High-Current field emission electron source using a reticulated vitreous carbon (RVC) cathode

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A high current density field emission source with high brightness could have many applications in science, medicine and engineering. High field emission current densities have been demonstrated from a large-area, Ar-ion irradiated, reticulated vitreous carbon (RVC) cathode, in a triode configuration. The RVC cathode contains many small nanowires, <50nm in diameter, that serve as excellent field emission tips. The field modification generated by a voltage applied to a grid electrode placed around the cathode increases emission at a given cathode potential. This triode configuration is robust and inexpensive.

It has been shown that Ar-ion bombardment of RVC results in self-assembly of nanoscale features such as cones, nanowires, and nanowiskers [1][2]. RVC is a glassy carbon network of struts and pores that exhibits properties of graphite and diamond. When exposed to an Ar-ion flood bombardment treatment, several self assembly processes occur notably, the surface mobility of free carbon is increased resulting in the migration and build up of carbon in locations that are energetically favorable. This build up appears as agglomerations on the surface that typically have long carbon nanotubes and whiskers emanating from their center. Figure 1 shows the triode structure that employs an RVC cathode. The grid electrode that has been placed around the RVC cathode locally increases and redistributes the extraction field over the surface resulting in increased current at any fixed anode potential, as expected from a traditional triode configuration. The isopotentials were electrostatically-simulated, as seen in Figure 2, to confirm the local increase and redistribution of the field.

Electrical measurements were performed using the triode, examining (using a phosphor screen) spatial patterns and (using a polished stainless-steel anode) total current under a pressure of < $5x10^{-7}$ Torr. Emission occurs in isolated areas over the surface, due to the porous structure of RVC, as evidenced by the beam pattern, shown in Figure 3, observed on a phosphor screen. The electric field generated by the grid electrode increases local field enhancement on the cathode surface and, as expected, increases the extracted current over diode mode. For example, with a field of 1.3V/μm applied by the anode (diode mode), a current density of 0.098mA/cm^2 is obtained. If 300V is applied to the grid, a current density of 0.269mA/cm^2 was measured, and the minimum extraction field correspondingly drops, shown in Figure 4 This resulting current is 2.5 times greater than the diode configuration, and makes possible very-high total current in single field-emission triodes. The electric field required for the onset of emission (defined as: 0.1 μA/cm^2) was measured to decrease by about 25% from 0.9 V/μm to 0.65V/μm with 300V applied to the grid electrode.

Unlike CNT cathodes, the self-assembly process in RVC allows the cathode to continue, in good vacuum, over long durations without failure through damage or poisoning. Current density, as in Figure 4, was evaluated as the current over the entire cathode surface. If only the emitting areas are taken into account, current densities are actually 2-3 times greater. Further work is being done to optimize the triode geometry. Selective Ar-ion irradiation, or an increased RVC porosity may further increase emission.

References

[1] C. E. Hunt, O. J. Glembocki, Y. Wang and S. M. Prokes, *Appl. Phys. Lett.*, **86**, pp. 163112 (2005).
[2] R. Chacon, C. E. Hunt, 21th International Vacuum Nanoelectronic Conference, Volume 21, page168-169 (2008).

