CONF-8110118--2(Draft)

Draft

Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract W-7405-eng-26 with the Union Carbide Corporation.

INDIRECTLY HEATED CATHODES AND DUOPLASMATRON TYPE ELECTRON FEEDS FOR POSITIVE ION SOURCES

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Summary

Development of indirectly heated cathodes and duoplasmatron type electron feed assemblies is being pursued for use on positive ion sources of neutral beam systems. The cathodes utilize La_2O_3 doped molybdenum emission surfaces which supply ionizing electrons for a large

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rectangular (28 cm. × 60 cm.) magnetic multi-cusp confinement chamber. Single and double electron feed assemblies with different electrode geometries were tested at discharge currents of ≥1000 A and pulse lengths of ~35 sec. Details of construction and performance results such as plasma uniformity are discussed.

Introduction

Future fusion experiments such as MFTF-B, TFTR and ATF will require neutral beam heating with pulse durations of $\lesssim 30$ seconds. Positive ion source based neutral beam systems continue to be the choice at present to meet these requirements.

At ORNL, development to improve and upgrade components of the duoPIGatron type ion source continues. The electron emitter(s) or cathode(s) and the accompanying electron feed assemblies are some of the components that are being improved. Two designs of indirectly heated cathodes utilizing lanthanum oxide (La_2O_3) doped molybdenum (LM cathode)[2] emission surfaces have been built and tested in two different versions of duo-plasmatron type electron feed geometries. This type of electron feed includes an electron emitter(s), or cathode(s), an intermediate electrode(s) with a solenoidal (source) coil and an anode(s) 2. Each feed assembly supplied the ionizing electrons to a large rectangular (28 cm. × 60 cm.) magnetic multi-cusp confinement chamber (anode 2) ("bucket") of an ion source.

Cathode and Electron Feed Assemblies

Type 1

One type of cathode assembly tested is shown in Fig. 1 with its accompanying electron feed geometry. This assembly utilized three individual cathode structures, but single units or pairs of units can and have been used. The basic cathode structure started with a pure molybdenum tube of 1.9 cm. O.D.

× 0.75 mm. wall × 10.2 cm. long. A 1.5 mm. thick disk was tungsten-inert-gas welded into one end. Then a 7.6 cm. length of the O.D. starting at the closed end was coated with a mixture of powders by plasma spraying to a thickness of ~0.7 mm. The mixture of powders consisted of 97.5% molybdenum, 2% lanthanum oxide (La_2O_3) and 0.5% platinum by weight. The cathode structure was then heat processed as follows: 1000°C for 5 hours in hydrogen, then

1500°C for 1 hour in hydrogen and finally carburized by packing in graphite powder and heating to $\sim$1700°C for 15 to 30 min. The emission area (coated area) is $\sim$49 cm^2. The cathode structures are attached to a copper support by means of tantalum clamps. The copper support attaches to the water cooled copper flange. The heater for each cathode is machined from fine (EDM) grade graphite in the shape of a cylinder 1.27 cm. in diameter which is slit from one end, forming a "hairpin". Each side of the heater is attached to the slotted end of a tantalum pin by means of a molybdenum screw and the tantalum pins are clamped to "squirt" tube cooled copper support rods. The tantalum pins provide some thermal isolation. The copper support rods are mounted and insulated from the mounting flange with ceramic feed-throughs. A tantalum cover shields the heater connections from the discharge surrounding the cathode. Hydrogen (deuterium) gas introduced at the back of the mounting flange passes through apertures in the tantalum cover to the intermediate electrode chamber. The single intermediate electrode has two double tapered canals of ~ 1 cm. min. dia. through which the electrons (discharge) pass. Cooling water flows through annular channels surrounding each of these canals. The iron portion of the intermediate electrode is lined with copper that has internal cooling channels produced by an electroforming process. The anode 1 canal is elongated and tapered to match the intermediate electrode.

Type 2

Another type of cathode assembly tested is shown in Fig. 2 with its accompanying electron feed geometry. Two complete assemblies of this type (double feed) were operated simultaneously.

