Abstract

The plasma parameters of laser produced Zirconium plasma using Langmuir probe technique has been investigated. For this purpose a Q-switched Nd:YAG laser (532-nm, 6ns) at various irradiance ranging from 8.6 GW/cm^2 to 15.5 GW/cm^2 has been employed. All the measurements were performed under ultra-high vacuum condition while keeping the probe at two fixed distances of 4 mm and 10 mm from the target. By varying the biasing voltages from ±1V to ±75V the corresponding values of electron/ion currents were measured by the probe on the oscilloscope. Zr plasma parameters such as electron temperature, electron number density, ion temperature, ion density, plasma potential, Debye length and thermal velocity have been evaluated from I-V characteristics curves of Langmuir probe data The dissertation comprises of three independent parts.

In part A, the probe was kept at 4mm and only electronic measurements of Zr plasma were performed. The ion current measurements could not be done at this distance. It is found that both the electron temperature and thermal velocity of Zr plasma reveal an increasing trend from 18 eV to 41 eV and 2.8×10^8 cm/s to 4.3×10^8 cm/s with increasing laser irradiance which is attributed to more energy deposition and enhanced ablation rate. However, the electron number density of Zr plasma increases 6.5×10^{14} cm^{-3} to 6.7×10^{14} cm^{-3} with increasing irradiance from 8.6 GW/cm^2 to 10.9 GW/cm^2. Further increase in irradiance from 12 GW/cm^2 to 15.5 GW/cm^2 causes a reduction in the number density of Zr plasma from 6.1×10^{14} cm^{-3} to 5.6×10^{14} cm^{-3} which is attributed to recombination losses, three body recombination, self-regulating regime, as well as absorption by Laser Supported Detonation waves (Shock front).

Part B of this dissertation deals with both electron and ion current measurements when the probe was placed at a distance of 10 mm from the target. The evaluated values of electron temperature of Zr plasma vary from 9 eV to 26 eV, whereas, ion temperature varies from 10 eV to 33 eV with increasing laser irradiance from 8.6 GW/cm^2 to 15.5 GW/cm^2. Higher values of ion temperature than electron temperature represent peculiarity of large number of collisions at high density expanding laser generated plasma. With increasing laser irradiance from 8.6 to 15.5 GW/cm^2, the electron number density increases from 6.3×10^{14} cm^{-3} to 6.5×10^{14} cm^{-3} with an increases in laser irradiance 8.6 GW/cm^2 to 9.8 GW/cm^2. Further increase in laser irradiance cause a decreases in

electron number density of Zr plasma from 6.4×10^{14} to 5.5×10^{14} cm^{-3}. However, ion density increases from 4.7×10^{17} to 5.9×10^{17} cm^{-3} and then drops down to 5.7×10^{17} cm^{-3} as the laser irradiance increases up to 15.5 GW/cm^2. The monotonic decrease in electron density and observed drop in ion density of Zr plasma at particular irradiance are attributed to recombination losses and self-regulating regime formation. Both thermal velocity of electrons from 2.0×10^8 cm/s to 3.4×10^8 cm/s as well ion velocity from 1.65×10^5 cm/s to 1.55×10^5 cm/s show an increasing trend with an increase in laser irradiance. However, high velocity of electrons as compared to ions is attributed to their high mobility and faster speed due to smaller mass.

In part C Scanning Electron Microscope (SEM) analysis has been performed to reveal the surface morphology of irradiated Zirconium. It reveals the formation of cracks, ridges, cones and grains. It was observed at high irradiances the ridges are vanished, whereas, cones and cracks are dominant features.

The laser irradiance and probe distance are two investigated parameters on which electron/ion temperature as well as their density are strongly dependent. The laser generated Zr plasma with known flux and kinetic energies of ejected species is highly beneficial for thin film deposition as well as an ion source. It is also revealed that by controlling plasma parameters of Zr, the surface structuring of material can be controlled which has vast rang applications in the industry and medicine.