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Directed cesium deposition into a large volume negative-ion source

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A compact, safe system for directed cesium deposition into large volume sources is described. It consists of a small oven mounted on a feedthrough, which permits one to rotate and move the oven across the discharge chamber length or to remove it from the vacuum box to reload the oven. Special industrial pellets containing the cesium compound (30% of cesium chromate +70% titanium) were used for a pure cesium release. The pellets are insensitive to pollution by air and can provide the cesium release during several cycles of heating and cooling in long-term experiments. There was no ''poisoning'' impurities degassing (oxygen, water) during the standard oven operation. The Cs system was reliably operated for cesium deposition in multiampere negative-ion source experiments. © *1996 American Institute of Physics.* [S0034-6748(96)02902-5]

I. INTRODUCTION

Cesium is a good electron donor, and is widely used in various (charge-exchange, surface, surface-plasma, multicusp) negative-ion sources for negative-ion (NI) production enhancement. A small addition of cesium into a discharge produces a multiple increase of extracted NI yield, a decrease of the accompanying electron flux extraction, and permits one to reduce the operation pressure of hydrogen in the discharge.[1–3] A thin optimal Cs coverage of electrodes is necessary for the operation of surface-plasma sources (SPS) and large multicusp sources (LMS), and an adequate cesium feeding system must deliver a small amount of cesium and maintain the cesium coverage on the electrode surfaces.

Several methods were developed for Cs deposition into gas-discharged NI sources. The direct placement of Cs compounds into the cathode cavity was tested in the early versions of SPS,[1] and a few independently heated ovens were used for a spatial distribution of Cs feed over the gas-discharge gap of the large SPS.[4] The further redistribution of injected Cs over the large SPS electrode surface and a uniform activation of the surface was provided due to source conditioning by discharge (by plasma energetic particles bombardment).[4] A high rate of cesium ionization by a dense SPS plasma and cesium ions trapped by SPS discharge and extraction fields provides a small cesium consumption in the SPS (about 1 mg/h for 1 A NI beam production).[5]

A cesium feed from the external oven with metallic cesium was used for cesium injection to LMS.[3,6] A valve and a long connecting hot tube were used, and a local injection of cesium through a single Cs inlet to the source volume was produced. An additional heating of electrodes and a long (several hours) dead time are needed for Cs redistribution over the LMS surfaces and for NI production improvement in this case. A nonuniform Cs coverage with a multilayer deposition of the most cesium in the vicinity of the cesium inlet opening was recorded,[6] and an increased consumption of cesium was obtained in the LMS with the external cesium injection.

A compact, safe system for directed cesium deposition into large sources is described below. The directed flux of cesium atoms is ejected from the internal oven by the heating of special pellets. A distributed cesium injection onto the source surfaces is obtained with the moving and rotation of the oven during the cesium release. The described Cs system was reliably operated for cesium deposition in multiampere negative ion source (MANTIS) experiments.[7]

II. CESIUM SYSTEM

A cesium deposition system consists of a small detachable oven mounted on the feedthrough, which permits one to rotate and move the oven across the discharge chamber length or to remove it from the vacuum box to reload the oven (Fig. 1). A detachable oven unit cross section and its photo are shown in Figs. 2 and 3. It consists of a hollow body, of a cylindrical heater with an external shield, and a sealed plug with a cylindrical outlet (Fig. 2). The oven length is about 8 cm, its diameter is 1.5 cm. Cesiated pellets are loaded into the cylindrical hollow of the oven body. The cesium, released during the pellets heating, was transported through the plug cylindrical channel (diameter 2 mm, total length 3.5 cm) and an outlet opening in the plug side. The plug construction provides an inkpotlike labyrinth for stop-

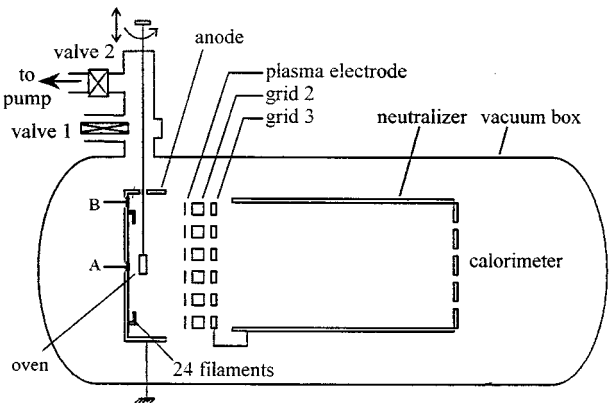

FIG. 1. Layout of MANTIS experiment and cesium oven position.

