Determination of the angular distribution function of the negative ions produced on the HOPG surface in H_2/D_2 plasmas using mass spectrometry

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1. Introduction

This work focuses on understanding of the negative-ion production mechanism on surfaces in low pressure H_2/D_2 plasmas. The aim is to enable the development of cesium-free negative-ion sources, which would be valuable for many applications, particularly for neutral beam injectors of future nuclear fusion reactors. The negative ions are produced on HOPG sample (Highly Oriented Pyrolitic Graphite) negatively biased in the plasma. Some of the positive ions attracted by the sample capture electrons at the surface and produce negative ions which are detected by mass spectrometry according to their energy. The shape of the measured negative-ion energy distribution functions (NIEDFs) depends both on the surface production mechanism and on the ion transport in the plasma and in the mass spectrometer. A model has been developed previously [1,2] in which NIEDFs are computed using SRIM calculation for the hydrogen particles created on the surface upon positive-ion bombardment. This output is further convoluted with the ion transmission function between the sample and the mass spectrometer. Here we present an improved model which takes into account the sample tilt with respect to the mass spectrometer. Based on this model, we propose a reconstruction method of the experimental angular distribution function of the negative ions created at the sample surface. The algorithm is purely geometrical and does not depend on the negative-ion surface production mechanism, so it can be applied to any type of material or negative ions.

2. NIEDF calculation for the tilted sample

The model is firstly adapted to calculate the trajectories of the negative ions in the plasma when the sample is tilted by an angle α, taken between the axis of the spectrometer and the normal to the surface of the sample.

In the Fig. 1, the NIEDFs from the experiment and the model are compared for different tilt angles of the sample from 0° to 20° in steps of 5°. When α grows, the minimum energy of the distribution increases. The shifts of those minimum energies between the NIEDFs are very well reproduced by the model. The ending energies of the distributions also correspond quite well, a small discrepancy in the distribution tails between the model and the experiment could emerge from the imperfect approximation for the energy of positive ions impinging on the sample. The global intensities are decreasing with α and each new curve fits to the end of the previous one.

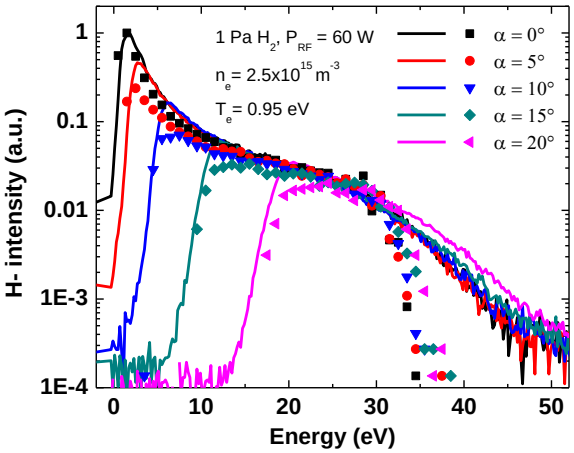

Fig. 1: *Comparison of the experimental NIEDFs (solid lines) with the calculated ones (points) for different tilts of the sample (from α = 0° to 20°, in steps of 5°)*

3. Determination of the angular distribution

The whole distribution of negative ions leaving the surface is reconstructed based on the NIEDF measurements at different tilt angles of the sample. The simulations show that the negative ions with a certain energy E are collected by the mass-spectrometer in a narrow angular range $[\theta_{\alpha,a}\ \theta_{\alpha,b}]$, which depends on the tilt angle α. The adjacent angular ranges are identified as a function of E and α; it allows to determine the angular distribution function for each energy E from a set of NIEDFs measured at different α. The global angular distribution is then the sum of these distributions.

The method is validated by the good agreement of the model with the experiment on many levels: the NIEDFs measured at different tilts of the sample, the global angular distribution function and the global energy distribution function at the surface of the sample.

References

[1] G. Cartry et al. 2012 *Phys. Plasmas* **19** pp 063503
[2] A. Ahmad et al. 2013 *Plasma Sources Sci. Technol.* **22** pp 025006