Effects of plasma-facing materials on the negative ion (H-/D-) current extracted from an ECR plasma source

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The possibility of enhancing the extracted negative ion (H-/D-) current due to plasma-surface interactions on selected materials (potential alternatives of Cs in NBI for tokamak), is herein demonstrated. Current results, from plasmas sustained at a few mTorr by ECR dipolar plasma sources, as obtained with laser photodetachment at 1064 nm, demonstrate that, when tungsten material faces plasma it induces an obvious enhancement of the negative ion density. An extracting system using magnetic cores and three cooled electrodes are used to evaluate effects of the material itself and its relative position in the plasma, on the extracted current. The influence of the dimensions and geometry of the extracting aperture on the beam intensity, are also studied.

1. Background

The ignition of fusion reactions in future reactors requires the injection in the bulk plasma of high-energy high power deuterium neutral beams (34 MW of 1 MeV D° beams on ITER, the international tokamak). These systems, called neutral beam injectors (NBI), are based on the acceleration of intense deuterium negative ion (NI) beams, followed by a neutralization in D_2 gas. These injectors require caesium to reach the demanded current intensity of 55 A. Despite its high efficiency to increase the negative ion extracted current, caesium induces a potential contamination of the accelerator resulting in high voltage breakdowns Hence, an alternative material becomes mandatory to achieve the negative ion current specifications of NBI designed for ITER.

2. Collaborations

LPSC has a long collaboration with CEA-Cadarache (in charge of French scientific research on NBI) searching for alternatives to Cs as a negative ion enhancers. LPSC operates electron cyclotron resonance (ECR) plasma at low power intake (up to 0.2 kW), while High Voltage Laboratory (Patras) investigates identical ECR plasma at higher power (up to 1 kW). Collaboration with the Topchiev Institute (Moscow), allows the development of optical emission spectroscopy diagnostics, as essential for considering plasma-surface interactions.

3. Experimental setup

ROSAE-III is a stainless steel cylindrical plasma reactor [1] (152 mm in diameter and 214 mm long) developed at the LPSC. It is operated with dipolar plasma sources [2] at low pressure (< 25 mTorr). A cylindrical wall-coverage of borosilicate glass (Pyrex™, 5 mm thick), tapped with two circular plates made of the same material, can be housed in ROSAE III. Hence, hydrogen plasma can be confined in a chamber of either low (γ_H = 0.005; Pyrex™ at 280 K) or moderate (γ_H = 0.1-0.5; stainless steel) recombination coefficient. Studied materials are mounted on the Pyrex™ surface to face the H_2/D_2 plasma. Absolute negative ion density has been already measured inside ROSAE-III by laser photodetachment at 1064 nm. Furthermore, recently, an extracting device has been designed, following 3D modelling (COMSOL software [3]), and it is being implemented for measurements of the negative current extracted from the plasma. It consists of three cooled electrodes. Two magnetic cores are used to prevent electrons from being co-extracted with negative ions.

4. Results

The above experimental device should validate recent results of photodetachment measurements that shown a significant enhancement, by a factor 2.5, of the negative ion density in the bulk plasma when tungsten coverage is used. It will not only allow to assess the effect of the materials nature (tungsten, tantalum, and graphite) on the extracted currents but also to determine its best location with respect to the extracting aperture to maximize the negative ion current.

5. References

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