The dynamical processes of laser-induced shock wave plasma generation at various surrounding gas pressures

Marpaung, Mangasi Alion, author

Abstrak

A comprehensive study has been made on the dynamical process-taking place in the laser-plasma generation induced by a TEA CO2 laser bombardment on metal target and non-metal target from low to high pressures surrounding gas. In the case of metal target, pure zinc plate was used as a target and bombarded with 400-mJ-laser pulse energy. Dynamical characterization of plasma expansion and excitation were examined in detail both for target atomic emission (Zn I 481.0 nm) and gas atomic emission (He 1 587.6 nm) by using a unique time-resolved spatial distribution measurement and conventional emission spectroscopic detection method. The results showed that the plasma expands and develops with time. The mechanism of plasma generation can be classified into three cases depending on .the surrounding gas pressures; target shock wave plasma in the pressure range between 2 Ton and 20 Ton, coupling shock wave plasma in the pressure range between 50 Torr and 200 Torr and gas break down shock wave plasma in the pressure range between 200 Ton and I atm. In all cases in the laser-plasma generation under TEA CO2 laser bombardment on metal target, shock wave process always plays important role for exciting the target atoms and gas molecules.
In the case of non-metal target, a museum glass was used as a target and bombarded with a 400 nd laser pulse energy. By using the conventional emission spectroscopic detection method, namely temporally and spatially integrated and time-resolved spatially integrated of plasma emission, it was shown that the plasma mainly consists of target atomic emission. Only weak gas atomic emission intensity could be observed even at I atm of surrounding gas pressure. These results indicate that the gas breakdown is not a major process responsible to the plasma formation even at high pressure surrounding gas. Shock wave process was considered as an important role in this plasma formation. By the use of shadowgraph technique to detect the density jump signal due to the shock wave front involving a He-Ne laser as a probe light, simultaneous detection of the shock wave front and the emission front was successfully implemented. The result showed that at the initial stages of plasma expansion shock wave front and emission front coincide and move together with time. At the later stages of plasma expansion the two fronts became separate with the emission front left behind the shock wave front. These results are completely coinciding with the shock wave plasma model. Unfortunately, in this experiment we succeed to detect the density jump signal only for high pressure surrounding gas, above 100 Torr. At the pressures lower than 100 Torr the density jump signal was very weak and it is difficult to distinguish with the noise including in the signal.
The other important experimental results that support the shock wave plasma model were also obtained in this experiment, namely the coincidence of emission front regardless of their atomic weight and sub-target effect. By using lead glass as a sample, which contain Pb, Si, and Ca, it was confirmed that the emission front of the Pb I 450.8 nm, Si 1288.2 nm and Ca I 422.6 nm almost coincide regardless of their atomic weight. This result also supports the shock wave plasma model because, by the stagnation of the propelling atoms, the front position of the all atoms coincides regardless of its mass. In the case of sub-target effect, confirm that plasma could be produced even for soft target if sub-target is set behind the sample. In this case

we use a quartz sample as a sub-target and a vinyl tape was attached to the quartz sample as a target. The TEA CO2 laser bombardment was used at 150 ml and at 1 atm of air. The main role of the subtarget is to produce a repulsion force for atom gushing with high speed. For shock wave, high speed is necessary condition to compress the gas.

Coincidence of the movement of the shock wave front and the emission front in the initial stages of plasma expansion is a direct proof of the shock wave plasma model. By improving the detection technique of the density jump associated with the shock wave, the correlation between the shock wave front and the emission front was examined in detail. For this purpose rainbow interferometer system, which has higher sensitivity compared with the shadowgraph technique, was used to detect the density jump signal. We succeed to realize simultaneous detection of shock wave front and emission front from 3 Ton until 1 atm of air when a quartz sample is bombarded with a 600 nil TEA C02 laser. In all pressure that were examined, the shock wave front and the emission front always coincide and move together with time in the initial stages and separate at the later stages with emission front left behind the shock wave front. The coincidence of the shock wave front and emission front and move together with time at the initial stages of plasma expansion was also obtained by using ruby as a sample at 10 Torr and 100 Ton of air as well as with museum glass at the same laser pulse energy.

Another important experimental result obtained in this experiment is that confirmation of the coincidence of the target atomic emission front and gas atomic emission front and density jump. This confirmation was obtained by examined a Quartz sample in 50 Ton of helium and a zinc sample in 100 Ton of helium. This result strongly supports the shock wave plasma model because, in ordinary shock tube experiment, gas emission takes place just behind the shock wave.

From a practical point of view of direct microanalysis for spectrochemicaI application of alloy metal samples such as brass, selective vaporization effect was also studied. The results showed that even for Nd-YAG laser with short pulse duration (8 ns) and high power density (30 GWcm 2), selective vaporization take place to a certain extend. It was demonstrated in this experiment that selective vaporization is enhanced if the laser irradiation was repeated on the same spot of sample surface. Meanwhile it was also shown in this experiment that the effect of selective vaporization could be significantly suppressed by increasing the surrounding gas pressure from 2 Toff to around 50 Torr of air.