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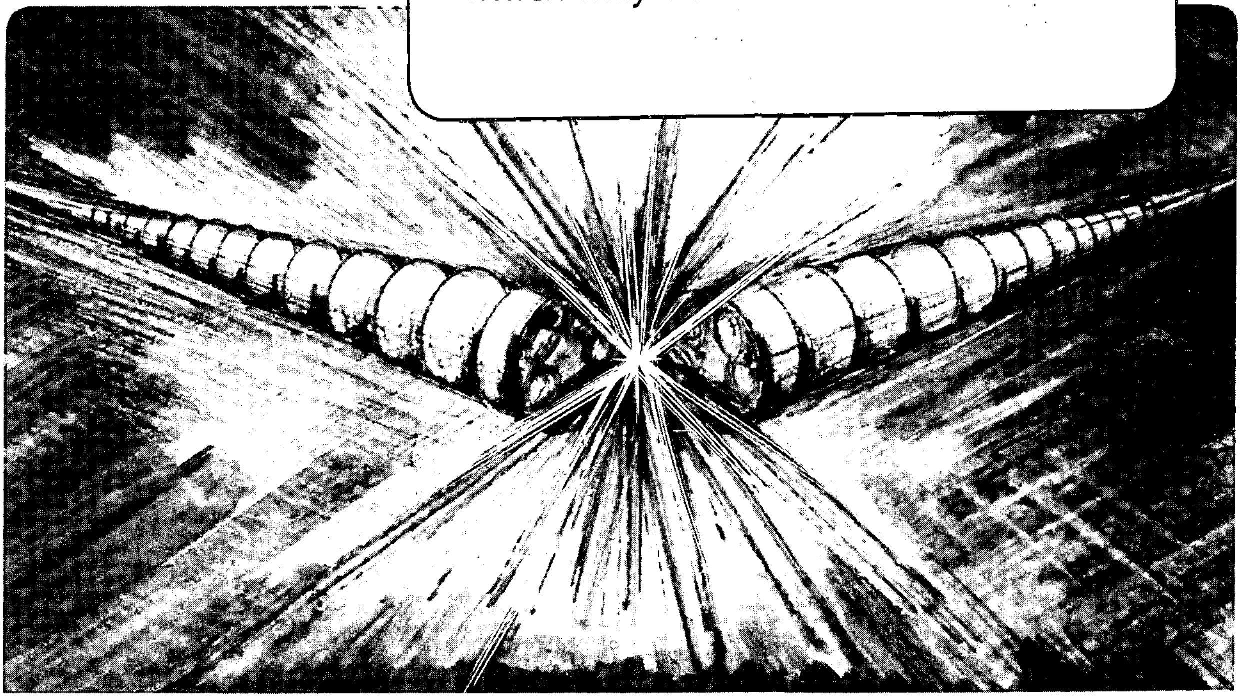

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H^- PRODUCTION IN A SMALL MULTICUSP ION SOURCE WITH ADDITION OF BARIUM*

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Abstract

The effect on H^- production by adding barium to a hydrogen discharge, in a small magnetically filtered multicusp ion source, has been investigated. It is found that the addition of barium can increase the H^- output by a factor of 30. A strong dependence of H^- output on the temperature of the ion source wall has also been observed.

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Sources of H^- and D^- ions are required to generate efficient neutral beams with energies in excess of 150 keV.[1] Previous experiments have shown that addition of cesium to a filtered multicusp ion source can result in large increases in H^- output.[2] H^- current densities exceeding 1 A/cm^2 have been extracted from a multicusp ion source which is seeded with cesium.[3] In order to avoid the problems associated with cesiated ion source operation (voltage breakdown, cesium handling), a substitute material for cesium with a much lower vapor pressure is desirable. Recent work with barium converters has shown that the H^- conversion efficiency of a barium converter is similar to that of a cesium on molybdenum converter.[4,5] In addition, barium has a much lower vapor pressure than cesium.[6] This paper reports experiments on H^- production when the hydrogen plasma in a filtered multicusp ion source is seeded with barium.

