Single Walled Nanotube (SWNT) Fiber Field Emission Cathodes

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Field emission DC cold cathodes continue as an important area of research for uses such as electron microscopy, novel x-ray sources, vacuum electronic devices, THZ sources, and high power microwave tubes. Each of these applications typically requires high current densities with a high brightness electron beams driven by cathodes exhibiting long lifetime in the presence of deleterious conditions such as ion back bombardment and excessive heating. For example, high frequency traveling wave tube (TWT) amplifiers have small beam tunnels (<100μm) that require small diameter, high current density electron beams. The Air Force Research Laboratory (AFRL) began research on small diameter single fiber DC cathodes for this application. Two types of fibers were tested. Fibers made from graphite were compared to fibers made solely from single walled carbon nanotubes (SWNTs). Field emission testing has been performed. Graphite fiber cathodes suffered serious degradation due to joule heating after only 25 hours of operation while only producing up to 200μA of current. SWNT fiber cathodes operated stably to within 0.6% with a 5 mm gap at 7 keV and 2.4 mA current for hundreds of hours while showing minimal physical damage [1].

SWNT fibers consist only of highly aligned nanotubes without any surface contaminants or impurities. They are made by spinning dispersions of SWNTs in 102% sulfuric acid into different coagulants [2]. Acid intercalates SWNT bundles and promotes the formation of a nematic liquid crystal with polydomain morphology. This liquid crystalline SWNT dispersion can be extruded and coagulated in a controlled fashion to produce continuous lengths of macroscopic neat SWNT fibers. The resulting macroscopic fibers are approximately 40 to 100 microns in diameter with a density that is 70-80% that of the theoretical close-packing density for 1.0 nm diameter SWNTs. Electrical resistivity of the fibers ranges from 0.2-2 milli Ohm cm, and thermal measurements have given a

conductivity of roughly 20 W/Km. Typically, fibers posses a Young Modulus of 100-120 GPa and a tensile strength of 50-200 MPa.

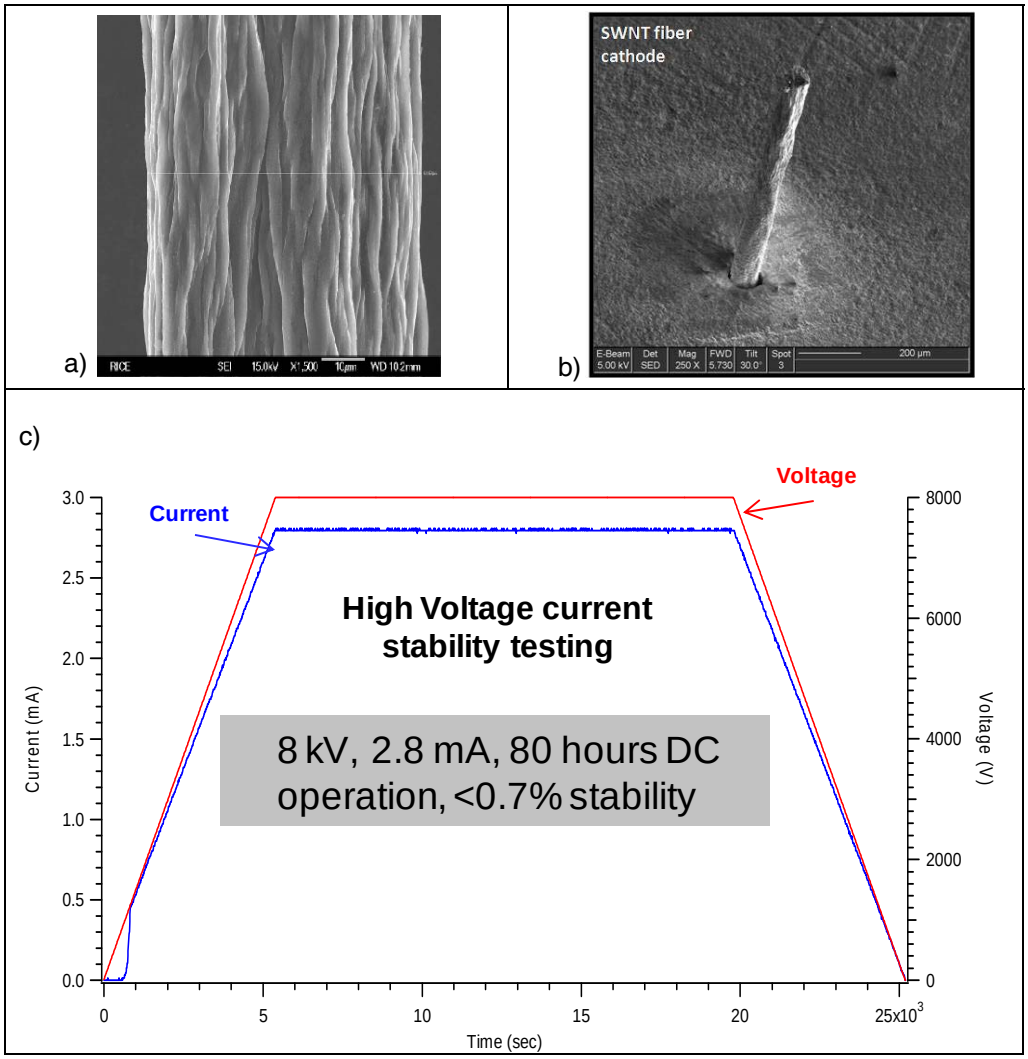

Figure 1. a) SWNT fiber, b) SWNT fiber cathode, c) field emission results for SWNT fiber cathode.

[1] D. Shiffler, S. Fairchild, W. Tang, B. Maruyama, K. Golby, M. LaCour, M. Pasqualli, and N. Lockwood, "Demonstration of an Acid Spun Single Wall Nanotube Fiber Cathode", submitted to to Journal of Applied Physics

[2] L.M. Ericson, H. Fan, H. Peng, et al, "Macroscopic Neat Single-Walled Carbon Nanotubes Fibers," *Science*, Volume 305, Issue 5689, September 3, 2004.