Barium Dispenser Cathode Operation in a Cesium Vapor Environment for Applications in Thermionic Converters

Daniel Velázquez, Hsin-I Lu, Mark Stone, Daniel Merthe
Modern Electron, LLC
Bothell, WA 98011

Abstract: *Thermionic converters are devices that convert heat directly into electricity with no moving parts. Thermionics require a high current density emission source. Historically, Ba dispenser cathodes have not been used in thermionic converters due to practical limitations surrounding poor background pressure in thermionics. Here we measure the impact of cesium exposure on the performance of a Ba dispenser cathode that that had previously been exposed to air. Measurements indicate that cesium exposure accelerates cathode activation and increases current density, even in the case of unconventionally high base pressures (>10^{-7} Torr).*

Keywords:
Barium dispenser cathode; cesium vapor; cathode activation; cathode reactivation; thermionic converters.

Introduction

Thermionic converters are devices that convert heat directly into electricity with no moving parts. Thermionics require a high current density emission source. Barium dispenser cathodes provide high current density electron sources for a variety of vacuum electronic devices [1]. There are several reports of Ba dispenser cathodes used in thermionic converters [2,3]. However, historically Ba dispenser cathodes have not been applied to thermionic converters because they require a highly clean environment with pressures below 10^{-7} Torr [1]. Such ultraclean operating conditions are not compatible with thermionic converters, which require low pressure vapor, usually containing cesium, in the interelectrode space. Herein, we show initial data on the activation and operation of dispenser cathodes in a vapor of Cs. Results indicate that Ba dispenser cathodes are more promising than previously assumed for thermionic converters.

Experiment Details, Results, and Discussion

A 311 barium dispenser cathode (HeatWave Labs) was activated in an ultra high vacuum environment (~ 10^{-9} Torr base pressure) by slowly ramping up the heater power over several hours and allowing the pressure to stabilize while never exceeding 10^{-7} Torr. Emission from the cathode was monitored in a diode configuration by using a clean platinum anode and sweeping its potential in reference to the cathode. The cathode was heated to ~1050°C as measured via pyrometer and corrected for the emissivity of an opaque tungsten surface (i.e. that of the dispenser's tungsten matrix). The final emitter current density was ~ 0.6 A/cm^2, with an approximate surface-

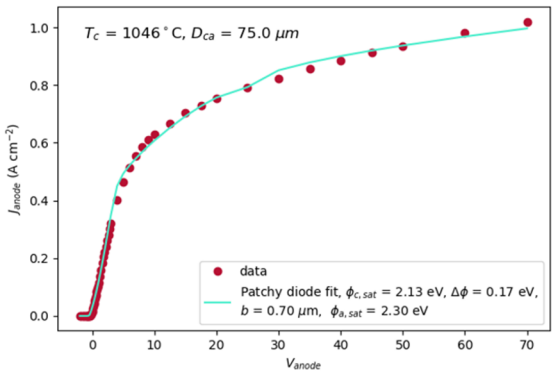

Figure 1. Characteristic IV curve and fit of a 311 BaD cathode as activated in a UHV environment.

average work function (WF) fit to 2.13 eV. Although the details of the fit are outside of the scope of this report, it suffices to say that the fit accounts for a patchy surface of dissimilar WF domains to yield an average surface potential. Figure 1 shows the IV curve for this diode as well as the fit described here.