978-1-4244-3588-3/09/$25.00©2009 IEEE

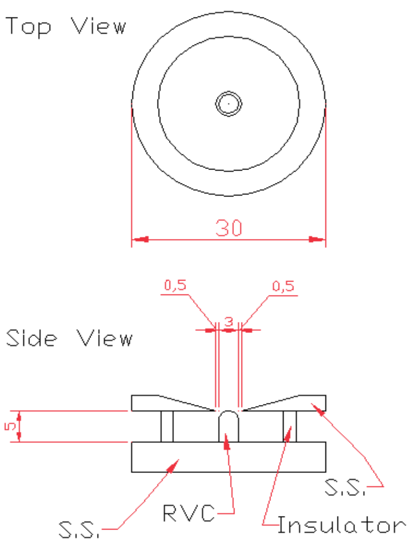

Fig. 1: Triode Configuration. RVC diameter is 3mm

Full triode diameter is 30mm

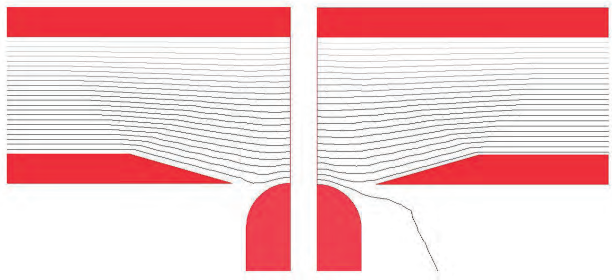

Fig. 2: Isopotentials for 5kV applied to top plate,

left: grid voltage set to 0V, right: grid voltage set to 300V

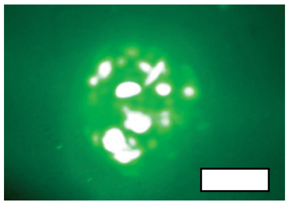

Fig. 3: Beam Pattern, scale bar length is 2 mm

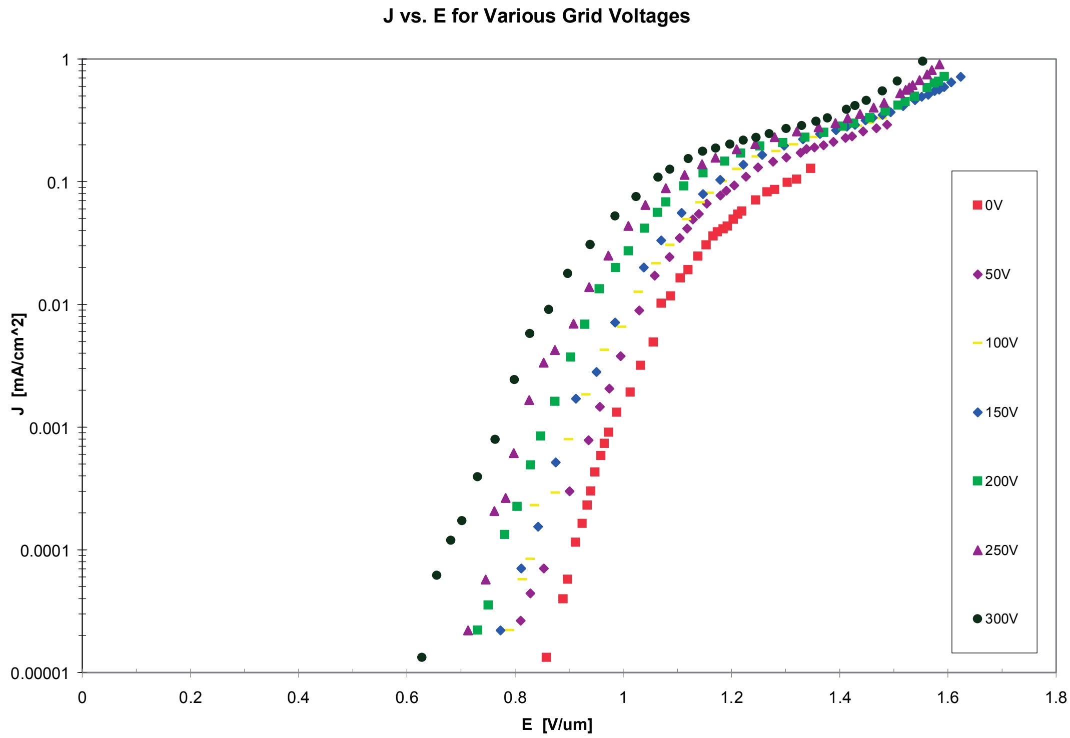

Fig. 4: Field emission characteristics for increasing grid voltages