Defined Emission Area and Custom Thermal Electron Sources

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Rare-earth hexaborides[1], specifically LaB_6 and CeB_6, are used commercially in a wide array of SEM, TEM, and lithography systems. However, they do have limitations needed for certain applications. Our research has covered emission from single-crystal boride and carbide thermionic and field emitters[2]. These materials have electron emission properties making them attractive candidates for stable emission sources in moderate vacuum applications. CeB_6(310) has a work function of 2.4 eV and a relatively low evaporation rate in low 10^{-7} Torr pressures and at <1800 K giving commercial lifetimes >2000 hours.

We describe several thermionic electron sources having unique properties including a defined emission area. These are beneficial for a range of applications including x-ray generation, electron microscopy, lithography, and microwave devices. The source can be a CeB_6(310) cylinder mounted flush in a specially shaped carbon guard-ring. We have made these carbon guard-ring structures[3] from graphite which is mounted in a conventional mini-Vogel type system, using separate pyrolytic carbon blocks as the heating element (see Fig. 1). The work function of the carbon guard ring is >1.5 eV higher thereby suppressing emission from its surface and limiting the emission to the CeB_6(310) surface. Cathodes have been built with source diameters from 50 μm to 1 mm and guard ring diameters from 100 μm to 3 mm.

For particular low current and extreme operating conditions we fabricate embedded cathodes from HfC(310). This is an extremely robust cathode material capable of operation in poor vacuum conditions and able to withstand ion back streaming successfully. These sources can be circular or shaped as depicted in Fig. 2.

Also discussed will be mounting methods to increase emission current stability (see Fig. 3).

[1] L.W. Swanson and D.R. McNeely, "Work functions of the (001) face of the hexaborides of Ba, La, Ce, and Sm," Surface Science 83 11-28 (1979).

[2] K.J. Kagarice, G.G. Magera, S.D. Pollard, and W.A. Mackie, "Cold field emission from HfC(310)," J. Vac. Sci. Technol. B 26 (2), Mar/Apr (2008).

[3] W. A. Mackie, K.J. Kagarice, C.L. Fast, "Development of a (100) hafnium carbide thermionic electron source with built-in guard ring and heater," *IVEC/IVESC 2006 Conference Proceeding*, IEEE Electron Devices Society, Apr (2006).

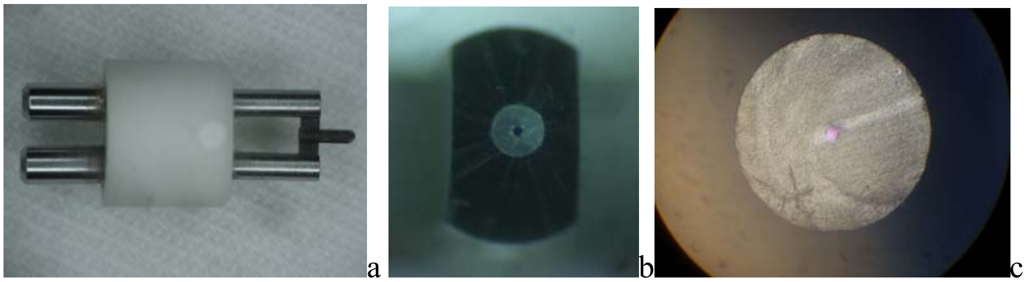

Fig. 1: a) Vogel mount using pyrolytic carbon blocks sandwiching a shaped graphite structure, b) & c) end view of the shaped graphite structure showing central flat with embedded 50 µm CeB_6(310) crystal.

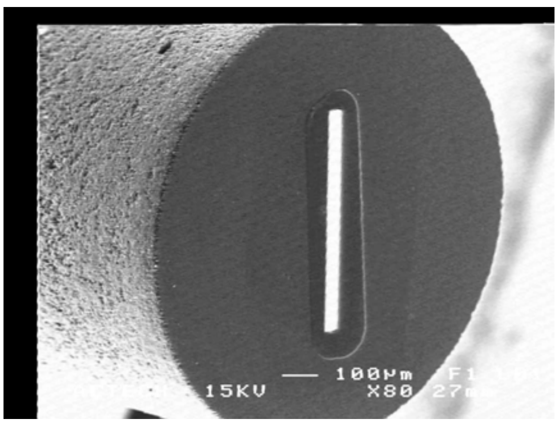

Fig. 2: HfC(210) line cathode embedded in carbon for emission suppression; source size, ~53 mm x ~750 mm.

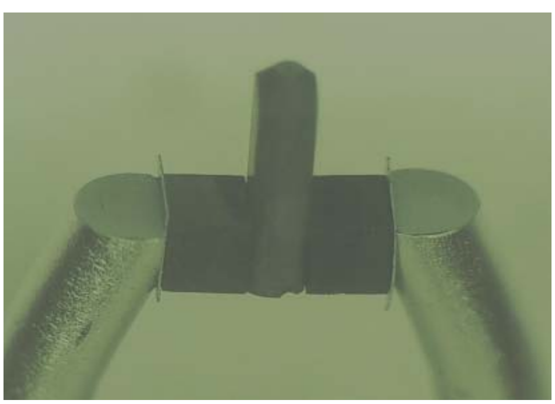

Fig. 3: Vogel mount showing central carbon embedded crystalline cathode, pyrolytic carbon heater blocks, the barrier or shim, and finally the Mo/Re clamping posts.