HfC(310) High Brightness Sources for Advanced Imaging Applications

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We report using an XL40 SEM to demonstrate the performance of HfC(310) emitters operating in extended Schottky mode. We work with transition metal carbide electron sources which have high current emission capability, are resistant to ion sputtering, and are capable of stable operation over a range of temperatures and fields. HfC(310) specifically provides a relatively low work function (~3.4 eV), has a high melting point (~4000 K), and very low surface mobility. In this study we operate in the extended Schottky emission regime with temperatures from 1800 – 2000 K and fields to ~2 x 10^9 V/m. Several emitter apex end-forms are analyzed experimentally (see Fig. 1) and through modeling to show very high reduced brightness values. Experimentally measured angular intensity values are in the range 0.05 mA/sr < I' < 70 mA/sr which demonstrates the capability of these emitters for high angular intensity operation.

It is known that surface tension and field forces contribute to blunting or build-up on W field emitters and conventional Zr/O/W(100) Schottky sources. HfC emitters have activation energy for surface migration much larger than for W which translates into very stable end-forms once obtained. Typical Zr/O/W sources are processed to facet the (100) plane at the apex[1]. However, the physical properties of HfC require us to artificially facet or truncate etched CFE type emitters and operate in Schottky mode using standard electron optical configurations.

Noise and energy spread measurements were collected which show ΔE lowering as temperature is increased into the extended Schottky regime. Flicker noise levels were comparable to Zr/O/W(100) sources. Experimental data as well as modeling results give electron optical reduced brightness levels to ~4 x 10^6 A/cm^2/sr/V, roughly 10-100x higher than commercial Schottky sources.

HfC(310) emitters with several end-form geometries were operated in an XL40 SEM and compared with Zr/O/W(100) emitters operated under similar conditions. We found smaller measured spot sizes (by ~2x, see Table I) and higher beam currents (by ~10x, see Fig. 2) for rounded end-forms as compared to commercial Schottky sources.

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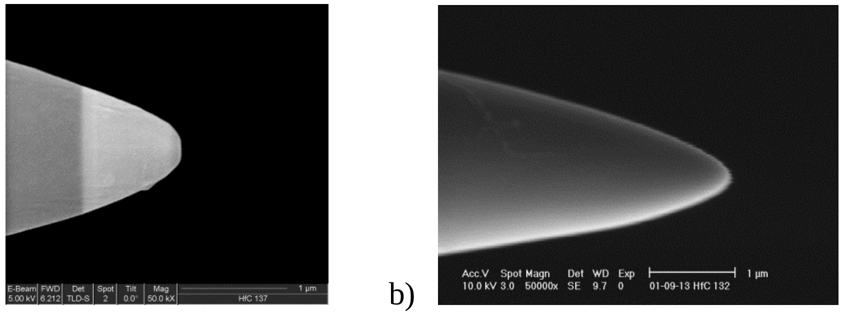
[1] L.W. Swanson and G.A. Schwind, in Handbook of Charged Particle Optics, edited by J. Orloff (CRC, Boca Raton, FL, 1997), Chap. 2, pp. 77-102.



a) b)

Figure 1: Micrographs of HfC(310) tips a) #137 and b) #132.

Table I: HfC Schottky emitter spot size comparisons.

Emitter	Truncation (D)/radius (R)	Spot size
Zr/O/W(100)	D = ~300 nm	26.4 nm
HfC(310) – tip #137	D = ~200 nm	19.0 nm
HfC(310) – tip #130	D = ~125 nm	13.2 nm
HfC(310) – tip #132	R = ~150 nm	9.9 nm

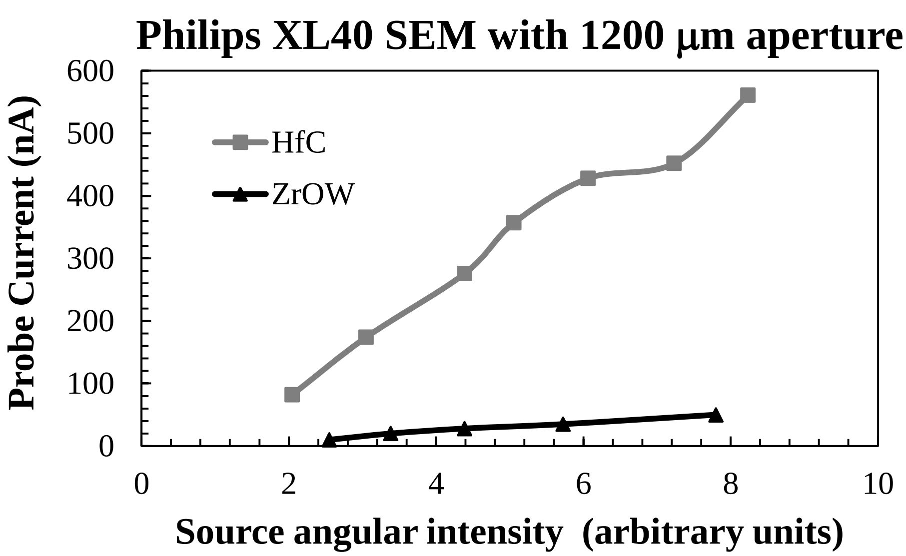


Figure 2: Beam current comparisons at several angular intensity levels.