Study of negative-ion surface production and extraction in low-pressure plasmas: application to fusion

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Subject description:

The present work deals with negative-ions for fusion applications in the context of the international project ITER and its successor DEMO, which aim to demonstrate controlled nuclear fusion for energy production. In tokamaks (nuclear fusion reactors), a plasma composed of deuterium and tritium is magnetically confined and heated to very high temperatures, around $1.5 \cdot 10^8$ K to achieve nuclei fusion. In the ITER and DEMO devices, the heating of the plasma will mainly be produced by Neutral Beam Injectors (NBI). The ITER NBIs are required to inject 1 MeV beams of neutral deuterium atoms (D) into the tokamak, providing plasma heating. The production of such D beams relies on neutralization of high-intensity D^- beams. D^- negative-ions are produced in a low-pressure plasma source and subsequently extracted, accelerated and neutralized. The only up to date solution to produce the high intensity (40 A) beam required is to inject in the plasma source caesium (Cs). Caesium deposits on all surfaces and lower the material work function, thus enhancing the capture of electrons by incoming deuterium ions or atoms. While the solution is efficient, it has many drawbacks that could complicate NBI operation.

Several laboratories in France are associated in the development of a completely new concept of Neutral Beam Injector. At PIIM laboratory we participate to this effort by focusing on the alternative solutions to caesium. The experiments are conducted on a small scale plasma reactor well equipped with many diagnostics allowing for in depth investigation of negative-ion surface production in caesium free plasmas. The goal is to find solutions to produce high yields of negative-ions without injecting caesium.

PIIM laboratory has developed many tools, both numerical and experimental, to study negative-ion surface production in low-pressure low temperature plasmas. It is proposed here to investigate the fundamental parameters of negative ion production and extraction in Cs-free hydrogen/deuterium plasmas by using these tools: Langmuir probes, mass spectrometry with energy analysis, Magnetized Retarding Field Energy Analysis, surface analysis such as Raman spectroscopy, SEM, XPS, UPS and the newly developed Photoemission Yield Spectroscopy (PYS) diagnostic allowing in situ measurements of material work function, a key parameter in negative-ion surface production... Materials with interesting electronic properties such as diamond will be investigated, as well as other insulators and recently developed innovative low work function conductive ceramics.

Skills and knowledge: Knowledge in plasma science and/or surface science is required. The experimental aspect of physic research must motivate the candidate.