxation and load transfer mechanisms.**

Mechanical loading of a sample on a neutron spectrometer is usually performed with a customized load frame (small enough to fit into the typically limited available space) with the load axis horizontal. Diffraction data are recorded using detectors that surround the sample and strains are determined from changes in the measured interplanar lattice spacings in directions determined by the scattering geometry. These *elastic* strains indicate how the applied stress is shared throughout the microstructure. During a test, conventional strain gauges also record the macroscopic strain; that is the sum of the plastic and elastic contributions. Beyond yield the plastic contribution usually dominates the total strain *but* the elastic phase strains respond to the applied stress at any given load and provide clues about which phase (in a multi phase system) or which crystal orientation (in a single phase polycrystal) dictates failure.

Results

Examples of *in situ* deformation measurements will be discussed including;

Twinning during tensile deformation of a Uranium - 6 Niobium alloy

When Uranium 6%Nb (an important material to defense programs at LANL) is deformed, either in tension or compression, it exhibits stress/strain behavior characterized by two stress plateaus. The first plateau occurs immediately after yield and is short, about 3% strain in compression and less than 0.5% strain in tension. The material hardens very rapidly after the first plateau almost tripling its yield stress. This steep hardening behavior occurs for about 4% strain, in both tension and compression, then the material hardens at a normal rate for a metal undergoing plastic deformation. In the 80's X-ray studies[1] proposed a combination of twinning and a martensitic phase transformation to explain the first plateau. However since the supporting measurements, used a conventional X-ray source they were limited in penetration to a few microns of the surface. Consequently ambiguities in interpretation arose because of the difference in surface constraint

(with respect to the interior) as well as questions concerning the state of surface damage (following machining). *In situ* neutron measurements, in which a volume of about 1 cm^3 was irradiated, showed evidence of twinning but none of any martensitic phase transformation (Fig 1).

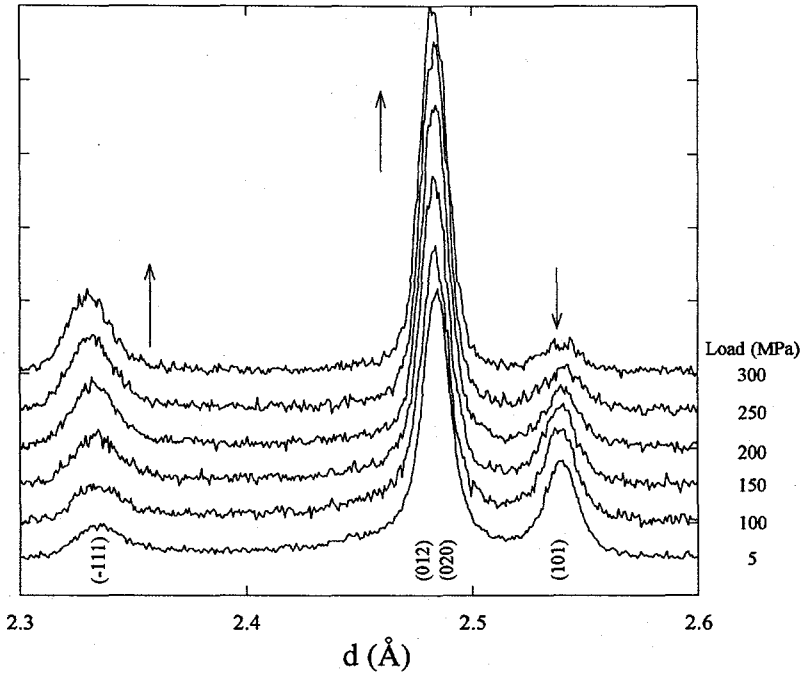

Fig 1; A short section of the normalized diffraction spectra (offset for increasing loads) recorded during a tensile test on U-6Nb. The scattering vector is perpendicular to the load. The arrows indicate peak intensities changing with the applied stress which can be explained by twinning.

Load partitioning at 20°C & at 300°C in a CuMo composite

The macroscopic load bearing capability of a composite is related to the strain partitioning occurring between the individual phases within it. Structural composites in many applications experience sustained or periodic temperature and stress fluctuations. If one is to understand their creep performance, the respective behavior of their constituents must be studied under realistic conditions. Using neutron diffraction, mean phase strains were measured during *in-situ* loading of a model system (Cu-15% Mo particulate metal matrix composite[2]) at room temperature and at 300°C. In figure 2 the differences in morphology and inflections of the elastic mean phase responses indicate that the load transfer (from matrix to reinforcement) is qualitatively and quantitatively different at low and high temperatures. Specifically, the load transfer from the copper to the molybdenum is much less effective when the matrix creeps.

