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BEAM APPLICATION

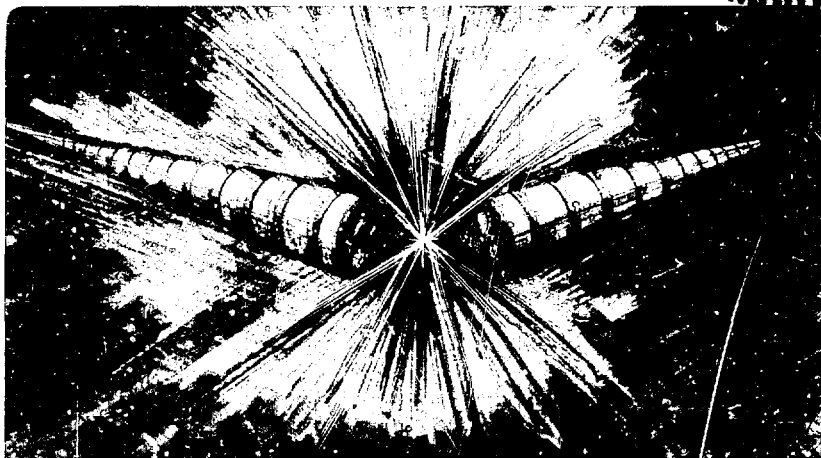
K.N. Leung, K.W. Ehlers, D. Kippenhan,
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RF Ion Source Development for Neutral Beam Application*

K. N. Leung, K. W. Ehlers, D. Kippenhan, and M. C. Vella

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Neutral beam injection has proven to be an effective way to heat plasmas in tokamaks as well as mirror devices.^{1,2} Long pulse or steady state high energy neutral beams will be required for plasma heating and for current drive in some future fusion reactors. Since the cathode filaments in ordinary discharge plasma sources have limited hours of operation, RF plasma generators become good candidates for the operation of a long pulse neutral beam system.

At Lawrence Berkeley Laboratory, a 24 x 24 cm² RF source has been tested with beam acceleration. Recently, we have been investigating the characteristics of plasmas generated with different kinds of antenna coatings. The antenna coil was installed inside a cylindrical multicusp source (20-cm diam by 24-cm long) and was driven by a 500 W amplifier. A tiny light bulb filament was used to start a background plasma. The RF was then switched on and a steady-state hydrogen plasma of moderate density ($n \approx 10^{11}/\text{cm}^3$) could be sustained even with the filament turned off.

We first tested antennas covered with ceramic and with woven sleeving material of glass or quartz. With a residual

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gas analyzer, we observed that the amount of impurity (mainly O_2 and H_2O) generated by the ceramic coating was always very high. After several hours of operation, many cracks had developed on the ceramic layer. Considerable outgassing occurred when ordinary glass or quartz sleeving was used on the antenna, but the amount of impurity gas coming from the glass or quartz sleeving was much reduced if the binder was first burned away from the sleeving in a vacuum oven.

Recently, a special technique has been developed to apply a very thin (0.12 mm) and uniform layer of glass enamel on the surface of the copper antenna tubing. This glass enamel has about the same expansion coefficient as the copper and it is estimated that the insulation can easily withstand a heat flux of approximately 50 W/cm^2 . When the enamel-coated antenna was tested in the source chamber, it produced the least amount of impurity gas of all the coatings tested. After several hours of operation, the enamel coating was found to be still intact.

There are two reasons for applying an insulation coating on the antenna tubing. First, the insulation layer floats electrically at a higher potential than the antenna. Thus the rate of sputtering the antenna material by the plasma ions is much reduced. It was also observed that when the same antenna was operated without any insulation but under similar source conditions, the ion density and therefore the efficiency of the source was reduced by a factor of two. The reason for the drop in source efficiency when the bare antenna was used is not yet understood.

Since the peak potential applied on the antenna can be very high, an ideal antenna coating should be able to withstand a high potential gradient between the plasma and the antenna. The voltage holding ability for different dielectric materials applied on the antenna has also been measured. The results are summarized as in Table 1.

Table 1. Breakdown voltage for various antenna coating material.

<u>Material</u>	<u>Breakdown Voltage</u>
Anodized aluminum	500 V
Glass or quartz sleeving	1.25 kV
Ceramic coating	500 V
Plasma sprayed ceramic coating	400 V - 1.25 kV
Glass enamel coating	5 kV

Thus the glass enamel coating also proves to be the best insulating material against high voltage breakdown.

In some applications, such as the P_2B_2 beam-line in MFTF-B at Lawrence Livermore National Laboratory,³ a high concentration D_2^+ ion beam is desired. Previously, we have succeeded in generating a high percentage of H_2^+ or D_2^+ ions by using dc discharge in a short multicusp source (20-cm diam by 9 cm long).⁴ In that scheme, the large amount of radiation from the nearby hot tungsten filaments produces a sizable amount

of heat loading on the plasma grid. We have tested RF plasma production in the same short multicusp source. When 200 W of RF power was coupled to the plasma, the extracted hydrogen ion current density was about 2.8 mA/cm². The mass-spectrometer output signal showed that more than 80% of the ion species was H₂⁺. The plasma density profile was found to be uniform within the 10 x 10 cm² extraction region.

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