High intensity negative oxygen ion beam production with RF method

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Abstract

A compact radio frequency (RF) driven ion source has been developed to produce negative oxygen ion beams for secondary ion mass spectrometry (SIMS) application. The RF ion source operates in inductively coupled plasma (ICP) mode and RF power is coupled into discharge chamber by a capacitive auto-matching network. A 3.5 turns water-cooled planar antenna made of 3 mm copper tube is used to generate plasma. A maximum ion beam 113.2 μA is obtained through a Ø1 mm extraction aperture. O_2^- proportion in the extracted beam is always more than 35% and it shows a strong dependence on the RF injection power. The energy spread and lateral distribution of extracted ion beam are measured by a retarding field energy analyzer and a knife-edge sweeping device respectively. The preliminary experimental results show that the ion beam is Gaussian distribution in the transverse direction, and the full width at half maximum (FWHM) energy spread is about 21 eV when the ion beam energy is 10 keV.

① RF Produced Oxygen Plasma and ion source design

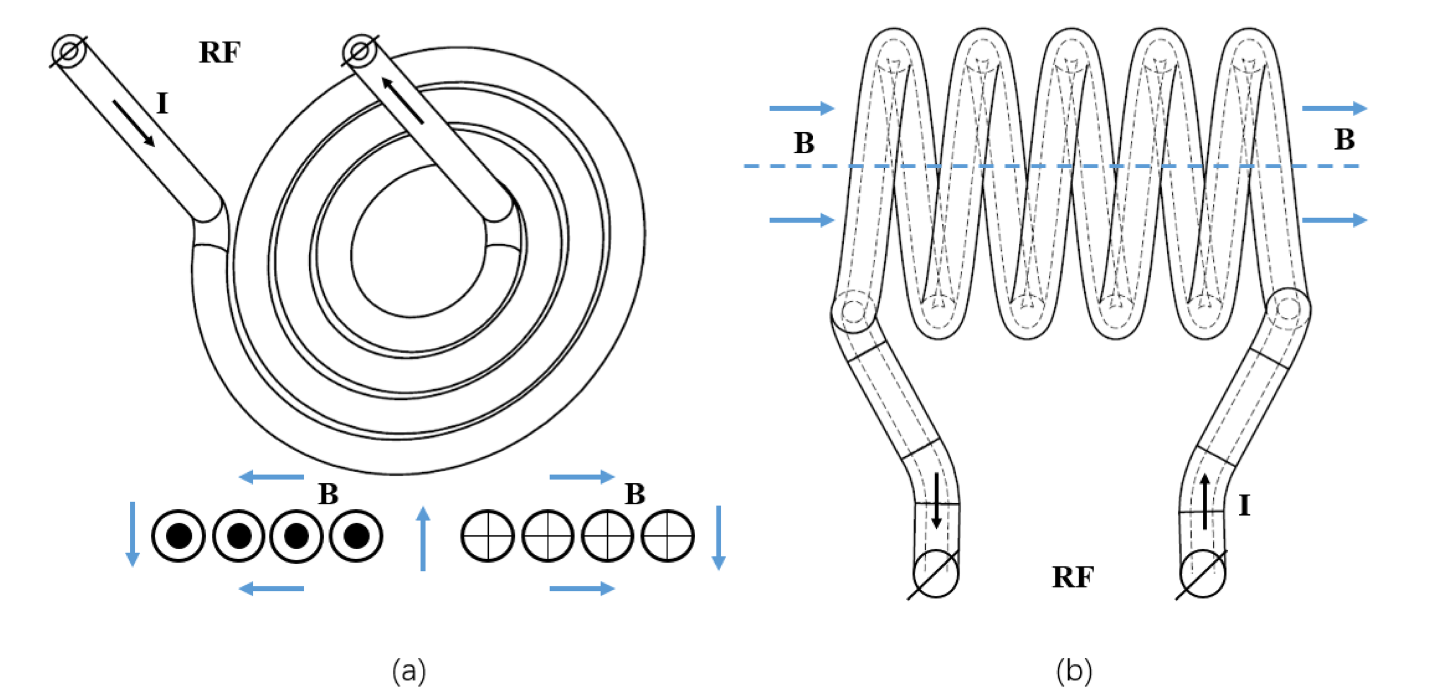


Fig. 1 Two RF antenna patterns used for inductively coupled plasma: (a) planar antenna (b) cylindrical antenna.

