Abstract

The dissertation deals with the investigation of magnetic field effect on plasma parameters and surface structuring of two metallic alloys (Cu & Mg) after laser irradiation. The plasma parameters are evaluated by using Laser Induced Breakdown Spectroscopy (LIBS) technique, whereas, micro/nano structuring of metallic alloys is explored by Scanning Electron Microscopy (SEM) analysis. This dissertation consists of following two parts.

In part (A) the effect of magnetic field on ns-LIBS analysis and surface modifications of both metallic alloys has been investigated. Part (A) is further divided into sections. In section I, the effect of laser irradiance on metallic alloys plasma is exposed in the presence and absence of Transverse Magnetic Field (TMF) while keeping the pressure of environmental gases constant i.e. 5 Torr. For this purpose both metallic alloys were exposed to Nd: YAG laser (1064 nm, 10 ns) pulsed energies ranging from 25 mJ to 200 mJ. Cu-alloy is exposed at various ns laser irradiances ranging from 1.9 GW/cm^2 to 5 GW/cm^2, whereas, for Mg alloy irradiances are ranging from 0.3 GW/cm^2 to 2.6 GW/cm^2 under Argon (Ar), Neon (Ne), and Helium (He). Section II of this part deals with the investigation of different pressures of environmental gases with & without magnetic field by keeping irradiance constant. For this purpose time integrated Laser Produced Plasma (LPP) parameters of metallic alloys evaluated under Ar, Ne and He environments at different pressures ranging from 1 Torr to 100 Torr at constant irradiance of 4.4 GW/cm^2 (Cu-alloy) and 2 GW/cm^2 (Mg-alloy) and at constant time delay of 1.25 μs have been explored. The values of excitation temperature (T_{exc}) and electron number density (n_e) of LPP of metallic alloys are higher in the presence of 1.1 Tesla magnetic field as compared to field free case. Both Cu & Mg alloys show similar trends for used range of ns laser irradiances in the presence of Ar, Ne & He. It is also found that trends of both excitation temperature and electron number density are increasing with increasing laser irradiances from 1.9 GW/cm^2 to 4.4 GW/cm^2 for Cu-alloy & from 0.3 GW/cm^2 to 2 GW/cm^2 for Mg-alloy. For the highest used irradiance for both metallic alloys the decrease in both parameters is observed. In the case of pressure variation an increase in both plasma parameters is observed by increasing pressure from 1 Torr to 5 Torr at fixed irradiance of 4.4 GW/cm^2 & 2 GW/cm^2 for Cu-alloy and Mg-alloy respectively. A decrease in LPP parameters by increasing pressure from 5 Torr to 100 Torr for both metallic alloys is observed. The magnetic confinement validity is confirmed by analytically evaluating thermal beta (β_t), directional beta (β_d), confinement radius (R_b) and diffusion time (t_d) for LPP of both Cu and Mg-alloys. Surface modifications of laser ablated Cu & Mg alloys is performed by Scanning Electron Microscope (SEM) analysis. The formation of less distinct surface structures are observed on Cu-alloy in the presence of TMF as compared to field free case. Whereas, for Mg-alloy distinct and well-defined structuring is observed with TMF as compared to absence of field.

In order to investigate the effect of femtosecond laser irradiation effects on plasma parameters and surface modifications, part (B) is performed. In part (B), the effect of magnetic field on fs-LIBS analysis and surface modifications of both metallic alloys has been investigated. Femto second pulses of Ti: Sapphire laser system (800 nm, 35 fs, 1 KHz) are employed as source of irradiation. Part (B) is further divided into sections. Section I, deals with measurements performed at various irradiances ranging from 0.011 PW/cm^2 to 0.117 PW/cm^2 for Cu-alloy and irradiances ranging from 0.0052 PW/cm^2 to 0.0526 PW/cm^2 for Mg alloy under fixed 15 torr pressure of Ar and Ne with & without TMF. This section also deals with exploring the effect of different pressures of Ar ranging from 1 Torr to 35 Torr with & without TMF at fixed irradiance of 0.082 PW/cm^2 & 0.043 PW/cm^2 for Cu-alloy and Mg-alloy respectively. For fs-LIBS analysis the same trends of T_{exc} and n_e are observed as have been observed for ns-LIBS for both metallic alloys for irradiance variation as well as pressure variation. In order to confirm the validity of magnetic confinement for fs- LIBS analysis. The values of β_t, β_d, R_b and t_d are also evaluated. To correlate the LPP parameters of metallic alloys with surface modifications Field Emission Scanning Electron Microscope (FE-SEM) analysis is performed. It reveals the formation of Laser Induced Periodic Surface Structures (LIPSSs). These LIPSSs are of two kinds LSFL (Low-spatial-frequency LIPSSs) and HSFL (High-spatial-frequency LIPSSs) along agglomers and nano rims which are not formed in case of ns-laser ablation. For both metallic alloys distinct and well-defined surface structuring is observed in the presence of the field as compared to absence of field.

The comparison is made between ns-LIBS and fs-LIBS analyses. It is observed that both LPP parameters i.e. T_{exc} and n_e for both metallic alloys are higher for ns-LIBS as compared to fs-LIBS. It is also revealed that ns laser irradiation is responsible for micro scale surface structuring, whereas, in case of fs laser ablation nano scale well defined LIPSSs are formed. When comparison is made between Cu-alloy and Mg-alloy, it is observed that higher excitation temperature is associated with Mg-alloy plasma whereas, electron number density for Cu-alloy plasma is greater for both ns and fs laser. It is also revealed that both excitation temperature and electron number density play a substantial part for the growth of surface structures on both metallic alloys. It is concluded that by applying external magnetic field during laser irradiation, controlled material surface structuring is possible for applications such as formation of gratings and field emitters where spatial uniformity is critically important.