P1-3 The Effect of Selective Vaporization on Laser Induced Shock Wave Plasma

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Introduction

We have shown in our previous experiments that a laser-induced shock-wave plasma is generated when a high pulsed laser such as, TEA CO_2 laser or Nd-YAG laser, is focused onto a solid target at a reduced gas pressure around 1 Torr. We have found that the secondary plasma have some characteristics favorable to spectrochemical analysis because it emits sharp atomic spectral lines with low background. We have referred this analytical method as Laser Induced Shock Wave Plasma Spectroscopy (LISPS)[1].

One of the key factors affecting the quality and characteristics of the secondary plasma as well as the emission intensities is the vaporization process of atoms from the target. Therefore, as an initial effort to extend the application of LISPS technique to mixed targets, it is important to examine the vaporization process from a target of simple alloy such as brass, because selective vaporization was already observed by Baldwin and Russo[2] in laser atomization on brass. We have already reported that when a 500 mJ TEA CO_2 laser with 100 ns pulse width was focused onto brass sample, the characteristic (secondary plasma) bright green color associated with the copper atoms was only seen for several initial laser shots repeated on a fixed position of the sample. While the green color disappeared completely thereafter, the blue color associated with zinc remained very bright throughout the repeated irradiation and over the entire hemispherical region occupied by plasma. This was an unexpected new phenomenon unknown in the case of an ordinary laser plasma produced at the atmospheric pressure. A selective vaporization effect was suspected to the responsible for this phenomenon.

The present study is under taken to clarify how this selective vaporization takes place in our LISPS and how it influences spectrochemical analysis. For this purpose, various factors affecting the process are examined by employing a TEA CO_2 laser and Nd-YAG laser on different target materials. The results of the analysis will be discussed in connection with the physical mechanism of LISPS, specifically with the assumption of shock wave model and expected to provide useful clues for overcoming or at least minimizing the selective vaporization effect.

Experimental Procedure

The experimental arrangement is shown in Fig. 1. The TEA CO_2 laser (130 mJ, 100 ns, 10.6 μm) and the Nd-YAG laser (50 mJ, 8 ns, 1.064 μm) was focused by a focusing lens (f=100 mm) through a window onto the surface of the sample. The sample were placed in vacuum-tight metal chamber which could be evacuated with a vacuum pump. Two optical quartz windows were positioned around the laser plasma for visual and spectral observation.

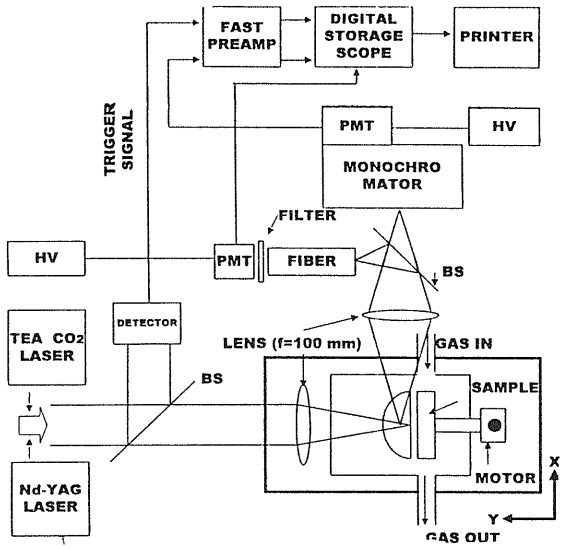

Figure 1. Experimental setup

For single channel measurement the plasma iradiation was observed by imaging (1:1) quartz lens (f =100 mm) with an aperture of 7 mm x 7 mm onto the entrance slit of a monochromator (Spex, model M-750, Czerny Turner configuration, f = 750 mm, 1200 groves/mm). For dual channel measurements, the image of the plasma was split by means of a quartz beam splitter, and the second image light was collected using a quartz optical fiber and fed directly to another photomultiplier after passing through a blue filter which was used to pick up the blue emission lines associated with Zn atoms. In order to get the time profiles of the spatially integrated emission intensities of Cu atoms and Zn atoms, the plasma radiation was collected by quartz optical fiber and transmitted to a gated-intensified optical multi channel analyzer (OMA), (Princenton Instruments, IRY 700).

Emission spectra of the brass sample were detected and recorded under time-integrated mode of OMA.

