Field Emission Cathodes Fabricated from Bulk Carbon Nanotube Fibers and Films

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Abstract: *Carbon Nanotube (CNT) fibers and films have demonstrated excellent field emission (FE) properties and thus hold significant potential for use as electron sources for vacuum electronic devices (VEDs). FE cathodes made from 100µm diameter CNT fibers were fabricated on an industrial grade 3D knitting machine. A 1" diameter cathode was tested using 30kV, 30A power supply with a 300ns pulse width. An applied field strength of 3V/µm produced a measured current level of approximately 15A. A CNT film cathode was fabricated from a 20mm wide film arranged in a corrugated geometry. This cathode was tested in a low impedance linear transformer driver (LTD) system operating at 30kV with a 200ns pulse width. The measured current level was approximately 2kA for an applied field strength of 6V/µm.*

Keywords: field emission; carbon nanotube; cold cathode

Introduction

Recent advances in the development of bulk carbon nanotube materials have resulted in the commercial availability of fibers and films made from high quality CNTs. One method of production is via the wet spinning technique. In this approach fibers are made from concentrated dispersions of CNTs dissolved in a superacid at a concentration of 2 to 8 wt. %. [1]. This solution is filtered to remove particles in order to form a spinnable liquid crystal dope. The dope can then be spun into either fiber or film depending on the extrusion and winding mechanism. Fiber diameters can be from 10-100µm and have demonstrated excellent field emission properties [2-4]. CNT films have been fabricated with widths from 4-30 mm. These fibers and films can then be used to make large area, robust field emission cathodes.

Experimental

Cathode Fabrication: CNT fiber cathodes were fabricated at the Functional Fabric Center at Drexel University. A 100µm diameter CNT fiber was twisted into 4-ply yarns to make a rope with an approximate diameter of 400µm. This rope was then fed into a Shima 3D knitting machine to fabricate a 1" diameter CNT fiber cathode. The cathode was then mounted in a custom holder for testing at the Air Force Research Laboratory (AFRL) as shown in Figure 1.

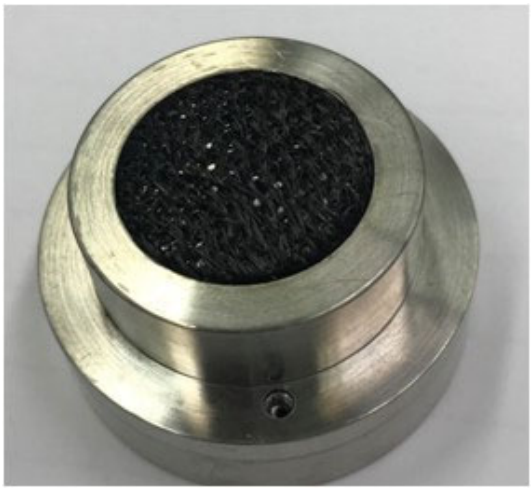

Figure 1. Field emission cathode fabricated from CNT fiber using the 3D knitting facilities at the Functional Fabric Center at Drexel University.

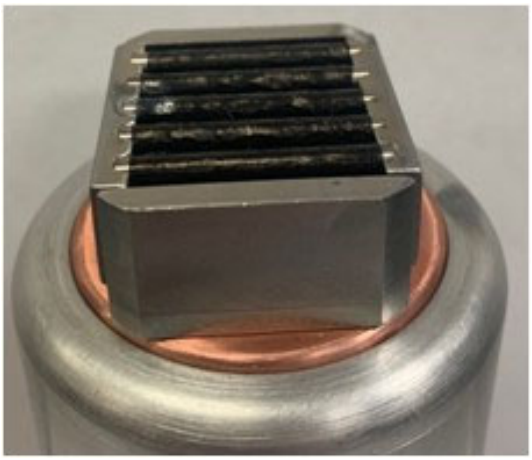

Figure 2. Field emission cathode fabricated at AFRL using a CNT film and a custom made holder allowing for a corrugated configuration.

A CNT film cathode was fabricated at AFRL by using a precision machined cathode holder consisting of mounted parallel rods of alternating heights. This allowed the film to be folded over and under the rods in a corrugated configuration. The cathode is shown in Figure 2.

Cathode Testing: The 3D knitted CNT fiber cathode was tested in custom designed field emission characterization system at AFRL The voltage source was an Eagle Harbor Tech pulser operating at 30kV with a 300ns pulse width. The A-K gap was varied from 10-30mm with current measurements made at incremental steps. The maximum current measured was >15A for an applied field strength of of 3.0V/μm as shown in Figure3.

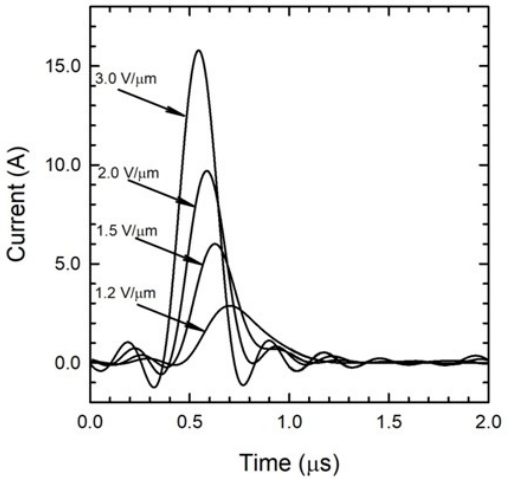

Figure 3. Current vs. time plot for the CNT fiber cathode at varying A-K gap distances for an applied voltage of 30kV with 300ns pulses.

The CNT fiber cathode was tested in custom built linear transformer driver (LTD) system in the Pulsed Power, Beams, and Microwaves Laboratory at the University of New Mexico. LTDs are low impedance, compact devices that can deliver very fast high-current and high-voltage pulses [5]. For this experiment the LTD was operated at 30kV with a 200ns pulse width. The A-K gap was set to 5mm for an applied field strength of of 6.0V/mm. The maximum current measured was >2kA as shown in Figure 4. The change in polarity of the pulse is due to an impedance mismatch in the A-K gap.

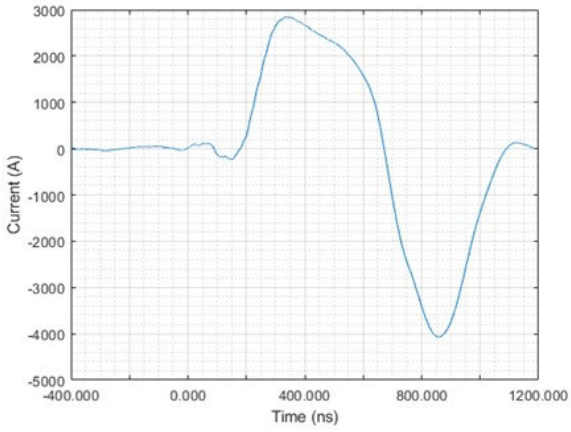

Figure 4. Current vs. time plot for the CNT film cathode tested in the LTD with an applied voltage of 30kV and a 200ns pulse width.

Summary

Carbon nanotube materials offer excellent potential for use as field emission cathode materials. These materials are now available as both CNT fibers and films in bulk form. We have developed innovative fabrication approaches towards scaling up these materials for into large area field emission cathodes. Preliminary experimental results are encouraging and demonstrate the potential use of these materials as robust high current density cathodes for next generation vacuum electronic devices.

Acknowledgements

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