# DC Training Process for Field Emission Cathodes Based on Reticulated Vitreous Carbon

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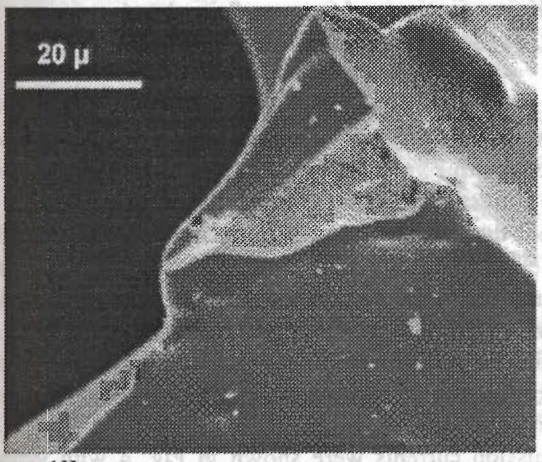
Field emission cathodes fabricated from carbon materials are known as capable of producing significant emission currents in relatively modest vacuum. We investigate here field emission from reticulated vitreous carbon (RVC) [1]. RVC is an open-pore foam of glassy carbon produced from a raw polymeric resin. Compared to other forms of graphite, RVC has (1) greater chemical inertness and (2) more uniform nano-structure. A 3-D porous structure, with up to 97% void volume, RVC has greatly increased surface area. Countless emission sites result from simple machining of the RVC. Porosity ranges from 10 to 100 ppi (pores per inch) [2]. We demonstrate emission from material with differing porosities and compression values.

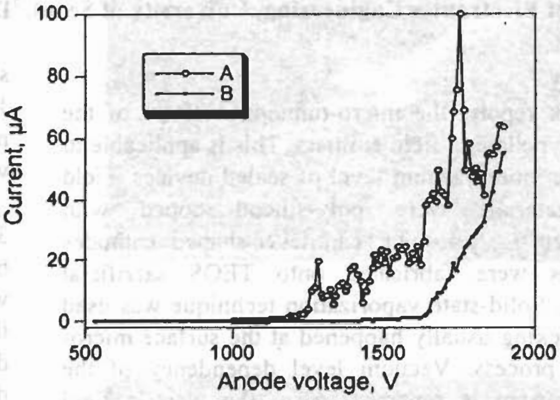
## EXPERIMENT and RESULTS

We measured emission from 3-5mm cubes, cylinders or rectangular blocks machined from bulk RVC material. Sharp and hard edges of the RVC 3-D structure are formed as a result of machining across carbon ligaments. Typical edges with characteristic radii of curvature from 0.5-5 μm (fig. 1) possess millions of nano-scale field-enhanced emission sites. The cathodes were mounted on a stainless electrode imbedded 2-4 mm deep into the RVC. Mechanical and electrical contact was provided using a colloidal graphite with isopropanol. Cathodes were measured in pressures from $10^{-9}$ to $10^{-6}$ Torr for comparison. Measurements were in diode configuration with phosphor screen anodes (P-22 phosphor) on ITO-coated glass positioned 2-5 mm from the cathode with DC voltages 500-6000 V. RVC emitters behave similar to carbon fibers or bulk graphite cathodes: at first turn-on, current "spikes" occur, followed by emission current changes corresponding to changes of the I/V characteristics and field emission pattern on the phosphor screen. Following a period of unstable operation, lasting 100-5000 s, emission behavior stabilizes. Typical I/V characteristics of a cathode during the first turn-on, and after training, are shown in fig. 2 along with F-N shown in fig. 3. Our "training" is performed in several steps with subsequent 20-25 % increase of emission current. The training may involve (1) desorption of contaminants from the surface and (2) destruction of the sharpest emission sites. At that point, the current distributes uniformly among numerous emission sites. Training of RVC varies with different porosities. Even after a long training periods, the current never becomes absolutely stable; fluctuations of 10-20 % persist over the lifetime of the cathode, being accompanied by slight changes in the field emission pattern. This behavior is likely due to a steady state between the destructive and recuperative processes over the large number of emission sites. The inclusion of a series ballast resistor of 10 to 500 M has been demonstrated to reduce the magnitude of fluctuation. Sample emitters of 100 ppi RVC at 50, 120 and 200 μA over 20 hours (Va = 4,000 and 6,000 V, with 100 and 500 M ballast) show no change beyond 20% of average value.

## CONCLUSIONS

Field emitters from Reticulated Vitreous Carbon were examined. The high void volume and porous structure of this material naturally helps to create a large number of emission sites on the surface. Emission centers are formed by sharp edges of carbon ligaments resulting form simple mechanical machining. Initial "training" of the cathodes helps to improve reproducibility of the emission currents. Field emission was studied in modest vacuum ambient at voltages of 500-6,000 V, resulting in currents up to 200 μA. Short-term life tests of 20 hours were performed. RVC field-emission cathodes are viable low-cost sources for various electron-beam applications.




(1) (2)

**Fig. 1. An SEM micrograph showing the fragment of RVC 3-D structure with sharp edges resulting from mechanical machining**

**Fig.2. typical I/V characteristics of an RVC emitter in a DC mode:**
**A - "fresh" surface, B - after 30-min "training"**

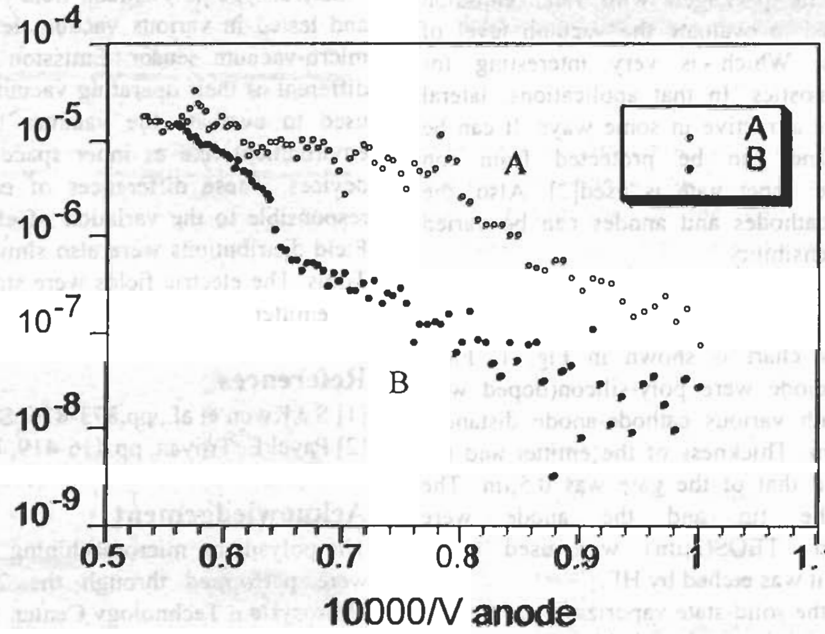



Fig. 3. Fowler-Nordheim characteristics of an RVC emitter:
A - "fresh" surface, B - after 30-min "training"

REFERENCES

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