Confined plasma induced by Nd-yag laser bombardment at low pressures

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Abstrak

The role of shock wave in the generation of laser induced secondary plasma was first suggested by Kagawa et al. from an experimental result employing N2 laser on metal targets at reduced surrounding air pressure. This so-called shock wave induced plasma model has since been reexamined and confirmed in a series of experiments performed by Kurniawan and Kagawa et al. using TEA (Transversely Excited Atmospheric) CO2 laser and XeCI excimer laser. All of these experiments were performed at reduced gas pressures. The most important characteristics revealed by those experiments consist of the typical hemispherical shape of the plasma with a thin emission shell at the plasma front, which moves with a propagation length proportional to t°-4, in excellent agreement with the shock wave characteristics predicted theoretically by Sedov. It was further demonstrated that ionic emission was generally insignificant compared to neutral atom emission. While those results have provided relatively solid and comprehensive supports for the model, additional evidence on the density jump characteristic of shock wave generation and other on some unique aspect concerning interaction of shock wave with an object will still be desirable for further clarification on the role of the model.

A series of experiment have been carried out on the dynamical process taking place in the secondary plasma induced by normal oscillation and Q-switched Nd-YAG (yttrium aluminum garnet) laser on brass, copper and zinc targets at reduced air pressures. Accurate dynamical characterization of the cross-sectional view of the plasma expansion has been made possible by the unique confinement technique using two parallel glass plates. In order to detect the shock front and the emission front simultaneously, a new shadowgraph technique involving a He-Ne laser as a light probe was also developed. Furthermore in an experiment intended for giving support to the shock wave excitation model qualitatively, the plasma was forced to collide with a wedge placed in front of the target in order to examine the reflection and diffraction phenomena. Measurements were also performed on the time-profile of the plasma emission to provide a description of the plasma temperature variation with time. The study was further substantiated by measurement of the time-resolved spatial distributions of emission intensities.

The results showed that the plasma was generated through the shock-wave and the dynamical process of the secondary plasma is divided into two stages, namely, the "shock excitation stage" and the "cooling stage". During the shock excitation stage, the atoms gushing out from the target were adiabatically compressed against the surrounding gas, resulting in a rapid rise of the plasma temperature up to around 9,000 K. For the case of 2 Ton gas pressure, with the laser pulse of 86 m7 targeted on copper sample, the shock excitation stage lasted for about 1 μs, which was followed immediately by the cooling stage and the plasma temperature decreases gradually to around 7,500 K in about 3 .is. The excitation stage and the cooling stage periods became longer with increasing laser pulse energy.

The multiple excitation processes associated with the secondary plasma emission, and generated by successive multiple shock wave, was clearly observed when the normal oscillation laser was focused onto the surface of the target. The emission characteristics of this secondary plasma showed an extremely low ion and background emissions. This condition is suitable for highly sensitive spectrochemical analysis, as the temperature of the plasma is still high enough (around 7,000 K) for the excitation of neutral atoms. Another favorable conditions is the large amount of material ejected in the process (amounting to 10 μg), which permits an average analysis.

For a practical consideration, the condition to increase sensitivity by suppressing the background was also studied. The result showed that the sensitivity of laser induced shock wave plasma spectroscopy could be increased by reducing laser pulse energy, in which the less expensive time-integrated detection method can be applied. On the other hand, when the sample requires a high power laser beam, the sensitivity could also be enhanced with the aid of a time-gated DMA (Optical Multi channel Analyzer) system by cutting-off the ionic emission coming from the shock excitation stage.