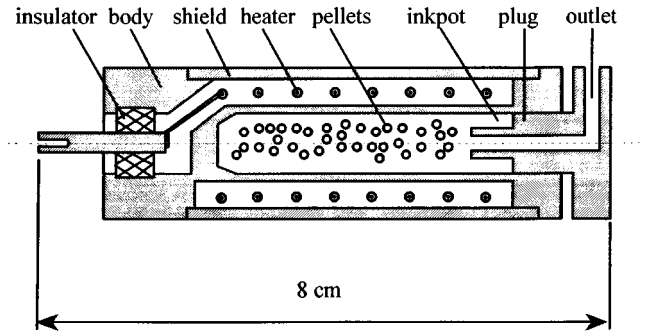

FIG. 2. Cross section of cesium oven.

ping the liquid cesium. The body and plug are made of a stainless steel, the heater of tantalum, and a thermal shield of molybdenum.

Special pellets containing a mixture of cesium chromate (30%) and titanium (70%) were used for a cesium release. These pellets are industrially produced and are used for cesium deposition in industrial electronics. The pellets have low sensitivity to pollution by air and can be stored or reloaded under atmospheric pressure. They can provide the controlled cesium release during several cycles of heating and cooling in long-term experiments. A new pellet (with a diameter of 2.4 mm, and a thickness of 0.8 mm) contains about 1 mg of cesium and produces the cesium release at a rate of about 10^{-5} mg/min (at temperature of 800 K) and at a rate of about 3×10^{-3} mg/min at temperature 1100 K. The dependence of the cesium release rate on the pellet temperature, measured with the cesium atom detector,[5] is shown in Fig. 4. The release rate is proportional to the quantity of cesium chromate, and it gradually decreases (''exponential decay'') with the cesium consumption. The high temperature ''threshold'' of cesium release from the compound permits one to easily control the cesium yield by changing the oven heater power. The described compact oven operates with a 8 V×5 A power supply. The oven temperature is controlled by a thermocouple or by heater resistivity (V/I).

The geometry of a cesium stream, ejected from the oven outlet, was determined by measurements of the deposited cesium spot sizes and by separate measurements of cesium plasma light emission. The hollow cathode discharge with

FIG. 3. Photo of oven and cesium pellets.

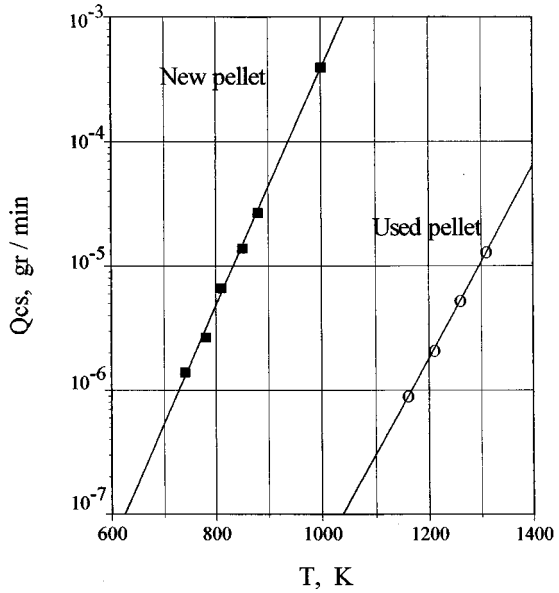

FIG. 4. Cesium release rate from a new (a) and used (b) pellet vs pellet temperature.

the oven biased negatively with respect to the additional anode was ignited for an ejected cesium ionization and for the light emission measurements. It was found that a cesium stream with a total divergence of about 90° is produced at an oven temperature of 1000–1100 K.

The total cesium yield from the oven can certainly be limited by the amount of loaded pellets, and was varied in the range from 5 to 200 mg (for the compact oven used). No accompanying poisoning impurity degassing (oxygen, water) was observed during oven heating and cesium release under standard oven operation.

III. CESIUM DEPOSITION INTO MANTIS

The MANTIS device was developed for a pure volume NI production in a large volume multicusp discharge. Its discharge chamber is immersed a large vacuum box at ground potential. The MANTIS anode is made of copper and has a shallow box form with dimensions of 790 mm height by 490 mm width by 227 mm depth. An insulated plasma electrode (PE) having 288 apertures for NI extraction, separates the discharge area from the extraction region. It is believed that cesium coverage of the PE surface is responsible for the NI enhancement in a LMS.[3] The initial goal was to deposit cesium onto an internal PE surface. The oven was placed into a MANTIS discharge box through the small opening in the anode top with the help of a long feedthrough ''stick'' (Fig. 1).

