IMPROVED VERSION OF SURFACE PLASMA NEGATIVE ION SOURCE

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Abstract

The best features of two independently developed surface-plasma negative ion sources with separated function (independently controlled plasma generation and negative ion emission), have been combined in an optimized configuration; as a result, we propose to add a new mode of operation that will allow a 50-fold reduction in the negative ion temperature. The process of cesium injection developed for the semiplanotron negative ion source at the Budker Institute of Nuclear Physics (BINP), Novosibirsk [1-6], along with the hot cathode, first anode configuration and neutral gas injection of the ion source development at Oak Ridge National Laboratory (ORNL) [7-8], combines the best features of both for the continuous wave (CW) high-density, low-pressure generation of negative ions. Converter-generated cw negative ion densities of 750 mA/cm^2 are expected from the existing data base. These ions are generated with a temperature of about 7 eV; focusing these ions by a factor of 5 increases the current density to 3500 mA/cm^2 (with some mutual neutralization loss included). The ion temperature becomes 50 eV; however, according to Louville's theorem, the brightness of the beam remains at a value of 100 mA/cm^2 eV (Volume ion sources with a cw current per channel of 100 mA, have a brightness one-third this value.) The configuration of the source geometry and atomic gas control is optimized for maximum charge exchange reduction of the ion temperature by a factor of 50. The configuration involves appropriate shaping of the converter, anode slot, and hot cathode use of a supersonic gas jet of H0, and pumping the jet into the source. Increasing the beam brightness to 1000 mA/cm^2 eV corrects for a factor of four loss in recovery of charge-exchanged ions. The concept proposed here results in a net cw brightness increase of 10, which is about 30-times greater than that otherwise available.

1 INTRODUCTION

Many modifications of surface-plasma sources (SPS), with cesium catalysis of negative ion generation, have been constructed, tested, and optimized for various applications since 1971. [1-8]

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2 APPROACHES TO THE IDEAL SURFACE PLASMA SOURCE-A MODIFIED SITEX CONFIGURATION

Understanding the main processes and problems of negative-ion formation in surface plasma sources with cesium catalysis allows us to start the development of an ideal SPS. An ideal SPS with cesium catalysis would have a highly ionized plasma with very low gas density. The plasma must be dense enough to supply the required high positive ion current density on the converter-emitter surface, but thin enough for transparent transport of negative ions into the accelerator. An independently biased converter-emitter must be used for additional optimization of negative ion generation in the surface-plasma interaction. The careful optimized distribution of catalyst (cesium) on the emission surface must be developed. The emission surface must have a special curvature for a good focusing of negative ions moving across the magnetic field lines to the emission hole of the extraction system. In this variant of SPS, it is possible to have negative ion beam production with high emission current density and high gas efficiency, but the transverse temperature of the ions emitted from the surface is quite high, and this reduces the brightness of the negative ion beam. For additional improvement of the beam brightness, it is necessary to cool the very dense negative ion flux.

The basic operating principles and the construction features of the modified SITEX SPS are shown in the figures.

In using the Penning plasma discharge, it is helpful to have the plasma column with a high ion density near the emitter surface and in a thin plasma sheet to minimize the negative-ion destruction. This is very important for high current density negative ion production. The negative ions focused toward the emission slit can be extracted by the extraction system formed in the beam and accelerated for future applications. This configuration of plasma generator and surface-plasma emitter is helpful in combining the high-current density from the emitter with the large surface of the emitter (R ~ 1 cm) for convenient dc operation. We can separately optimize plasma generation and the conditions for the surface plasma production of negative ions. However, the energy spread of negative ions emitted from the emitter surface is quite high-as is the momentum spread.

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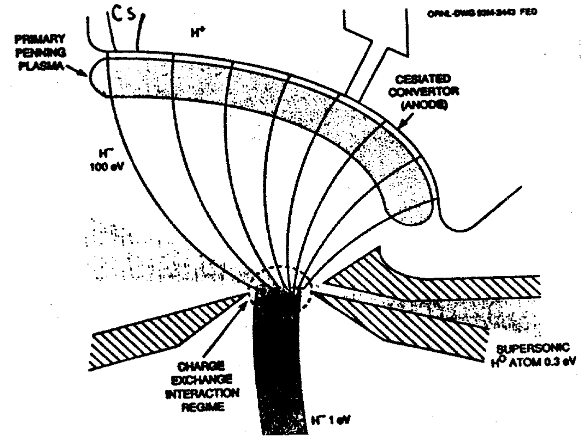

Fig. 1 Elevated view of hydrogen negative ion source showing connector, cesium feed, Penning discharge region, supersonic atomic jet, accelerator, primary, and negative ions formed at the connector and secondary charge exchange negative ions.

The negative ion flux can be cooled by conversion into cold-negative ions in a resonance charge exchange process with cold atoms. The cross section of resonance charge exchange for H- with an energy of 0.1 keV is 5×10^{-15} cm^2 and for effective cooling of H^- flux in volume on a mm scale near the emission slit, it is necessary to have an H^0 density of > 2×10^{-15} cm^2. A high-gas density throughout the 1-cm gaps between the emitter surface and the emission slit can destroy the negative ions.