After activation the cathode was then removed from the UHV environment and stored for several weeks away from organic contaminants in the typical dry air environment of an electronics laboratory. The cathode was eventually reinstalled in a different vacuum chamber equipped with flange heaters that enable uniform heating of the entire chamber, a requirement for maintaining cesium vapor. This chamber also featured a commercially available all-metal valve that was used to reduce the pumping speed of the main turbo pump when needed. A metallic cesium reservoir was attached to the chamber with independent active heating and cooling and separated from the rest of the chamber by a commercially available all-metal valve in order to control the Cs pressure [4]. Once the diode (Ba dispenser cathode and Pt anode) and the Cs reservoir were installed in the chamber, the system was pumped down and baked. Cathode reactivation followed a

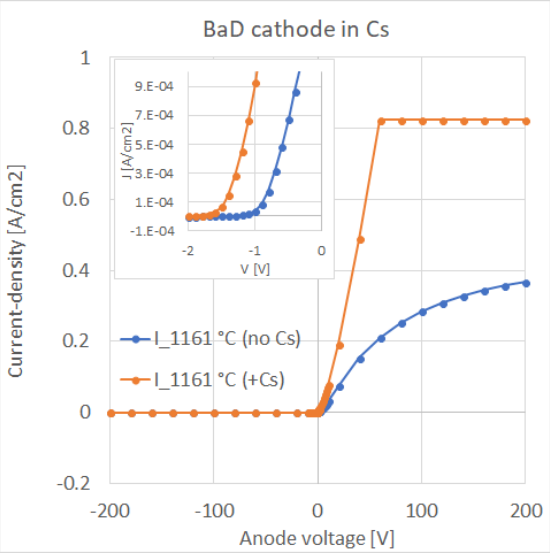

Figure 2. Comparative plot of IV curves recorded before and after Cs exposure for the reactivated Ba dispenser cathode.

similar procedure as described above. The cathode was heated to ~1150°C, though its emission, ~0.4 A/cm^2, was clearly lower than that expected from a new cathode.

Next, the cathode was cooled back down to room temperature to reattempt reactivation in the presence of Cs. Use of Cs requires increasing the chamber wall temperature to >150°C to preclude Cs condensation. The base pressure increased to ~10^{-7} Torr. The Cs reservoir was then heated to 80°C. Reactivation was yet again restarted as described above by heating the cathode to ~1150°C.

Current-voltage (IV) curves indicate that the measured current density significantly increased compared to the pre-Cs measurements. Figure 2 shows the comparison between the instances when the cathode was reactivated in vacuum versus in a Cs vapor. The flat apparent saturation of the cesiated version is an artifact of the measurement electronics, which reached a current compliance limit during the measurement. The inset shows the near retarding regime, which displays the WF-lowering effect of Cs in the anode as well, evidenced by a shift of the IV of about 0.5 V in the output voltage of the diode. To measure saturation at high power, a diode-cascade voltage multiplier was built and coupled to a digital multimeter (DMM). IV curves of the cesiated diode with both power supply configurations are shown in Figure 3. In this case, the saturation current is >1 A/cm^2.

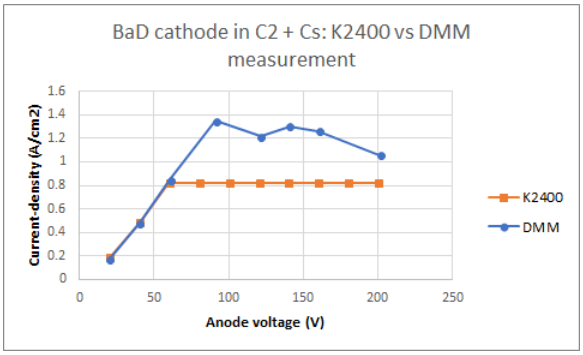

Figure 3. IV saturation measurement of cesiated Ba dispenser-Pt diode using a high voltage power supply.

Conclusion

We have shown the reactivation and rejuvenation of an air-exposed 311 Ba dispenser cathode by exposure to a Cs vapor. Measurements indicate that exposure to Cs vapor during cathode reactivation following air exposure yields increased current density (by ~2x) compared to activation in ultra high vacuum. This result has broad implications, suggesting that Cs may enhance Ba dispenser cathode performance in thermionic converters, in contrast to what was previously understood in the field. Further improvements for the operation of BaD cathodes in Cs include the initial activation in Cs with potentially higher Cs pressures in order to optimize emitter and collector WF for output power.

References

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