Title

GENERATION OF OXYGEN, CARBON AND METALLIC ION BEAMS BY A COMPACT MICROWAVE SOURCE

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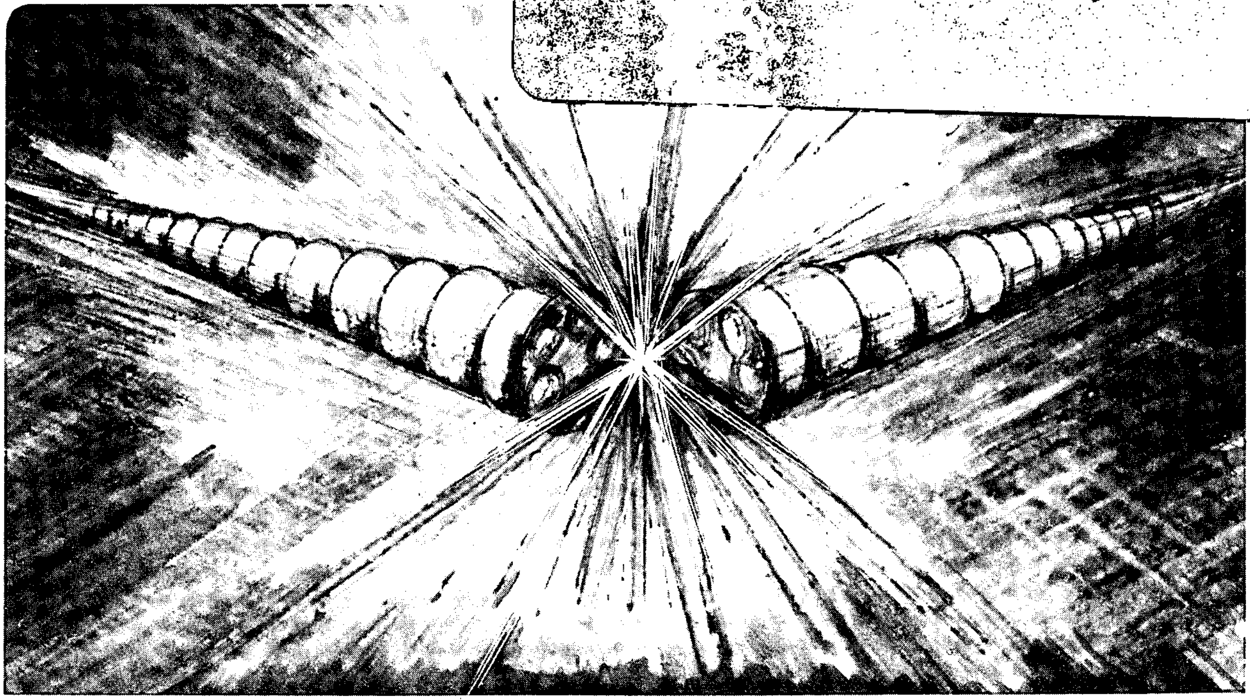

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Generation of Oxygen, Carbon and Metallic Ion Beams by a Compact Microwave Source*

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Abstract

A small microwave ion source fabricated from a quartz tube and enclosed externally by a cavity has been operated with different geometries and for various gases in a cw mode. This source has been used to generate oxygen ion beams with energy as low as 5.5 eV. Beam energy spread has been measured to be less than 1 eV. By installing different metal plates on the front extraction electrode, metallic ion beams such as (Be, Cu, Al, etc.) can be produced. It has also been demonstrated that the source can be used to form steady state beams of volume-produced negative ions such as H^-, Li^- and C^-.

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I. Introduction

In recent years, there has been extensive research and development of ion sources for ion implantation and ion beam etching in the semi-conductor industry. The compact microwave ion source[1] newly developed at Lawrence Berkeley Laboratory is well suited to these applications. This source can be made quite small, and requires only one power supply for the whole source operation. There are no lifetime-limited components such as filaments or cathodes, so stable cw operation is possible for long periods of time even for reactive gases. Since there is no magnetic field in the extraction region, the beam optics for this source should be better than most ECR sources. This microwave source has been operated successfully to generate positive ion beams of gases such as H_2, He, Ne, Ar, and Xe. Experiments conducted at the Los Alamos National Laboratory demonstrated that the ion energy spread for the source is extremely small (< 1 eV).[2] In this paper, details of the arrangement for the production of low energy oxygen ion beams, positive and negative carbon ion beams, and metallic ion beams is presented.

