Residual Stress in Sputtered Au-Cu Thin Films

Brent Edgerton, Jaron Moon, Chris Liu, Roseanne Warren
Department of Mechanical Engineering, University of Utah
Salt Lake City, UT 84112, USA, roseanne.warren@utah.edu

Engineered thin films are ubiquitous in atomically precise fabrication with applications in electronics, optics, and materials science. Residual stress in these films is process induced and can have both desirable and undesirable effects. Residual stress in thin films is generally well-characterized on Si substrates, but not on rough, metallic electrodes. This work explores the effect of sputter deposition parameters on film roughness, morphology, stress, and optics of Au on Cu films. Au films are important for their high conductivity, corrosion resistance, and ability to form stable alloys with lithium. Thin films of Au on Cu are important interlayer materials in lithium metal batteries, as they improve wettability and prevent cross-contamination.

Residual stress can be controlled by varying the deposition power and pressure in a DC sputtering process. Power and pressure affect the kinetic energy of the sputtered particles by changing the ionization rate of argon and the number of collisions between the sputtered atoms and the ambient gas. The coupling of substrate-film material properties is also important.

In this work, the effect of sputter power and pressure of Au on Cu films was measured, and the results compared with Au on Si. Forty-five samples and a total of eight different sputtering conditions were tested including two power conditions (100 and 400 W) and four pressures (3.75, 11.25, 30, and 50 mT). Film properties were measured using scanning probe microscopy, scanning electron microscopy, X-ray diffraction, and spectrophotometry.

Cu substrates result in unique Au film behavior when compared to Si. Our observations reveal the grain size of Au on Cu to be double that on Si for comparable sputter conditions. Au on Cu films deposited at high power (400 W) and low pressure (3.75 mT) are extremely tensile (> 140 MPa) due to film recrystallization under high sputtering effective energy (Figure 1). This is notable as Au-Si films are generally compressive. Tensile Au on Cu films exhibit a lower work function than compressive films, as evidenced by the redshifted spectrum (Figure 2). This result has important implications for Au thin films integrated in energy devices such as lithium metal batteries and solar cells.

Overall, our findings provide opportunities for micro/nanoelectromechanical systems to more precisely design the physical and chemical properties of thin films on metallic substrates by controlling residual stress during deposition.

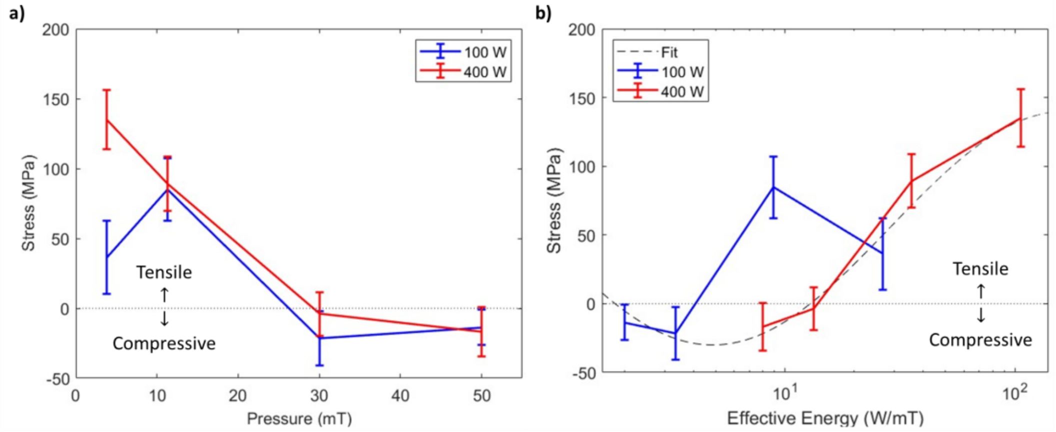

Figure 1. Stress evolution of Au on Cu as a function of deposition parameters. a) The stress profile of the sputtered gold films correlates with pressure and power, with pressure having a stronger influence. b) The stress profile of Au on Cu plotted vs effective energy (power/pressure), aligns with the sinusoidal pattern predicted by established literature for stress development based on the kinetic energy of the deposited particles. Error bars are standard deviations.

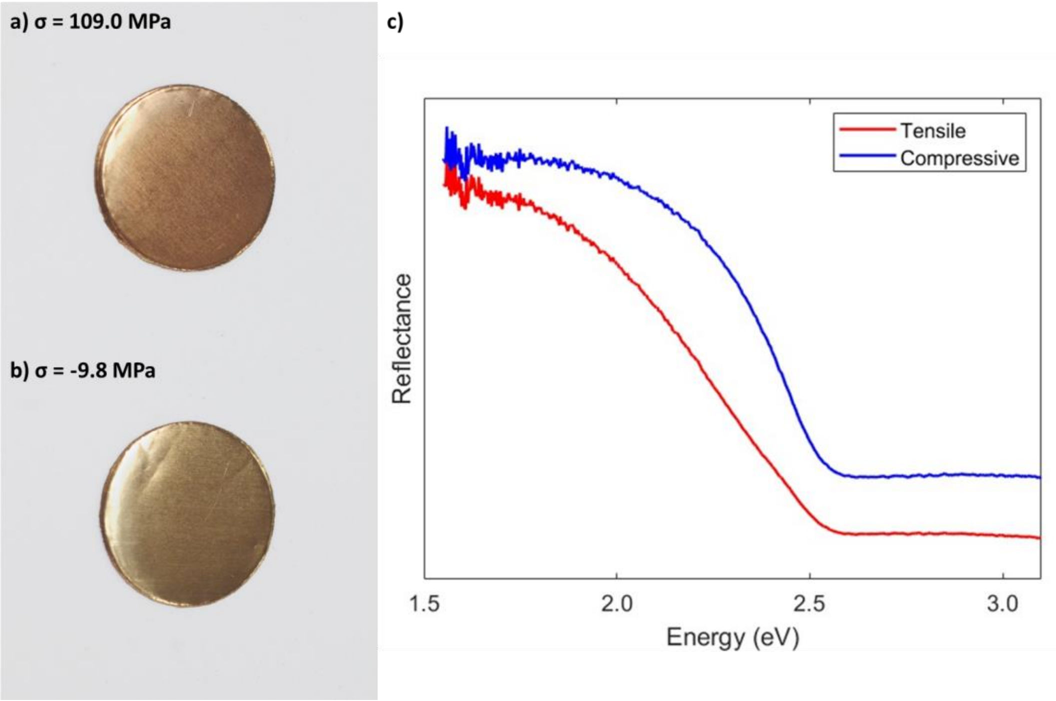

Figure 2. Optical behavior of Au on Cu film. Highly tensile (109.0 MPa) Au films (a) appear redshifted compared to compressive (-9.8 MPa) stress films (b). c) Near infrared reflection spectra of Au on Cu films from (a) and (b) are plotted vs photon energy, confirming the observed redshift.