Charge exchange note: A major development in this concept is the utilization of charge exchange "temperature reduction" of the negative hydrogen ions. This process relies on the cross section of charge exchange. A convenient and much referred to source on charge exchange is the "Red Book" which has posted editions in 1977 (Ref. 9) and 1990 (Ref 10). The experimental work quoted for energies below 1kV is from Hummer et. al., (Ref. 11). However, the 1977 edition erred in the scaling of the Hummer (Ref. 10) measurements. For the energies of 100 V that are of interest here, the error is a factor of 8 too small (1.5×10^{-15} vs. the real values of 1.0×10^{-14}). In the 1990 edition, the error was corrected without comment. This inconsistency was discovered by accident by one of the authors. From 1977 to 1990, this error could have inhibited negative ion source development.

A practical solution to this problem is to use the supersonic atom flow with high-local density of H^0 near the emission slit and to decrease gas density in all other volumes of its discharge chambers. A possible configuration of this high density atomic flux generator is shown in Fig. 2.

It is convenient to use the RF dissociator and a flat nozzle located near the emission slit. The expanded atomic flux must be pumped at high speed. For testing, it is convenient to use the pulse regime of dissociator operation.

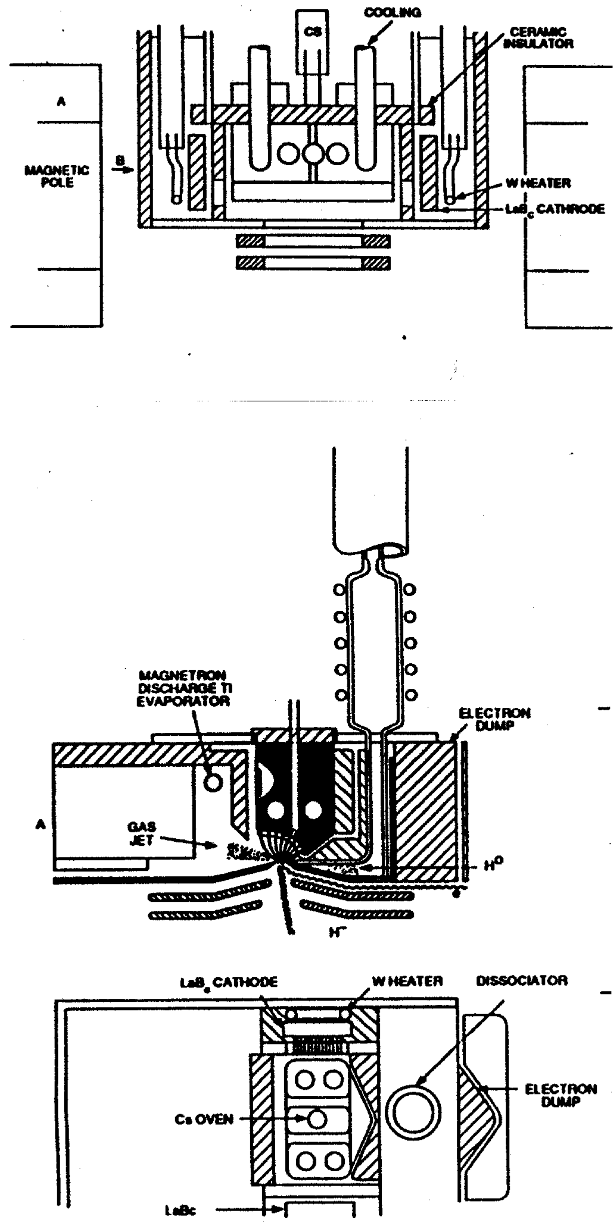

Fig. 2 Basic operating principles and the construction features of the modified SITEX SPS.

3 SUMMARY AND CONCLUSIONS

We have combined the best features of two independently developed and independently controlled surface-production negative-ion sources and added a new mode of operation that causes a 50-fold reduction in the negative ion temperature. The features of cesium injection, magnetron operation of the ion source development at INP, Novosibirsk, with the features of hot-cathode and first-anode configuration and neutral gas injection of the ion source development at ORNL, combine the best features of both; namely, the cw high density low-pressure generation of negative ions. Converter generated cw negative ion densities of 750 mA/cm^2 are expected from the extant mutual data base. These ions are generated with a temperature of about 7 eV; focusing these ions by a factor of 5 increases the current density to 3500 mA/cm^2 (some mutual neutralization loss). The ion temperature becomes 50 eV; however, due to Louville's theorem, the brightness of the beam remains at a constant value of 100 mA/cm^2 eV. (Volume ion sources with a cw current per channel in excess of 100mA have a brightness one-third this value.) The configuration of the source geometry and atomic gas control is optimized for maximum charge exchange reduction of the ion temperature by a factor of 50. The configuration involves appropriate shaping of the converter/anode slot and hot cathode, use of a supersonic gas jet of H^0 , pumping the jet in the source, and increasing the beam brightness to 1000 mA/cm^2 eV (correcting a factor of four loss in recovery of charge exchanged ions). Thus, the concept proposed here achieves a net cw brightness increase of 10, which is about 30-times greater than otherwise available.

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