The ion source consists of a cylindrical water cooled copper chamber (2.5 cm diameter by 5 cm long) with the open end enclosed by a two grid ion extraction system. A schematic diagram of the ion source is shown in Fig. 1. The source chamber is surrounded externally by 16 columns of ceramic magnets to form a longitudinal line-cusp configuration for primary electron and plasma confinement. The magnet columns on the cylindrical wall are connected at the end flange by two rows of samarium cobalt magnets that are also in a line-cusp configuration. A samarium cobalt magnetic filter[7] near the plane of extraction divides the chamber into an arc discharge and an extraction region. The filter magnets provide a transverse magnetic field (B = 250 gauss at the center) which serves to prevent energetic primary electrons from reaching the extraction region. However, positive ions, negative ions, and low energy electrons can diffuse across the filter into the extraction region to form a plasma.

Inside the source chamber is a cylindrical liner constructed of molybdenum sheet metal (7.6 x 10^{-3} cm thick). During source operation, the liner and the plasma electrode, which is thermally isolated, are heated by the discharge. The temperature of the liner can be monitored with a thermocouple in contact with the outer surface of the liner. Seeding of the source with barium is accomplished by placing a solid sample of barium metal on the liner. The barium evaporates during source operation due to discharge heating of the liner. In this manner, barium can be deposited on all surfaces of the liner and the plasma electrode.

A two-electrode acceleration system is attached to the open end of the chamber. The source and the first (or plasma) electrode of the accelerator are biased negative for negative ion extraction and positive for positive ion extraction. The second electrode is electrically grounded. A plasma is produced by primary electrons emitted by a 0.5-mm-diameter hairpin tungsten filament, which is placed in the magnetic 'field-free' region at the center of the source. The chamber wall, liner and plasma electrode serve as the anode for the discharge.

Located downstream from the second electrode is a compact magnetic deflection spectrometer[8] for measurement of the negative or positive ion species in the extracted beam. For these experiments, the hydrogen pressure in the source is maintained at ~30 mTorr. With the ion source operating steady state at a discharge voltage of 80 V and a discharge current of 0.5 A, the mass spectrometer signal in Fig. 2(a) shows the negative ion species for pure hydrogen operation. It can be seen that H^- is the only negative ion detected in the accelerated beam. Fig. 2(b) shows the ion species in the extracted positive ion beam for pure hydrogen operation. The dominant ion species is H_3^+, with a smaller fraction of H^+. H_2^+ ions are also present in the discharge, but are not resolvable as a peak for this scale.

The extracted positive ion species for the source seeded with barium are detailed in Fig. 2(c). The spectrometer output signal shows the presence of H^+, H_3^+, Ba^{++}, and Ba^+ ions. In this case, the negative ion spectrometer signal shows only H^- ions, but with a much larger amplitude when compared with that in Fig. 2(a). In this measurement, both the H^- and the Ba^+ (also Ba^{++}) signals showed a strong dependence on the temperature of the liner. Fig. 3 is a plot of the H^- and Ba^+ signal amplitude as a function of liner temperature. The baseline value of the H^- signal amplitude for pure hydrogen operation is also displayed in the same figure. The maximum H^- output for the discharge with barium is more than thirty times that for pure hydrogen operation. The maximum H^- output occurs for measured liner temperatures of ~150 °C, which occurs a short period of time after the discharge was turned on. A much higher liner temperature of ~600 °C was obtained for steady state operation. The liner had an apparent thermal time constant of about a minute.

The dependence of the two signals (H^- and Ba^+ ions) on liner temperature is very strong. The Ba^+ ion signal behaves rather predictably, requiring a high liner temperature before barium can be vaporized and enter the plasma. (It should be noted that the dynamic response of the thermocouple used to measure the temperature may be slow because it samples the outside of the liner, not the inside.) The H^- signal is initially ~10 times larger than the baseline value for pure hydrogen operation, and increases rapidly with temperature. At a temperature of ~150 °C, the H^- signal reaches a maximum and then decreases for higher liner temperatures. The H^- output starts to decrease when a significant amount of barium is in the plasma. The effect of barium in the plasma on H^- production is not understood, and these results show that it may reduce the H^- yield. The decrease in H^- output at high liner temperature may also be due to a depletion of barium from the liner surfaces or coating of the liner with tungsten evaporated from the filament. In all cases, the barium seeded discharge produced a significantly larger H^- output than the pure hydrogen discharge. It is also found that the H^- output for pure hydrogen operation is relatively insensitive to liner temperature.

