Materials Science & Engineering Doctoral Defense

Deformation Behavior of Co-Sputtered and Nanolaminated Metal/Ceramic Composites

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abstract

Nanolaminate materials are layered composites with layer thickness ≤ 100 nm. They exhibit unique properties due to their small length scale, the presence of a high number of interfaces and the effect of imposed constraint. This thesis focuses on the mechanical behavior of Al/SiC nanolaminates. The high strength of ceramics combined with the ductility of Al makes this combination desirable. Al/SiC nanolaminates were synthesized through magnetron sputtering and have an overall thickness of ~ 20 µm which limits the characterization techniques to microscale testing methods. A large amount of work has already been done towards evaluating their mechanical properties under indentation loading and micropillar compression. The effects of temperature, orientation and layer thickness have been well established. Al/SiC nanolaminates exhibited a flaw dependent deformation, anisotropy with respect to loading direction and strengthening due to imposed constraint. However, the mechanical behavior of nanolaminates under tension and fatigue loading has not yet been studied which is critical for obtaining a complete understanding of their deformation behavior. This thesis fills this gap and presents experiments, which were conducted to gain an insight into the behavior of nanolaminates under tensile and cyclic loading. The effect of layer thickness, tension-compression asymmetry and effect of a wavy microstructure on mechanical response have been presented. Further, results on in situ micropillar compression using lab-based X-ray microscope through novel experimental design are also presented. This was the first time when a resolution of 50 nms was achieved during in situ micropillar compression in a lab-based setup. Pores present in the microstructure were characterized in 3D and sites of damage initiation were correlated with the channel of pores present in the microstructure. The understanding of these deformation mechanisms paved way for the development of co-sputtered Al/SiC composites. For these composites, Al and SiC were sputtered together in a layer. The effect of change in the atomic fraction of SiC on the microstructure and mechanical properties were evaluated. Extensive microstructural characterization was performed at the nanoscale and Al nanocrystalline aggregates were observed dispersed in an amorphous matrix. The modulus and hardness of co-sputtered composites were much higher than their traditional counterparts owing to denser atomic packing and the absence of synthesis induced defects such as pores and columnar boundaries.

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