Field Electron Emission from Zirconium Carbide; Controlled Stability Even at Elevated Pressures

W.A. Mackie, G.M. Magera, and K.J. Kagarice
Applied Physics Technologies, Inc. 1600 NE Miller St., McMinnville, OR 97128

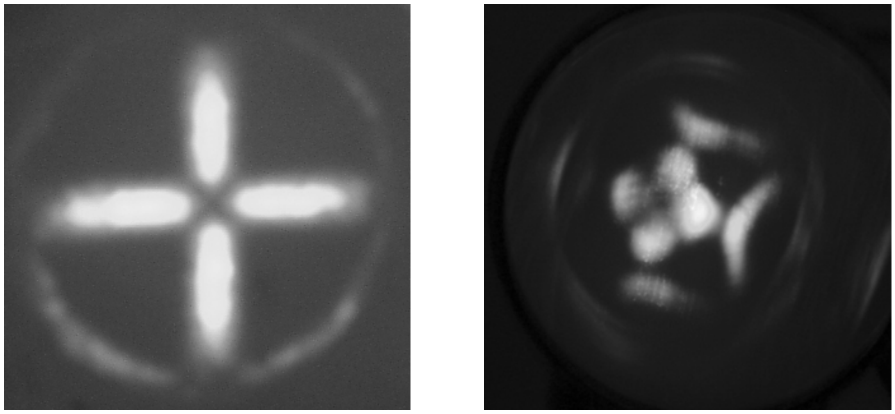
We have studied electron emission from transition metal carbides where research has covered emission from single-crystal carbide field and thermionic emitters[1], thin film carbide coatings on individual emitters and arrays[2]; and deposition of niobium carbide emitter cones in the conventional field emission array geometry[3]. These carbide cathodes have electron emission properties making them attractive candidates for stable emission sources in moderate to poor vacuum applications. The use of ZrC(310) provides a relatively low work function (3.4 eV) emitting surface that has a low evaporation rate, is resistant to ion bombardment and sputtering[4], has a high melting point (~3800 K), and a very low surface mobility. These properties enable the carbide sources to operate at high current densities and also to have long lifetimes in poor vacuum conditions. The robustness of this material has been demonstrated in both field emission and thermionic studies.

We report on field emission from (310) oriented single crystal zirconium carbide. These crystals are electrochemically etched and Vogel mounted to enable flash cleaning and operation at elevated temperatures as needed. Fig. 1 shows typical clean field emission patterns from a (100) and a (310) oriented carbide emitter.

We have operated these emitters in a large range of pressures and compiled data on emission stability. Through processing with methane and oxygen we have achieved emission stability over hour periods in UHV. Through use of a relatively simple analog feedback circuit we have achieved even greater stability without gas processing and have done so for pressures from UHV to 1×10^{-7} Torr. In UHV operation at 300 K these cathodes have low energy spread which makes them attractive over typical Zr/O/W Schottky sources for several applications.

---

1. W.A. Mackie, J.L. Morrissey, C.H. Hinrichs, and P.R. Davis, *Journal of Vacuum Science and Technology A*, **10** (4) 2852 (1992).
2. W.A. Mackie, Tianbao Xie, and P.R. Davis, *Journal of Vacuum Science and Technology B*, **17** (2) 613 (1999).
3. W.A. Mackie, L.A. Southall, Tianbao Xie, G.L. Cabe, and P.H. McClelland, *Journal of Vacuum Science and Technology B*, **21** (1), Jan/Feb (2003).
4. W.A. Mackie, Tianbao Xie, M.R. Matthews, B.P. Routh, Jr., and P.R. Davis, *Journal of Vacuum Science and Technology B*, **16** (4), Jul/Aug (1998).



(a) (b)

Fig. 1: Typical field emission microscope images of patterns from carbide emitters. (a) Clean pattern of a (100) oriented emitter with four (310)/(210) bright emission areas surrounding the (100). (b) Pattern from a (310) oriented field emitter.