§18. Kinetic and Potential Energy of Excited Atoms and Molecules on Wall Surfaces Bombarded with Light Ions

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Tungsten is considered to be the most suitable candidate as plasma-facing materials for ITER. However, radiation cooling by tungsten ions in the plasma core is an issue. It has been pointed out that tungsten atoms sputtered on the wall surface penetrate into the plasma core across the magnetic fields and that the penetration depth into the plasma depends on the velocity. Therefore, it is important to determine the velocity of sputtered neutral atoms. We measured the mean velocity of excited tungsten atoms by observing ion-beam induced light emission (IBLE).

The experiment was carried out at the National Institute for Fusion Science (NIFS). A Kr^+ ion beam was introduced into the collision chamber after analyzing the mass to charge ratio (m/e) by using a sector magnet. A polycrystalline tungsten surface set on a movable stage was installed in the collision chamber. The ion beam entered perpendicular onto the tungsten surface. The stage could be moved in a direction parallel to the ion beam axis. After passing through a quartz window and a condenser lens, the light from the sputtered atoms was focused onto the entrance slit of a monochromator equipped with a charge coupled device (CCD). The optical axis crossed the ion beam axis at a right angle. We measured the light intensity as a function of the distance z from the surface by moving the stage linearly. The pressure of the chamber was maintained below 7×10^{-5} Pa during the measurements. A high current density (=150 $\mu A/cm^2$) of the ion beam maintained the equilibrium surface-oxygen coverage less than 0.04 [1].

Fig. 1 shows a two-dimensional (2D) image taken by the CCD. The most intense single peak at 400.88 nm was assigned to WI $5d^5(^6S)6p(^7P_4) \rightarrow 5d^5(^6S)6s(^7S_3)$. This line has been used to the standard for quantification of sputtered tungsten atoms in the actual fusion devices [2]. Fig. 2 shows the photon intensity of the WI 400.88-nm line as a function of the distance z from the surface for the case of 45-keV projectile energy. The data was well fitted by a double exponential function with two characteristic distances of z_C = 0.32 and 1.6 mm. The observed photon intensity $I(z)$ is written by the following equation: The observed photon intensity $I(z)$ is approximately written by the following equation [1]:

$$I(z) \cong \sum_k I_{0k} \exp\left(-\frac{z}{\langle v_z \rangle \tau_k}\right), \qquad (1)$$

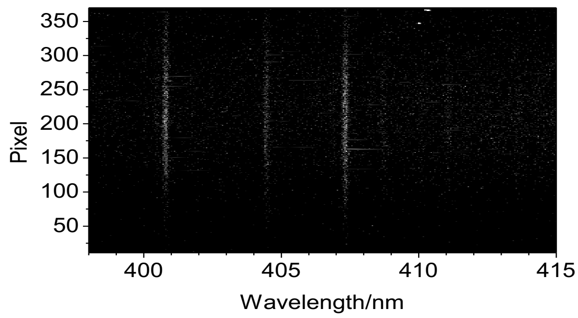

Fig. 1 A typical IBLE spectrum of a polycrystalline tungsten surface bombarded by Kr^+ ion beam.

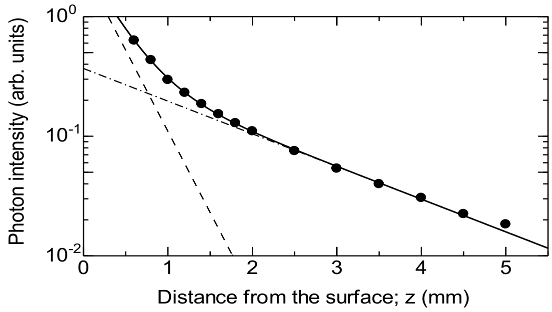

Fig. 2 A z-dependence of the photon intensity of WI (400.8 nm) line.

where I_{0k} is the intensity of k_{th} transitions with lifetime τ_k from the upper state at z = 0. The characteristic distance z_C equals the product of the mean velocity component normal to the surface $\langle v_z \rangle$ and the lifetime of the excited state of $W^*(6p\ ^7P_4)$ atoms τ. Then, $\langle v_z \rangle$ = 5.4 km/s was obtained by substituting τ = 59.4 ns [3] for the steeper decay curve with z_C = 0.32 mm. Fig. 3 shows $\langle v_z \rangle$ as a function of the projectile energy. No remarkable change was found. The average of all $\langle v_z \rangle$ values was 5.6 ± 1.7 km/s [1].

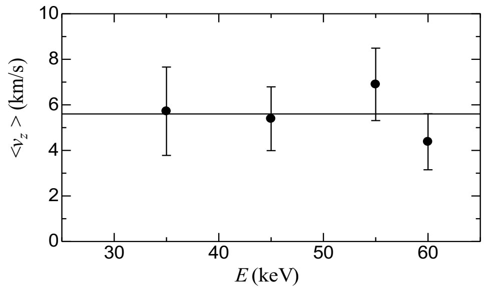

Fig. 3 The $\langle v_z \rangle$ value of W^* ($6p\ ^7P_4$) atoms as afunction of projectile energy.

1) Motohashi, K., et al., Nucl. Instrum. Meth. Phys. Res. B (to be published).
2) Brezinsek, S.et al., Phys. Scr. **T145** (2011) 014016.
3) Kramida, and A.E., Shirai, T., J. Phys. Chem. Ref. Data **35** (2006) 423.