Contribution ID: **79** Type: **Poster**

Investigating the Potential of an ECR Large-Area Plasma Source for Hydrogen Negative Ion Production in Fusion Applications

Monday, 8 September 2025 16:30 (1h 30m)

H^- ions play a crucial role in hydrogen plasmas, with important applications in plasma-based material processing, accelerator technology, and, most notably, thermonuclear fusion. In fusion research, H^- ions are indispensable for plasma heating and current drive in magnetically confined fusion devices. Currently, most H^- ion sources employed in fusion rely on inductively coupled plasma (ICP) systems driven by radio frequency (RF) power at levels ~ 1 MW. Electron cyclotron resonance (ECR) presents a more efficient alternative, but its potential in large-area, high-current ion sources remains insufficiently explored. This study investigates an ECR-based, large-volume plasma system with a focus on enhancing the volume production of H^- ions. Experiments were conducted in a cylindrical expansion chamber, called the ECR-based Large Negative Ion Beam Source (ELNIBS), measuring ~ 1 meter in height and diameter. Plasma was generated using a compact ECR plasma source (CEPS) mounted on the chamber's top dome. The source's magnetic field decayed exponentially into the expansion chamber, facilitating plasma spread. To further reduce plasma losses to the chamber walls, a set of three-dimensional magnetic fields was superimposed using permanent ring magnets placed around the periphery of the expansion region. Plasma characterization was performed under varying microwave power inputs (400–600 W) and gas pressures (1–3 mTorr). Axial and radial Langmuir probes were used to measure key plasma parameters, while both positive and negative ions were detected using a low-pressure plasma sampling (PSM) probe attached to a Hiden HPR-60 quadrupole molecular beam mass spectrometer (MBMS). The results demonstrated the formation of a uniform plasma with an electron density ne ~ 10^11 cm−3 and a low electron temperature Te ~ 1 eV. These plasma conditions are conducive to the volume production of H^- ions, which were successfully identified through MBMS measurements.

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Session Classification: Poster Session

Track Classification: Negative ion sources and sources for fusion facilities