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§14. Plasma Atomic Processes Explored by Optical Emission Spectroscopy of Excited Atoms Sputtered from the Metal Surface by Ion Bombardment

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Sputtering and backscattering processes of polycrystalline tungsten surfaces by ion impact have been studied by an optical emission spectroscopy. Since neutral atoms sputtered from the wall surface penetrate into the plasma across the magnetic fields and they play a role of cooling processes of the plasma, the clarification of these mechanisms is demanded from the point of the control of the fusion plasma. We have already reported as follows.[1),2)]

(1) The mean velocities of excited tungsten(W) atoms in direction normal to the surface under the irradiation of krypton ion (Kr^{+}) as a function of the perpendicular distance from the surface were almost independent on the incident beam energy.

(2) They depended on the energy difference between the work function and the ionization potential of the excited state.

In this work, we report about the mean velocities under the irradiation of Ar^{+} ion.

The experiments were carried out in the National Institute for Fusion Science (NIFS). The experimental procedure was same as the Kr^{+} cases. Briefly, we measured the intensity of light emission from sputtered atoms on W surfaces under the irradiations Ar^{+}, as a function of the perpendicular distance from the surface. Using the analysis of decay curve, we estimated the mean vertical velocity component in direction normal to the surface. The intensity decay follows the well-known relation,

$$I = \sum_k I_{0k} \exp\left(-\frac{z}{< v_{\perp} > \tau_k} \right) \quad . \qquad (1)$$

Where I_{0k} is the intensity from a particular transition k at the surface (z=0), $v_{\perp}$ is the vertical velocity component normal to the surface, τ_k is the lifetime of the excited state.

Figure 1 shows a typical optical emission spectrum obtained at z=0, in the wavelength of 380-440 nm. Even if projectiles were different from Kr+ cases, the intensity ratio of each peak in a spectrum was the same in essence. The excited W lines are classified into four types of transitions that consist of a combination of two upper and two lower states: $5d^56p \rightarrow 5d^56s$ (A, D, H, I), $5d^56p \rightarrow 5d^46s^2$ (K), $5d^46s6p \rightarrow 5d^56s$ (B, E, F), and $5d^46s6p \rightarrow 5d^46s^2$ (C, G, J). In addition, the backscattered Ar^{+} ions appear in the spectrum as broad peaks. It means that the backscattered Ar^{+} ions have large parallel velocity component.

Although we also carried out the experiment with the incidence energy to 15 to 60keV, we were not able to find out a large difference in each spectrum except for the absolute intensity.

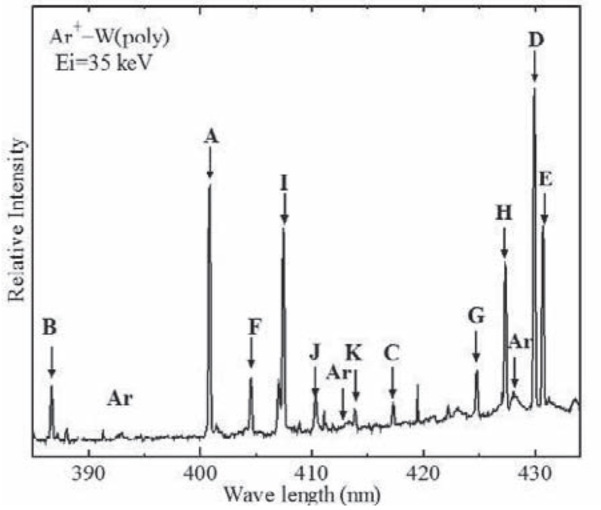
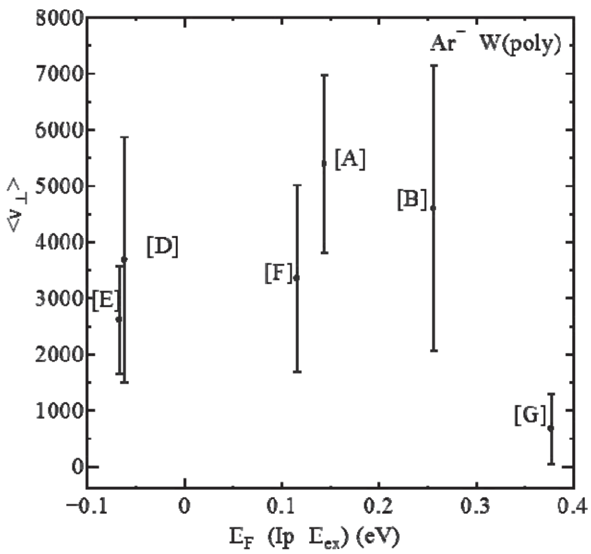


Fig. 1. A typical survey optical emission spectrum obtained at z=0 mm, under the irradiation of Ar^{+}.

Fig. 2. The mean vertical velocity of various excited



states of W as a function of the energy gap between the work-function E_f and I_p minus excitation energy E_{es}.

The estimated mean vertical velocities are almost same as the Kr^{+} cases. Therefore, we were able to confirm that the relationship of the energy gap between the work-function E_f and I_p minus excitation energy E_{es} is the same as the Kr^{+} case, as shown in Fig.2. The level-energy-dependent velocity suggests any inelastic processes play an important role in the excitation of sputtered atoms. The resonant electron transfer is considered to be one of the candidates of such inelastic collision processes.

1) K. Motohashi et.al.: Nucl. Instrum. Meth.B, **283**,(2012) 59.
2) Y.Sakai et al.: Research Report NIFS-PROC-**91**, 1,(2013).