Ground state population of sputtered tungsten atoms by peak emission analysis in PSI-2 argon plasmas

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Tungsten (W) is one of the most promising materials for plasma-facing components (PFCs) in future fusion reactor [1]. The lifetime of W divertor PFCs will finally be determined by the erosion. The initial level population of sputtered W atoms from PFCs is of big interested for interpretation of spectroscopic data used for the estimation of gross erosion rates. Monoenergetic ion beam experiments with different metals (e.g. Fe) suggest a ground level population of released atoms of over 95 % [2] - Sputtering experiments in the tokamak TEXTOR with W PFCs exposed to a hot edge plasma ($T_e > 30\,\mathrm{eV}$) lead to the assumption of a local thermal equilibrium in the fivefold ground term ^{5}D and the $^7D_3$ level with an effective temperature T_W of 0.1 to 0.3 eV of physically sputtered W atoms by energetic Carbon ions at surface temperatures (T_{surf}) of more than 720 K [3].

To investigate the level population in more detail, we exposed a W sample ($1.3\times1.3\,\mathrm{cm}^2$; $T_{surf} = 300\,\mathrm{K}$) to an argon plasma in the linear plasma device PSI-2 ($T_e \approx 2\,\mathrm{eV}$). We measured with an imaging spectrometer the line emission of several neutral tungsten (W I) transitions with a high spatial resolution of $50\,\mu$m over the first few mm penetration depth in front of the target. The axial distance of the peak of emission d_x from target surface is approximately proportional to the velocity of the sputtered atoms v_{atom} times the lifetime of the upper energy level τ [4]. This lifetime is equal to the reciprocal sum of the Einstein coefficients A and v_{atom} is transfered due to the ion collisions during sputtering to the sputtered atoms.

The axial peak position of the investigated ground state transition at 498.26 nm ($^7F_1 \rightarrow ^5D_0$) is consistent with the expected velocity and the Einstein coefficient. Whereas the lines at 484.38 nm and 424.43 nm, whose upper levels are not mainly fed by the $^5D_0$ level, peak further away from the target than expected. This experimental data shows that W is sputtered primarily in the ground level by a monoenergetic Ar ion beam for an impact energies between 100 and 200 eV, if the W sample is at room temperature. The other levels of the ground term are in this experimental condition populated subsequently of the plasma.

References

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