§10. Luminescence from Reactor Relevant Material Surfaces induced by Slow Highly Charged Ions

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When a solid surface is irradiated with a single highly charged ion (HCI), various effects characteristic of HCI-surface interaction will take place such that hundreds of electrons are emitted from the nanometer-sized area around the impact site, secondary particles (ions and neutral species) and photons are also emitted, and the atomic structure of nanometer-sized area over the surface in the depth range of few atomic layers is modified. Much attention has been paid to Er_2O_3 thin film fabricated by Metal Organic Chemical Vapor Deposition (MOCVD) for the coating material of a thermonuclear reactor blanket. It is known that the luminescence of Er_2O_3 provides information on its crystallinity. We have observed spectral distributions of luminescence of Er_2O_3 thin film during the irradiation with highly charged ions (HCIs) produced by an electron beam ion source (EBIS).

We used Kobe EBIS installed at the Kobe University for the production of HCIs. The Kobe EBIS is designed for the application of ion beam processing of materials so that it is constructed and operated easily without demanding expertise of EBIS using a separate, commercially available super-conducting magnet. Maximum designed values of electron beam energy and electron current are 40 keV and 300 mA, respectively. For the present experiment, the acceleration potential of HCIs extracted from the Kobe EBIS is 3kV, and beam current is in the range of 100 pA. Spectral distribution of light emission from the sample irradiated with HCI (Ar^{q+}, q = 6 ~11) was measured using a polychromator with the effective wavelength range of 420 ~ 670 nm.

Secondary ions released from the surface irradiated with HCIs were also observed in the present experiment. A quadrupole mass analyzer (QMS) modified for the detection of emitted ions by replacing the ion source with an electrostatic lens system, so that the QMS will detect only ions emitted from the sample surface.

In the present experiment, Si and graphite (HOPG) were used as samples as well as Er_2O_3. The preceding results on the charge state dependence of emission intensity in the 650 – 670 nm region using a bandpass filter showed strong charge state dependence ($I \sim q^4$), however, the spectral measurements with a grating spectrometer have shown that the Balmer light from excited atomic hydrogen released from the surface under potential sputtering process of HCI is the main contribution to the light intensity. On the other hand, the intensity of band spectrum characteristic to bulk transitions in Er_2O_3 crystal has a weak charge state dependence.

Then we observed spectral distribution of light emission from other samples during irradiation with HCIs. Fig.1 shows an emission spectrum from Si irradiated with Ne^{6+} HCIs. Emission lines of Balmer series are significant, and the resonance line of Na (D line) is also remarkable. The origin of Na is contamination. These lines always exist in the spectra of Er_2O_3 samples. The origin of Balmer lines come from desorbed hydrogen atom in excited state which created from hydrogen or water molecules adsorbed on the surface by potential sputtering process of HCIs. On the spectrum from HOPG, the D line was not observed. Fig. 2 shows a secondary ion mass spectrum obtained from the Si surface irradiated with Ar^{11+} HCIs. Besides proton and Si ions, Na ions are detected. The signal of hydrogen molecule is also recognized, however, the intensity is much less than that of proton signal. Considerable signal of Na urges us to clean the sample surface thoroughly.

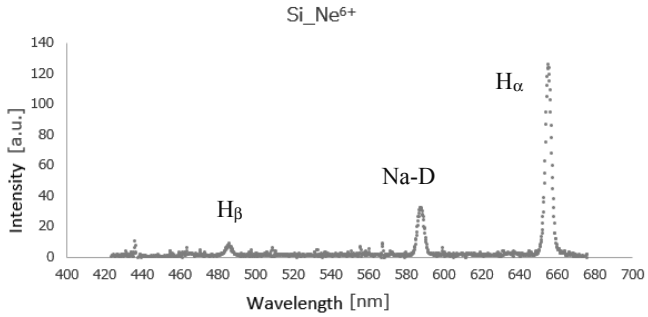

Fig. 1. Emitted light spectrum in the visible region during irradiation of Si surface with Ar highly charged ions.

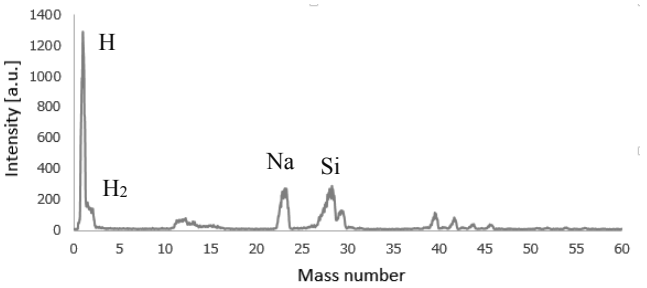

Fig. 2. Secondary ion mass spectrum obtained from the Si surface irradiated with Ar highly charged ions.