The basic cathode structure has an emission area of ~100 cm² on the inside surface of a cone with a dia. of ~5 cm. and a spherical end. The cone was made by plasma spraying the mixture of powders described earlier for coating the type I cathode, onto an aluminum mandrel to a thickness of ~1.5 m.m. After removing from the mandrel and machining the open end square, the cone was heat processed as described earlier. A molybdenum thermocouple well was tungsten-inert-gas welded to the spherical end. The cone was then welded to a molybdenum "washer" which was welded to a tantalum cylinder that attaches to the copper mounting flange. The heater, machined from fine grade graphite in the shape of a hollow cylinder, surrounds the outside of the cathode cone. Longitudinal slots spaced radially around the cylinder form resistive paths which terminate in two support feet. Tantalum pins threaded into these feet, attach the heater to water cooled copper rods. These rods are supported and insulated from the mounting flange with ceramic feed-throughs. Thin (~0.13 mm.) tantalum sheet (4 to 6 layers) separated with tantalum wire provide heat shielding around the outside of the heater.

The intermediate electrode had one 1.27 cm. dia. double tapered canal and the anode I had a larger tapered cylindrical canal. Water cooling was on the periphery of the mounting flanges.

Operation and Results

Fig. 3 shows the general arrangement when the ion source was operated with either cathode/feed assembly. Several Langmuir probes were used to scan different portions of the anode 2 chamber for plasma uniformity.

Type I

The heaters of the three cathode units were connected in parallel to a common D.C. supply. A total power of ~ 7 KW (~11V, ~640A) was required to bring the cathodes up to ~ 1600°C operating temperature. Running with arc parameters of 150V and 1000A for relatively short (~250 ms) pulse lengths, the plasma uniformity was scanned. The uniformity was determined to be ≤ ± 10% over an area ~ 17 cm. x ~ 48 cm. The hydrogen gas flow required during the pulse was ~ 15 torr-l/sec. The arc pulse length was increased to ~ 30 sec. Fig. 4 shows oscilloscope traces of the arc voltage, anode currents and signals of Langmuir probes positioned near the side of the anode 2 chamber. The arc voltage was ~150 V and the total arc current was ~1100 A. After several 30 sec. pulses, the arc supply started inhibiting (turn off due to high current surges) frequently so operation was terminated.

When the cathode and feed assembly were removed, it was found that the end of one of the cathodes had been melting. The other two had nearly reached that point. The discharge apparently tended to concentrate toward the ends of the cathodes and caused them to become overheated during the long pulses. Figs. 5 and 6 are photographs of the cathode and feed assemblies after operation.

Type 2

The heater requirement for each type 2 cathode was ~3KW (~9V, ~340A). Separate supplies were used to provide electrical isolation between cathodes.

A common arc supply had to be used so a small resistance of ~0.02 Ω was connected between each cathode and the negative side of the arc supply to balance the currents from each cathode. Likewise a resistance of ~0.5 Ω was connected in each anode 1 lead.

Plasma uniformity was found to be comparable to that obtained with the type 1 arrangement. Arc parameters of 125 V and 1200 A. for 35 sec. pulse lengths were obtained. See Fig. 7. The hydrogen gas flow for this arrangement was ~25 Torr-l/sec. The source was operated for several (~10) 35 sec. pulses with no discernible misbehavior and was still operating well when operation was terminated. Figs. 8 and 9 are photographs of the cathode and feed assemblies after this operation. No significant damage is apparent on either assembly.

Discussion

The lanthanum oxide (La_2O_3) doped molybdenum material seems to be an excellent candidate for cathodes in long pulse (≥ 35 sec.) hydrogen (deuterium) ion sources. Although the type 2 cathode was operated at a current density level 20 to 25% lower than that for the type 1 cathode ($\sim 6 A/cm^2$ vs. $\sim 7.5 A/cm^2$), the type 2 cathode geometry is preferable to that of the type 1 as it appears to be less susceptible to overheating by the discharge. More testing needs to be done to determine that lifetimes will be adequate; however, lifetime should not be a problem, as the cathodes can easily be increased in mass and emission area.

The single electron feed with two or more exits should be pursued also, as it produces the necessary plasma uniformity utilizing a less complex assembly.

Work continues in these areas.

References

1. C. Buxbaum, Baden, Brown Boveri Rev. 1-79.