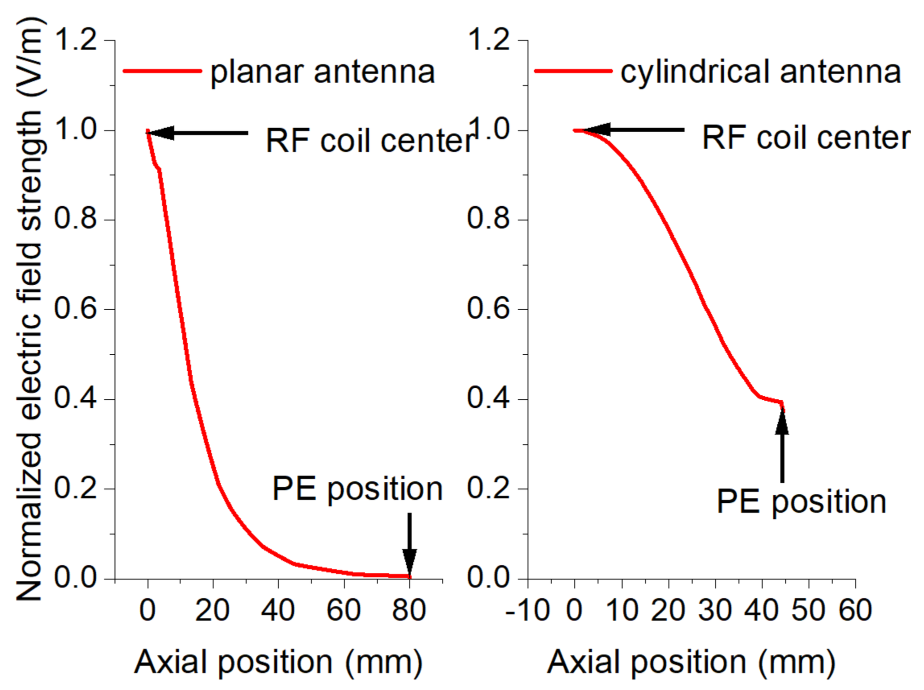


Fig. 2 Simulated RF electric filed distribution along axial position.

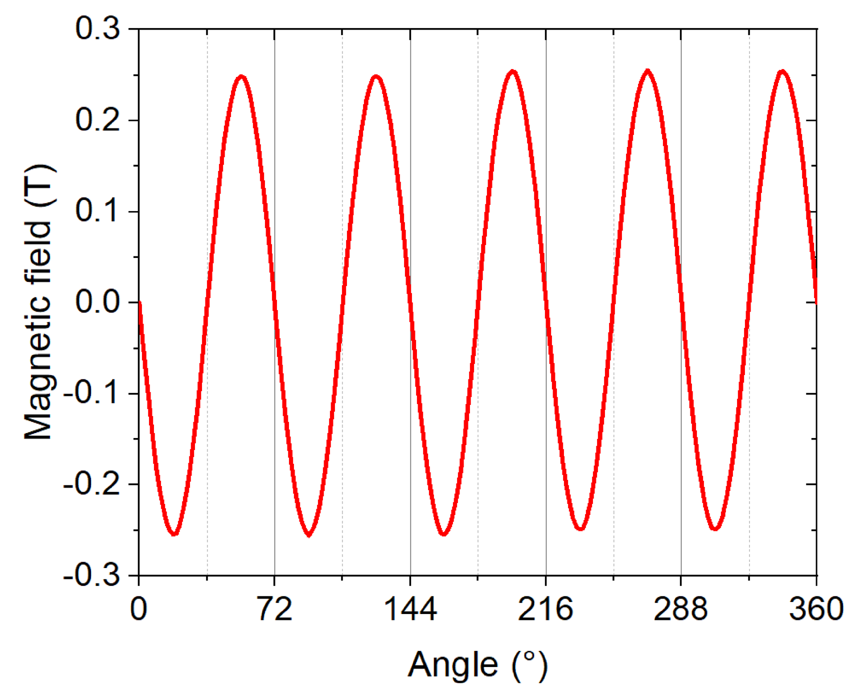


Fig. 3 Cusp magnetic field distribution at discharge chamber wall position.

