ABSTRACT

The present work is motivated by the remarkable mechanical and tribological properties of carbon based nanocomposite thin films. This thesis reports the successful growth of carbon composite thin films like $TiC_x/SiC/a\text{-}C:H$, Al/a-C and $a\text{-}CN_x:H$ using 3.3 kJ plasma focus device as well as describes the structural, compositional, morphological and mechanical properties of these films. The synthesis of these films using different deposition techniques have been reported earlier but the use of plasma focus technique is one of the prospective hybrid deposition method which is not only economical, simple efficient but also provide high deposition rate and good adhesion in less time compared to other available thin film synthesis techniques. The following three different experiments were performed:

In the first experiment, thin films of $TiC_x/SiC/a\text{-}C:H$ were synthesized on Si substrates using a complex mix of high energy density plasmas and instability accelerated energetic ions of filling gas species, emanated from hot and dense pinched plasma column, in dense plasma focus device. The conventional hollow copper anode of Mather type plasma focus device was replaced by solid titanium anode for synthesis of $TiC_x/SiC/a\text{-}C:H$ nanocomposite thin films using CH_4:Ar admixture of (1:9, 3:7 and 5:5) for fixed 20 focus shots as well as with different number of focus shots with fixed CH_4:Ar admixture ratio 3:7. XRD results showed the formation of crystalline TiC_x/SiC phases for thin film synthesized using different number of focus shots with CH_4:Ar admixture ratio fixed at 3:7. SEM results showed that the synthesized thin films consist of nanoparticle agglomerates and the size of agglomerates depended on the CH_4:Ar admixture ratio as well as on the number of focus shots. Raman analysis showed the formation of polycrystalline/amorphous Si, SiC and a-C for different CH_4:Ar ratio as well as for different number of focus shots. The XPS analysis confirmed the formation of $TiC_x/SiC/a\text{-}C:H$ composite thin film. Nanoindentation results showed that the hardness and elastic modulus values of composite thin films increased with increasing number of focus shots. Maximum values of hardness and elastic modulus at the surface of the composite thin film were found to be about 22 and 305 GPa, respectively for 30 focus shots confirming the successful synthesis of hard composite $TiC_x/SiC/a\text{-}C:H$ coatings.

In the second experiment, Al/a-C nanocomposite thin films were synthesized on Si substrates using a dense plasma focus (DPF) device with aluminum fitted anode and by operating the device with CH_4/Ar admixture. XRD results confirmed the formation of metallic crystalline Al phases using different number of focus shots. Raman analysis showed the formation of D and G peaks for all thin film samples confirming the presence of a-C in the nanocomposite thin films. The formation of Al/a-C nanocomposite thin films was further confirmed using XPS analysis. SEM results showed that the deposited thin films consist of nanoparticles and their agglomerates. The size of agglomerates increases with increasing number of focus deposition shots. Nanoindentation results showed the variation in hardness and elastic modulus values of nanocomposite thin films with increasing number of focus shots. Maximum values of hardness and elastic modulus of the composite thin film were found to be about 10.7 and 189.2 GPa, respectively for sample prepared using 20 focus shots.

In the third experiment, hydrogenated amorphous carbon nitride films were synthesized by operating the dense plasma focus device with different CH_4/N_2 admixture gas ratios and fixed 20 focus shots. The pressure and axial distance from anode tip were kept constant at 3 mbar and8 cm respectively. Raman and X-ray Photoelectron Spectroscopy (XPS) techniques were used to observe the effect of CH_4/N_2 ratio on carbon nitride bonding. The XPS analysis showed that the terminating group C≡N is more dominant for the films synthesized using higher concentration of nitrogen which gives softer films. Field Emission Scanning Electron Microscopy (FESEM) results showed that the deposited films consist of nanoparticles and their agglomerates. The size of agglomerates increases with decreasing concentration of nitrogen in CH_4/N_2 admixture gas. **Nanoindentation results showed the increase in hardness and elastic modulus values of films with decreasing concentration of nitrogen in CH_4/N_2 admixture gas. The hardness** and elastic modulus values were found to be dependent on sp^3 content in the film as well as the C≡N. The hardness and elastic modulus values of 10.7 and 229.8GPa respectively were achieved for the films deposited with fixed 20 focus deposition shots and using CH_4/N_2admixture gas ratio of 7:3.