Nanostructured Anode and Cathode Materials for High Pulsed Power Electromagnetic (HPEM) Devices

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High Pulsed Power Electromagnetic (HPEM) devices are used in numerous applications including vacuum electronics, particle accelerators, and microwave generators. Stable, long term HPEM device operation is hampered by plasma formation in the anode-cathode gap region which results in pulse shortening and cathode damage caused by ion back bombardment. Plasma originates from gas molecules that are desorbed from both the cathode and anode surfaces when heated. Secondary electron emission (SEE) from the anode surface leads to ionization of the molecules near the surface. Improved materials for electron beam emission and collection are needed to mitigate these effects, and novel nanostructured materials have shown considerable promise towards this realization.

Field emission (FE) cathodes made from carbon nanotube (CNT) fibers have demonstrated high emission currents, low turn-on voltages and long lifetimes. The CNT fibers were ~50um in diameter and showed increasing electrical and thermal conductivity with increasing fiber alignment. Fiber alignment was characterized with wide angle x-ray diffraction and fiber morphology was investigated with SEM and scanning 3D X-ray microscopy with 50 nm resolution. Stable field emission currents exceeding 1 mA for 10 hours and at an operating field strength of $< 1V/\mu m$ were achieved [1]. Residual gas analysis (RGA) was used to identify the species desorbed during field emission which showed a sharp threshold for H_2 desorption at an external field strength that coincides with a breakpoint in the FE data [2]. Graphene was used to improve anode material performance during electron beam collection experiments. Hydrogen outgassing was induced by repeated pulses (60 s duration) of 60 keV electrons onto anode material samples and recording the H_2 signal with a line of sight RGA. A nickel – graphene surface reduced the H_2 outgassing and SEE by factors of three and two respectively over a bare nickel surface. Additionally, metallic anode samples were treated with the laser surface melting (LSM) technique to further reduce hydrogen outgassing. The samples were irradiated with a continuous high energy laser beam which resulted in melting, flow and re-solidification of the surface which decreased the number of grain boundaries through which hydrogen can diffuse. The data show at least a five-fold reduction in hydrogen outgassing from the LSM treated sample, compared to those that were untreated. Graphene applied to an LSM treated metallic surface offers the ideal combination of reduced SEE and H_2 outgassing for anodes. Experimental results for these layered structures will be discussed.

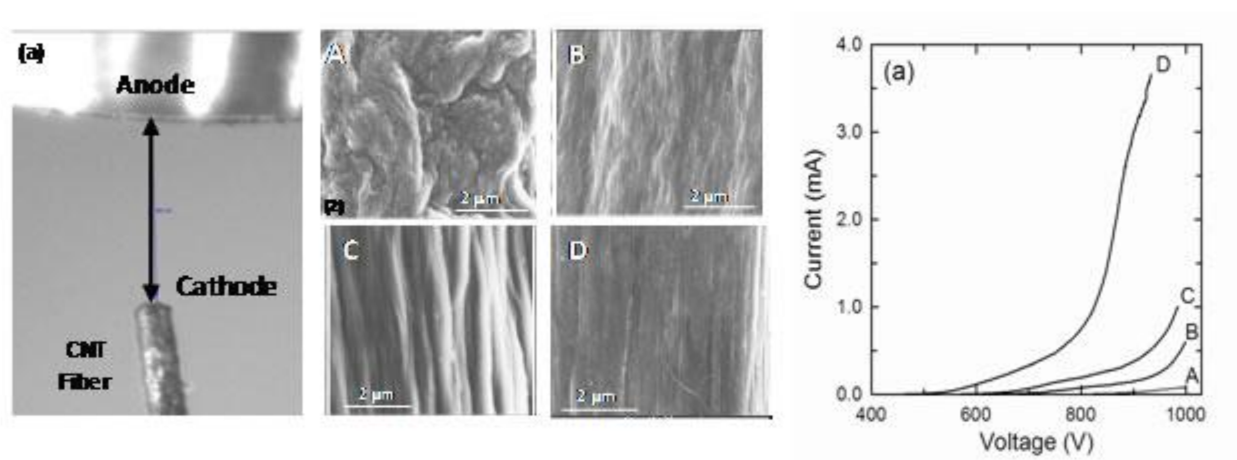

Figure 1. (a) CNT fiber cathode. (b) SEM images of CNT fiber samples A,B,C, and D with corresponding orientation parameters as determined by wide angle x-ray diffraction of S_d = 0.34, 0.43, 0.64, and 0.80. (c) Corresponding field emission data for fiber samples A,B,C, and D [1].

[1] S B Fairchild *et al* 2015 *Nanotechnology* **26** 105706
[2] P T Murray *et al* 2013 *Appl. Phys. Lett.* **103** 053113