- Planar antenna is chosen for ion source design based on simulated RF field distribution
- Operation with any kind of gas, especially corrosive oxygen gas
- RF power: 13.56 MHz, maximum output 1 kW,
- Planar antenna: 3.5 turns/3 mm diameter copper tube
- Discharge chamber: pressure 10^{-3} - 10^{-2} mbar , enclosed by cusp magnets
- 1 mm plasma electrode aperture
- 160 G filter magnets to separate co-extracted electrons

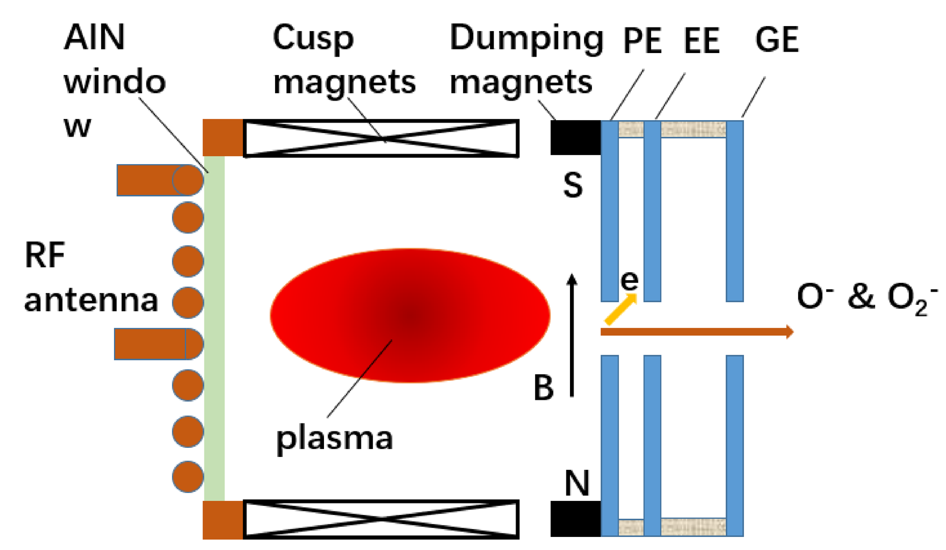


Fig. 4 Schematic diagram of RF negative oxygen ion source.

