# §16. Extraction of Hydrogen Negative Ions from a 14 GHz Microwave Ion Source

Wada, M., Nishida, T. (Doshisha Univ.),
Shinto, K. (JAEA),
Yamaoka, H. (RIKEN),
Shimozuma, T., Nishiura, M.

High frequency electromagnetic field is widely utilized to excite plasmas in electron cycle resonance (ECR) ion sources for producing beams of multiply charged ions. Fast electrons rapidly accelerated by the microwave electric field produce plasma of high electron temperature in a strong confinement magnetic field. These electrons destroy $H^-$ as the electron affinity of hydrogen atom is only 0.754 eV, and ECR ion sources have been considered unsuitable as negative ion sources. However, if the high energy electrons are confined locally inside the plasma, they form vibrationally excited hydrogen molecules which breed $H^-$ through collisions with low energy electrons in the plasma. Thus, with the ion source structure of localized confinement of high energy electrons, one may realize an efficient $H^-$ source based upon ECR plasma excitation.

Figure 1 shows a schematic diagram of the compact ion source driven by 14 GHz microwave. A pair of permanent magnets creates a magnetic field of the intensity greater than 5 kG corresponding to the ECR condition at 14 GHz. In the strong magnetic field region a 20 mm inside diameter 91 mm long alumina ceramic tube has been inserted with the axis aligned perpendicularly to the magnetic field lines of force. The tube serves as the vacuum sealing wall of the ECR discharge region. A slow leak valve to feed hydrogen gas is installed at one end of the alumina tube, while a multi-hole metallic plate is attached at the other end of the tube in order to shield microwave leakage. The plasma diffuses out of the multi-hole plate expands toward the extraction hole, and plasma species having negative electric charges are accelerated to the beam diagnostic section.

Beam intensities are monitored with a Faraday cup array located 665 mm downstream of the extraction electrodes. This array can travel in the direction perpendicular to the beam transport to create a two-dimensional beam intensity distribution diagram. However, as electrons are also extracted with $H^-$, a small *EXB* probe has been placed in front of the Faraday cup array. This probe separates the ion beam species by the principle of *EXB* Wien filter, and makes the measurement of pure $H^-$ beam current possible.

The source was operated with the microwave power from 50 W to 300 W, while the pressure was changed from 0.5 to 1.0 Pa. The beam extraction potential was fixed at 1.5 kV, and the $H^-$ beam was formed with a single-stage extraction geometry. The results are shown in Fig. 2. As shown in the figure, the detected $H^-$ current has shown a saturating behavior against the increase of microwave power. At 0.6 Pa pressure at the extraction region, the extracted $H^-$ beam current had shown the maximum. The reduction in $H^-$ current intensity by the increase of gas pressure seems to indicate the beam loss associated with neutral collisions.

Further reduction in ion source pressure is not possible in the current design of the ion source, probably because of the size of the alumina discharge chamber. The velocity spectrum of the $H^-$ spectrum measured by the *EXB* probe has clearly indicated that there is a region inside of the ion source of deep negative plasma potential about -200 V. Thus, high energy electrons are expected well confined inside of the source. However, the source may not have enough volume to supply low energy electrons necessary to form $H^-$ through associative detachment of vibrationally excited molecules to $H^-$. Or, the produced $H^-$ cannot reach the extractor as the magnetic field is too strong for low energy $H^-$. Modifications of the ion source extractor to shorten the distance between the discharge region and the extraction electrode are being made.

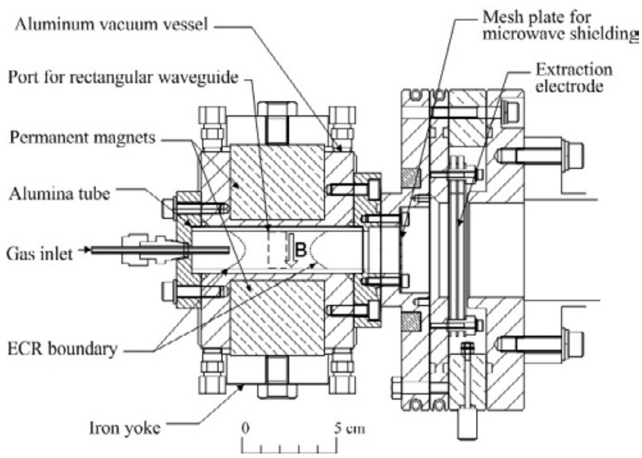


Fig. 1. A schematic of a compact 14 GHz microwave $H^-$ source.

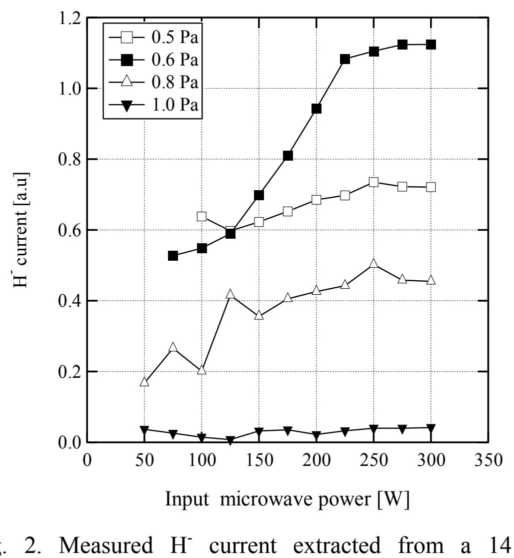


Fig. 2. Measured $H^-$ current extracted from a 14 GHz microwave ion source.