Characterization of ECR produced hydrogen plasma for H^- generation

P. Singh, R. Gaur, D. Sahu, R. Narayanan, A. Ganguli, R. D. Tarey

Centre for Energy Studies, Indian Institute of Technology Delhi, New Delhi, 110016

Experiments have been carried out in low pressures (≤1.5 mtorr) hydrogen plasmas in a vacuum chamber attached to a compact electron cyclotron resonance (ECR) source. The electron temperature and density, measured by a Langmuir probe, are seen to fall slowly along the axis away from the ECR source. Using the experimental data and a global model the density of different positive ion species, H^+, H_2^+, H_3^+ are estimated. It is found that H_3^+ is the dominant species at low pressures. It also turns out electron temperature plays a pivotal role in determining collisional energy loss. Work is in progress to determine the optimum conditions for H^- generation.

1. Introduction

Negative hydrogen ion (H^-) beams have great importance for neutral beam heating of fusion plasmas because they can be efficiently charge-neutralized to form neutral beams at particle energies of ~ 1 MeV [1]. In order for the scheme to be successful it is important that one be able to produce high density, robust, very-large volume hydrogen plasma over a large cross-section so that the required ion current (~ 30 – 40 amps over an area of 1sq.m.) can be extracted. To make such a technology viable and sustainable, it is important to be able to produce the starting hydrogen plasma extremely efficiently in terms of power input to the device. Since very few studies [2] exist on the characterization of non-equilibrium hydrogen plasma at low pressures, it becomes important to undertake such studies. In addition, most of the plasma sources for H^- production are RF based, whereas the present study is Electron Cyclotron Resonance (ECR) based.

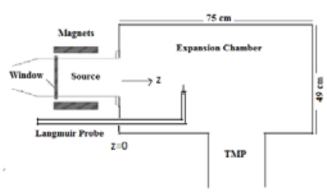

Fig.1 Schematic of Experimental Setup

2. Experimental Setup

Experiments were performed inside a stainless steel cylindrical chamber (length ≈ 75 cm, ID ≈ 50 cm) attached coaxially to a Compact ECR Plasma Source (CEPS) as shown in Fig. 1 [3]. The CEPS has a cylindrical plasma source section (ID ≈ 9.1 cm, length ≈ 11.5 cm) with coaxially arranged NdFeB permanent ring magnets. Microwaves at 2.45 GHz are used to produce plasma inside the CEPS. The magnetic field of the ring magnets not only provides the ECR magnetic field, but also penetrates the larger expansion chamber into which the plasma diffuses, guided by the magnetic field.

3. Results and Discussion

Experiments were performed at 0.5mTorr-1.5mtorr pressure and 200-1000W power. At 1mtorr pressure and 500W power it is found that the electron density (n_e) decreases slowly along the chamber axis from ≈ 4.0×10^{10} cm^{-3} (at z ≈ 15 cm) to ≈ 0.7×10^{10} cm^{-3} (z ≈ 60 cm), with the corresponding electron temperature (T_e) decreasing from ≈ 6.2 eV to about 2.7 eV.

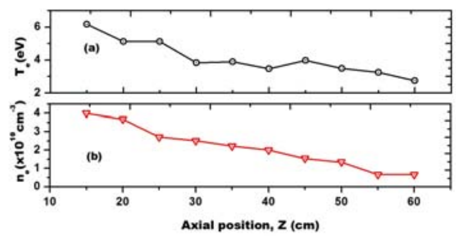

Fig.2 Variation of (a) Electron temperature and (b) density with axial position. Pressure ≈ 1 mtorr and power ≈ 500 W.

Taking T_e as input, a global model is used to determine the positive ion species in the plasma. Although n_e (Fig.2) is calculated assuming the positive ions are H^+, simulation from a global model indicates that different ion species, H^+, H_2^+, H_3^+ are present and at low pressure H_3^+ might be the dominant species. In that case n_e will be increased by a factor of 1.732. Further it was found out that if the neutral species is mostly H_2 rather than H, the collisional energy loss hence the input power to the plasma would need to be higher. Effort is under way to determine the optimum conditions for H^- production. Detailed results will be presented at the conference.

4. References

[1] M. Bacal and M. Wada, Appl. Phys. Rev., **2**, (2015) 021305.

[2] D. Sahu and S. Bhattacharjee, J. Appl. Phys., **112**, (2012) 063304 .

[3] A. Ganguli et al., Plasma Sources Sci. Technol., **25,** (2016) 025026.