Abstract

Singly charged carbon (C^+) ions irradiation effects on surface, structural, electrical as well as mechanical properties of metallic nitride films has been investigated. The thin metallic nitride films of Titanium Nitride (TiN), Zirconium Nitride (ZrN) and Chromium Nitride (CrN) were grown by using Pulsed Laser Deposition (PLD) technique. All films were deposited by the ablation of pure metals of Ti, Zr and Cr targets in reactive nitrogen atmosphere. Nd:YAG (532 nm, 140 mJ, 6 ns, 10 Hz) laser beam was employed as source of irradiation for PLD. The optimization of deposition parameters especially the nitrogen gas pressure and substrate temperature for the growth of good crystalline metallic nitride films has been performed. In order to study the effect of singly charged carbon (C^+) ions irradiation on deposited films, they were exposed to ions of different energies of 1 MeV and 2 MeV at different doses ranging from 0.4×10^{14} to 1.8×10^{15} ions/cm^2. The surface topography and structural properties of as deposited and ion irradiated films were investigated by Atomic Force Microscopy (AFM) and X-ray Diffractometer (XRD) respectively. A four point probe setup was used to investigate electrical behavior of ion irradiated thin films. The variations in surface hardness by ion irradiation were examined using Vickers microhardness tester. For 2 MeV carbon ion irradiation, nanohillocks are formed on both TiN and ZrN films. Whereas, for CrN films, island like structures with perturbed surface morphology are formed. The exposure of TiN films with 1 MeV carbon ions is also responsible for the growth of nanohillocks. It is revealed that the density of nanohillocks strongly depends upon irradiation dose and increases with increasing the ion dose up to certain critical value. Beyond that critical value, the hillocks density decreases and hillocks size increases. It implies that the growth of nanoscale structures is strongly dependent upon the nature (TiN, ZrN, CrN) of nitride films as well as energy and dose of ions. The formation of nanohillocks is explainable on the basis of thermal spike model and is attributed to the localized energy deposition of incident ions that leads to abrupt temperature rise. If temperature rise is higher than the melting temperature of the film, it generates thermal spikes which lead to mechanical stresses by thermal expansion and are responsible for the emergence of nanohiloocks. Structural analysis by X-ray Diffraction (XRD) reveals that ion irradiation produces considerable modifications in structural parameters like lattice constant, crystallite size, dislocation density, strain and residual stresses. Initially an increase in ions dose improves the crystallinity of films up to certain range and then beyond this limit, the crystallinity decreases and causes amorphization. The new carbide phases of TiC and ZrC are also formed due to carbon ion implantation. Four point probe analysis of ion-irradiated films shows the variation in electrical resistivity with ion dose. The modifications in electrical behavior are well correlated with the ion induced modifications in crystallinity as well as phase transformations. The microhardness measurements shows that, ion irradiations significantly changes the surface microhardness of metallic nitride films. The modification in surface microhardness depends upon, ion produced structural modifications especially the variation in crystallite size, formation of new carbide phases and ion induced defects generation. However, more pronounced increase in surface microhardness has been observed for that energy and doses which are suitable to generate harder carbide phases. The carbon ion irradiation is found to be suitable for surface nanostructuding of metallic nitride films and formation of harder carbide phases. The nanostructured metallic nitride electrode is the requirement of electrochemical capacitors and lithium ion batteries to improve their performance. In addition the carbon ion induced formation of carbide phases in metallic nitride films improves their mechanical properties, which is important in the fields of hard and wear resistive industrial coating applications.