MULTI-AMPERE METAL ION SOURCE

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Abstract.

A new embodiment of MEVVA (metal vapor vacuum arc) ion source has been constructed with which pulsed metal ion beams of current in the range 1 - 10 Amperes can be produced. The source efficiency (ratio of beam current to arc current) has been increased and the ion beam current raised by an order of magnitude, by allowing the plasma to expand to large diameter and forming the beam with a set of large area extractor grids. Here we describe this new version of the source and outline some very preliminary results.

Introduction

In the MEVVA ion source, a metal vapor vacuum arc discharge is used for plasma formation. This kind of ion source has been developed at LBL for particle accelerator injection and for ion implantation, and several different embodiments have been described in the literature [1-4]. Beam extraction voltage is up to 100 kV, and the pulsed ion beam current has in previous versions of the source been typically a few hundred milliamperes and up to a maximum of about 1 Ampere. Beams of a wide range of ion species have been produced, including Li, C, Mg, Al, Si, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Y, Zr, Nb, Mo, Rh, Pd, Ag, In, Sn, Gd, Ho, Hf, Ta, W, Ir, Pt, Au, Pb, Th, U.

For use for metallurgical ion implantation, there is need for the time-averaged beam current to be virtually as high as possible. We have designed and fabricated an embodiment of MEVVA source in which the plasma generated by the vacuum arc is utilized much more efficiently than in past versions, and from which a pulsed beam current in the Ampere range can be extracted. This source is described, and first results presented, in the following.

Description of the Source

The metal vapor vacuum arc is a prolific generator of metal plasma. So much so, that in earlier versions of MEVVA ion source it has been necessary to limit the plasma presented to the extractor. Ie, in order to form a directed ion beam from a plasma by means of a set of extractor grids, the plasma density at the extractor must not be too high, or else the beam will be of poor quality and/or the grids will break down (plasma between the grids will cause electrical breakdown between them). Thus the geometry of the sources in the region between the arc, where the plasma is formed, and the extractor, where the beam is formed, has been such as to allow a considerable loss of plasma.

It has been shown in prior work that by more efficiently utilizing the plasma that is formed in the MEVVA, a beam of over 10 Amperes could be obtained - and this without any increase in the arc current drive [5]. This was demonstrated by applying a magnetic field of up to 200 Gauss so as to effectively duct all of the plasma that is created at the cathode to the extractor (or collector plate, for these measurements). Results of such a measurement, performed using a slightly modified MEVVA II ion source, are shown in Figure 1, where the ion saturation current ('plasma ion current') collected by a biased collector plate is plotted as a function of the applied axial magnetic field strength. For these measurements the arc current was held constant at a value I_{arc} = 270 Amperes, and the 'efficiency factor', I_{beam}/I_{arc}, is also plotted. It can be seen that the ion current and source efficiency increase with field strength up to a saturation value of somewhat more than 5%. This is consistent with the results of earlier workers, who have found that the ratio of total ion current to arc current in the vacuum arc is, quite generally, about 8 - 12%. Thus the measurements shown in Figure 1 indicate that approximately one half of the plasma that is created at the cathode can in principle be presented to the extractor for beam formation. However, the plasma is much too dense for a practical extraction, and it is necessary to reduce the equivalent ion current density by increasing the size of the extractor grids and allowing the plasma to expand to fill this enlarged cross-sectional area.

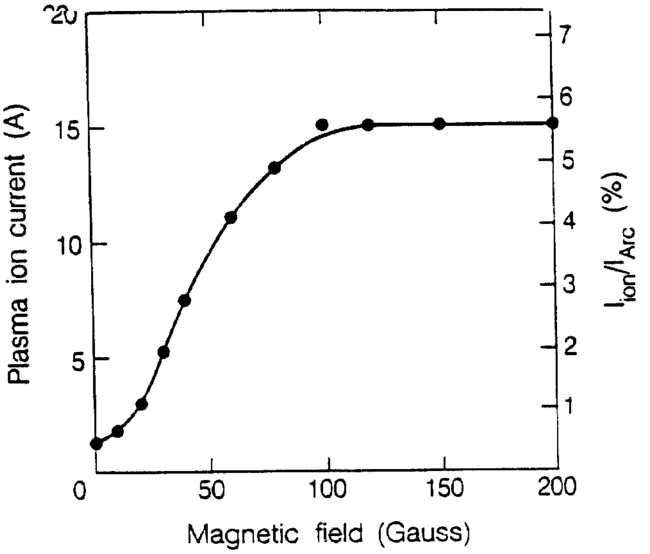

Fig. 1 Plasma ion current I_{ion} and efficiency factor I_{ion}/I_{arc} as a function of magnetic field strength. I_{arc} = 270 Amperes. Data taken using a modified MEVVA II configuration [5]) (XBL 873-8937).

