Materials Science and Engineering Doctoral Defense

Synthesis and in situ Characterization of Nanostructured and Amorphous Metallic Films

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abstract

Nanocrystalline (nc) thin films exhibit a wide range of enhanced mechanical properties compared to their coarse-grained counterparts. Furthermore, the mechanical behavior and microstructure of nc films is intimately related. Thus, precise control of the size, aspect ratio and spatial distribution of grains can enable the synthesis of thin films with exceptional mechanical properties. However, conventional bottom-up techniques for synthesizing thin films are incapable of achieving the microstructural control required to explicitly tune their properties. This dissertation focuses on developing a novel technique to synthesize metallic alloy thin films with precisely controlled microstructures and subsequently characterizing their mechanical properties using in situ transmission electron microscopy (TEM). Control over the grain size and distribution was achieved by controlling the recrystallization process of amorphous films by the use of thin crystalline seed layers. The novel technique was used to manipulate the microstructure of structural (TiAl) and functional (NiTi) thin films thereby exhibiting its capability and versatility. Following the synthesis of thin films with tailored microstructures, in situ TEM techniques were employed to probe their mechanical properties. Firstly, a novel technique was developed to measure local atomic level elastic strains in metallic glass thin films during in situ TEM straining. This technique was used to detect structural changes and anelastic deformation in amorphous TiAl films. Finally, as the electron beam (e-beam) in TEMs is known to cause radiation damage to specimen, systematic experiments were carried out to quantify the effect of the e-beam on the stress-strain response of nc metals. Experiments conducted on aluminum and gold films revealed that e-beam enhances dislocation activity leading to stress relaxation. The effect was also found to be more pronounced at lower accelerating voltages.

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