Abstract

In this dissertation three important aspects of laser-matter interaction for four selected metals i.e. Zinc (Zn), Copper (Cu), Molybdenum (Mo) and Tungsten (W) are addressed. These aspects include: (1) Understanding of physical processes involved in laser ablation and surface structuring, (2) The role of two important laser induced plasma parameters i.e. electron temperature (T_e) and electron number density (n_e) for the growth of various surface structures and (3) Applications of these surface structures for enhancing the field emission properties of the selected metals. The laser induced surface structuring is performed by employing both nanosecond (ns) and femtosecond (fs) i.e. Nd:YAG (1064 nm, 10 ns , 10 Hz) and Ti: sapphire (800 nm, 30 fs , 1kHz) laser irradiation. The crater depth is investigated using optical microscope analysis. The surface morphology is explored by Scanning Electron Microscope (SEM) analysis. For the estimation of plasma parameters Laser Induced Breakdown Spectroscopy (LIBS) analysis is employed. The field emission properties are explored by using the self-designed and fabricated set-up in a diode configuration under ultrahigh vacuum condition. The whole dissertation is divided into three parts.

Part A deals with the laser induced surface structuring of metals and its correlation with the plasma parameters at various irradiances ranging from 6 GW/cm^2 to 50 GW/cm^2.The irradiation is carried out for three metals i.e. Zn , Mo and W with low, moderate and high melting points. SEM analysis of laser ablated Zn reveals the formation of microscale ripples, wave-like ridges with cones and cavities. For Mo, large sized grains along with cavities and conical interiors, dense ridges with droplets are seen. For W, the formation of grains with pronounced cracking and large sized cones are observed. The evaluated values of T_e explored by LIBS analysis vary from 5973 K to 6240 K for Zn, 6526K to 9305 K for Mo and 7800 K to 16383 K for W. Similarly The values of n_e vary from 1.35861×10^{18} cm^{-3} to 1.44331×10^{18} cm^{-3} for Zn, 0.58,878 $\times$ 10^{18} cm^{-3} to 0.72,067 $\times$ 10^{18} cm^{-3} for Mo and 0.46,085 $\times$ 10^{18} cm^{-3} to 0.69,679 $\times$ 10^{18} cm^{-3} for W. It is found that surface structuring of selected metals strongly depend on the laser irradiance and plasma parameters. Part B and C of the dissertation are independent and deal with ns and fs laser induced surface structuring of selected metals for the enhancement of FE properties. The part B deals with the investigation of FE properties of the ns laser irradiated Cu and W metals at four laser irradiances ranging from 13 GW/cm^2 to 50 GW/cm^2. SEM analysis revealed the formation of ridged protrusions, localized melt pools, cones and pores for Cu, whereas, cones, grains and mounds covered with porous structures are observed for W. The Fowler-Nordheim (FN) plots are found to be linear and confirm the quantum mechanical tunneling phenomena for the structured metals. The values of turn-on field, field enhancement factor and maximum current density range from 5 V/ µm to 8.5 V/ µm , 1380 to 2730 and 147 µ A / cm^2 to 375 µ A / cm^2 for Cu and 5 V/µm to 8.5 V/µm,1300 to 3490 and 107 µA/cm^2 to 350 µA/cm^2 for W respectively.

Part C deals with the investigation of FE properties of fs laser irradiated W carried out at six different irradiances ranging from 0.2 $\times$ 10^{14} W/cm^2 to 6.9 $\times$ 10^{14} W/cm^2. The SEM analysis revealed particulates, grains and nanoscale ripples formation. The values of turn on field, field enhancement factor and maximum current density range from 7 to 15 V/µm, 460 to 6120 and 134 µA/cm^2 to 341 µA/cm^2 respectively. The obtained FE parameters are well correlated with the surface morphology and comparable to the previously reported values.

Overall dissertation presents the idea that both laser irradiance and plasma parameters can provide a better control over micro/nano structuring of metals which make them potential candidate for the enhancement in the FE properties as well as other applications.