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SURFACE BIASING INFLUENCE ON THE PHYSICAL SPUTTERING OF PLASMA-FACING COMPONENTS IN FUSION DEVICES

Understanding plasma-surface interaction (PSI) processes is important for the successful realization of the ITER project. PSI processes are determined to a large extent by the Debye sheath and magnetic pre-sheath effects. For the correct calculation of ions trajectories just before the surface impact and in the presence of the oblique magnetic field, it is necessary to include the precise sheath electric field distribution. Furthermore, in a number of experiments the surface biasing up to several hundred Volt is applied to the plasma facing components (PFC) that also influences greatly the sheath potential.

In this work the simplified analytical expression for the electromagnetic field is suggested including surface biasing effects. The previously derived analytical expression [1] is modified taking into account the potential redistribution in the Debye sheath so that the potential drop and the sheath length both increase, while potential distribution in the magnetic presheath does not change [2, 3]. The resulting sheath electric field is in good agreement with the numerical solution of the integral equation for the potential distribution in the Debye sheath. The energy and angular impact distributions and, therefore, the surface sputtering yields were analyzed for different initial ion velocity distributions in the presence of an oblique magnetic field and surface biasing.

In linear plasma devices, the magnetic field is often directed normal to the target surface, making the influence of the angular distribution of impacting ions negligible. However, the surface biasing of up to several hundred Volt (applied to the target to vary the sputtering ion energies) has considerable influence on the energy distributions, and thus, it must be treated as a parameter in the analytical solution. The analytic expression mentioned above was used to estimate the sputtering yield of the tungsten target under Ar plasma for various biasing values in PSI-2 experiments [4]. The simulation and experimental results are in a good agreement, the trend being reproduced and absolute values agree within 20%.

In the case of modelling of PSI processes at the JET ITER-like wall, it is necessary to also take into account the oblique magnetic field, which is typical for tokamak main wall PFCs. This highlights the high importance of the sputtering ion angle distributions on impact for sputtering yield estimation. The same analytic expression derived above has been applied for updating of ERO modelling of enhanced radio-frequency (RF)-induced erosion of the outer wall JET Be limiter near the Ion Cyclotron Resonance Heating (ICRH) antenna [5]. This effect has been associated with magnetic connections between the affected PFCs and high electric fields induced by the antenna, the latter being treated as an additional negative surface biasing of up to 200V [6]. The influence of the safety factor (q), which affects impacting ions' angles, on the effective Be sputtering yields is also taken into account. The related comparison of the revised ERO-simulated RF-induced Be emission with the experimental observations is presented. The sputtering yield was calculated for two different cases: a pure beryllium target ('ERO-max') and assuming 50% D concentration in the surface interaction layer ('ERO-min'). It was shown that for the latter, the sputtering yield increases 2-3 times with biasing, which is in good agreement with the experimental results: the characteristic spectroscopic emission of beryllium varies with the antenna toggling by the same factor. This provides additional confidence in 'ERO-min' fit for the physical sputtering yields for the plasma-wetted areas of PFCs.

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