Plasma structure in the extraction region of a negative ion source

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The production, destruction and transport of H^- in the extraction region of a radio frequency inductively coupled plasma (RF-ICP) negative ion source have been investigated by means of a 1D(z)-3V Particle-in-Cell electrostatic code. The motion of charged particles (e, H^+, H_2^+ and H^-) in their self-consistent electric field is coupled with the neutral particles (H(n=1) and $H_2(X^1\Sigma_g^+$, v=0,…,14)) dynamics. Surface and volumetric processes involving plasma and neutral systems are included by using different Monte Carlo Collision methods.
For the first time it is shown that plasma potential has not a simple classical behaviour. Due to negative ion volume production, a potential minimum is recovered in the bulk (Fig. 1), in agreement with experimental measurement [1] and different numerical calculation [2]. In fact, the production of H^- by electron detachment takes place in the low temperature region (z>-0.02 m). The negative ions have a small velocity in comparison to the disappeared electrons. Although there is no net charge production, the lack of mobility of the negative ions will redistribute the negative charge to places with large H^- production. In a stationary situation, the electric field setup will transport negative ions away at the same rate as they are produced. Thus there will be a mutual interaction between the plasma-chemical reaction of H^- formation on one hand and the electric field on the other hand (chemo-electric effect).
A potential drop of about 15 V is found in front of the PG in the case of 0 PG bias. This confirm the fact that in order to extract negative ions, the sheath surrounding the plasma must be opened up by biasing the plasma grid so that it is sufficiently strongly positive [3-5]. In fact, as shown in Fig, 1, in the case of PG biased at +36 V (red line), the sheath is completely reversed assuming the characteristic "Z" shaped curve. The bias induces two transport modes: one where negative ions are pushed by the grid and one where negative ions are attracted by the grid.

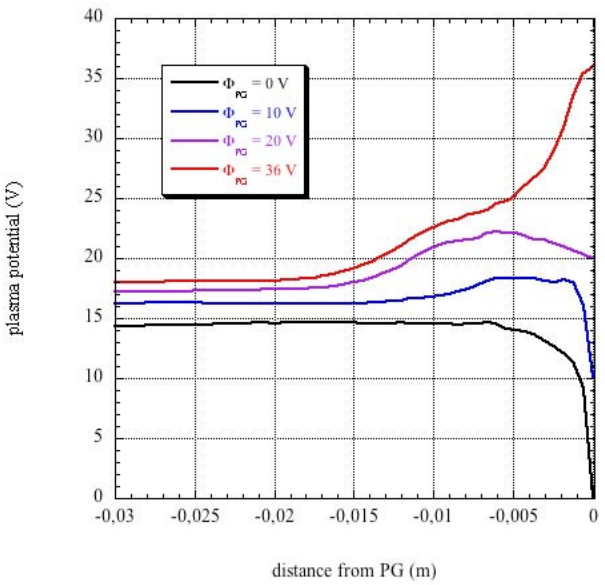

Figure 1. Axial electric potential profiles in the extraction region using three different PG bias (0, 10 and 20 V)

References

[1] M. Bandyopadhyay, A. Tanga, H. D. Falter, P. Franzen, B. Heinmann, D. Holtum, W. Kraus, K. Lackner, P. McNeely, R. Riedl, E. Speth, R. Wilhelm, "Analysis of plasma dynamics of a negative íon source base don probe measurements," *J. Appl. Phys.*, Vol. 96, no. 8, pp. 4107-4113, 2004.

[2] T. Sakurabayashi, A. Hatayama, M. Bacal, "Effects of transverse magnetic field and spatial potential on negative transport in negative ion source," in *Proc. 10th International Symposium on Production and Neutralization of Negative Ions and Beams*, AIP Conf. Proc. no. 763, New York: American Institute of Physics, pp. 96-106, 2004.

[3] M. Bacal, J. Bruneteau, P. Devynck, "Method for extracting volume produced negative ions," *Rev. Sci. Instrum.* Vol. 59, no. 10, pp. 2152-2157, 1988.

[4] H. Takahashi, T. Kasuya, M. Wada, "Effects of bias potential upon H^- density near a plasma grid of a negative ion source," *Rev. Sci. Instrum.* Vol. 77, 03A513, 2006.

[5] O. Fukumasa, M. Hosoda, H. Naitou, "Relationship between extraction of H^- ions optimized by plasma grid potential and plasma parameters in a bucket source," *Rev. Sci. Instrum.* Vol. 63, no. 4, pp. 2696-2698, 1992.

Topic: 1. Fundamental processes and modelling

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