II. Experimental apparatus:

The microwave ion source, as shown in Fig. 1, is fabricated from a quartz tube with one end enclosed by a plasma electrode and a gas inlet at the other end. This tube is formed by joining a section of quartz tube with a 10 mm outside diameter to a section of a larger tube with a 27 mm outside diameter. The smaller tube is enclosed by a microwave cavity operating at a frequency of 2.45 GHz. Microwave power as high as 500 W can be coupled to the cavity via a coaxial cable. Cooling air is directed at the discharge tube through an opening in the body of the cavity. Additional cooling of the source is provided by an air blower. Ionization of the gas in the tube is initiated by a hand-held Tesla coil. A tuning stub and coupling slider are provided in the cavity to properly match the impedance of the discharge to that of the generator. Forward and reflected microwave power are measured using a bi-directional power meter. Ion beam energy and species composition are both determined with the help of a compact magnetic-deflection spectrometer.[3]

III. Experimental Results

(a) Low energy oxygen ion beams

In order to generate low energy positive oxygen ion beams, the source is operated without any externally applied extraction voltage. The positive ions (and some electrons) are self-extracted from the source due to the positive plasma potential. The energy of the beam ions striking a target surface is equal to the difference between the plasma potential and the target potential. If the target is an insulator, then it can be charged to a positive potential and the resultant ion impact energy is reduced. For a conducting target, however, it can be at ground or zero potential and the ion impact energy is equal to the plasma potential.

Initial measurements showed that the oxygen ions were escaping from the source with energies between 15 and 20 eV. In order to obtain a lower ion energy, the source plasma potential was reduced by installing a magnetic filter in front of the plasma electrode. With this filter arrangement, an ion beam energy as low as 5 eV was achieved.[4]

A single 0.8 mm diameter hole was initially employed to extract a positive ion beam from the microwave source. In order to increase the ion flux, a new extractor with 25 0.8 mm-diam holes was fabricated. The resulting beam current was ~ 18 times larger than that of the single aperture and it could be used to irradiate large target areas. To further improve the self-extracted beam current, a 70% transparent tungsten screen of 1 cm-diam was used in place of the 25 small holes. The combination of a magnetic filter and the tungsten screen extraction system produced a nearly gaussian beam profile as shown in Fig. 2 with flux rate > 1×10^{14} $cm^{-2}s^{-1}$ at the lowest beam energy. The distribution of O^+ and O_2^+ ions is about equal.

(b) Production of positive and negative carbon ion beams

C^+ ion beams can be easily generated by this microwave source by using gases such as CO, CO_2, or CH_4. In addition to C^+ ions, the spectrometer output signal shows that positive ions of other radicals such as CO, CO_2, O, O_2 etc are present. A pure C^+ beam can only be obtained after the extracted beam is mass analyzed. Attempts have been made to produce C^- ions by using these gases. However, no C^- ion signal can be detected for different source operating conditions. By replacing the first or plasma electrode of the extractor with a graphite disc together with a negative bias, a large C^- ion signal is observed (Fig. 3). In this arrangement, some carbon atoms are sputtered from the graphite electrode by the background Ar^+ ions. They then react with the plasma electrons to form C^- ions.

(c) Production of metallic ion beams

Different positive metallic ion beams (such as Be, Al or Cu) have been produced in a source arrangement similar to that used for generating C^- beams. In this case, only a portion of the plasma electrode around the extraction aperture is replaced by the target metal which now forms the second electrode of the extraction system. The metal is biased several hundred volts negative with respect to the plasma electrode to allow ion sputtering. The metal atoms removed by sputtering can be ionized by the energetic electrons, and the positive ions formed will fall back into the sheath and are then available for extraction. Production of different metallic ions by this source geometry is in progress. Results of these study will be reported in the near future.

Acknowledgment

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References

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2. E. Chamberlin, Los Alamos National Laboratory (Private communication).
3. K. W. Ehlers, K. N. Leung, and M. D. Williams, Rev. Sci. Instrum. 50, 1031 (1979).
4. S. R. Walther, K. N. Leung, and W. B. Kunkel, Lawrence Berkeley Lab. Report LBL-21376, May (1986).

Figure Captions

1. Schematic diagram of the microwave ion source.
2. Low energy oxygen ion beam profile of the source using a tungsten screen plasma electrode and filter magnets.
3. Spectrometer output signal showing the presence of C^- ions in the beam.

