Caesium free negative ion sources for neutral beam injectors: a study of negative ion production on graphite surface in hydrogen and deuterium plasma

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ITER neutral beam injectors provides to plasma heating and current drive. In each injector, a D^- ion beam is partially neutralized to form a D^0 neutral beam. The D^- negative ion plasma source of the neutral beam injector must produce a high D^- current density of 200 A/m^2. Efficient negative ion sources are thus required for ITER. Negative ions in plasmas can be formed through electron attachment on molecules or through atom or positive ion bombardment of surfaces. When caesium is deposited on surfaces, material work function is reduced and negative ion production yield on surface is increased. However, Cs can escape ion source and pollute the accelerator stage of the neutral beam injector. Therefore an important research effort is presently undertaken to go towards caesium free sources. The present work deals with H^- negative ion production on caesium free graphite surface in hydrogen and deuterium plasma. Graphite is a candidate material for negative ion source walls due to its ability to form highly excited hydrogen molecules upon hydrogen atom surface recombination (electron attachment being enhanced by vibrational excitation of molecules), and due to the large negative ion flux created upon positive ion bombardment.

Our plasma source is a helicon reactor equipped with a mass spectrometer allowing for energy and mass analyses. This mass spectrometer is placed in the diffusion chamber of the helicon reactor and faces a one square centimetre sample (graphite, copper…). The sample is negatively biased with respect to the plasma. Positive ions (H^+, H_2^+, H_3^+ and their isotopes for deuterium) strike the sample in normal incidence and negative ions formed (mostly H^- and D^-) upon bombardment are repelled from the surface toward the plasma and collected by the mass spectrometer. Under low pressure considered, they reach the mass and energy analyser without any collision. Our aim is to understand basic mechanisms governing negative ion production on graphite surface in hydrogen plasma. This knowledge is necessary to improve and optimize negative ions sources.

An example of negative ion distribution function is shown on figure 1. On this graph is indicated the energy E_0 acquired by a negative ion created at rest on surface and accelerated by the sheath: $E_0 = e(V_p - V_s)$ where V_p and V_s are respectively plasma and surface potentials. One can see that most ions have energy higher than E_0 indicating they are not created at rest. By studying shape and intensity of these ion distribution functions, we establish the different negative ion production mechanisms. We show for instance that two electronscapture by an incident positive ion is one of these mechanisms.

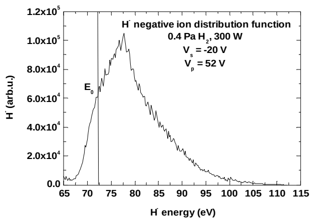

Figure 1: Surface produced H- negative ion distribution in hydrogen plasma

We also demonstrate that negative ion production on graphite surface is proportional to the ion flux and have a bell shape dependence with positive ion energy, with a maximum production yield around 60eV. This dependence is not yet understood and is still under investigation.

We roughly estimated negative ion surface production yield to be in the range 0.5 to 5%. We plan to measure more accurately this yield; however, this estimation is encouraging and suggests graphite could be an excellent material for caesium free negative ions sources.