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Oxide Cathode Lifetime Improvements at RTNS-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 the RTNS-II. The oxide cathode assembly originally designed for lower power operation has been modified and redesigned for higher electron current yield, longer life and serviceability. A factor of 2.5 has been gained in cathode lifetime due to these changes. The details of the changes and results and benefits in operation and performance are given. In addition, the technique used for manufacture of the filament is described.

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1. Introduction

The production ion source in use at RTNS-II, described elsewhere in detail,[1,2] is a modification of the MATS-III. The cathode assembly and the cathode/arc power supply configuration were designed for an arc power of up to 3.5 kW. The filament is a 1.016 mm diameter tantalum wire 15 cm long, wrapped with an 80 mesh platinum-rhodium (90/10) screen and coated with a commercially prepared oxide, RCA 33-C-185A.

Cathode lifetime is significant for several reasons. Once the facility began 24-hour, 5-day operation using two neutron sources, the consumption of cathodes increased two-fold. Examinations of these filaments after use showed that the striking region was consistently on the one negative leg and the discharge current was from the center (negative arc connection) of the single heater. Cathode life was dependent upon, not only the survival of the center-tai, but also on the negative leg lifetime for striking the arc. Nominal lifetime for striking the arc. Nominal lifetime was on the order of 150 hours. With an increase in arc power to 5 kW, the cathode lifetime dropped to typically 100 hours.

It was no longer possible to have uninterrupted neutron production with cathode replacement prior to failure on scheduled weekly maintenance. Also, since the ion source is mounted vertically, cathode failure usually causes filament fragments to fall into the extraction electrode region which results in reduced voltage holding capability.

2. Operation

The source is started in the following manner: first setting gas and extraction voltage to operating levels, raising the filament current to the arc striking level, then applying arc voltage and striking the arc. The source is then run with no cathode power applied, relying upon the arc discharge and bombardment to sustain emission. Upon loss of extraction voltage due to sparkdown, the standard procedure would be to extinguish the arc, restore high voltage and then restrike the arc.

3. Modifications

To extend cathode lifetime modifications to the cathode assembly and filamentation were made (fig. 1). The geometry of the cathode was altered to put as much oxide area in the central axis region. The copper feed-through conductors which had also served as filament holders were modified to take molybdenum holders. Another holder of the same design also replaced the small molybdenum bracket. The 0.508 mm molybdenum reflector was replaced with one of 1.56 mm thickness. The negative arc connection to the reflector is maintained to repel electrons back into the column that passes through the zwischen to the anode.

The arc and filament power supply configuration was also changed (see ref. 3) to maximize utilization of the filament. With effectively two filaments in parallel there is an enhancement of arc striking capability which greatly reduces the effect of arc strikes on lifetime.

The arc and filament power increase required replacement of the arc and filament connectors used. The original 50 A rated banana plugs were replaced with 125 A Multilam S Type plugs and receptacles.

These modifications, which all more complete replacement of parts, have also made replacement less frequent. At this point, cathode lifetime had become typically greater than 150 hours.

A procedural change was permitted by re-adjustment of the extraction voltage power supplies for proper over-current protection. The threshold had been too low in once case and malfunctioning in the other. The procedure now is to merely lower the arc current below the point of significant loading of the decel electrode (but high enough for a self sustained discharge); the extraction voltage is restored to the source and then the discharge returned to full level. In this manner we reduce the number of times the arc must be struck, thereby extending the effective life of the cathode, to as few as three times in a lifetime. This prevents loss of an aging cathode and increased lifetime to about 200 hours.

A modified cathode assembly with a typical filament having been used for more than 200 hours is shown in figure 2.

4. Cathode assembly redesign.

Encouraged by the results of the modifications, the cathode assembly was completely redesigned. The filament position in relation to the zwischen electrode was found to be not critical and was standardized. The design of the new cathode assembly (fig. 3) is based upon several considerations: supply adequate electrons for the discharge, extend lifetime, reduce the number of filament feed-through penetrations, eliminate the unwanted discharge region behind the reflector, remove upper cathode chamber heat, reduce the need for and increase the ease of part replacement. Boron nitride insulators were used in the short space between the reflector and the wall to cover the filament conductors.

Limited running of this style of cathode assembly has shown lifetimes on the order of 250 hours thus far. As yet there is no data to evaluate the effort to reduce the frequency of component failure.

The prototype uses the same filament evolved for the modified cathode assembly. The filaments are fabricated in much the same manner as they had been before, but with particular attention to the points described below and shown in the figures.

5. Filament fabrication technique

The filament is made up of two 1.016 mm diameter tantalum wires each about 8.6 cm long. Each is wrapped with platinum-rhodium screen, then shaped on the existing bifilar bending fixture. A step by step procedure was evolved to establish the location and the proper amount of doping material and the most desirable shape of the filament for enhanced arc striking capability. As shown in fig. 2, the active area is well within a 8 mm circle at the very center of the assembly, on the axis of the solenoidal magnetic field.

The filaments are made and the coating applied in a manner consistent with recommendations found in the literature[3,4] and by the oxide manufacturer.

The formed filament is readied for dipping by twice washing with isopropyl alcohol and complete dryings.

While applying the oxide the filament is heated with a power supply at about 10 A. The cup containing the oxide is not allowed to sit long without agitation while dipping filaments. This is to avoid separation and settling of the mixture and an unsatisfactory coating. The bare wire is coated not more than about 3 mm from the mesh and not at all on molybdenum parts.

Application of excessive oxide is avoided (wetting the wire and mesh only) as is excessively applied heat (to maximize density). Repeating the process of dipping and drying, and removing drips before they dry, builds up an even coating of material until the screen mesh texture is totally obscured. It has been found that adding more oxide than it takes to cover the mesh does not extend the life of the cathode or incease emission, but merely increases the time required for baking out and "activation".

It is not clear that a bakeout in vacuum is more effective than "toasting" in air. At some point data accumulated may clarify this. Typically we have the cathode assembly on the vacuum system at about 10-5 Torr, with a heater current of about 20 A for 2 to 3 hours. This causes the binder to decompose and drives out the carbon from the coating before the cathode assembly goes on the source, where it is outgassed to full current and activated in about 2 hours.

6. Conclusions

The modified cathode assemby lifetime is about 200 hours and the redesign gives about 250 hours compared to the 100 hours for the original cathode.

With longer lasting filaments and cathode assembly components there have been many occasions where the cathodes could be recoated and reused. This had been the case when much lower power levels (D^+ beam to target currents << 90 mA) were obtained. The longest cumulative cathode lifetime, running a modified cathode assembly in the source with target currents of about 130 mA, has been about 350 hours.

The new cathodes have resulted in a savings in cost of materials and assembly time and, most significantly, down time.

7. Acknowledgements

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FIGURE CAPTIONS

Fig. 1. Modified cathode assembly.

Fig. 2. a) Side view.

b) Tob view.

Filament used for over 200 hours. Note only slight damage at very center of spiral.

Fig. 3. New cathode assembly.