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Measuring Interfacial Shear Strength of Cu_xNi-Nb Alloys

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Multilayer nanolaminates composed of immiscible alloys provide high-strength, good thermal stability, and a high-density of stable interfacial sinks for point defect recombination under irradiation.[1-3] A number of recent reports have focused on understanding the structure of these interfaces, their efficiency in promoting point defect recombination, and their effect on mechanical properties.[4-6] Interfacial shear strength has been shown to underlie bulk mechanical response[3] and recent efforts have focused on predicting and characterizing their properties both in the pristine state[4] and after exposure to irradiation.[6] It is anticipated that interfacial shear strength should relate to both the density of constitutional interfacial dislocations[1] and the heat of mixing of the alloy components (i.e. the bond strength at the interface). While simulations can simply vary these parameters in isolation[7] performing analogous experiments is challenging given restrictions imposed by the periodic table.

In this work, we attempt to quantify the interfacial shear strengths of Cu-Nb, Ni-Nb, and Cu_xNi-Nb, where Cu_xNi indicates solid-solution alloys of different compositions (x=1 or 3). Cu-Nb is relatively immiscible with a large heat of mixing while Ni-Nb has a negative heat of mixing. Cu and Ni mix almost ideally and have very similar atomic radii. By interfacing Nb with solid-solution Cu-Ni alloys, it is possible to tailor the average bond strength at the interface and characterize how the shear strength varies with this parameter with little change in the average atomic misfit. Cu-Nb and Ni-Nb both grow with strong preference for the Kurdjumov-Sachs misorientation relationship. This allows the effect of chemistry to be probed for interfaces of the same crystallographic character.

We prepared 45 ^{o} pre-tilt pillars on Si wedge-shaped substrates (Hysitron) by focused ion beam (FIB, FEI Company, Helios 600i) milling. This pre-tilt angle maximizes the resolve shear stress on the interface. Prior experiments indicate that the properties of these multilayers are neither pillar diameter nor pre-tilt angle dependent.[6] Multilayers were then grown from elemental targets by magnetron sputtering in $2x10^{-3}$ torr Ar in a chamber with a base pressure of $\approx 10^{-8}$ torr. Each layer was grown to be ≈50 nm thick. Nanocompression experiments were performed in-situ in a 200 kV JEOL 2010LaB_6 TEM using a Hysitron PI-95 picoindenter. Performing such experiments in-situ is useful for determining the stress associated with the onset of interfacial shearing and to observe any non-ideal deformation modes.

Figure 1 shows example images of Cu-Nb and Ni-Nb samples before and during compression testing that demonstrate how Cu-Nb interfaces shear, while Ni-Nb interfaces do not. In the Ni-Nb samples, a large dislocation content develops in the lattice. Notably, the Cu-Nb interfaces exhibit interfacial shear strengths of 0.60 ± 0.05 GPa, while Ni-Nb interfaces that do not shear and experience a maximum shear stress of 1.97 ± 0.63 GPa. The negative heat of mixing in Ni-Nb must strongly affect the interfacial shear strength causing it to be more than a factor of three greater than in Cu-Nb. Interfacial shearing also did not occur in the Cu_3Ni-Nb and CuNi-Nb samples, where the maximum shear stress was 0.81 ± 0.09 GPa and 0.51 ± 0.06 GPa, respectively. Again, these values represent lower bounds since interfacial shearing did not occur in any of the 7 alloy samples tested.

References:

[1] MJ Demkowicz and L Thilly, Acta Mater. **59** (2011). p. 7744-7756.
[2] A Misra, et al., Mater. Res. Soc. Symp. Proc. **1188** (2009). p. No pp. given, 1188-LL06-01.
[3] J Wang and A Misra, Current Opinion in Solid State and Materials Science **15** (2011). p. 20-28.
[4] N Li, et al., Scripta Materialia **67** (2012). p. 479-482.
[5] S Mao, et al., Acta Materialia **82** (2015). p. 328-335.
[6] S Mao, et al., Scripta Materialia **90–91** (2014). p. 29-32.
[7] XY Liu, et al., Acta Materialia **58** (2010). p. 4549-4557.
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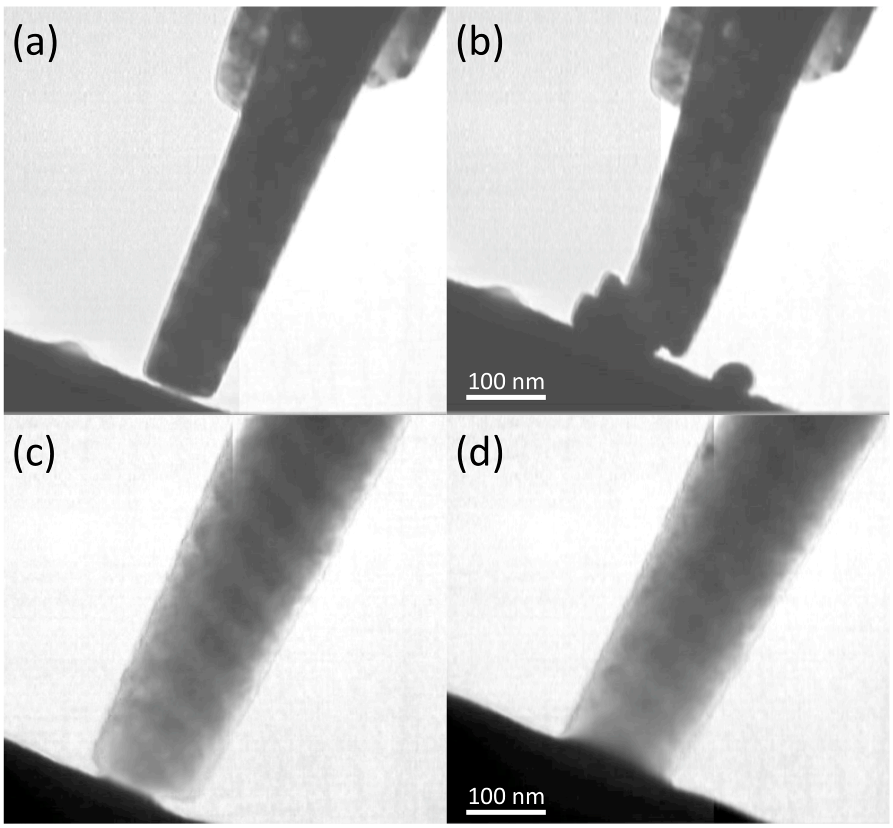

Figure 1. Time-lapse images of Cu-Nb (a) before and (b) after yield and Ni-Nb (c) before and (d) after yield. Note that Cu-Nb multilayers shear along the interface, while Ni-Nb multilayers do not.