§13. Determination of Plasma Temperature and Density in Laser Produced Tin Plasmas

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High-density and high-temperature plasmas have attracted a great deal of interest for potential applications to high brilliance x-ray sources, which are expected to provide the useful tools in the fields of biology, medicine, and solid-state and atomic physics. Especially, in order to realize the next generation semiconductors with a node < 45 nm, the development of extreme ultra-violet (EUV) light source suitable for the lithography has been considered to be one of the urgent issues. For the purpose of this, xenon and tin plasmas produced by a high-intensity laser and z-pinch have been used so far. However, since the properties of these plasmas drastically change during plasma expansion as well as energy deposition into plasmas, the studies of elementally processes, which are strongly dependent upon the plasma parameters such as electron density and temperature, are not feasible. Therefore, we investigate the stationary high-density Sn and Xe plasma from the view point of the atomic physics. Indeed, the TPD (Test plasma by Direct current) device that can readily generate high-density ($\sim 10^{14}$cm^{-3}) and low-temperature (<10 eV) plasmas was extensively studied for the application to a VUV laser by Sato *et al* [1] and Otsuka *et al.*[2].

In this report, we show the results of preliminary researches concerning the derivation methods of plasma density from the Stark broadening spectrum in a laser produced Sn plasma, instead of TPD-plasma, to study the validity of this method.

The experiments were carried out by using a YAG laser (wavelength:355 nm, pulse width: ~5ns, energy: ~100mJ). The plasma emissions were measured by a visible spectrometer whose detector was a charged-coupled device (CCD) camera with a gated image intensifier (gate width: 20 ns). The target was high-purity tin disk (20mmϕ, t=5mm).

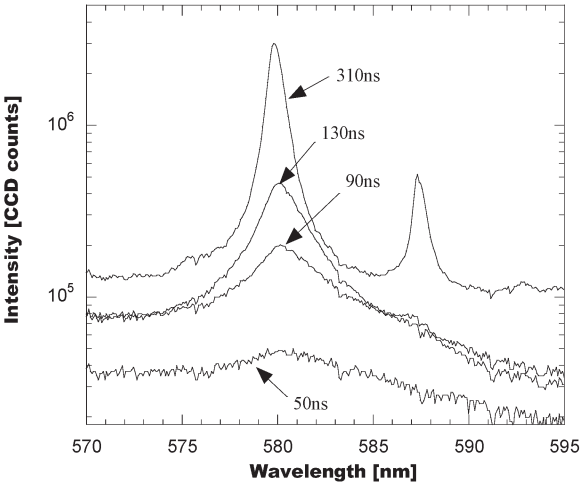

Fig. 1. Time evolution of Sn II579nm spectrum.

Figure 1 shows the temporal evolution of Sn II 579nm. In the early stage, the broadened spectrum due to Stark effect was observed, and gradually its width became narrower. Considering that instrumental width was 0.36nm, the broadening indicates the production of high-density plasmas in the initial stage. From the width of this transition, the electron densities can be deduced, and its relationship (FWHM of the spectral profile) is expressed by [3],

$$w_{eG} = 8\left(\frac{\pi}{3}\right)^{3/2}\frac{\hbar}{ma_0}n_e\left(\frac{E_H}{kT}\right)^{1/2}\left[\left\langle i\left|\vec{r}^{\,2}\right|i\right\rangle\overline{g}_{se}+\left\langle f\left|\vec{r}^{\,2}\right|f\right\rangle\overline{g}_{se}\right], \quad (1)$$

where a_0 is the Bohr radius, E_H is the ionization potential of hydrogen atom, i and f are the levels corresponding to the transition, $\overline{g}_{se}$ the Gaunt factor and the others are the usual meanings. In order to determine the Stark width w_{sG} accurately, the observed spectra were deconvoluted by Lorentzian profile. The electron temperature that is involved in this equation was estimated from the Boltzmann relationship in terms of the population densities between the excited levels. By substituting the parameters into Eq. (1), we successfully obtained the plasma density and temperature as a function of time after the laser irradiation (see Fig. 2).

In the next fiscal year, we will measure the plasma densities of Xe and Sn plasma produced by TPD-II, and also investigate the possibility as an EUV light source as well as the atomic structure of these elements.

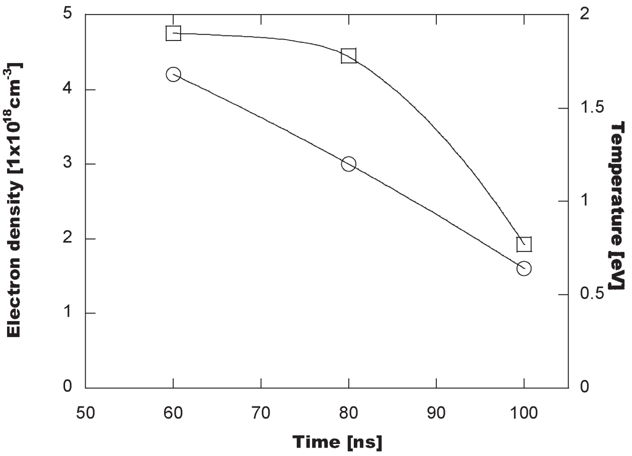

Fig. 2, Electron density and temperature as a function of time after the laser pulse.

References

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[3] Griem, H.R., Phys. Rev. **165**, 258 (1968).