PREPRINT UCRL- 79705

CONF-771029--103

Lawrence Livermore Laboratory

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October 20, 1977

This paper was prepared for inclusion in the Proceedings of Seventh Symposium on Engineering Problems of Fusion Research, Knoxville, Tennessee, October 25-28, 1977.

A LONG-LIFE CATHODE FOR THE BERKELEY-TYPE ION SOURCE*

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Summary

Preliminary experiments indicate that a hollow cathode, made from impregnated tungsten emitters, can be adapted for the Lawrence Berkeley Laboratory(LBL)/Lawrence Livermore Laboratory (LLL) ion source. Such cathodes could be the basis of a long life, continuously operated positive-ion source.

Advantages of Hollow Cathodes

This is a preliminary report on an investigation of hollow cathodes made from impregnated tungsten emitters[1] in hydrogen. These cathodes are being considered as a future replacement for the tungsten hairpin filaments used in a version of the LBL/LLL ion source.[2,3] Although considerable effort is required to develop an effective source from such cathodes, our investigations indicate that it can be done.

In contrast to tungsten hairpins, which have an operating life of less than six hours, impregnated tungsten emitters can deliver several A/cm² of electrons for tens of thousands of hours. Reported emitter temperature, current density, and life in vacuum are shown[1] in Fig. 1. References in the literature indicate that comparable performance and life should be expected in a hydrogen environment.[4,5,6]

Aside from enhanced life, there are other advantages to be gained from these cathodes. They are indirectly heated, so that any interaction between heater current and emitted current is avoided. The hollow cathode operates at a low temperature, below 1100°C, delivering electrons out of the "hollow" at a current density equal to that of tungsten hairpins. Finally, compared with other types of emitters, "impregnated" tungsten requires little activation, gives off little gas, is not subject to degradation by ion bombardment, and can be repeatedly exposed to air.

Cathode Location and Performance

Our original intention was to house the cathode in the same location as the hairpin filaments. However, we found satisfactory performance of the hollow cathode required hydrogen pressures of about 10^{-1} Torr. Because the arc chamber must be at 10^{-2} Torr, the cathode had to be located in a separate chamber at an ambient pressure suitable for best emission.

Bell Jar experiments, as shown in Fig. 2, are now being conducted to optimize the geometry and get the best cathode performance. Two emitters, 4 x 4 x 0.05 cm, are mounted face-to-face. They are heated by tungsten heaters passing in and out of a series of alumina insulating rods. Below the cathode is an auxiliary electrode with a 4 x 1 cm slot that separates the cathode chamber from the arc chamber, while a cylindrical anode is mounted in the arc chamber.

To ignite the discharge, the auxiliary electrode is brought up to the anode potential (about 70 V in current experiments). Subsequently, it is left floating. The discharge glows between the two emitter faces, becoming intense in the region of the slot and more diffuse around the anode. To date we have drawn over 25 A through the 4-cm² slot for short intervals, but we expect to get as much as 100 A in the near future.

The cathode's performance in an ion source can be appreciated by considering Fig. 3. With emitter height H and an emission current density J_E, the emitted current density per unit length will be

$$I/L = 2 J_E H .$$

Thus, an emitter height of 4 cm and an emitted current density of 3 A/cm² will result in I/L equal to 24 A/cm². The corresponding gas load per unit length flowing through a slot of width W, caused by the pressure difference between the 10^{-1} Torr in the cathode chamber and the 10^{-2} Torr in the arc chamber, is

$$Q/L = 3.64 (T/M)^{1/2} W \Delta P .$$

Assuming T = 1000 K, M = 4 for the deuterium gas, W = 0.5 cm, and $\Delta P = 10^{-1}$ Torr,

$$Q/L = 3 T \ell s^{-1}/cm .$$

The operating source is shown in Fig. 4. If each of the two parallel slots were 50-cm long, the cathode could support an arc current of 2400 A. The pumping load at the periphery of the arc chamber would be 300 $T \ell s^{-1}$ at a pressure of 10^{-2} Torr. If the slot width can be reduced, the pump load will be reduced. An additional mechanical pump will be required, nevertheless. As shown in the diagram, the periphery of the arc chamber will be separated from the pump duct by a screen or by a sequence of magnets to form a Mackenzie picket fence around the arc chamber.