②Negative Oxygen Ion Beam Production

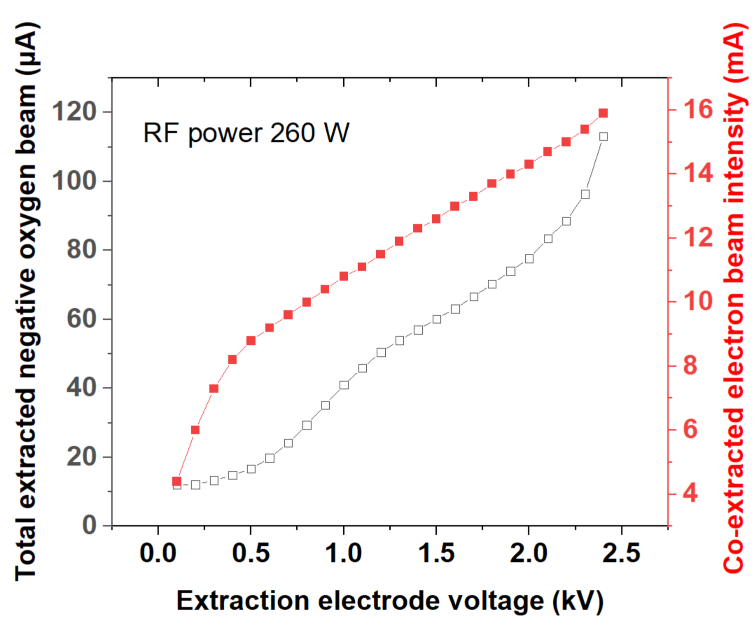


Fig. 5 Ion beam intensity VS. extraction voltage

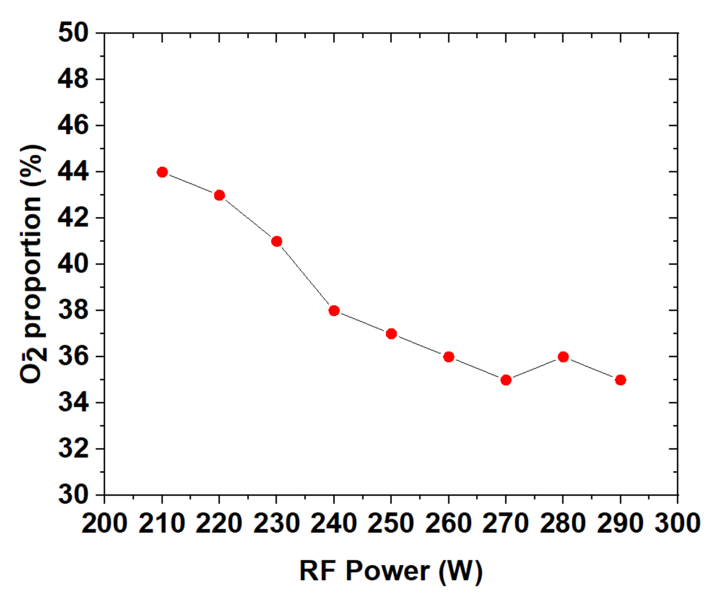


Fig. 6 The O_2^- proportion in total extracted beam

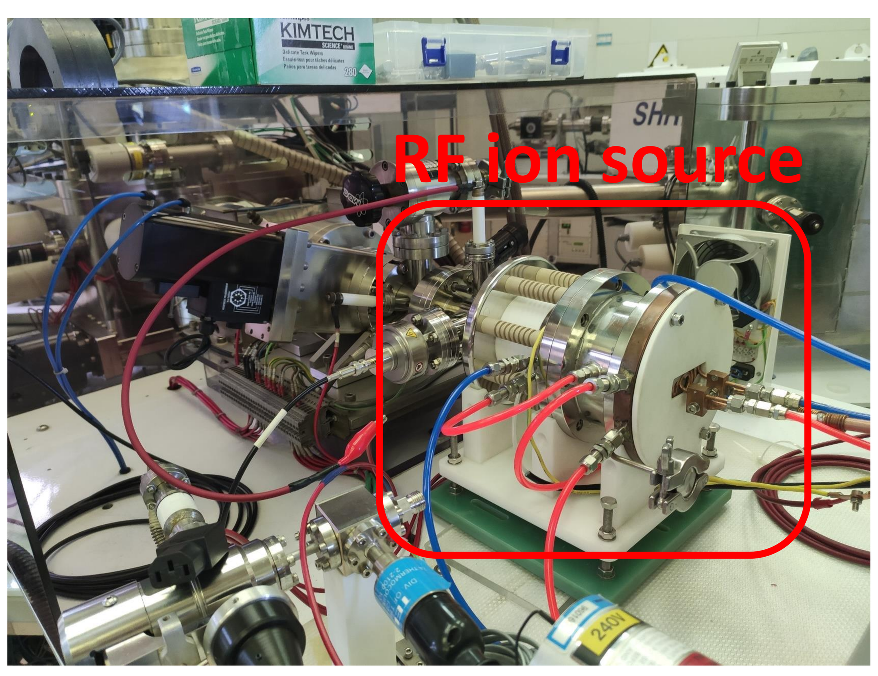
•Comparison of ion source performance

	IMP-RF ion source	duoplasmatron
Ion	O_2^- / O^-	O_2^- / O^-
O_2^-	> 40%	<20%
brightness	1000 $Am^{-2}sr^{-1}$	50 $Am^{-2}sr^{-1}$
Life time	2000 h	50-200 h
Energy spread	21 eV (Preliminary result)	5-20 eV
stability	1%	10%

- Primary goal of RF negative ion source: O_2^- and O^- ions, energy 10-20 keV, ion intensity 10 μA, better lifetime and stability than duoplasmatron.
- Figure 5: Negative oxygen beam intensity with increasing extraction voltage. Electron beam intensity is two orders of magnitude higher.
- Figure 6: The yield of O_2^- and O^- in RF oxygen plasma is analyzed by Wien filter. With the increase of RF power, the proportion of O_2^- in the total extracted beam decreases from 44% to 35%. When RF power increases, electrons in the plasma are heated by the RF field to higher energy, which results in a greater yield of O^- ions.

③Ion source commissioning on SIMS

- SIMS: ASI company-SHRIMP II
- Extraction electrode voltage 2 kV
- Ion energy 10.4 keV
- Ion beam on target: 30 μm, 10 nA
- Stability ~ 2%



④ Summary

A compact external spiral radio-frequency antenna ion source has been tested at IMP. Negative oxygen ion beam with density 15 mA/cm² is extracted when RF power is 260 W. In RF produced plasma, the proportion of O_2^- reaches 44%, and this is an encouraging result for SIMS applications. RF ion source first commissioning on SIMS has been tested, and primary beam on target shows a similar performance with duoplasmatron. In the near future, further studies will be carried out, including match between ion source and beam optics system and optimization of energy spread measurement.

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