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[1] A. Misra, J.P. Hirth, R.G. Hoagland, Acta Materialia, 53 (2005) 4817-4824. [2] I. Knorr, N.M. Cordero, E.T. Lilleodden, C.A. Volkert, Acta Materialia, 61 (2013) 4984-4995. [3] M.A. Phillips, B.M. Clemens, W.D. Nix, Acta Materialia, 51 (2003) 3171-3184. [4] J.M. Wheeler, R. Raghavan, V. Chawla, J. Zechner, I. Utke, J. Michler, Scripta Materialia, 98 (2015) 28-31. [5] S. Lotfian, M. Rodríguez, K.E. Yazzie, N. Chawla, J. Llorca, J.M. Molina-Aldareguía, Acta Materialia, 61 (2013) 4439-4451.

TRANSITION IN PLASTIC DEFORMATION OF NANOLAYERED THIN FILMS: ROLE OF INTERFACES AND TEMPERATURE

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Insights into the parameters governing the plasticity of immiscible, nanocrystalline metals stacked in the form of layers are pivotal both from scientific and applications' perspectives. An outstanding case consists of the contact metallurgy of pure copper used ubiquitously as metallic interconnects in electronic devices. Diffusion barrier layers such W or TiN are necessary to prevent undesirable diffusion of Cu into the Si-based device during synthesis and service. Also, supersaturated Cu-Cr alloys are desirable for improving the strength, while retaining optimal functional properties required for the application. The scientific curiosity lies in understanding the effects of reducing microstructural length scales on the mechanical properties of both of these materials at elevated temperatures. In addition, alternate layering with an immiscible element forms a viable solution to the difficultly in synthesis and application of pure nanocrystalline materials due to their poor microstructural stability.
The mechanical behavior of several nanolayered thin films consisting of soft and relatively hard metals or brittle ceramics have been extensively studied at ambient conditions [1-3] by using various models predicting strength as function of grain size or layer thickness. But, few have investigated the elevated temperature mechanical response [4] of similar systems and have been restricted to a specific metal (Al) – ceramic (SiC) combination [5]. This presentation attempts to highlight the role of interfaces and diffusion in plastic flow and failure of mutually immiscible, nanolayered systems at elevated temperatures. The nanolayered thin films consist of mainly sub-100 nm thick layers of pure Cu sandwiched by layers of pure metals of Cr and W and a pure ceramic of TiN, which were grown on Si(100) substrates to thickness of 2-5 µm by using direct current magnetron sputtering. The mechanical response at elevated temperatures of the films was studied by compressing micropillars, which were fabricated using a focused Ga^+ beam, *in situ* SEM using an Alemnis® indenter modified for high temperature testing. Lateral flow of Cu promoted by stress-assisted diffusion at homologous temperatures as low as 0.35 occurred in all three systems in contrast to interfacial shear-dominated flow at lower temperatures (Fig. 1). Predictions of discrete dislocation and continuum plasticity models were used to evaluate the change in the yield strengths of the films with respect to the layer thicknesses of Cu in the different systems.

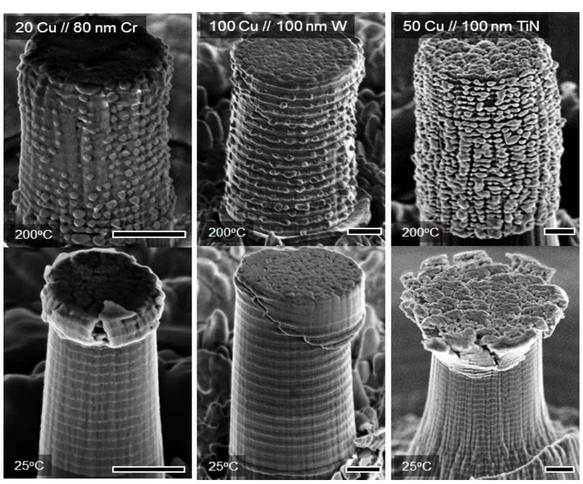

Figure 1 – High resolution SEM images of micropillars micro-machined within the nanolayered layered films and compressed in situ SEM at 25ºC and 200ºC. Length of micron-marker is 500 nm.

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