RETICULATED VITREOUS CARBON FIELD EMISSION CATHODES FOR LIGHT SOURCE APPLICATIONS

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ABSTRACT

Field emission cathodes, fabricated from reticulated vitreous carbon (RVC), have been used in cathodoluminescent light source applications. Electron emission has been evaluated at different current levels (10 to 500 μA) for over 5000 hours in sealed glass devices.

INTRODUCTION

Carbon field emission cathodes are known as electron sources capable of supplying significant currents in relatively modest vacuum. Reticulated vitreous carbon has been investigated as a field emissive material for various vacuum microelectronics applications including low-energy cathodoluminescent light sources. RVC is pyrolytically obtained from an open-pore plastic foam. RVC has demonstrated greater chemical inertness and more uniform nano-structure than other forms of natural graphite. The porous structure has a high void volume (up to 97%), and greatly increased the surface area, making RVC an ideal field-emission cathode material. We present here a mercury-free, high-efficiency cathodoluminescent light source using an RVC field emission cathode.

EXPERIMENTAL SET-UP AND SURFACE TREATMENT

Several configurations of RVC emitters were evaluated, including 3 to 5 mm cubes and cylinders with up to 20mm diameters. The characteristic radii of curvature of emission sites, resulting from machining the RVC, range from 0.2 to 2 microns, as estimated by SEM analysis. Measurements were performed in a UHV chamber and in sealed-glass tubes. The cathodes were positioned 2-5mm from a phosphor-coated or metal anode. DC or pulse-mode measurements were at 500-6000V, in diode configuration. An initial transient, followed by an abrupt current change, was observed; after a few hours, emission current tends to stabilize, typically at lower current. Stable emission current, resulting from electrical "training", as shown in Fig. 1 has been previously reported [1]. This training process results in morphological changes of the emission surface, consisting of a large number of nano-sized emission sites with sharp edges, as can be seen in Fig. 2 (left). There are several explanations of these morphological changes. Recently, we have obtained identical morphological changes using thermal surface treatments, as seen in Fig. 2 (right), without requiring vacuum or emission from the cathode. This corresponds to morphological results seen in thermal treatment of graphite composites [2]; similar results have been reported using Si emission surfaces [3]. Cathodes, thus treated, emit identically to electrically-trained samples.

0-7803-7197-6/01/$10.00

EXPERIMENTAL RESULTS

Emitters made of 100 ppi RVC were measured in the 10-500 μA range for ~5000 hours in a specially-designed test rack, using sealed vacuum tubes, with aluminized phosphor-coated anodes at 6 kV. The vacuum was maintained using a barium getter. No significant changes of the current was observed; in most cases, the current remained within 20% of the initial value. Operation of the RVC cathodes was also observed in a vacuum of 10^{-6} Torr at much higher acceleration voltages - up to 55 kV- in pulsed and DC mode. Because of the x-ray risk, the chamber walls required lead protection. During the high-voltage tests, a stable emission at the current level up to 10 mA has been observed over 4. These results show that RVC material can be used as an electron source in a wide range of light device applications, such as cathodoluminescent lamps and x-ray sources. Design and performance characteristics of some vacuum microelectronic light sources are presented.

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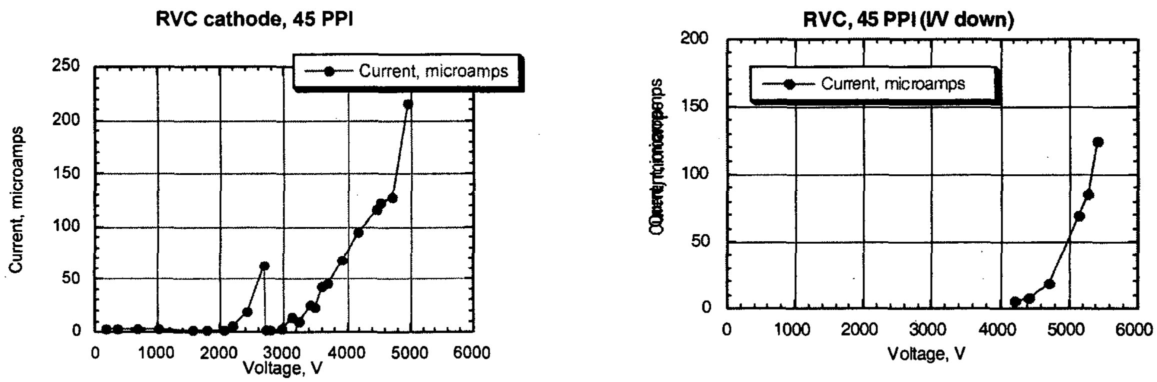

Fig. 1. RVC (45 PPI) training, by DC current, after 1 hour shows I-V shift to higher voltages during the training, but becomes more stable (from [1])

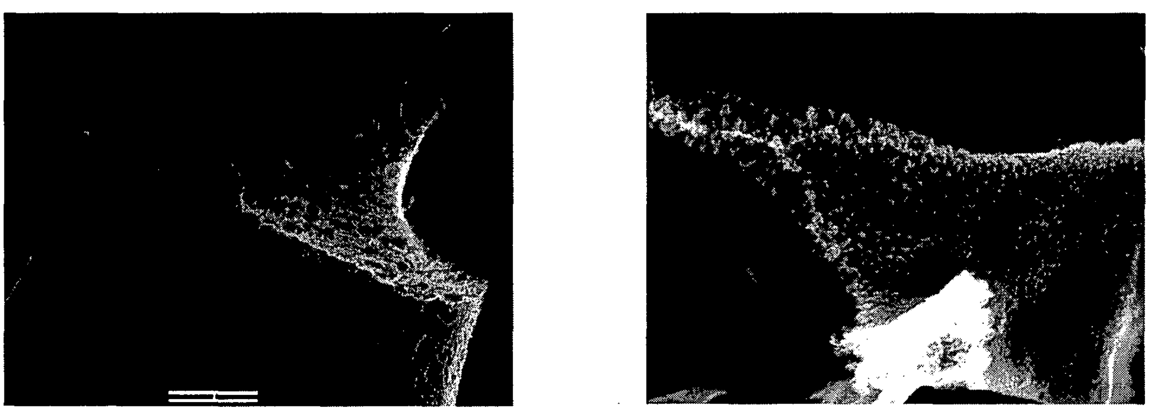

Fig. 2 Emission surface after conditioning by DC current for 1 hour (left). SEM, magnification 1000x, scale bar corresponds to 10 μm. RVC surface after thermal treatment in open air. (right).