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3.4: Gas Poisoning of 612-M and 311-XM Cathodes

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Abstract: *A 2 kA cathode was successfully developed for the DARHT-II injector [1]. Since the DARHT injector cannot be baked and there may be virtual leaks, the local pressure near the cathode was not ideal even though the system pressure was in the 10^{-8} Torr range. In a series of experiments using quarter-inch size button cathodes, we showed that gas poisoning was a significant factor in this pressure range. Furthermore we found that the 311-XM (doped with scandium and has an M coating) cathode was less affected by gas poisoning than the 612-M, corresponding to a lower effective work function. Water vapor was found to be the worst contaminant among the various gases that we have tested. With a 6.5" diameter 311-XM cathode, the DARHT-II injector produced >2 kA corresponding to a current density of 10 A/cm^2.*

Keywords: M type dispenser cathode; scandium; gas poisoning; DARHT injector.

Introduction

The dispenser cathode initially used for the DARHT II injector was the 612M type made by Spectra-Mat. This cathode was supposed to produce more than 10 A/cm^2 of current density. Earlier test has demonstrated 6 A/cm^2 at 1140 °C with pulses of a few µs long. Vacuum was a major concern in considering the cathode's performance. Although the gauges on the injector vessel indicated 10^{-8} Torr, the region near the cathode in the central region of such large vessel may not be as good. Poor vacuum near the surface of the cathode could degrade the work function.

In an off-line experiment at LBNL, we tested quarter-inch size cathodes, and confirmed that the 311XM, doped with scandium and with a osmium-ruthenium (M) coating, had the best combination of low work function and low radiation heat loss when compared to the 612M and 311XW ("W" means tungsten coating, this type was used in ETA-II at LLNL). Subsequently a 6.5" diameter 311XM cathode, also made by SpectraMat, was installed in DARHT II and 2 kA beam current pulses were successfully achieved. It was found that the beam current was sensitive to the partial pressure of various gases in the vacuum chamber. Our data showed that the required vacuum for emitting at 10 A/cm^2 was in the low 10^{-8} Torr range.

Experimental Set Up

An accel-decel structure was used to extract electrons from a ¼" diameter cathode into a Faraday cup. We designed the experiment to allow easy replacement of cathodes that are simply "buttons" with no built-in heater. With a button placed in a cup holder, heating was done by 4 filaments surrounding the cup holder. The cathode assembly was at ground potential. Electrons were extracted when a positive high voltage pulse was applied to the extraction electrode (A small negative dc bias was used to suppress dc extraction). The housing of the Faraday cup was at +2.5 kV to keep electrons from stalling before entering the collector biased at +3.5kV. With +25 kV extraction voltage, a space charge limited current density of >10 A/cm^2 can be obtained. Using EGUN simulation, the electron beam envelope was designed to be well inside the collector. There was a small opening at the rear end of Faraday cup such that the cathode temperature could be monitored by using an optical pyrometer ("disappearing filament" type). The amount of beam current leaking through this small opening was a very small fraction of the total beam current.

Since it usually took more than 2 seconds to obtain a good reading from the manually operated optical pyrometer, it was not always possible to obtain the cathode temperature simultaneously with the current measurement while the temperature was dropping. We determined the instantaneous temperature from a calibrated cooling curve of cathode temperature vs. time after turning off the heater.

The vacuum tank was thoroughly cleaned, and we used metal seals in order to be able to bake the vacuum tank. Typical vacuum base pressure was in the 10^{-9} Torr range when the cathode heater was turned off. Given the small cathode size, the system was able to maintain pressure in the high 10^{-9} Torr range even when the cathode was hot.

Test Results

From the heater power vs. temperature measurement, we found that for the same surface (brightness) temperature the 311XW always required more power than the 311XM and 612M. The difference in emissivity was probably due to the difference in coating material. For example, for both 311XM and 612M 100 W of heater power was required to reach a brightness temperature of 1000°C_b whereas it took 117W for the 311XW to reach the same temperature. Thus the 311XW emissivity was higher and radiates more heat. This can be a serious issue when the maximum filament power and the heat dissipation are critical in the cathode design. In fact, the 6.5" DARHT cathode was not able to use the 311XW type cathode for this reason.

We observed hysteresis effect on the emission as a function of temperature. It only took 2-3 minutes for the cathode to reach a new equilibrium temperature after turning down the heater power. During this time the emission dropped according to the temperature dependence in the Richardson Equation. However, the emission could continue to reduce slowly over the next tens of minutes depending on the vacuum condition. The drop is faster and deeper when the vacuum was poor. This phenomenon suggests that the work function of the cathode is dependent on the dynamic equilibrium between the diffusion of the impregnated material to the surface and the contamination rate from the surrounding gas. Going up in temperature usually did not take as long to reach the steady state emission.

