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Optical emission spectroscopy of sputtering atoms on tungsten surfaces under ion irradiation

イオン照射タングステン表面上でのスパッタリング粒子の発光分光

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Visible spectroscopy of the sputtering atoms on tungsten surfaces bombarded by Kr^+ ions (30−60 keV) was performed. Many W lines were observed in the wavelength range of 300–600nm. The emission intensity of 400.9nm line (WI: $6p\ ^7P_4 \rightarrow 6s\ ^7S_3$) was measured as a function of the distance from the surface. The mean velocity of the $W^*(6p\ ^7P_4)$ atoms was obtained by analyzing the exponentially decaying curves. As a result, the mean velocity in direction normal to the surface was found to be 5.6±1.7 km/s. There was no remarkable change of the velocity among different projectile energies.

1. Introduction

Tungsten has been considered to be a good candidate of wall materials of fusion reactors because of the highest melting point, low sputtering yield, and low hydrogen absorption rate. However, high emission probability of radiation from the excited atoms emitted from the wall surface due to interaction with various energetic particles is one of the weak points because it makes plasma temperature low. Thus, it is very important to know the kinematics of the excited atoms produced in the sputtering processes. Optical measurement is one of the most powerful methods of high-temperature plasma diagnosis. We measured the mean velocity of excited tungsten atoms in direction normal to surface by observing ion induced light emission.

2. Experimental apparatus and procedures

The experiment was carried out at a beam line of medium current ion implanter (ULVAC IM-200MH-FB) in National Institute for Fusion Science (NIFS). A schematic illustration of the experimental apparatus is shown in Fig. 1. Kr^+ ion beam extracted from a Freeman ion source was introduced into the collision chamber after analyzing the mass to charge ratio (*m*/*e*) by a magnet. A polycrystalline tungsten surface set on a movable stage was installed in the collision chamber. An electrode with a hole of 5 mm diameter applied −100V to the surface was also installed at 30mm forward the target to retard secondary electrons. The ion beam (~30μA) entered normally onto the tungsten surface. The stage can be moved in direction parallel to the ion beam axis within the range of 50mm.

After passing through a quartz window and the ultra violet (UV) condenser lens, the light from the excited atoms was focused onto the entrance slit of a monochromator equipped with a charge coupled device (CCD). The optical axis crosses with the ion beam axis at right angle, since it was set in direction parallel to the surface. We measured the light intensity as a function of the distance from the surface by moving the stage linearly.

The pressure of the chamber maintained below 7×10^{-5} Pa by a turbo molecular pump during the

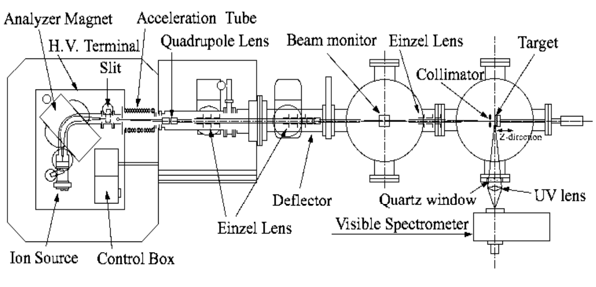

Fig.1. Schematic illustration of the experimental apparatus

measurements, though it reached $<1\times10^{-5}$ Pa when ion beam does not enter onto the tungsten surface.

3. Results and discussion

Figure 2 shows a typical high resolution wavelength scanning of emitted light under Kr^{+} (33keV) irradiation. We observed a number of W lines due to sputtering and several Kr ones due to back scattering. The most intense single peak of 400.9nm labeled with "A" in Fig. 2 is assigned to WI $5d^5(^6S)6p(^7P_4) \rightarrow 5d^5(^6S)6s(^7S_3)$. There are many lines of similar transitions corresponding to 6p→6s with different total angular momentum. We measured the ion-beam current dependence of the photon emission of the line "A". Clear linear dependence observed in the measurement confirms that no secondary process affects the photon emission.

