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§6. Spectroscopy and Atomic Modeling of EUV Light from LHD Plasmas

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i) Introduction

Radiations from high-Z elements are of great importance to understand energy balance in fusion plasmas. Such radiations also attract attention as a highly bright light source including 13.5 nm extreme ultraviolet (EUV) for use in next-generation lithography of semi-conductor devices. A lot of issues associated with atomic modeling must be addressed to realize a clean and efficient EUV source. Magnetically confined plasmas such as LHD are one of the best standard plasma sources because plasma profiles are uniform, and temperature and density profiles are well diagnosed.

This year, temporal evolution of EUV spectra from Sn plasma confined in the LHD were observed. Spectroscopic analyses are now underway by using Flexible Atomic Code (FAC) [1] and a simple atomic model.

ii) Spectroscopic observation

Sn coated graphite pellets were injected into the LHD using a pressurized gas gun. The size of pellets was typically 0.9 mm in diameter and 0.9 mm in length. By adjusting the Sn overcoat thickness to an adequate range, discharges could be maintained without radiation collapse. Typical spectra are shown in Fig. 1. The time of pellet injection was 1.02 sec. After then, due to ionization and diffusion of Sn ions throughout LHD plasma, emission intensity drops rapidly. Around 1.07 to 1.14 sec, steady emission was observed. EUV spectra during this stage will be useful as benchmark data for atomic modeling. Plasma temperature and density at this stage are respectively 1-2 keV and 3x10^{13} cm^{-3}. In the wavelength region around 13-14 nm, intense emission arising from $Sn^{8+\sim12+}$ 4d-4f transition is obvious.

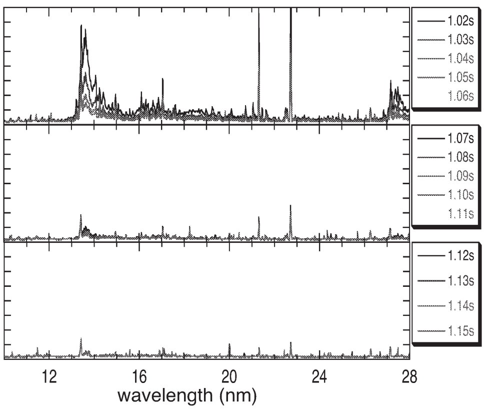

Fig. 1 Time resolved Sn spectra from LHD plasma

iii) Analysis with the atomic code FAC

Disagreement of emission lines of Sn ions between experimental results and theoretical results ware reported. Line correction of 4d-4f, 4p-4d, 4d-5p and 4d-5f transitions wa s performed by comparing with the results of Charge Exchange Spectroscopy (CXS) of Tanuma *et al*, in the present study. Energies and *A* coefficients of $Sn^{8+\sim13+}$ were calculated using FAC. Figure 2 shows the results of line correction. For comparing with Sn spectra from LHD plasma, theoretical Sn spectra were obtained from the results of *A* coefficients with line correction in Fig. 3.

Next step, collisional-radiative atomic kinetics model will be performed to analyze the time resolved Sn spectra from LHD plasma.

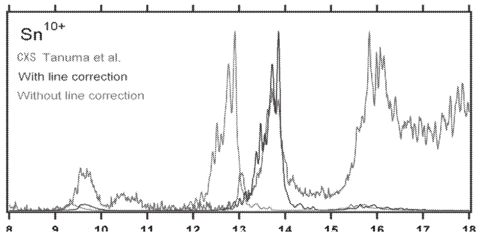

Fig. 2 Emission of Sn^{10+} from CXS and FAC

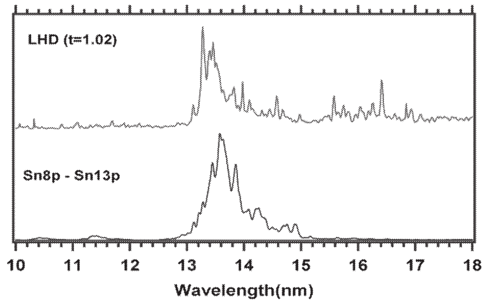

Fig. 3 Sn spectra from LHD plasma and simple atomic model.

iv) Report

- S. Morita, et al., J. of Plasma Science and Technology, Vol.8, No.1 pp.55-60 (2006).

vi) Collaborators

The author would like to express his sincere appreciation to all contributors for their invaluable collaborations by listing their names below: Morita, S., Goto, M., and Katai, R., Suzuki C. (NIFS), Nozato, H. (AIST), Amano, T. (Prof. Emeritus of NIFS), Nishihara, K., Noritmats, T., Fujioka, S., Nagai, K., and Kai T. (ILE, Osaka U.).

[1] M. F. Gu, Astrophys. J. vol.582, pp.1241 (2003).