Growth-induced defect generation and intrinsic stress in Ta sputtered films : a comparison between alpha-Ta and beta-Ta phases

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Abstract

The metastable tetragonal beta-phase of Ta is commonly observed in tantalum sputtered films. This phase is characterized by a higher hardness and electric resistivity, compared to the equilibrium body centered cubic (bcc) alpha-phase allotrope. Despite its use in a variety of applications (resistor, capacitor, X-ray optic), the mechanical properties of the beta-Ta phase are not well known.
In the present work, we comparatively study the stress development during growth, and subsequent evolution during post-growth ion irradiation, in alpha- and beta-Ta sputtered films, by combining in situ wafer curvature and X-ray Diffraction (XRD). The influence of substrate bias voltage on the intrinsic stress and related lattice-expansion was investigated for both phases. Ion irradiation with 360 keV Kr ions, with low ion dose varying from 0.16 to 2 dpa, was used as an effective tool to study stress relaxation.

Alpha- and beta-Ta films were deposited by magnetron sputtering in Ar atmosphere on neutral (a-Si) and crystalline bcc Mo (110) template layers, respectively. The elastic strain field in as-deposited and irradiated states was determined from XRD using the sin2psi method, adapted for the case of textured layers, while the microstrain was obtained from a Williamson-Hall analysis of diffraction lines integral breadth.
Beta-Ta films were found to be more sensitive to the applied bias voltage, resulting in larger compressive stress (up to -2.4 GPa at -190 V) compared to alpha-Ta films (typically around -1.5 GPa). This different stress behavior is explained by a higher propensity to point-defect creation during growth, and their subsequent instability under ion irradiation, in the metastable beta-Ta lattice compared to equilibrium alpha-Ta.

Keywords: stress, Ta films, atomic peening, in situ curvature, X, ray Diffraction

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