Emission Stability and End-form Changes in High Brightness HfC Electron Sources

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We continue work on a new electron source for high brightness applications. Presently, commercial high-brightness sources operate in the extended Schottky emission (ESE) or cold field emission (CFE) modes both using tungsten as the base material. It is known that surface tension and electric field forces contribute to blunting or build-up on these W-based emitters which limits I', the angular intensity. Generally the maximum value of I' for ZrO/W sources is ~1 mA/sr.[1] HfC sources can be operated at high temperatures and high fields without surface migration thereby not limiting I' to a relatively small range; HfC sources have been operated to >60 mA/sr.

Experimental performance on test stands and in a Philips XL40 FEG SEM are reported for HfC(210) and (110) cathodes where emission is studied for temperature ranges of 1500-1900 K. High electric fields on curved end-forms gives rise to the very high optical reduced brightness levels to ~8 x 10^9 A/m^2/sr/V.

A typical test stand plot of probe current over time is shown in Fig. 1. At a probe current of 1.8 nA the angular intensity is 0.8 mA/sr. This operating temperature is 1850 K and the pressure was ~2 x 10^{-9} torr. Toward the end of the scan I' was set to 1.0 and 0.5 mA/sr respectively. The flicker noise was calculated as the average for each point of the deviation from mean. This gave noise levels of 1.7%, 1.15%, and 1.0% for I' of 0.5 mA/sr, 0.8 mA/sr, and 1.0 mA/sr respectively.

When operating these sources at these high temperatures and slightly elevated pressures we note that preferential sublimation can occur. This enlarges the (100) and at least the (111) planes which gives a small radius protrusion or linear ridges on the (110) direction which persist as in Fig. 2. We have grown (110), (100) and (210) HfC crystals, fashioned them into emitters, and operated in similar environments. Operation of a (100) oriented emitter develops the flat apex as seen in Fig. 3a which decreased I' but increased emission stability as was expected. Measurements of I' will be shown along with data from operation in the XL40 FEG SEM.

These data demonstrate the potential for the HfC(210) or HfC(110) sources. 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 or angular emitter end-form in the Schottky-type emission regime.

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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.

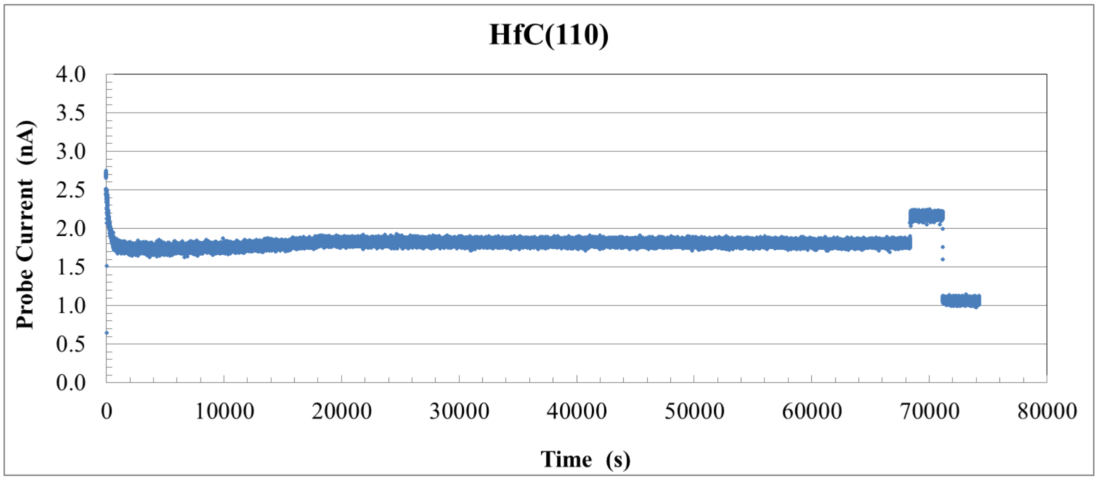

Figure 1: Typical current traces of an HfC(110) emitter operated at 1850 K and a pressure of 2 x 10^{-9} torr. This probe current translates into an I' of 0.8 mA/sr for the majority of the time and 1.0 and 0.5 mA/sr at the end of the scan respectively.

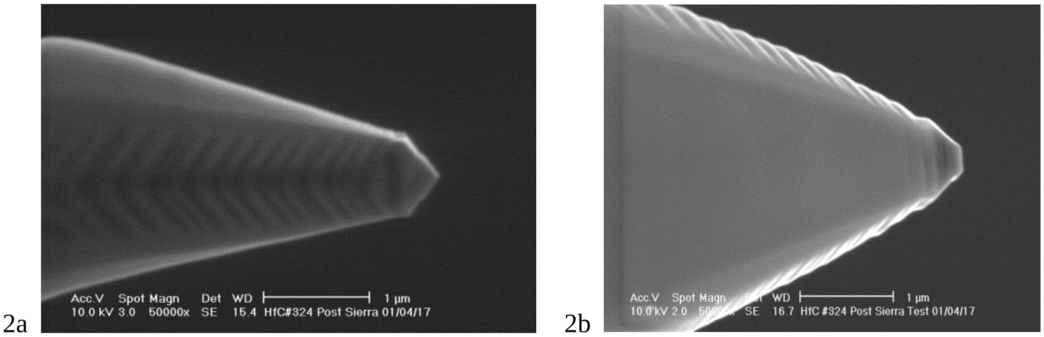

Figure 2: SEM images of the preferentially evaporated HfC(110) emitter. The left (2a) and the right (2b) images are 90 degree rotations of the same emitter.

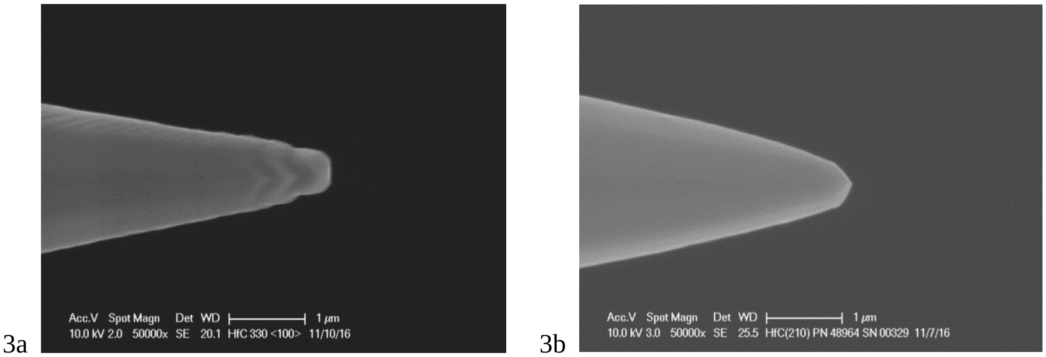

Figure 3: SEM image of the preferentially evaporated HfC(100) emitter on the left (3a). The right image (3b) shows a preferentially evaporated HfC(210) emitter.