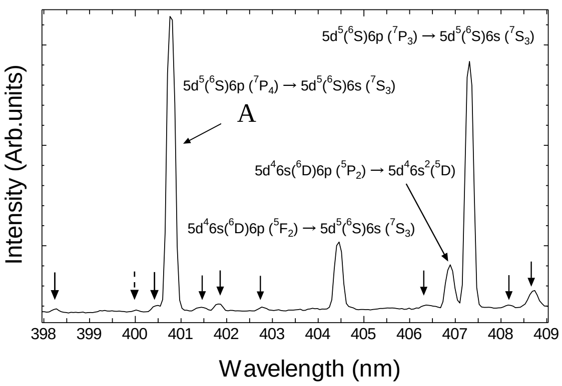

Fig.2. A typical result of high resolution wavelength scanning of emitted light under Kr^{+} (33keV) irradiation. The solid and broken arrows indicate W and Kr lines, respectively. The most intense single line of WI (400.9nm) is labeled with "A".

Figure 3 shows the photon-emission intensity of the 400.9nm line in 45keV projectile energy as a function of the distance from the surface *z*. The curve was well fitted with two exponential functions with a characteristic distance z_C. The observed photon intensity $I(z)$ is approximately written as $I(z) \approx I_0\exp(-z/z_C)$, where I_0 is photon intensity at z = 0 (surface) [1]. The distance z_C equals to the product of the mean velocity component normal to the surface $\langle v_z\rangle$ and the life time of the excited state of $W^{*}(6p\ ^7P_4)$ atoms τ. Thus, the $\langle v_z\rangle$ value can be obtained by the fitting procedure when we assume τ = 59.4ns [2] for the steeper decaying curve with z_C = 0.32mm.

Figure 4 shows the $\langle v_z\rangle$ as a function of projectile energy. No remarkable change is found as expected simply from Thompson-Sigmund velocity distribution [3], though there may be a slight increase around 55 keV. The average of all $\langle v_z\rangle$ values becomes 5.6±1.7 km/s. This velocity corresponds to the kinetic energy of ~30eV which was given to the sputtered W atoms in direction normal to the surface. This value is very close to one obtained by the analysis of a Doppler brodening of Al line ($4s\ ^2S_{1/2} \rightarrow 3p\ ^2P_{3/2}$: 396.2nm) in 45keV Ar^{q+} (q=1-9) irradiation on Al and Al_2O_3 surfaces [4].

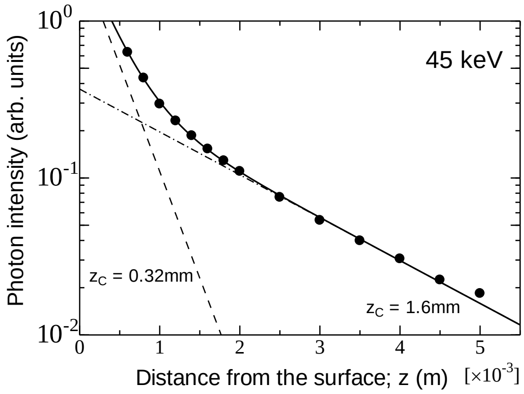

Fig.3. Photon-emission intensity of the 400.9nm line (labeled with "A" in Fig. 2) as a function of the distance from the tungsten surface.

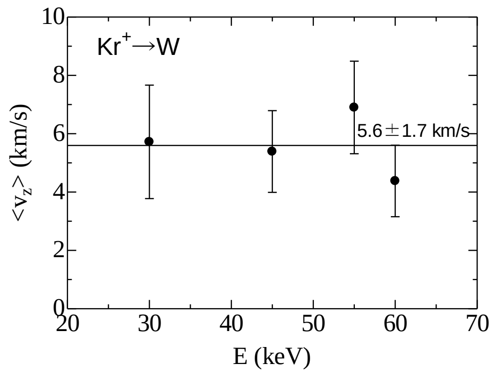

Fig.4. $\langle v_z\rangle$ of $W^{*}(6p\ ^7P_4)$ atoms as a function of the projectile energy

Acknowledgments

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