Stresses in Mo/Si and W/Si multilayer films

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The stresses in sputtered Mo/Si and W/Si multilayer (ML) films have been measured using the wafer curvature technique. In one experiment[1], a strong dependance of stress on background pressure was observed in Mo/Si ML films, i.e., the ML stress becomes increasingly tensile with increasing background pressure. For example, in the case of ML films containing 40 periods of 4.3 nm Si layers and 2.6 nm Mo layers, the stress increases from approximately -450 MPa (compressive) to -280 MPa as the background pressure in the deposition chamber (i.e., measured just prior to deposition) increases from 6.0×10^{-8} torr to 1.0×10^{-5} torr. For MLs of the same period but with thicker Mo layers, the dependence on the background pressure is even stronger. These observations indicate that while the Mo layers become more tensile with increasing background pressure, the Si layers become more compressive. We also find that the variation in ML stress correlates with the concentration of incorporated hydrogen in these films, i.e., increasing hydrogen concentrations correspond to more tensile films, and the concentration of hydrogen increases linearly with background pressure. The most likely explanations for the observed variation in ML stress with background pressure are (a) that the stress is due to incorporation of hydrogen atoms, and (b) that the surface mobility of adatoms is decreased with increasing background pressure due to the affect of adsorbed residual gas atoms.

In another set of experiments, the stresses in Mo/Si and W/Si MLs were measured as a function of the individual metal and Si layer thicknesses; the stresses were measured for both as-deposited and 300 C-annealed films. The microstructure of the polycrystalline metal layers (i.e., grain size, lattice parameter, and out-of-plane strain) was investigated using X-ray diffraction. In the case of Mo/Si multilayers, the film stresses can be understood in terms of the measured strains in the Mo layers, assuming a simple dependence of the stresses in the amorphous Si layers as a function of thickness. In contrast, in the case of W/Si multilayers, two W phases are present, depending on the W layer thickness, making the strain analysis significantly more complicated. In both the Mo/Si and W/Si systems large irreversible stress changes occur on thermal cycling. These stress changes can be either positive or negative, depending on the specific metal/Si layer thicknesses involved, and are likely the result of diffusion, i.e., resulting from a net volume transport from one type of layer to the other, leaving one layer more compressive, and the other more tensile.

1. D. L. Windt, W. L. Brown, C. A. Volkert, and W. K. Waskiewicz, *J. Appl. Phys.,* **78**, 2423-2430 (1995)