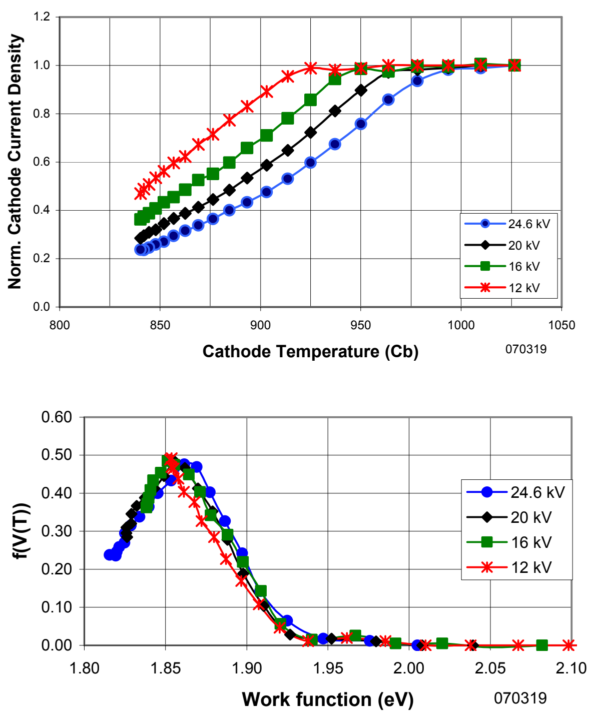

Figure 1. (a) Miram curves, (b) PWFD curves of 311XM.

Figures 1a and 1b show the data obtained from the 311XM cathode, plotted in the forms of Miram (cathode loading) curves and the practical work function distribution (PWFD) curves [2]. In this case, the cathode had been activated at 1025C_b and the pressure was 1.2 x 10^{-8} Torr. Each data series was taken during the few minutes after turning off the heater to allow the cathode to drop in temperature. The space charge limited current density (J_s) at the 100% normalized level for the case of 24.6kV diode voltage was 10 A/cm^2. At 20kV, 16kV and 12kV diode voltages, the corresponding J_s were 7.5, 5.2 and 3.5 A/cm^2. The PWFD peaked at about 1.86 eV.

In order to select the proper cathode for DARHT II, we studied the critical temperature required to reach J_s = 10 A/cm^2 for 612M and 311XM under various types of gas and pressure. Figure 2 shows that the critical temperature increases with normal air pressure, and Fig. 3 demonstrates the effect of various types of gas. As expected, high temperature is required to maintain the emission when the gas poisoning increased with pressure.

The 311-XM cathode was found to be less affected by gas poisoning than the 612-M. Water vapor was the worst contaminant among the various gases that we have tested. The required vacuum for emitting at 10 A/cm^2 was in the low 10^{-8} Torr range. Pressure at 10^{-7} Torr was already considered as being too high. Test results from quarter-inch cathodes were in agreement with the most recent data obtained from the 6.5" 311-XM cathode at DARHT II where it has achieved 2 kA of beam current.

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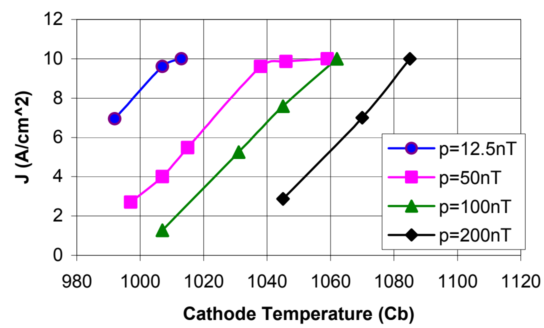

Figure 2. Emissions at various pressure of normal air.

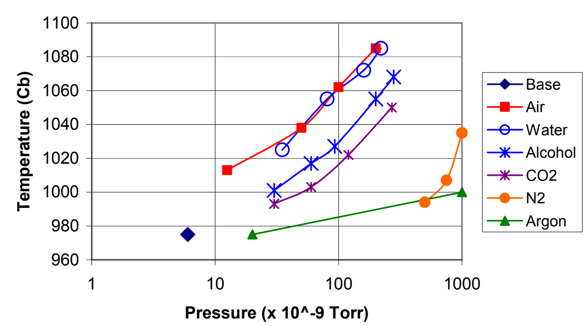

Figure 3. Critical temperature for 10A/cm^2 emission from a 311-XM cathode as a function of gas pressure.

References

1. C. Fortgang, C. Hudson, D. Macy, M. Monroe, K. Moy, and D. Prono, Proc. 19th Linear Accelerator Conf., Chicago, Il, pp. 171-173, 1998
2. M. Cattelino, and G. Miram, Appl. Surface Science, 111, (1997) 90-95.