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Mechanical Testing of Metallic Thin Films at Elevated Temperatures

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1. Introduction

Thin films are widely used as functional and structural elements in micro-electronic devices, large-scale integrated circuits, thin-film solar cells, electrical sensors, and electronic textiles. Therefore, understanding the mechanical behavior of thin films at different length scales and environmental conditions is essential for the design of reliable devices. However, it is difficult to precisely measure the properties of small-scale materials with the methods that are employed for bulk materials; probing micro/nano scale samples is challenged by the inherent difficulties associated with fabricating and handling of extremely small specimens. Advanced instrumentation and manufacturing techniques with enhanced characterization capabilities are required to better understand the properties and deformation mechanisms of technologically relevant materials.

2. Body of abstract

In this presentation, I will introduce experimental studies utilizing micro/nano scale manufacturing to understand the mechanical behavior of thin films and to develop metallic alloys for metal MEMS applications. Measurements at elevated temperatures are performed through use of a custom-built in-situ SEM mechanical tester and two silicon-based micro heaters that support the sample and allow us to study the mechanical behavior of metallic thin films at temperatures up to 740°C [1, 2]. Using this technique, I will present ongoing efforts in our laboratory utilizing the apparatus to understand the effect of an ultra-thin (< 10 nm) passivation layer on the mechanical behavior of these metallic thin films. Metallic thin films with an ultra-thin passivation layer exhibit significant strain hardening at room temperature, but expected to show lower strain hardening rate at elevated temperatures due to thermally activated recovery mechanisms.

In addition, I will discuss the mechanical behavior of sputter deposited NiMoW and NiTi alloy thin films annealed at various temperatures. NiMoW alloy thin films will be shown to be linear elastic to 3.1 GPa as-deposited, and can be heat-treated to result in 9% plasticity while maintaining a yield strength of 1.25 GPa [3, 4]. This brittle to ductile evolution suggests that sputtering and subsequent heat treatment offers an attractive route for developing metallic MEMS materials with tailorable mechanical properties, e.g. linear-elastic with ultra-high strength or ductile with high strength and superior toughness. Finally, I will introduce our ongoing study on understanding the microstructural length-scale, chemical composition effect on superelasticity (isothermal phenomenon where the material recover strain triggered by mechanical stress) of NiTi SMA thin films.

3. Equations, figures, and tables

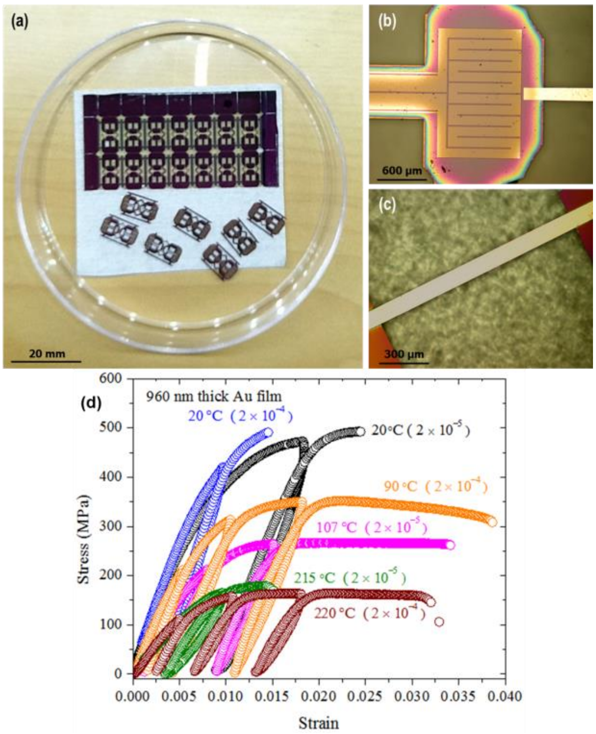

Fig.1 Image of (a) the fabricated microheater with magnified view of (b) the tungsten heating layer and (c) the thin film gauge length; (d) True stress–strain curve of 960 nm thick Au films, showing both temperature and strain rate effects

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