Use of HfC(210) as High Brightness Electron Sources

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We continue our work to demonstrate a new electron source for applications where high brightness is required. Thermionic and cold field emission are ends in a continuum of electron emission processes; between lays extended Schottky emission (ESE) and thermal-field emission (TFE). Presently, commercial electron sources operate in the ESE or cold field emission (CFE) modes both using tungsten as the base material. It is known that surface tension and field forces contribute to blunting or build-up on these W based emitters. However, HfC sources have activation energy for surface migration much large than for W. This coupled with loosely bound surface contaminants mean operation at elevated temperatures can keep the surface clean but not trigger geometric changes.

Both modeling and experimental performance in a Philips XL40 FEG SEM (see Fig. 1 and Table I) are reported for HfC(310) and (210) cathodes where emission is studied for temperatures to ~2000 K which covers TFE and ESE modes. Operation in ESE mode resulted in electron optical reduced brightness levels to ~8 x 10^9 $A/m^2/sr/V$, >10x higher than commercial Schottky sources. We use $B_r = I'/(\pi r_v^2 V_E)$ to calculate reduced brightness where I' is angular intensity, r_v is the virtual source radius obtained from modeling, and V_E is the beam voltage.

HfC sources are capable of higher angular intensity levels and potentially higher pressures than ZrO/W sources due to the nature of the materials. ZrO/W sources require a balance of field and temperature to keep the W-substrate end-form constant and to allow proper flow of ZrO to the apex, but this limits angular intensity. HfC sources have no need for a material supply and because of their robustness can be operated at high temperatures and high fields thereby not limiting the angular intensity to a relatively small range. Generally the maximum value of I' for ZrO/W sources is ~1 mA/sr[1] whereas HfC sources have been operated to >60 mA/sr. We have also documented operation at varying pressures from 10^{-10} to 5 x 10^{-8} torr. Operating these emitters at or below 1 x 10^{-8} torr yielded stable angular intensities at relatively constant extraction voltages and virtually constant and low total emission currents.

These data demonstrate the potential for the HfC(210) source. Higher angular intensities are possible as well as the potential for higher electron optical brightness which is due primarily to the ability to use the rounded emitter end-form in the Schottky emission regime.

[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.

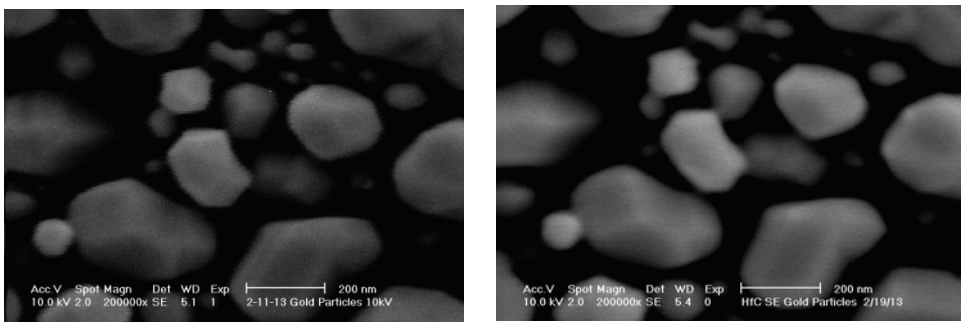

Fig. 1: Philips XL40 FEG SEM image comparison; ZrOW and HfC source images on left and right respectively

Table I: SEM Spot Parameter Measurements Compared

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