The direction and area of cesium deposition was changed by stick moving and rotation along the source vertical axis. The localized cesium deposition to the small area (about 10 cm in diameter) of the anode backwall was obtained with the oven outlet oriented toward the anode back, while about 0.1 m^2 area of the anode and PE walls was deposited by cesium with the ''grazing'' injection, when the oven outlet was oriented perpendicular to the Fig. 1 plane.

Oven rotation and the 45 cm shift along the vertical axis during grazing injection permits one to produce the directed cesium deposition onto about 60% of the anode and PE surfaces. The initial cesium deposition into MANTIS was usually produced with the oven cesium outlet oriented toward the anode back or sidewalls to prevent the direct injection of cesium into the extraction–acceleration channels. The local cesium deposition onto the PE surface with masked emission apertures was also tested.

The double-valve ''vacuum lock'' was used for removing the oven from the MANTIS vacuum box. It provides a Cs tablet reloading during long-term operation without introducing an atmosphere (air or inert gas) into the source volume and to have no source deconditioning. The Cs deposition into MANTIS was usually made under vacuum conditions ($2–4\times10^{-5}$ Pa) during a 30–50 min injection pause between the discharge pulses. Cesium deposition *in situ* during the discharge pulse with the oven immersed in 10 cm of plasma was also tested. The thermal shielding of the oven and the high temperature of the cesium release from the compound ($>$600 K) permits one to produce a controlled cesium feed in this case as well.

The amount of injected cesium was varied with oven temperature and heating interval change, and 0.1–50 mg cesium portions were usually injected. A conditioning of MANTIS surfaces by deuterium (hydrogen) discharges was usually made before cesium deposition. The deposition was usually produced onto part of the water-cooled surfaces of the anode and PE, while the cesium transport to other MANTIS parts occurred due to cesium diffusion, thermal desorption, and sputtering by discharge.

The local 5 mg cesium deposition onto the central or upper part of the anode backwall (A,B in Fig. 1) produces about 30–50% enhancement of H^- yield after about 2 h (10 discharge pulses) of ''conditioning'' and of cesium redistribution over the larger surface, while the 30 mg cesium deposition onto zones A, B, or the PE top produced a faster NI yield increase.

A distributed cesium deposition onto about 0.5 m^2 of PE and anode surfaces (about 30% of the MANTIS discharge box internal surfaces) was produced with the oven outlet at $\pm90°$ with respect to the anode backwall normal and with the oven shifting by 20 cm along the vertical axis. The distributed deposition of 30 mg of cesium onto this surface produced the instant NI yield enhancement.[7]

An oven load with 200 pellets was usually used for 2–3 cycles of cesium injection experiments. It was enough for a long-term (a few months) MANTIS operation without oven reloading. The deposited cesium produced an effect on NI yield even after several weeks of stops with the introduction of air. An atmosphere of gaseous nitrogen was introduced into the MANTIS volume before its evacuation to air.

The visual examination and the washing away of cesium, accumulated on the anode and plasma electrode, was regularly made after several cycles of cesium injection. The injected cesium distributed over most parts of the MANTIS water-cooled internal walls was detected combined into cesium hydroxide. Most of the injected cesium was accumulated in the ''wet brown spot'' in zone A or B if the localized 30–100 mg cesium deposition onto zone A or B was used, while the rest of the cesium was distributed over the whole area of the MANTIS internal surfaces. A more uniform distribution of cesium compound traces was detected in the case of 30–100 mg grazing injection with oven moving and rotation. The cesium deposited in the cathode filament zone is covered by a tungsten, sputtered from the cathode.

Traces of cesium were detected in the apertures of the extractor–accelerator electrodes. This cesium coverage of extractor channels can improve the transmission of NI through the extractor–accelerator system; namely NI and fast atoms having a grazing incident to the cesiated channel walls are effectively converted into NI and are returned to the beam. It was found that several percent of cesium was transported through the extraction–acceleration channels and condensed on the coldest parts of the neutralization box.

IV. CONCLUSIONS

The described system of internal cesium deposition operates safely and reliably. It produces controlled small directed amounts of cesium and provides a necessary thin initial cesium deposition onto large volume ion source surfaces. The oven thermal shield supplies the controlled cesium injection *in situ* during discharge operation.

It seems promising to use the directed deposition of cesium ions onto surfaces for producing more stable, well-determined cesium coverage of LMS surfaces. The described system can be converted to a cesium ion gun with a hollow cathode cesium discharge, produced by oven biasing with respect to an additional electrode. The cesium hollow cathodes can also be effectively used for an intense primary electron emission and for a pure (without pollution by sputtered tungsten) cesium deposition into LMS.

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