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Size effects in mechanical behavior of submicron and nanometer thick textured Pt films

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ABSTRACT

{111}-textured Platinum (Pt) thin films facilitate the growth of {001}-textured PZT films with high transverse piezoelectric coefficients, and serve as the electrodes for PZT films for MEMS. However, the film thickness, texture, and strain rate dependent mechanical behavior of magnetron sputtered {111}-textured freestanding Pt films are unknown, and are expected to control failure initiation of the PZT films. To this goal, freestanding Pt films with thicknesses of 50, 150, 200, 500, and 1000 nm and perfect {111}-texture were studied via uniaxial tension experiments at strain rates 10^{-6} ? 10 s^{-1}. The elastic modulus, E = 164 ± 8 GPa, was independent of strain rate and film-thickness and was in very good agreement with theoretical estimates for the in-plane modulus of {111}-textured polycrystalline Pt. The yield stress increased with decreasing film-thickness: thicker films, 500 and 1000 nm, yielded early and accumulated larger plastic strain (~0.6–0.7%) when compared with the 200- and 150-nm Pt films that accumulated only 0.15% plastic strain, and the 50-nm films that failed in a brittle manner. This thickness dependence could be the result of both intergranular (grain rotation, grain boundary sliding) and intragrain (dislocation motion) plasticity taking place in thicker films as compared to only intergranular plasticity taking place in the thinner films. Strain-rate hardening was low for 1000-nm thick films, with strain-rate sensitivity m ~ 0.01, and was practically absent for all other film thicknesses. All films failed at only ~1% strain which may be attributed to localization of slip due to texture. Fracture for the 1000 nm and 500 nm films occurred at ~45^{o} with respect to the loading direction with transgranular features and strain localization, whereas the failure of 200, 150, and 50 nm thick films was brittle.