# Abstract

The present research is motivated by the hard coatings on the substrate which improves the wear resistance that extends the working life of substrate material. Industrially, hard coatings are being used in automotive engine accessories, turbine blades, cutting and machining tools. Due to remarkable and desired mechanical, tribological and electronic properties of tungsten nitride thin films, these coatings are being applied in industry as well as for engineering purposes. The present research work reports the successful attempt to synthesis tungsten nitride films on Si, Zr and stainless steel substrates. Synthesis of WN/a-$Si_3N_4$, W-Zr-N and nano-crystalline tungsten nitride thin films on Si and Stainless steel substrates using Mather-Type plasma focus device. Tungsten nitride thin films have been synthesized on different substrates using various deposition techniques but the use of plasma focus technique is one of the prospective hybrid deposition methods that provides high deposition rate, deposition under reactive nature, good adhesion in small time, simple and economical technique for deposition purpose. The results of these experiments show the successful growth of tungsten based nitride thin films using plasma focus device of energy 3.3 kJ. The following four types of different experiments were performed.

In the first experiment, WN/a-$Si_3N_4$ thin films were synthesized by utilizing the energetic ion/electron species emanated from hot, dense pinched plasma column in UNU/ICTP plasma focus operated with nitrogen gas. Structural, chemical, morphological and mechanical properties of synthesized films were studied using X-ray diffraction (XRD), X-ray Photoelectron Spectroscopic (XPS), Field Emission Scanning Electron Microscopy (FESEM) and nano-indentation respectively. XRD spectra show $WN_2$, $W_2N$, $W_7N_6$, $WSi_2$ phases on exposed samples. XPS results confirmed the chemical bonding of W-Si-N in synthesized films. FESEM micrographs showed uniform granular structure of synthesized WN/a-$Si_3N_4$ thin films. Surface morphology of synthesized thin films showed that increase in focus shots strong effects on the grain size due to change in ion energy flux. Nano-indentation results show the significant increase in hardness with increase in focus shots with maximum hardness of 23.5±1 GPa was observed for 45 focus shots.

In the second experiment, nano-structure thin film of tungsten nitride was deposited onto Si-substrate at room temperature using Mather type plasma focus (3.3 kJ) machine. The substrate was exposed against 10, 20, 30 and 40 deposition shots

and its corresponding effect on structure, morphology and nano-hardness have been systematically studied. The XRD spectra of the exposed samples show the presence of various phases of WN and $WN_2$ that depends on number of deposition shots. Surface morphological study revealed the uniform distribution of nano sized grains on deposited film surface. Hardness of exposed substrate improved with higher deposition shots. XPS survey scan of 40 deposition shots confirmed the elemental presence of W and N on Si-substrate.

In third experiment, nano-crystalline tungsten nitride thin films are synthesized on AISI-304 steel at room temperature using Mather-type plasma focus. The surface properties of exposed substrate against different deposition shots are examined for crystal structure, surface morphology and mechanical properties using X-ray diffraction (XRD), atomic force microscope (AFM), field emission scanning electron microscope (FESEM) and nano-indenter. The XRD results show the growth of WN and $WN_2$ phases and the development of strain/stress in the deposited films by varying the number of deposition shots. Morphology of deposited films shows the significant change in the surface structural with different ion energy doses (no. of deposition shots). Due to the effect of different ion energy doses, the strain/stress developed in the deposited film that leads to improvement of hardness of deposited films.

In the fourth experiment, a plasma focus device was employed to synthesis of composite W-Zr-N thin film on Zr substrate at room temperature. XRD spectra show the presence of tungsten nitride and zirconium nitride phase like $W_2N$, WN, $Zr_2N$ and ZrN with different crystallographic planes. The intensity of peak increased at higher number of focus shots which indicated the increase in the phase concentration in the deposited thin films. The surface morphology of the deposited films was studied using FESEM that reveal the homogenous distribution on substrate surface. At 30 shots the various gains were present on the substrate surface having range from grain size ~80 nm to ~250 nm with average grain size about 180±20 nm. Significant agglomeration of these grains was observed on the higher number of focus shots which might be due to the heating effect that increases with the increase in the number of focus shots. AFM show the surface roughness increases with the increase in the number of shots and maximum roughness was observed at 50 focus shots. The microhardness of the exposed substrate samples improves with the number of focus shots and higher microhardness was observer for 50 focus shots.