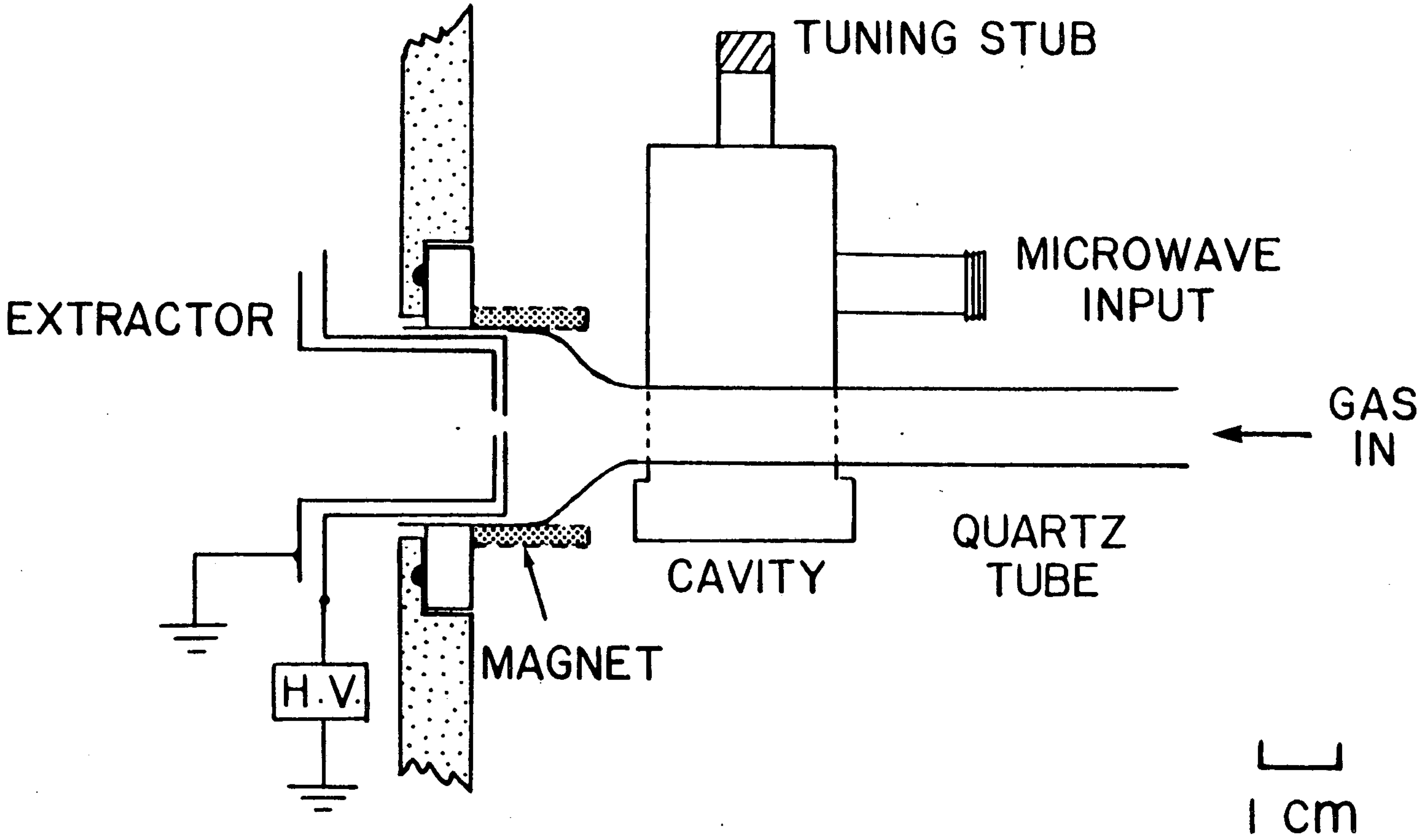

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Fig. 1

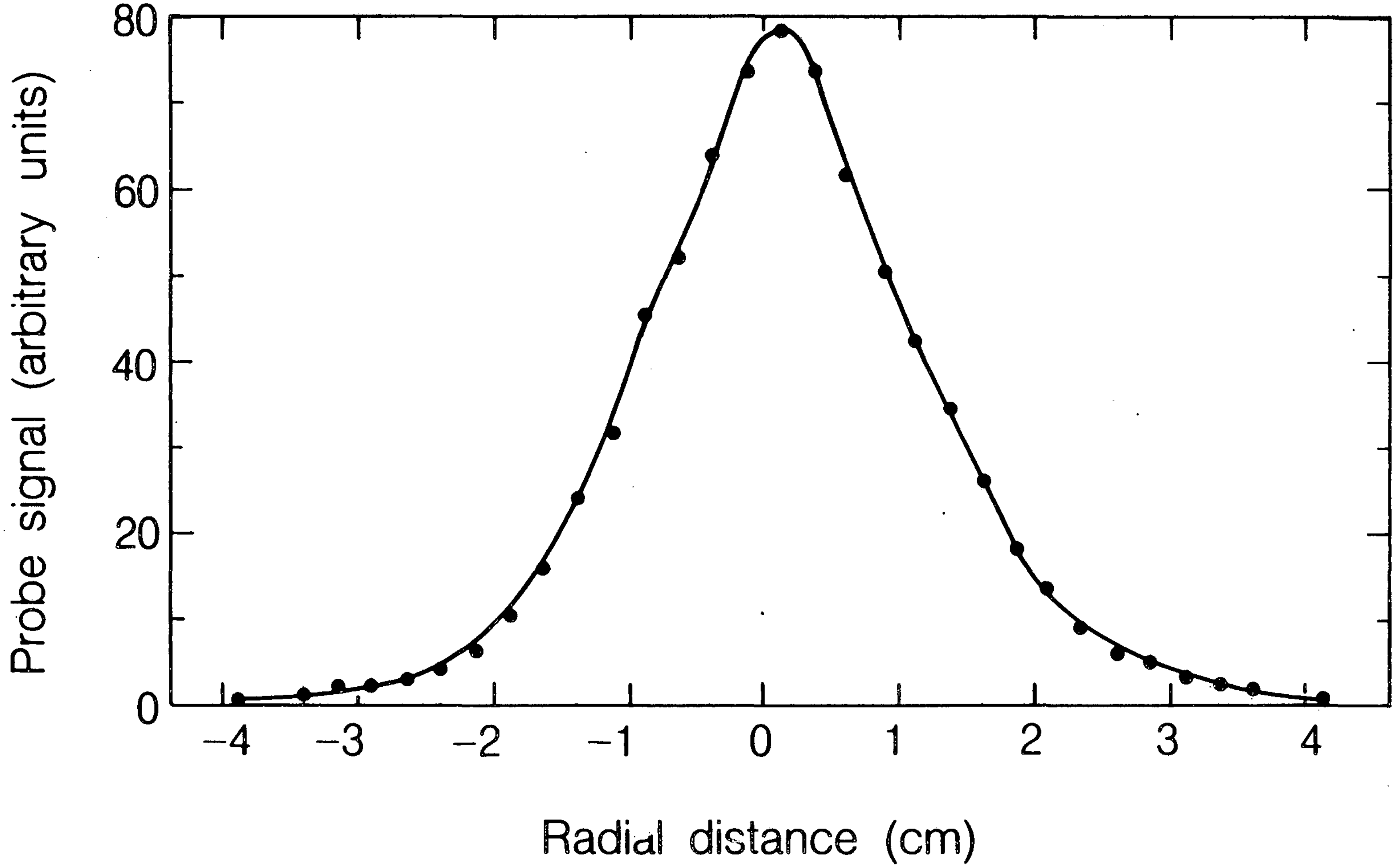

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Fig. 2

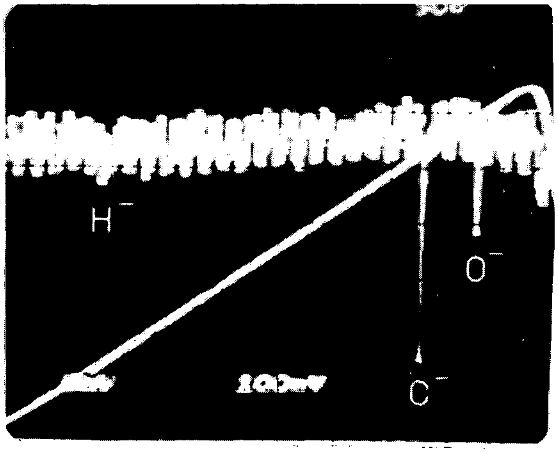

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Fig. 3

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