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Nanotwinned Ni Films with High Strength and Ductility

Background

Metallic films are commonly used as interconnects in semiconductor devices, flexible electronic devices, and micro-electronic-mechanical systems (MEMS). These applications typically require good mechanical (e.g., high strength) and electrical (e.g., low resistivity) properties. Nanocrystalline or nanolaminate films are commonly used, and they typically exhibit high strength, but their electrical resistivity is high and they have poor ductility.

Nanotwinned (NT) metals exhibit a superior combination of mechanical properties while retaining high electrical conductivity. However, not all metals can be readily synthesized with a NT microstructure. Metals with a low stacking fault energy (SFE) such as copper (Cu) and silver (Ag) readily form growth twins during electrodeposition or physical vapor deposition, and the twin density can be tailored by altering the deposition rates and temperature. However, it is difficult for growth twins to form in metals with high SFE including nickel (Ni) and aluminum (Al), and these metals typically have to be alloyed with other elements to lower their SFE and promote the formation of growth twins.

Most current methods of microstructural characterization and synthesis of NT metal films focus on micropillar compression or nanoindentation. There have been few studies on the mechanical behavior of NT metal films under tensile deformation, which is required to assess ductility.

Invention Description

Researchers at Arizona State University have developed nanotwinned (NT) Ni films with a synergistic combination of strength and ductility by tailoring the twin size distribution. These films are deposited on silicon (Si) substrates with a silver (Ag) buffer layer, and are composed of two crystallographic variants with out-of-plane orientation, which results in the formation of twin boundaries at their interfaces. The microstructure of these films is characterized using MEMS-based uniaxial tensile testing. Initial results showed that films with a larger mean and broader distribution of twin widths led to a uniform elongation of -10%.

Potential Applications

- Semiconductor devices
- Flexible electronic devices
- Micro-electro-mechanical systems (MEMS)

Benefits & Advantages

- Increased strength
- High ductility
- Effectively blocks dislocations networks
- Reduces propensity for void nucleation

Related Publication: High strength and ductility in a heterostructured nanotwinned Ni film.