The increase in extracted H^- current, when the discharge is seeded with barium, is very similar to that obtained when the source is seeded with cesium.[2] In that measurement, results showed a factor of ~16 improvement in the H^- output for steady state operation. Steady state operation of the source, with addition of barium and a much hotter liner than that used for cesium, produced approximately a factor of 5 increase in H^- output (see Fig. 3). If the optimum liner temperature and barium coverage can be achieved during steady state operation, it appears that the H^- yield can be substantially improved. In that case, barium may in fact provide an enhancement in H^- output comparable to or even greater than cesium seeded operation. The use of a temperature controllable liner, which does not rely entirely on discharge heating, may enable one to achieve the optimum liner condition and thus the best H^- output current.

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Figure Captions

Figure 1	A schematic drawing of the ion source and mass spectrometer.
Figure 2	Mass spectrometer output signals showing (a) the negative ion species for pure hydrogen operation, (b) the positve ion species for operation with pure hydrogen, and (c) the positive ion species when the source is seeded with barium.
Figure 3	A graph of the H^- and Ba^+ ion output as a function of liner temperature. (The single open circle (O) represents the baseline value of H^- output for pure hydrogen operation.)

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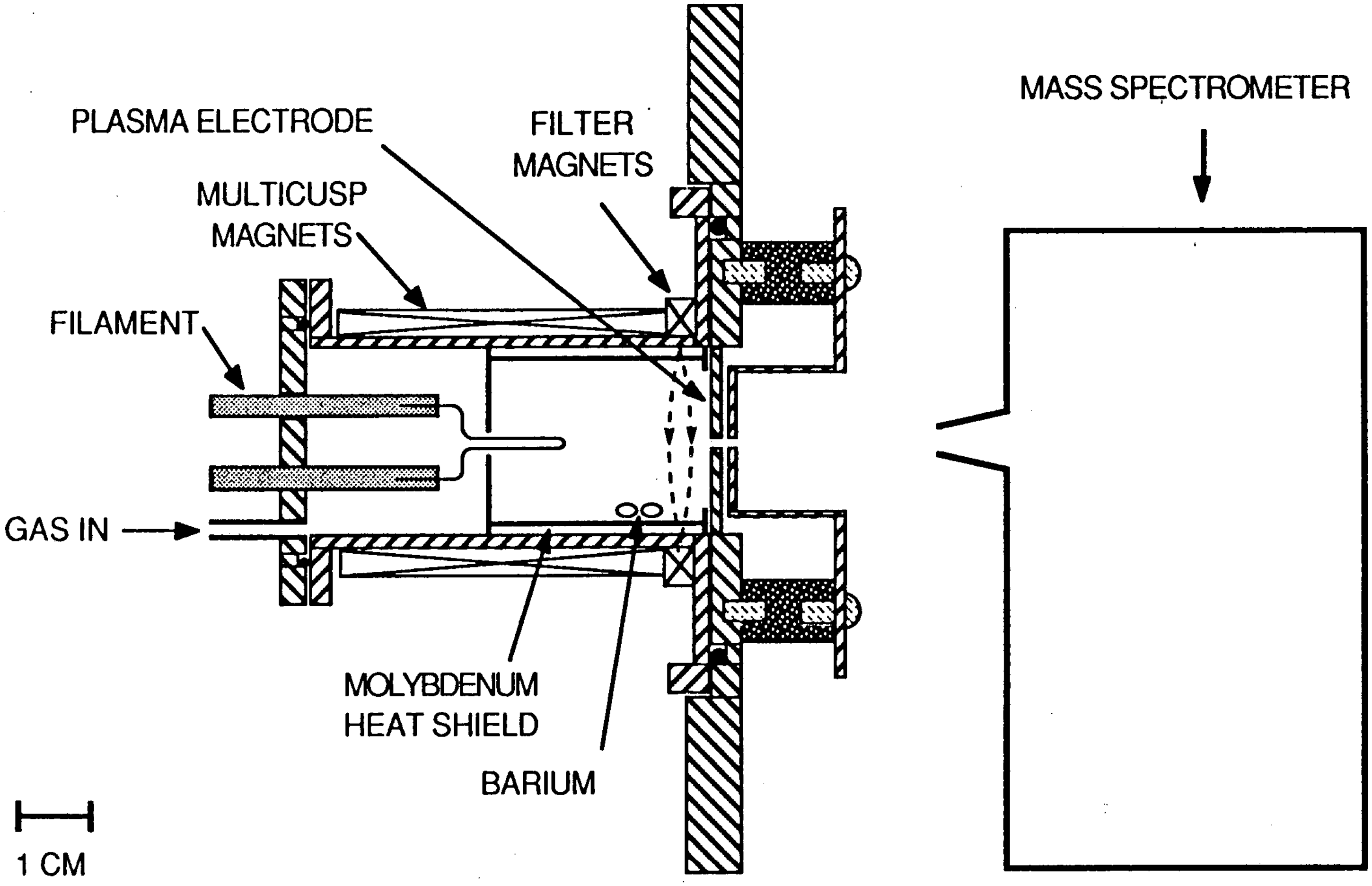
PLASMA ELECTRODE
FILTER MAGNETS
MASS SPECTROMETER
MULTICUSP MAGNETS
FILAMENT
GAS IN
MOLYBDENUM HEAT SHIELD
BARIUM
1 CM

