Studies of annealing impact on the morphological, opto-dielectric and mechanical behaviors of molybdenum-doped CrN coatings

ABSTRACT

In the present study, molybdenum doped chromium nitride coatings deposited onto silicon substrates via unbalanced magnetron sputtering, in as-deposited and annealed conditions, at 500–800 °C in steps of 100 °C, were studied to reveal their temperature dependent structural, morphological, optical and mechanical behaviors. An analysis of these features was carried out using X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), ultraviolet visible (UV–Vis) spectroscopy, nanoindentation and finite element modeling (FEM) techniques. XRD results exhibited a significant improvement in the crystallinity of the Molybdenum (Mo)-doped chromium nitride (CrN) coatings along (111) and (200) diffraction planes, as the annealing temperatures increased. The lattice parameters gradually decreased from 4.20 to 4.12 Å as the temperature increased. The same tendency was also observed for lattice microstrains and residual stresses. Smooth grain-like surfaces were observed by FESEM imaging techniques. At an annealing temperature of 700 °C, the spectral absorptance of Mo:CrN films attained its peak value (86%), whereas the energy band-gaps were reduced from 2.48 to 1.14 eV. The other optical parameters such as complex dielectric constants, Urbach energy values, and steepness parameters of these coatings were also discussed. The hardness and elastic modulus of the as-deposited Mo:CrN films were estimated to be 18.4 and 287 GPa, respectively. At a film thickness of 1.0 µm, the highest stress of 20 GPa was evaluated, via FEM studies, at the interface between the film and the substrate. As the film thickness was enhanced, the stress level decreased. At higher annealing temperatures, both the mechanical hardness (H) and the elastic modulus (E) of Mo-doped CrN coatings dwindled.

Keyword: Annealing temperature; Molybdenum doped chromium nitride; Thin film coatings; Lattice constants; Residual stress; Solar absorptance; Optical band-gap; Hardness