Things to Come

In subsequent Bell Jar experiments, we expect to increase the output current of the cathodes, as previously stated. In addition, we intend to reduce the width of the slot in the auxiliary electrode. However, a long life cathode is only part of an ion source. To make a useful source, a suitable geometry must be found to introduce the electrons into the arc chamber in a way that will produce a uniform ion density over the surface of grid #1.

References

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* Work performed under the auspices of the U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

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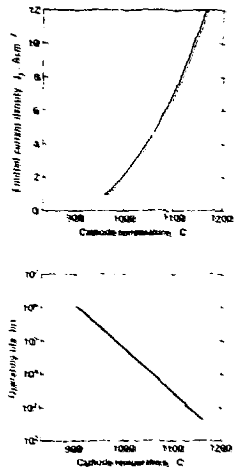
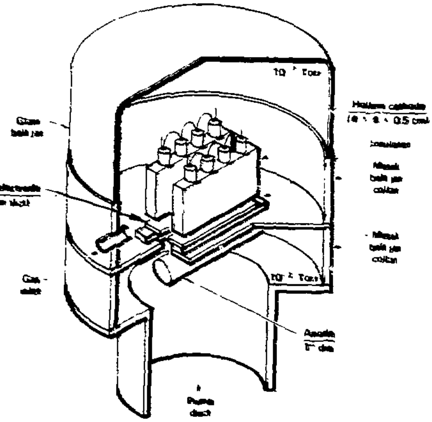


Tungsten dispenser cathode performance (in vacuum)
Fig. 1



Preliminary bell jar experiment to verify hollow cathode performance
Fig. 2

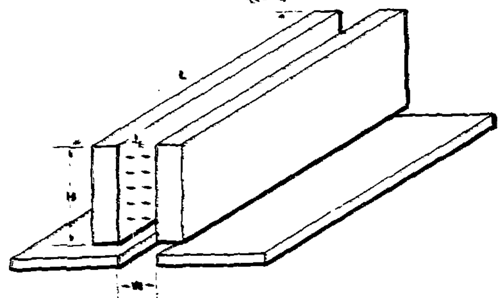


Fig. 3 Cathode performance

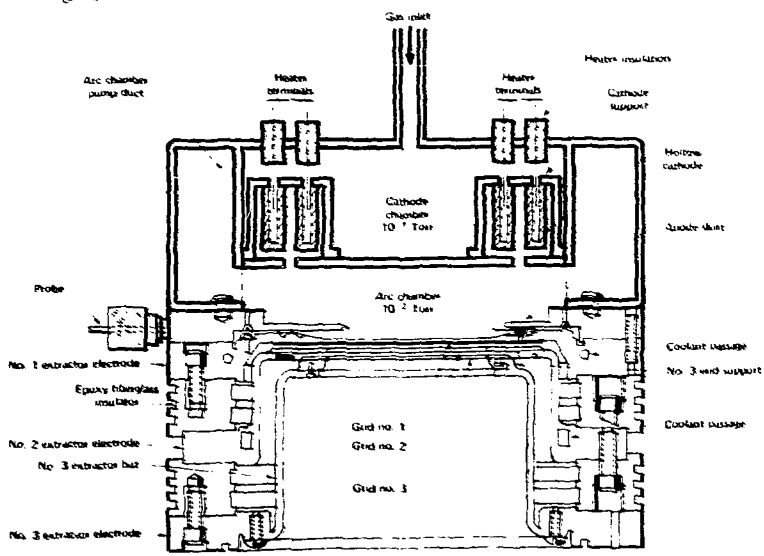


Fig. 4 Schematic design-long life Berkeley type ion source