In the MEVVA V, we have chosen to produce this plasma expansion by the use of a tapered magnetic bucket formed from an array of samarium cobalt permanent magnets. The tapered bucket configuration that we used for preliminary tests of plasma expansion is shown in Figure 2. The virtue of the magnetic multipole approach to doing the plasma expansion is that the radial uniformity of the plasma density distribution can be kept relatively flat; it is a condition for optimum beam formation that the plasma density profile at the extractor be uniform.

The extractor grid configuration chosen was a 3-grid, multi-aperture design that is quite conventional apart from their large size. The extractor diameter is 10 cm and the individual holes in the grids are of diameter 4.75 mm.

The multi-cathode concept that was developed for the MEVVA IV ion source [6] was incorporated into the MEVVA V also. The present cathode assembly holds 18 individual cathodes, between which one can switch simply and rapidly. Thus the source can produce beams of up to 18 separate metallic ion species with a single 'loading' of the cathode assembly. Furthermore, removing the cathode assembly, changing the individual cathodes, and re-mounting the cathode assembly can be accomplished quite straightforwardly also.

The MEVVA V source is shown in Figures 3 - 5. In Figure 3 the major sub-assemblies are shown separately and the multiple cathode assembly is visible. Figure 4 is a front view of the assembled source. Figure 5 shows the source from the rear, and the cathode-changing device can be seen. The vacuum wall is alumina, and the primary fabrication material is aluminum.

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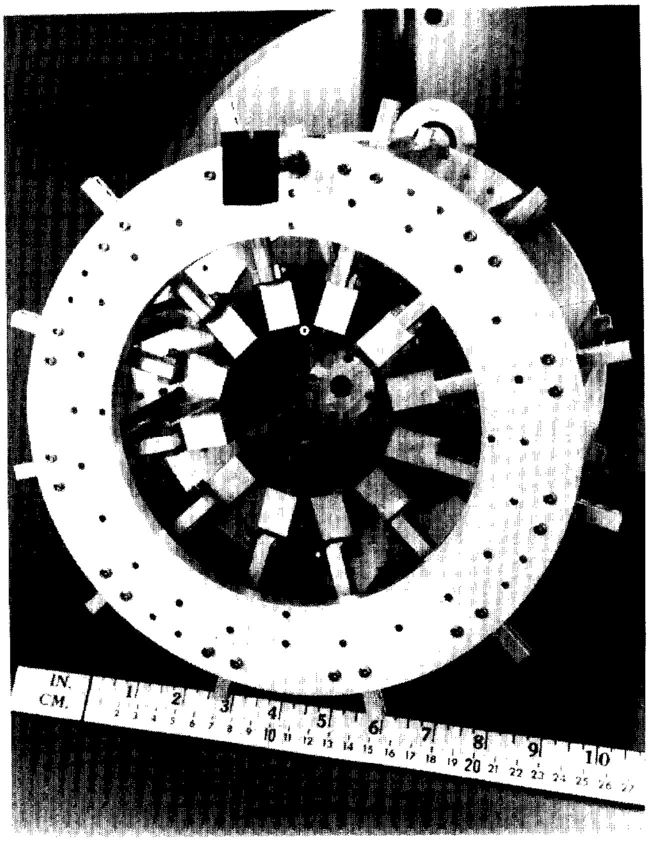

Fig. 2 Tapered multipole structure as used for pre-design experiments. (CBB 884-3261)

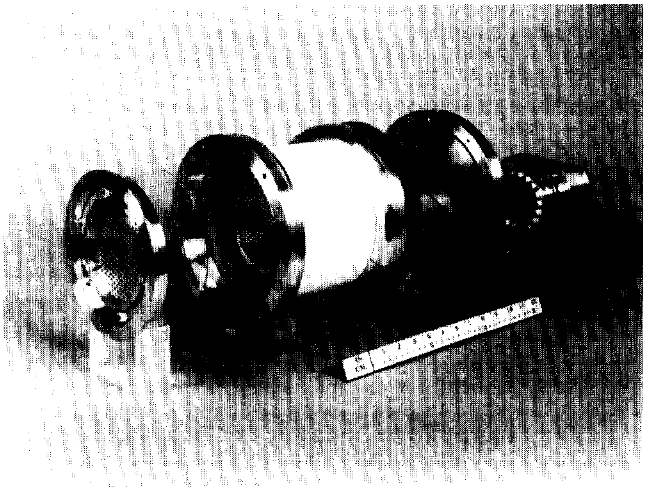

Fig. 3 Partially disassembled MEVVA V showing the large area extractor grids and the multiple cathode assembly. (CBB 892-1124)