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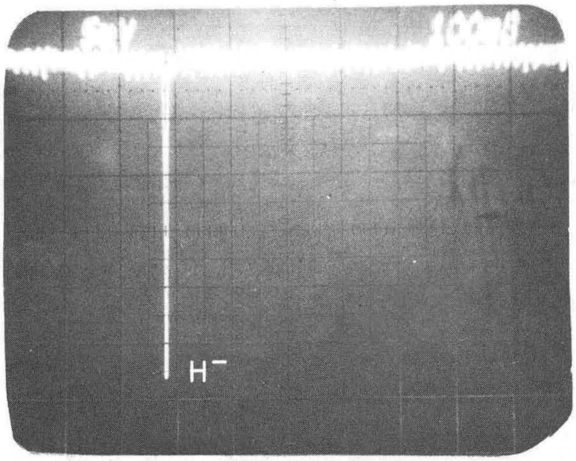
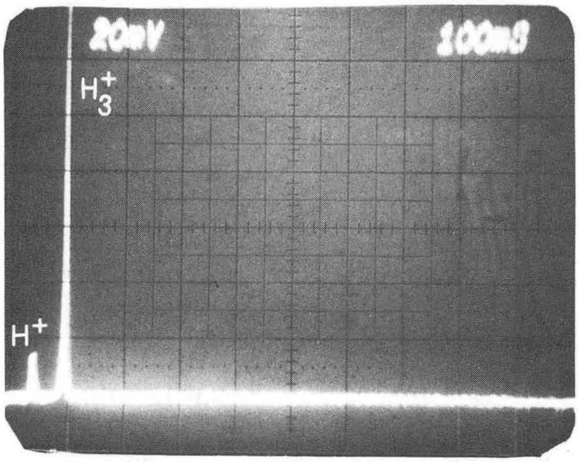


(a)



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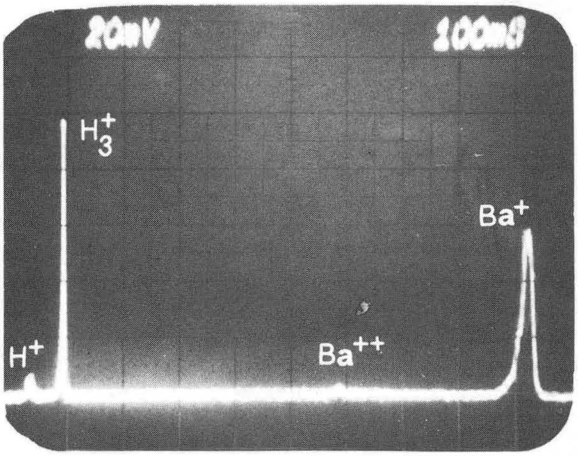

