Abstract

Laser Induced Breakdown Spectroscopy (LIBS) and Probe Beam Deflection (PBD) techniques are employed for the diagnosis of metallic plasmas. The dissertation consists of three parts.

Part A deals with the ns-LIBS analysis of Mg and Zr metals. A Q-switched Nd: YAG laser (1064 nm, 10 nsec, 50-200 mJ) is employed as an irradiation source to generate the metallic plasmas under different background pressures of Ar ranging from 5 Torr to 50 Torr. LIBS2500 spectrometer system is used for the collection of emission spectra for ns-LIBS. In order to explore the spatial confinement effects on metallic plasmas, two techniques have been employed. One is introduction of Ar gas at different lower pressures (5, 10, 20 and 50 Torr), whereas, in the second confinement technique, a metallic blocker is introduced. All measurements are performed in the absence and presence of blocker placed at various distances of 6 mm, 8 mm and 10 mm from the target. In addition to restrict the plasma expansion, this later technique is also responsible for the enhancement of kinetic energy and density of plasma species through shockwaves reflection. The plasma parameters; electron temperature (T_e) and electron number density (n_e) have been evaluated using Boltzmann plot method and Stark broadened profile of isolated lines respectively. It is revealed from ns-LIBS analysis that for each material, there is an optimal combination of laser fluence, pressure of environmental gas and distance of blocker that gives the maximum value of T_e and n_e. In the case of Mg plasma, the optimal combination for the maximum T_e of 12200 K is achieved at laser fluence of 18 Jcm^{-2} under Ar gas pressure of 20 Torr in the presence of blocker at a distance of 6 mm. However, the maximum n_e of 4×10^{16} cm^{-3} is obtained at the laser fluence of 21 Jcm^{-2} under Ar environment of 50 Torr at same blocker distance. For Zr plasma, the maximum values of both T_e i.e. 14940 K and n_e i.e. 21×10^{17} cm^{-3} are achieved at the same fluence of 32 Jcm^{-2} under Ar pressure of 10 Torr at blocker distance of 6 mm.

Scanning Electron Microscope (SEM) analysis has been performed to establish a correlation between plasma parameters and surface modifications of irradiated metals. It reveals the formation of ripples, channels and cavities and their appearance is more distinct for smaller values of T_e and n_e of Mg and Zr plasmas. Whereas, the maximum values of T_e and n_e lead to the growth of diffusive structures.

In part B of dissertation, a correlation between the metallic plasma parameters evaluated by two different techniques i.e. LIBS as well as PBD technique is established. LIBS analysis and PBD techniques are performed only for nanosecond laser induced metallic plasmas at various fluences under a fixed Ar pressure of 760 Torr. PBD measurements are not recorded at lower Ar pressures, because lower pressures are not favorable for the generation of density gradients between plasma particles and background gas. The maximum values of peak number density of Mg and Zr calculated through PBD technique are 4.9×10^{19} cm^{-3} and 29×10^{20} cm^{-3} respectively. The electron number densities of Mg and Zr plasmas evaluated by both techniques revealing the same trends and therefore are supporting to each other.

The part C of this dissertation addresses the fs-LIBS analysis of Mg and Zr plasmas. A Ti: Sapphire laser (800 nm, 35 fs, 0.05-0.8 mJ) beam is employed for the generation of metallic plasmas under vacuum as well as different background pressures of Ar ranging from 5 Torr to 50 Torr. USB4000 spectrometer system is used for the collection of emission spectra. The maximum T_e of 12609 K and n_e of 9.6×10^{17} cm^{-3} for Mg and T_e of 14463 K and n_e of 9.3×10^{18} cm^{-3} for Zr plasma are obtained under the same Ar pressure of 50 Torr. Field emission-SEM analysis reveals that lower values of T_e and n_e are responsible for the formation of LIPSS,

splashed nanocones, nanoglobules, nanocavities and nanorims for the ablation under vacuum. Whereas, micro-inhomogeneities, corrugations of the surface with the appearance of small cavities, cone formation and redeposited particles are observed in the presence of Ar environments. At higher values of T_e and n_e, the nano structures are transformed into micron sized cavities and craters under the vacuum condition and into micro-cones and pillars under Ar pressures.

The comparison of nanosecond and femtosecond LIBS analyses reveals that the values of electron temperature are almost same for nanosecond and femtosecond LIBS, whereas, the electron number densities in the case of fs-LIBS are higher for both Mg and Zr metals. In the case of nsnosecond laser ablation, only microscale structures are revealed, whereas, with femtosecond laser ablation, fine and nanoscale structures are grown on the surfaces of both metals.