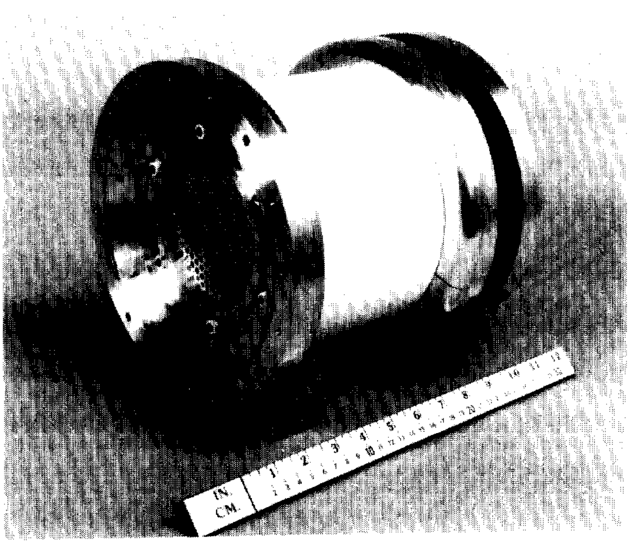

Fig. 4 Assembled MEVVA V. (CBB 892-1120)

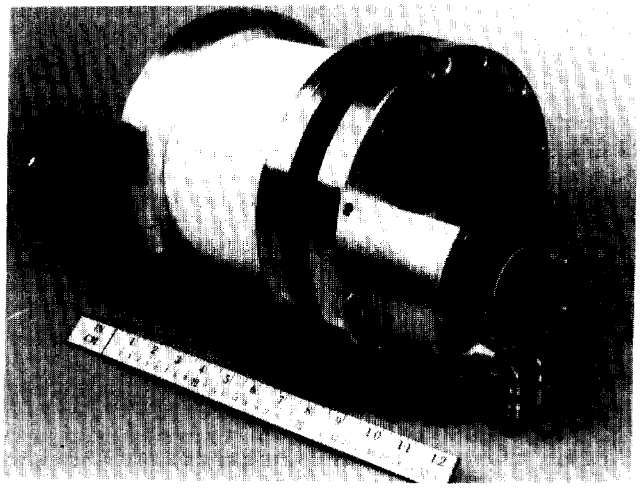

Fig. 5 Rear view. (CBB 892-1114)

Preliminary Source Operation

We have to-date carried out only quite preliminary tests of the source, and these tests have been successful. The tapered magnetic multipole structure was not installed for these measurements - we operated the source with the plasma expansion chamber empty. Thus these preliminary results provide an indication of minimum performance. Within a short time after initial application of high voltage we were able to maintain an extraction voltage of around 90 kV across the grids without sparking down across the extractor gap or across the insulator. Earlier tests, as part of the pre-design studies, indicated that the alumina insulator would hold off well over 100 kV. We measured the ion beam current by means of the current collected by a simple flat collector plate; thus an uncertainty of up to a factor of about two is expected because of secondary electron effects. The beam current so measured was up to several Amperes at 85 kV extraction voltage and 200 Amperes arc current. For this work we used an iron cathode. We then assembled a simple calorimeter, made from a 2 mm thick square copper plate of dimensions about 20 x 20 cm, adequate to collect the entire beam cross-section, with attached thermistor. The calorimetrically-determined beam current was 2 Amperes. As a final demonstration of beam power, we increased the pulse repetition rate to the limit set by our electrical system (sagging of extractor and arc power supplies), a repetition rate of about 15 pps. The time-averaged beam current in this case was 5 - 10 mA, and we were able to melt a 3-cm diameter hole in an aluminum target plate in a matter of several minutes. Further commissioning of the source is in progress.

Conclusion

A multi-Ampere, broad beam, multi-cathode, pulsed metal ion source, the MEVVA V, has been constructed and preliminary tests have been carried out. In a simplified configuration, the source can provide beam at over 90 kV and with a pulsed beam current of 2 Amperes. The tapered multipole plasma duct will be installed shortly for further tests and development.

Acknowledgements

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