(c)

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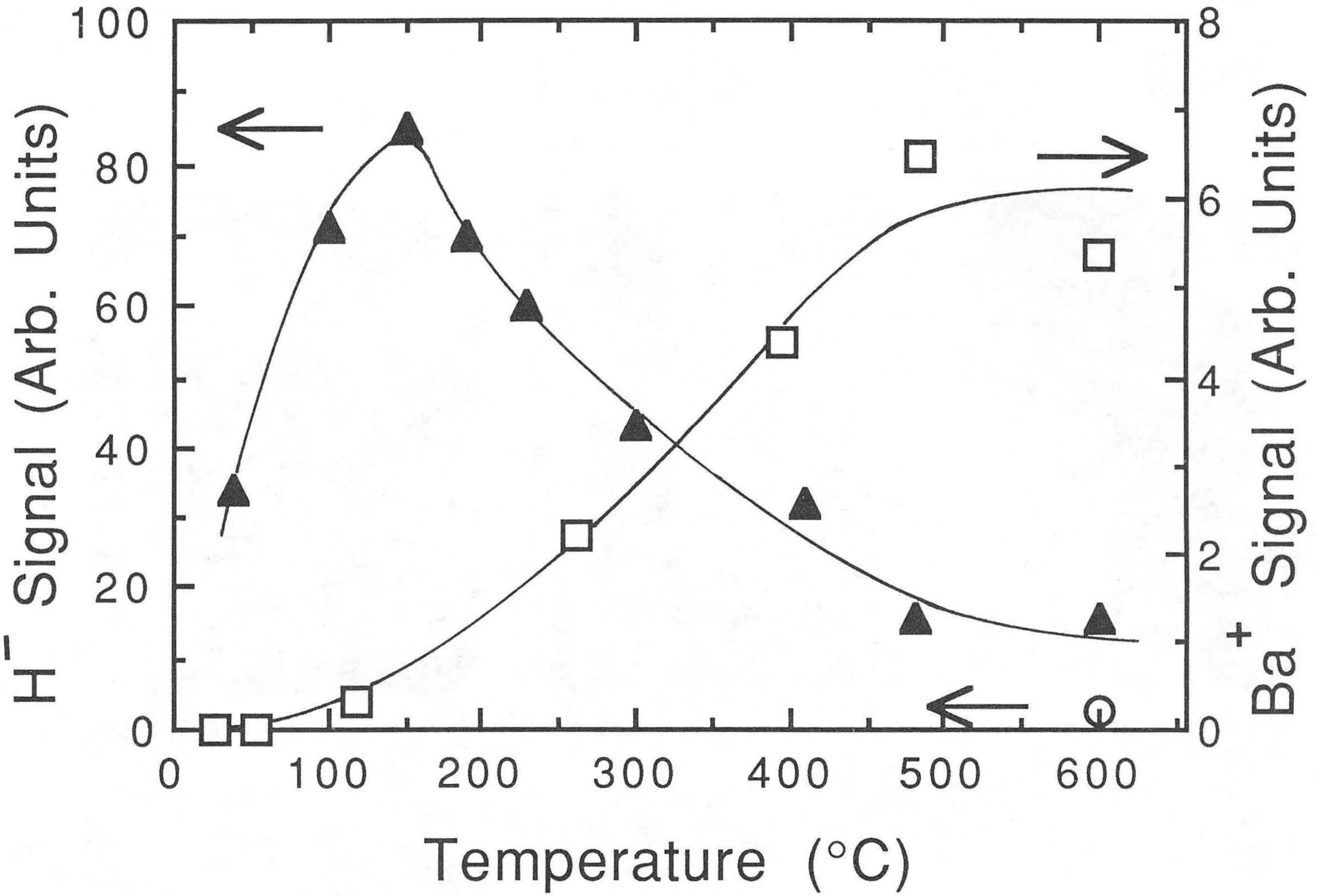
100
80
60
40
20
0
0
100
200
300
400
500
600
8
6
4
2
0
H⁻ Signal (Arb. Units)
Ba⁺ Signal (Arb. Units)
Temperature (°C)

XBL 888-2856