ESCAMPIG XXI, Viana do Castelo, Portugal, July 10-14 2012

Negative-ion surface production in hydrogen plasma: production mechanisms on different carbon surfaces

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Negative-ion surface production is studied in hydrogen plasma. A negatively biased sample facing a mass spectrometer is bombarded by positive ions from the plasma. H- negative-ions formed on the surface upon bombardment are repelled by the sheath and are analyzed in mass and energy by the mass spectrometer. In the present paper negative-ion surface production mechanisms are presented and comparisons between different carbon materials used as sample are made. In particular, it is shown that under certain experimental conditions, boron-doped-diamond surface can give five times higher yield than that of graphite, which had been best material so far for surface production of negative-ions.

Negative-ions in low pressure plasmas are widely studied because of their role on discharge kinetics and their use in many applications. In particular, negative ions are gaining strong interest for two main fields of application, magnetically confined fusion and microelectronic industry. The microelectronic industry will face soon a technological node (22nm transistors) where conventional plasma etching processes will start to fail. Among alternative processes, etching by neutral beams generated from negative ion beams is envisaged[1]. In magnetically confined fusion, neutral beam injection at high energy (1 MeV for ITER) is used to heat the plasma and to initiate the fusion reaction. To create the intense and energetic neutral beam, a negative ion (NI) source is required since neutralization of energetic NI (1 MeV) is much more efficient than positive ions.

Negative-ions in hydrogen are created in the plasma volume and on surfaces. Volume production in low-pressure hydrogen plasma is usually not efficient, and most of the high-performance hydrogen negative-ion sources use cesium injection in the plasma to enhance surface production. Indeed, cesium deposition on walls reduces the material work function thus increasing NI production yield. However, cesium injection leads to many drawbacks such as contamination, long term operation stability… and furthermore cesium is a chip pollutant and could not be used in microelectronic processes. Therefore, development of Cs free NI sources would be highly valuable.

Our goal is to study NI surface production in cesium-free hydrogen plasma with the aim of understanding surface production mechanisms and optimizing them. In the present experiment, a sample is placed in the diffusion chamber of a helicon plasma reactor, facing a Hidden EQP mass spectrometer. The sample is biased negatively with respect to the plasma potential. H- negative-ions formed on the surface upon positive ion bombardment are repelled by the sheath and are analyzed in mass and energy by the mass spectrometer.

The study of the negative-ion distribution functions under different experimental conditions allows for the understanding of the main production mechanisms. Details on these mechanisms are obtained thanks to a modeling of the ion distribution functions, using the SRIM software and calculations of the negative-ion trajectories. Finally, comparison between different sample materials, and surface analyses after plasma exposure, reveal surface parameters influencing negative-ion production.

In this presentation we will detail surface production mechanisms and present a comparative study between different carbon materials: graphite, diamond and fullerenes. In particular we will show that at 400^0C, diamond surfaces shows ~ 5 time higher yield than graphite, which has been the best material so far for surface production of negative ions [2,3,4,5]. Raman measurements reveal surface modifications after plasma exposure. Results will be discussed in details.

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