Hall-Petch behaviour of nanostructured lamellar Cu-Mo composites produced by high-pressure torsion

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Lamellar refractory metal-copper composites combine high thermal and electrical conductivity with high-strength and dimensional stability at high temperatures. Such composites are most commonly produced via asymmetric roll-bonding (ARB) which is capable of reducing the layer thickness to tens of nanometers [1].

Nanolamellar Cu-refractory composites have recently also been produced via high-pressure torsion (HPT). The quasi-hydrostatic deformation makes it possible to refine composites containing brittle refractory metals such as Mo and W.

In ARB composites the microstructure consists of continuous, essentially planar layers. These have strong texture with well-defined orientation relationships (OR). The development of a Kurjumov-Sachs OR for layer thicknesses of <1 micron is thought to permit slip transfer, leading to a change in the Hall-Petch coefficient. This OR is although believed to play a role in the high-radiation tolerance of Cu-Nb composites [2].

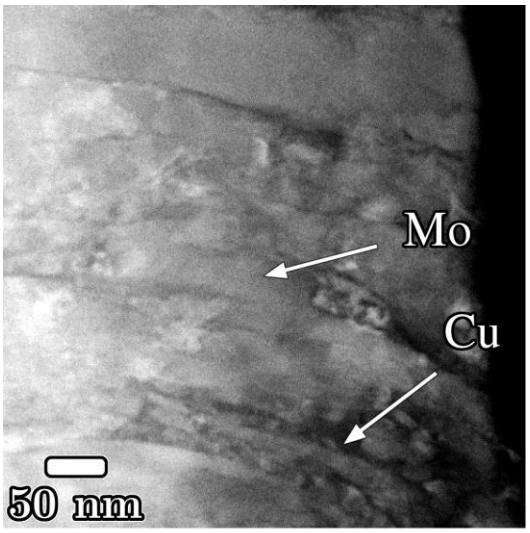


Figure 2-: HAADF-STEM micrograph showing the microstructure of a Cu30Mo70 (wt.%) composite. Cu and Mo lamellae vary in thickness and orientation. The shear direction is in the horizontal plane.

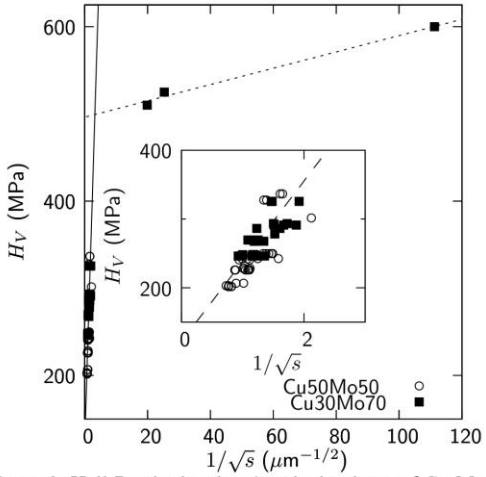
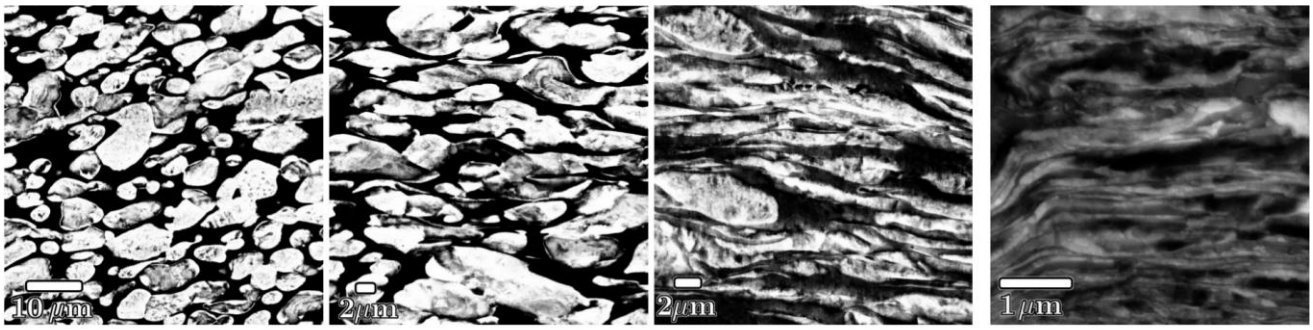


Figure 2: Hall-Petch plot showing the hardness of Cu-Mo composites versus the inverse square-root of the lamellar spacing, s.



N=0.2 N=0.5 N=1 N=5

Figure 1: Backscattered scanning electron micrographs showing the microstructure of a Cu30Mo70 (wt.%) composite with increasing number of rotations of HPT deformations, N.

Cu-Mo composites produced via HPT contain elongated, irregular refractory particles with a spread of orientations relative to the shear direction. Recent work employing a synchrotron X-ray source has showed that HPT Cu-Mo composites with lamellar thickness of 10-20 nm are only weakly textured [3]. Despite this, Cu-Mo composites appear to show a change in Hall-Petch behaviour.

A systematic study was carried out on the effect of microstructural refinement on the mechanical properties of Cu-Mo composites. HPT was applied to Cu-Mo refractory composites to refine the micron-scale starting materials to form nanostructured layers. The lamellar spacing of the composites was measured using scanning electron microscopy and high-angle annular dark field scanning transmission electron microscopy (HAADF-STEM) and correlated with the hardness. A transition in Hall-Petch behaviour occurred at thicknesses of ~50 nm, despite the absence of strong texture or flat planar interfaces which would permit slip transfer between the components.

References:

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