§11. Polarization of Photons Emitted from Excited Hydrogen Atoms in Plasma Surface Interaction

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High-energy (super-thermal) neutral hydrogen atoms are produced by backscattering at metal surfaces. Generally, particle and energy reflection coefficients are larger for metals of larger atomic numbers. Twin-limiter (Carbon and Tungsten) experiments at TEXTOR clearly showed larger penetration of neutral hydrogen in front of the tungsten limiter. From this experiment, it was inferred that the neutrals reflected at the tungsten surface possessed higher translation velocities into plasmas. Spectroscopic studies identified Doppler shifted Balmer line emission from high-energy reflected neutrals in plasmas. The line intensity and shape were analyzed taking account of collisions with plasma particles. In the analysis, it has been presumed that the reflected neutrals were initially in the ground state. This naive assumption has been widely adopted, since excited state population in the reflected neutrals was unknown.

The excited states would play characteristic roles in edge plasmas. Photon emission near the surface would be increased by presence of the excited states. Meta-stable excited states with the principal quantum number n have larger ionization and charge exchange cross sections; the ionization cross sections increase approximately as n^2 (electron-impact) and n^4 (proton-impact), and the charge exchange cross sections n^{4-5}. Accordingly, the ionization event per photon should be different from that obtained by assuming no initial population of the excited states.

In this work, polarization of photons emitted from excited hydrogen atoms formed above Mo surfaces was investigated theoretically. Present results show significant linear polarization of the emitted photons depending on translation velocities of reflected particles. Thus, measurement of the polarization may serve as a novel method to detect excited states in reflected neutrals from the plasma facing walls of nuclear fusion devices. In the present work, it is assumed that the excited states are formed via single electron capture from conduction bands of metals by receding hydrogen nucleus. A theoretical method to calculate electron capture probabilities has recently been developed by authors[1-2]. The present method adopts jelium models to represent electrostatic interaction of conduction electron gas and hydrogen atoms. Population of the excited states (see Fig. 1) and polarization of the emitted photons are evaluated by means of density matrix theories.

The present method has been validated by reproducing Doppler-shifts of Balmer-alpha line emission by neutrals in reflected deuteron-beams from Mo targets[3]. In geometries that photons are detected at 90 degree to the surface normal, differences in 3d→2p line intensities polarized parallel to the surface normal $W_{//}$ and perpendicular to the surface normal $W_{\perp}$ are calculated for incident deuteron-beam energies of 5-25 keV. In this case, significantly negative linear polarization degrees are obtained,

$$P = \frac{W_{//} - W_{\perp}}{W_{//} + W_{\perp}} < 0 .$$

The negative polarization degrees tend to be more significant (reaching about -0.2) at higher incident energies. More detail analysis on correlation of the polarization degrees and energy and angular distributions of the reflected particles are ongoing.

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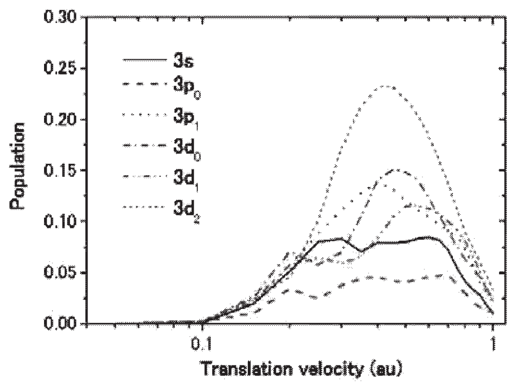

Fig. 1: Population of D($3lm$) states created via single electron capture from Mo surfaces. D atoms translating outward from Mo surface with angle of 60 degree to the surface normal. 1 au velocity = 2.2×10^6 m/s.

1) D. Kato et al.: J. Nucl. Mater. 390-391 (2009) 498-501.
2) D. Kato et al.: J. Plasma Fusion Research 7 (2006) 183.
3) Tanabe, T., Ohya, K., Otsuki, N.:J. Nucl. Mater. 220-222 (1995) 841.