The Use of Molybdenum Ion Source Electrodes
at RINS-II*

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Abstract

Results are reported for an ongoing effort to optimize D⁺ beam production by the MATS-III ion source used at RINS-II. The three seven-aperture electrodes, originally consisting of water-cooled copper, have now been tested using uncooled molybdenum and with water cooling on the second (decel) electrode only. Details of the change, the results of the testing, and the benefits in operation, performance and cost are given.

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1. Introduction

The production ion source in use at RINS-II is a modification of the MATS-III source.^{1,2} The extractor section consists of a triode with water-cooled copper electrodes. Since 1980 various changes in the plasma source and the extractor have been made and the source now has the form shown in fig. 1. The aperture geometry employs a 0.254 mm radial offset for beamlet steering as shown in fig. 2.

In an effort to extend accelerator lifetime a water-cooled decel electrode of the MATS-III design was made of molybdenum (Fig. 3). It was initially tested employing two production copper electrodes to make up the set. Subsequently performance testing continued with the same decel electrode combined with two uncooled molybdenum electrodes forming a complete molybdenum grid set for better comparison with the standard sources.

Since concern for the corrosion of molybdenum is well known in the neutral beam program³ the water cooling channel of the decel electrode was gold plated prior to brazing, to assure lifetime would not be limited by cooling circuit failure.

Additionally, complete sets of uncooled molybdenum electrodes are now being run for production and will determine the effect of cooling on lifetime.

2. Standard Source Operation

The lifetime for a set of electrodes is determined mainly by the deterioration of the decel electrode. The MATS-III plasma source, with a $\pm 40\%$ plasma non-uniformity across the extraction area,⁴ is run with a large fraction of beam power intercepted by the decel electrode. The decel electrode lifetime is significantly determined by downstream ion

bombardment (fig. 4). At the end of life, the decel electrode shows a distortion of the electrode which alters the gap spacing, enlargement of the apertures, and erosion by downstream ion bombardment to a depth which can approach more than 80% of the electrode thickness.

The copper, which is sputtered away, is redeposited in areas that reduce voltage holding capability. Moreover, with copper electrodes, sources operate with beam parameters varying with time and with a D^+ current that peaks at about 60% of useful life.

Early source operation at RINS-II using copper electrodes, with lower currents on the rotating target than are now achieved, gave lifetimes on the order of 1000 hours. After various improvements, beam currents have been increased from 45 mA up to 150 mA (130 mA nominal) but source lifetime has been reduced to typically less than 500 hours.

3. Molybdenum Electrode Source Operation

Water-cooled Decel Electrode set.

In three neutron production runs (separated by standard production source substitutions) preliminary evaluations of the molybdenum electrode source were made at 500 hours, 1000 hours, and 1150 hours. A thorough examination of the source was done at about 1200 hours. Throughout the operation, the extraction voltage was nominally 32 kV, the extraction current typically 450 mA, and the rotating target current typically 120 mA.

Uncooled electrode set.

In one 500 hour continuous neutron production run, an uncooled electrode set was operated at 34 kV with an extraction current of 510 mA (peak 590 mA) and a target current of 130 mA (peak 140 mA).

The D^+ beam current from operation with molybdenum and copper electrodes is comparable. However, in contrast to the copper electrodes, the beam parameters and D^+ yield from the molybdenum electrode source are almost independent of electrode age.

4. Postmortem.

Water-cooled Decel.

The electrode was replaced after 1200 hours due to fractures in the decel aperture webs although the source was still functional. The other electrodes showed little damage.

The characteristic ion bombardment erosion pattern on the downstream side of the decel reached a depth of about 0.3 mm or approximately 25% of the electrode thickness. There were no significant changes in electrode geometry. There was less than 0.25 mm decel distortion, no enlargement of the aperture diameters, and very little migration of molybdenum. The unplated o-ring surfaces at the water circuit joint on the decel had eroded, but not to the point of failure. Low conductivity water contact was about 3000 hours, much more than the total run time.

Uncooled electrode set.

The erosion pattern on the decel at the end of about 500 hours running reached a depth of about 0.3 mm or about 25% of the electrode thickness. There were no significant changes in electrode geometry, less than 0.4 mm decel distortion, no enlargement of the aperture diameters, and very little migration of molybdenum. Although otherwise comparable to damages seen on the cooled decel after 1200 hours there were no signs of fracturing. The other electrodes showed signs of impending failure after about 2000 hours cumulative use.

5. Copper Versus Molybdenum Electrode Cost

All three copper electrodes are water cooled and require brazing or electron beam welding. Over the years the cost of copper electrodes has varied from \$1000 to \$1400 for the set of three electrodes.

With molybdenum, we are able to use electrodes without water cooling channels and the expense for each one of these is about \$100. To obtain the longest lifetime, using a molybdenum decel electrode with water channel and gold plating, requires an expenditure for each decel electrode of about \$2500.

6. Conclusions

With these tests, we have demonstrated an increase in the life of the decel electrode by a factor of about 2.5 using water-cooled molybdenum. For an uncooled molybdenum decel electrode, performance is at least as good as the original water-cooled copper electrode. This translates directly into savings in replacement part expenses by simplifying manufacture as well as a commensurate reduction in assembly and alignment time cost. In addition the use of a refractory material has made performance more stable and can eliminate two or all cooling water circuit penetrations into the vacuum. We have begun employing uncooled molybdenum decel electrodes in production sources. Results thus far show that greater than 1000-hour lifetime can be expected.

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References

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Figure Captions

- Fig. 1. MATS-III assembly.
- Fig. 2. MATS-III Aperture Geometry.
- Fig. 3. Decel sketch showing water channel.
- Fig. 4. Decel downstream ion bombardment schematic. Ions drawn out of the region below the ground electrode terminating on the decel with an energy of about 3 keV.

Figure 1. MATS III Assembly

MATS III Aperture Geometry

Figure 2. MATS-III Aperture Geometry

Decel sketch showing water channel

Figure 3. Decel Sketch Showing Water Channel

Decel downstream ion bombardment.

Figure 4. Decel downstream ion bombardment schematic.

Ions drawn out of the region below the ground electrode terminating on the decel with an energy of about 3 keV.