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Experimental Characterization and Theoretical Studies of ECR Produced Hydrogen Plasma Ion Beams

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Hydrogen plasma with its multiple constituent species (H, H2 at ground and excited vibrational levels, H+, H2+, H3+, H-) offers a rich array of applications in diverse fields of science and technology such as in materials processing, production of ion beams for fusion plasma heating etc. In the present work, a combination of a solenoid and a set of five permanent ring magnets were used to produce ECR hydrogen plasma within a source section (ID=9.1 cm, length=11.6 cm) and allowed to expand into a larger cylindrical chamber (ID=48.2 cm, length=75 cm) in the pressure range 1-8 mTorr and 650W, CW microwave power. The experiments were undertaken to explore suitable regions of negative hydrogen ion production within the expansion chamber. The plasma has been characterized using a specially designed Langmuir probe (LP), with an on-axis Retarding Field Energy Analyzer (RFEA) being used for beam measurements.
LP measurements revealed, for most cases, that the plasma within the source region has a single electron population, which subsequently splits into two electron populations downstream. Suitable regions of H- production (Te ˜ 1 eV at p = 8 mTorr) were found in the downstream regions and at higher pressures. The point at which splitting occurs can vary from well inside the source to outside the source. At lower pressures, it is noted that there is a significant drop in the plasma potential from within the source into the expansion chamber. This ambipolar field would be ideal for ion acceleration. Hence, an axial RFEA [1, 2] was used to measure ion energies close to the mouth of the plasma source section. The RFEA shows ions having energy ≈ 62 eV and ≈ 36 eV (5 cm and 10 cm away from the source respectively) at 1 mTorr pressure. Hence, the source region not only pumps plasma into the expansion chamber, it also gives rise to high energy ion beams within the expansion chamber as the interconnecting opening provides both electrical and diffusive contact between the two systems, which helps generate flows and ion beams.
In order to corroborate the experimental observations of ion beams in the expansion chamber and the contribution of the different ionic/molecular hydrogen species, a 2-zone global model was developed with separate particle and power balance equations being setup for the two zones (the source section and the expansion chamber) taking into account particle and power flow across the two zones, wall losses, current balance across the interconnecting opening, etc. The two zone global model results obtained were compared with the experimental results both inside and outside the plasma source section and it was found that there is a reasonable match between the model and experimental results. The detailed results would be presented in this paper.

References

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Author: NARAYANAN, RAMESH (Department of Energy Science and Engineering, Indian Institute of Technology Delhi, India)

Co-authors: Prof. GANGULI, Ashish (Department of Energy Science and Engineering, Indian Institute of Technology Delhi); Dr SAHU, Debaprasad (Department of Energy Science and Engineering, Indian Institute of Technology Delhi); Ms SINGH, Priti (Department of Energy Science and Engineering, Indian Institute of Technology Delhi); Prof. TAREY, Ram Dattatraya (Department of Energy Science and Engineering, Indian Institute of Technology Delhi)

Presenters: Ms SINGH, Priti (Department of Energy Science and Engineering, Indian Institute of Technology Delhi); NARAYANAN, RAMESH (Department of Energy Science and Engineering, Indian Institute of Technology Delhi, India)

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