Results and Discussion

Fig.2 shows how temporally and spatially integrated emission intensities of Zn and Cu vary with the number of repeated laser irradiation on the standard brass sample (NBS C 1118, 75 % Cu, 25 % Zn) at a fixed position. In case of TEA CO_2 laser, the emission intensity of Cu I 515.3 nm spectral line could be detected only during the first and second shot with much lower intensity, despite the fact that the concentration of Cu was actually higher than that of Zn in the target.

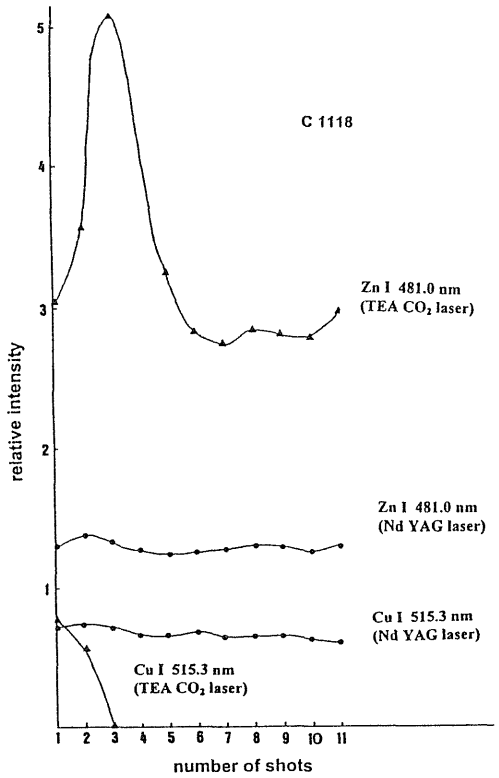

Fig. 2. Relationship between total emission intensity (time and spatially integrated) of Zn I 481.0 nm and Cu I 515.3 nm as a function of the number of shots of laser irradiation for TEA CO2 laser and Nd-YAG laser

A different result was obtain when Nd-YAG laser was used, as shown by the corresponding curves in Fig.2. Emission intensities of both Zn and Cu spectral lines remained nearly constant under the repeated irradiation at the same position. The power density for Nd-YAG laser employed was 5 times stronger (20 GW/ cm^2) than the case of TEA CO_2 laser due to the much higher beam quality of the Nd-YAG laser

It is suppose that atoms of elements with lower boiling point are evaporated sooner and gushed out from the target surface with high velocities to form a shock wave in the surrounding gas. Namely only the Zn atoms contributed to the formation of shock wave front, whereas the Cu atoms were left behind the shock wave and remained unexcited. The selective vaporization appeared to be less pronounced at the laser power density considerably higher than threshold of plasma generation. This is the case for Nd-YAG laser in Fig. 2.

In order to see more clearly the evaporation process, a comparison of time profiles for Zn I 481.0 nm and Cu I 327.4 nm emission intensities was conducted using a dual channel measurement of the emission at 5 mm from the surface. The result is shown in Fig. 3. It is perceptibly clear that the emission of Cu took place later and continued for long time. The Zn emission, on the other hand, started earlier and lasted only a short time.

It is also experimentally proved that selective vaporization in favour of Zn atoms takes place even for Nd-YAG laser irradiation to a certain extent. The effect of surrounding air pressure and repeated irradiation on the selective vaporization for Nd-YAG laser was studied in detail using OMA system, the result will be also reported.

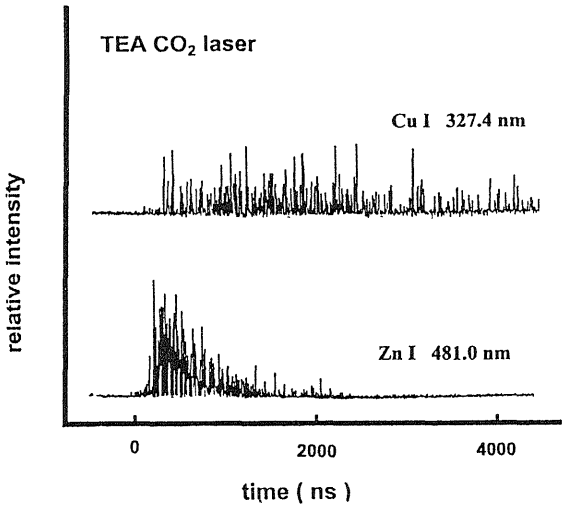

Fig. 3. Time-profile of the emission intensity of Cu I 327.4 nm and Zn I 481.0 nm using TEA CO2 laser. Data was collected at 5 mm above the sample surface at a reduced pressure of 1 Torr.

References

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