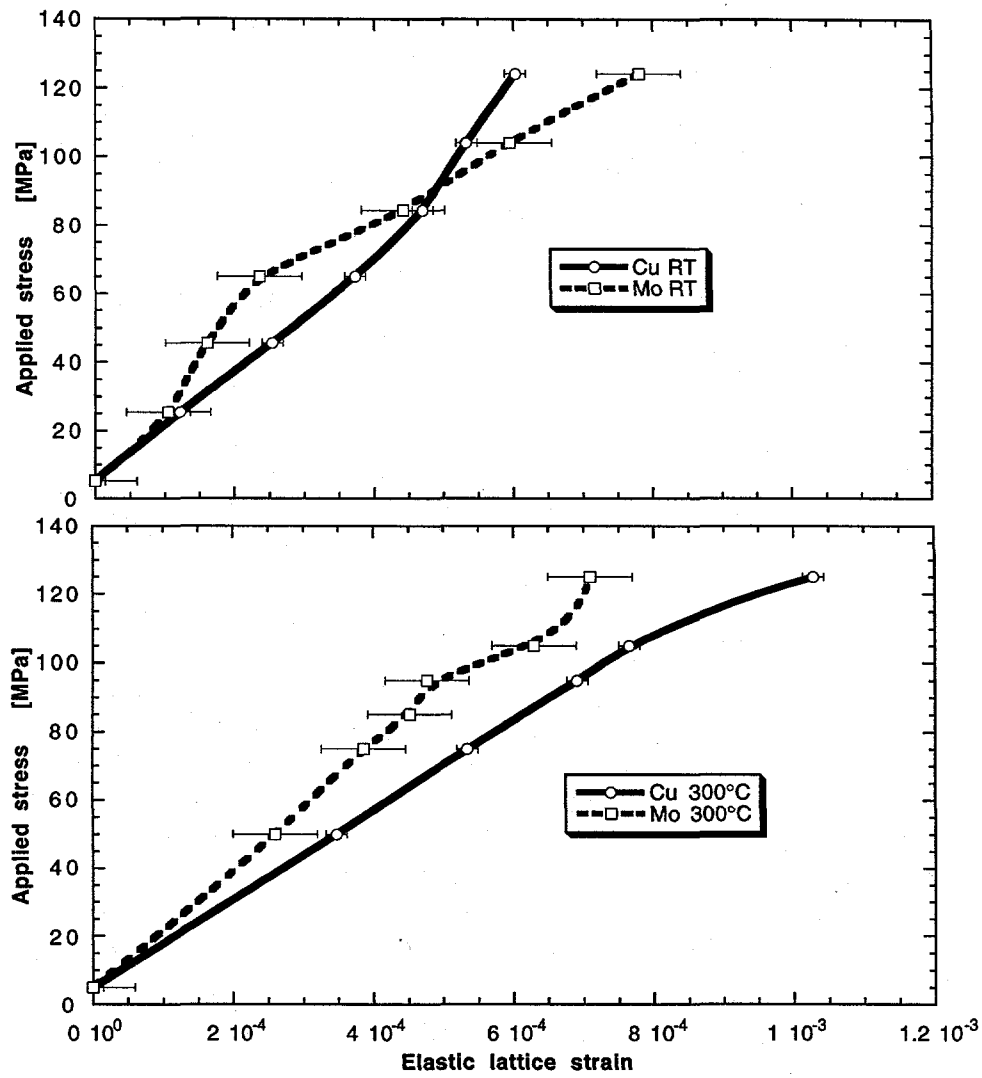

Fig 2; Mean phase elastic strain response for copper and molybdenum in a 15 vol% (Mo) discontinuous composite at room temperature (upper) and at 300°C (lower)

References

[1] Vandermeer, R.A., et al "Effects of Tensile Deformation on the Strain Memory Behavior of Uranium Niobium α" Martensite," in Proc. Int. Conf. on Solid Solid phase Transformations, eds. H.I. Aaronson, et al, The Metallurgical Society, Warrendale PA, pp. 1299-1303. (1982)

[2] Lund, C. "A study of deformation in metal matrix composites at room and elevated temperature using neutron diffraction" M.S. Thesis, Massachusetts Institute of Technology, 1997