Thermionic Electron Gun with Small Virtual Source Size for Electron Beam Lithography Applications

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A novel electron gun has been developed utilizing a thermionic emitter that has been embedded in a graphite rod. A CeB_6 crystal with a (100) orientation has been mounted flush in the end of a graphite rod with a 60 degree cone end. See Figure 1. Embedding the emitter allows the gun to run in a unusual configuration for a thermionic emitter where the emitter protrudes beyond the wehnelt into a high field region between the wehnelt and the anode. See Figure 2. In a typical thermionic cathode configuration the emitter is mounted behind the wehnelt to suppress electron emission from the sides of the emitter. This geometry forms a virtual source in front of the emitter with a virtual source size greater than 10 microns for current values of interest in electron lithography applications. However when the emitter protrudes into the high field region a virtual source is formed behind the emitter plane. In this geometry a much smaller virtual source size can be achieved than in the convention thermionic cathode configurations. The high work function of the graphite limits emission to just the exposed CeB_6 surface with almost no current emission from the emitter shank.

This geometry is useful for illuminating the programmable aperture arrays used in maskless electron beam lithography systems because the resulting emission has very uniform angular intensity, large emission angle, and relatively high current. The large area emitter can provide higher current than a point source emitter such as the thermal field emitters. The high brightness of a thermal field emitter is not required in this application. This electron gun can be used in combination with a suitable condenser lens to provide uniform illumination over large areas.

The emitter geometry was modeled using the Integrated Engineering Software's Lorentz program. With a protrusion of ~200microns, a virtual source size below 2 microns was achieved with highly uniform emission over +/-28 milliradians at a beam voltage of 5kV. A gun was built and tested with the experimental results closely matching the modeled parameters for the gun. Details of the electron gun modeling and experimental results are presented in this paper. This gun design has also successfully achieved lithography results on the IMS eMET tool.[1]

[1]Elmar Platzgummer, Christof Klein and Hans Loeschner, "eMET POC: realization of a proof-of-concept 50 keV electron multibeam mask exposure tool", Proc. SPIE 8166, 816622 (2011); doi:10.1117/12.895523

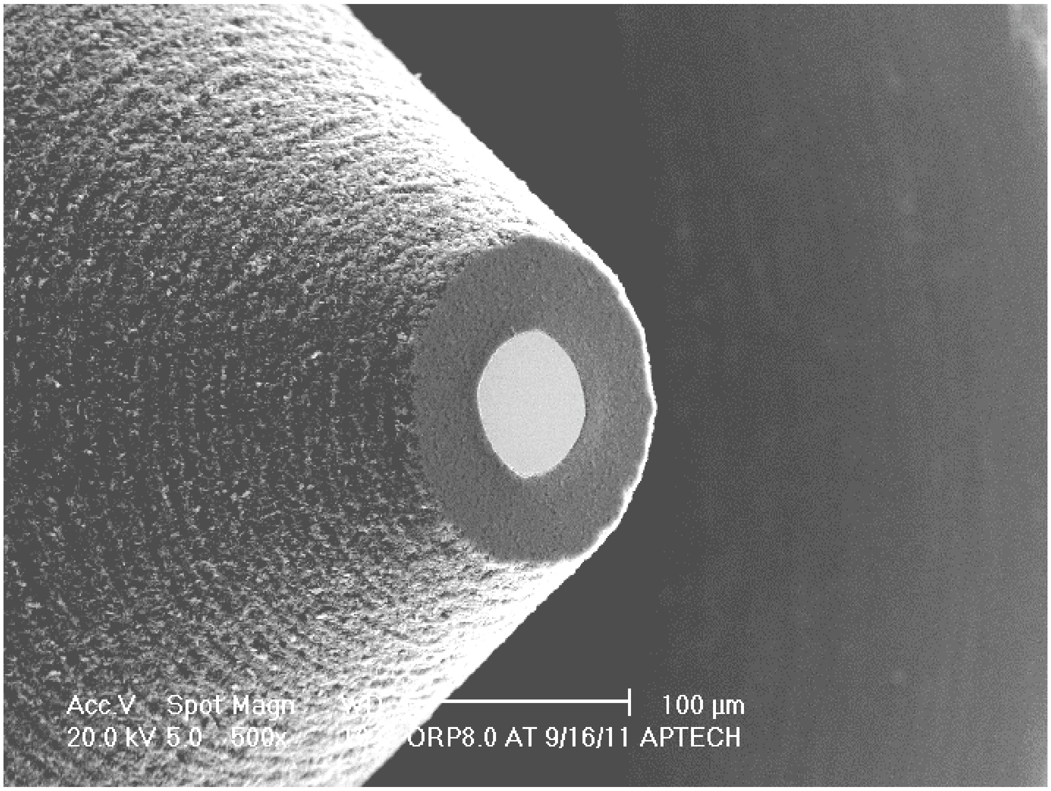

Figure 1 Embedded CeB_6 Emitter: A 70 micron CeB_6 crystal has been embedded in a graphite rod with a ~150 micron flat area, a 60 degree cone angle and a ~500 micron shank diameter.

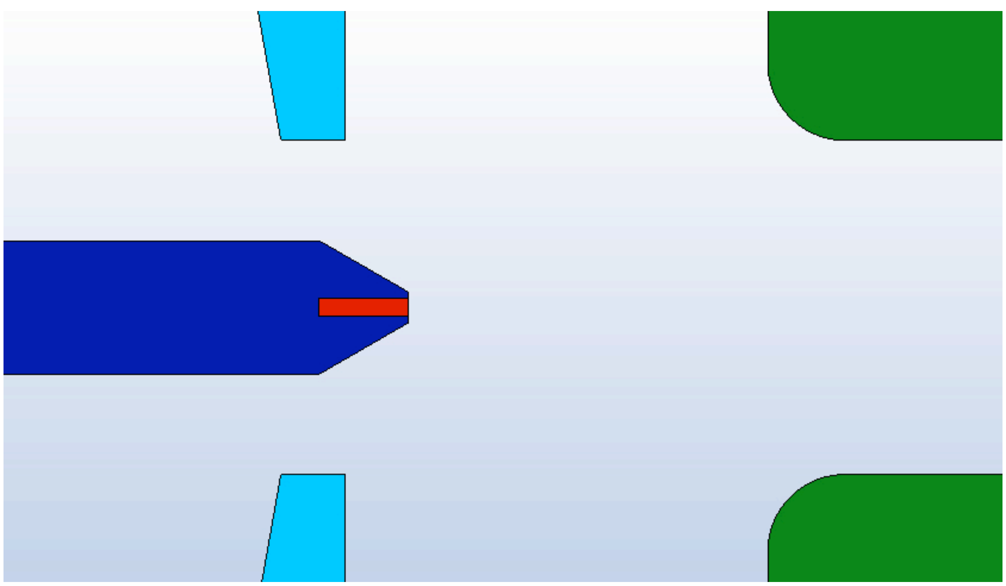

Figure 2 Electron Gun Extraction Geometry: An embedded *CeB_6* emitter (shown in red) with the graphite rod (shown in dark blue) protruding from the Wehnelt (shown in light blue) The extraction anode shown in green.