Hiden Reference: AP-EQP-0001
Hiden Product: EQP Mass & Energy Analyser

Negative-ion surface production in hydrogen plasmas: modelling of negative-ion energy distribution functions and comparison with experiments

Negative ions in low-pressure plasma sources are created either in the plasma volume by dissociative attachment or, at the plasma surface interaction due to surface ionization of backscattered or sputtered particles. Negative-ions formed on surfaces are accelerated towards the plasma by the sheath. They can influence the plasma kinetics through collisions with plasma species, or are self-extracted from the plasma thanks to the energy acquired in the sheath. Self-extraction of negative-ions can affect processes like sputtering, where the negative-ions formed on the cathode bombard the layer being deposited. In applications such as negative-ion sources for accelerator or fusion devices, it is taken advantage of negative-ion surface production. A low work-function material (usually caesium- covered metals) is in contact with the plasma and greatly enhances negative-ion production because of the low energy required to extract an electron from the surface. However, caesium free negative-ion sources would be greatly valuable for fusion applications because of the strong maintenance constraints induced by caesium injection.

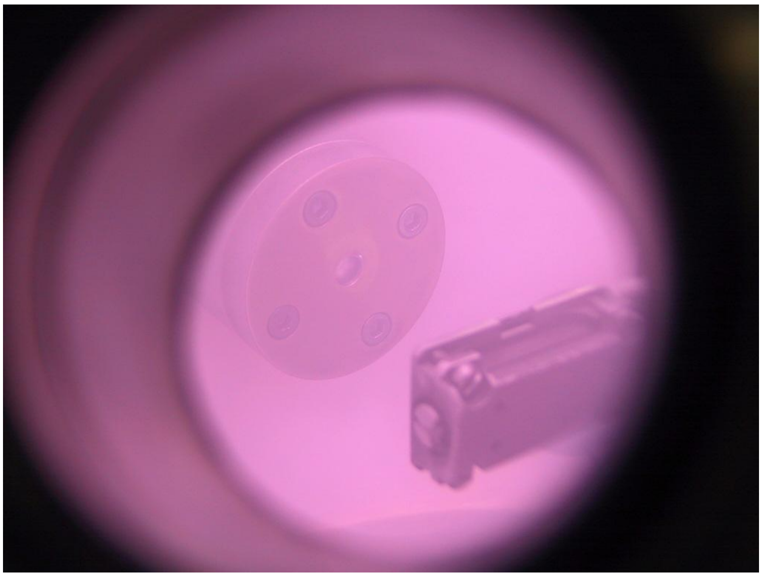

Figure 1. The sample holder facing the EQP 300 mass spectrometer nozzle

The present project deals with negative-ion surface production in caesium free H_2/D_2 plasma for fusion applications. It is conducted under strong collaboration between Aix-Marseille University and CEA Cadarache. The goal is to understand and optimize negative-ion surface production. To this aim, a carbon sample (graphite, diamond…) is negatively biased in a capacitively coupled plasma. Negative-ions formed upon positive ion bombardment are accelerated towards the plasma. Under the low pressure condition considered in this work (0.2 – 2 Pa) they reach without collision the Hiden EQP 300 mass spectrometer which is facing the sample (see Figure 1). H^- negative-ion distribution functions (NIDFs) are measured by means of the energy filter of the EQP mass spectrometer. In order to get insight into surface ionization mechanisms, surface-produced NIDFs have to be determined from the measured NIDFs. The first step is to choose a priori the solution, i.e. a reasonable function for the NIDFs on the surface f(E, θ). Based on this distribution, negative

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ion trajectories in the sheaths and in the plasma are computed to get the negative-ion arrival energies and angles at the EQP mass spectrometer entrance. The ion transmission probabilities inside the spectrometer are then calculated based on arrival energies and angles by using a full 3D modelling of the EQP mass spectrometer developed with the SIMION software. Finally the negative-ion distribution function of the ions reaching the mass spectrometer detector is calculated and compared to the experiments (see Figure 2).

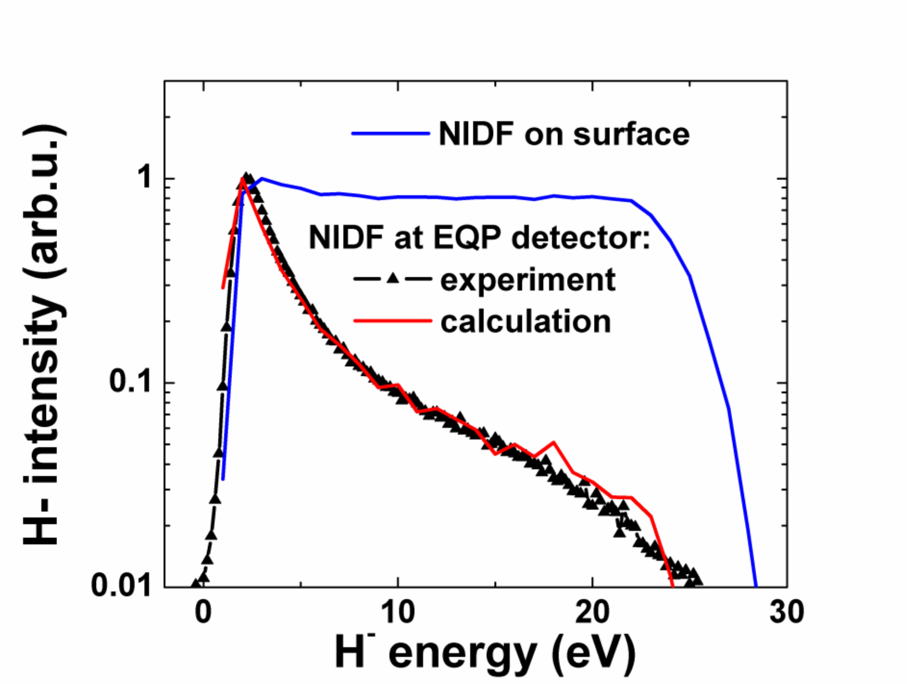

Figure 2. Comparison between measured and calculated NIDFs

Using this method it has been possible to obtain the angular and energy distribution function of negative-ions leaving the surface f(E, θ) (see f(E) on Figure 2). This NIDF strongly differ from the measured one (see Figure 2) because of the modifications of the trajectories induced by the sheaths. From the study of f(E, θ) it is shown that the collected negative-ions come from the centre of the sample and not from surrounding surfaces (clamp, sample holder…). Most of the negative-ions created at the surface originate from the backscattering of positive-ions (with electron capture), the rest coming from sputtering of adsorbed hydrogen atoms (with electron capture). Due to the broad distribution of emission-angle and emission-energy, only few percent of the emitted negative-ions are collected. Finally, comparative studies of NIDFs obtained on different carbon materials sheds light on the main surface parameters influencing surface ionization. For instance, diamond material can strongly enhance negative-ion surface production when heated up to 400°C. This enhancement has been correlated with an increased hydrogenation of the surface and a reduction of surface defects.

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Hiden Product:
EQP Mass & Energy Analyser

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