Mat. Res. Soc. Symp. Proc. Vol. 685E © 2001 Materials Research Society

# Emission Properties of Nanostructured Carbon Field-Emission Cathodes

[1]Chakhovskoi, A.G, [1]Chubun, N.N.; [1]Hunt, C.E.; [2]Obraztsov, A.N., [2]Volkov, A.P.

[1]University of California at Davis, One Shields Avenue, Davis, CA, 95616
Phone (530)752-2735, Fax (530)752-9217, e-mail: chakhovs@ucdavis.edu
[2]Department of Physics, Moscow State University, 119899, Moscow, Russia

## Abstract

*Planar field-emission cathode structures consisting of nanostructured carbon flakes have been investigated as an electron source for flat panel display application.*

*Layers of nanoflakes were grown on silicon and molybdenum substrates using a high-temperature pyrolitic plasma-assisted CVD method. The result is a vertically oriented nanocluster layer of 1-2 micrometer height chemically bonded with the substrates. Additional orientation of the flakes, occurring during the first activation of the cathodes, was observed.*

*Field emission properties of the emitters were studied in a vacuum chamber and in sealed flat-panel prototype devices with non-patterned low-voltage phosphor screens. Emitters with an area up to 1 square inch were tested under DC currents up to 100 microamps in diode mode. Anode bias up to 1.5 kV was applied. Current fluctuations of 1-2% were achieved using loading resistor.*

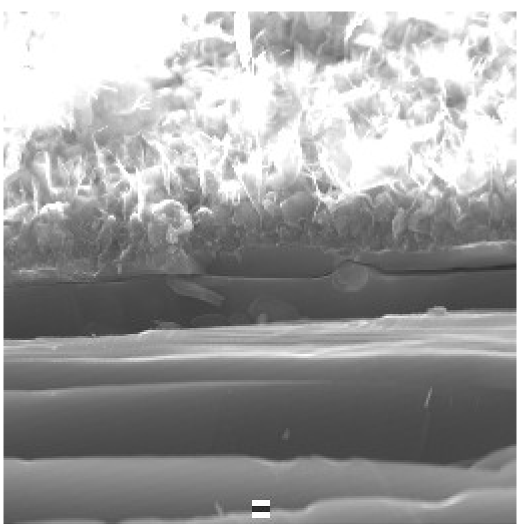
Keywords: Electron emission, field emission cathode, FPD

## Introduction

Oriented carbon nanostructures were recently reported as a viable material for fabrication of field emission cathodes applicable to flat panel displays (FPD) and vacuum light sources [1, 2]. Various carbon-based nanostructures, fabricated by different techniques, demonstrated very attractive field emission properties for practical applications in sealed devices [3, 4]. It was shown that carbon-based field emission materials are compatible with cost-effective printable technology of FPD fabrication [5]. In this research we have investigated field emission from carbon films consisting of nanoclasters (flakes) grown on silicon or molybdenum substrates using pyrolitic CVD method.

## Experimental

Carbon nanoclaster layers were grown on silicon and molybdenum substrates by direct discharge assisted CVD method. The plasma was activated by DC discharge at 100 Torr in a methane-hydrogen gas mixture with 10% of $CH_4$ under heating temperature of 1050°C. The substrate surface was preliminary treated with ultrasonically activated nanodiamond slurry (grain size 2-6 nanometers). The final nanoclaster films have an appearance of flakes of 1-2 micrometer height, while the individual flakes are 10-30 nanometers wide (fig.1). The nanoclaster films were strongly chemically bonded to both silicon and molybdenum substrates. The carbon flake films exhibited mainly vertical initial orientation parallel to DC electric field applied during the growth process. Deviations in orientation may depend on variation of the deposition process parameters. An additional orientation of the nanoflakes in electrostatic filed during first activation of the cathodes was observed during operation of test devices and confirmed by the SEM analysis. The orientation of the flakes during first turn-on of the test devices almost always was accompanied by brief oscillation of the phosphor screen brightness, an effect that never appeared at subsequent device operation.



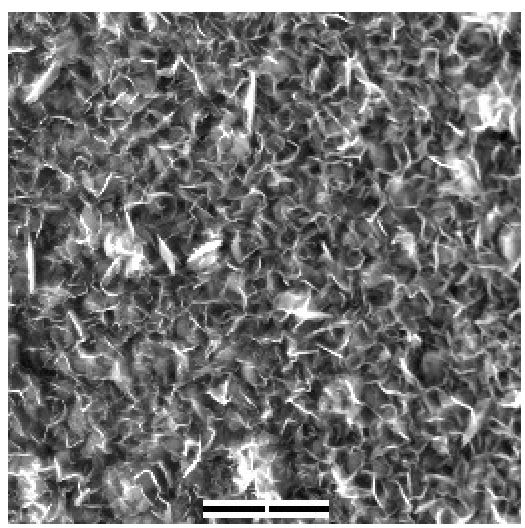


Figure 1. Carbon flake layer deposited on Silicon substrate:
Left – cross-sectional view, scale bar corresponds to 1 micron;
Right – top view, scale bar corresponds to 10 micron.




https://doi.org/10.1557/PROC-685-D5.26.1

Field emission properties of diodes with oriented carbon nanostructured cathodes were studied in sealed glass flat panel prototype devices. Flat-panel diode display packages shown in Figure 2 were used for testing of the square 25x25 mm cathodes. The upper and lower glass panels were made from tempered glass coated with conductive indium tin oxide (ITO) layers. The size of the panels was 40x50 mm, the upper panel was turned 90 degrees with respect to the bottom one to provide an easy electrical contact to ITO layers. Monochrome low-voltage phosphors were electrophoretically deposited on top plates forming non-patterned anodes used to monitor the distribution of the filed emission sites. External ballast resistors of different values ranging from 1.1 to 8.8 MΩ were used for stabilization of the emission. The prototype devices used non-evaporable titanium sponge getters placed in the exhaust tubes. The figure 2 shows a prototype sealed device and a cathode plate (left), and a device during operation (right).

The devices were tested using DC voltage source using a set up described in [6,7]. The first turn-on was usually observed at the anode voltages in the range of 200-250 V in DC mode of operation with the cathode-phosphor screen gap of 0.2 mm. The anode voltages of 600-750 V were required to achieve the total current up to 100 μA.

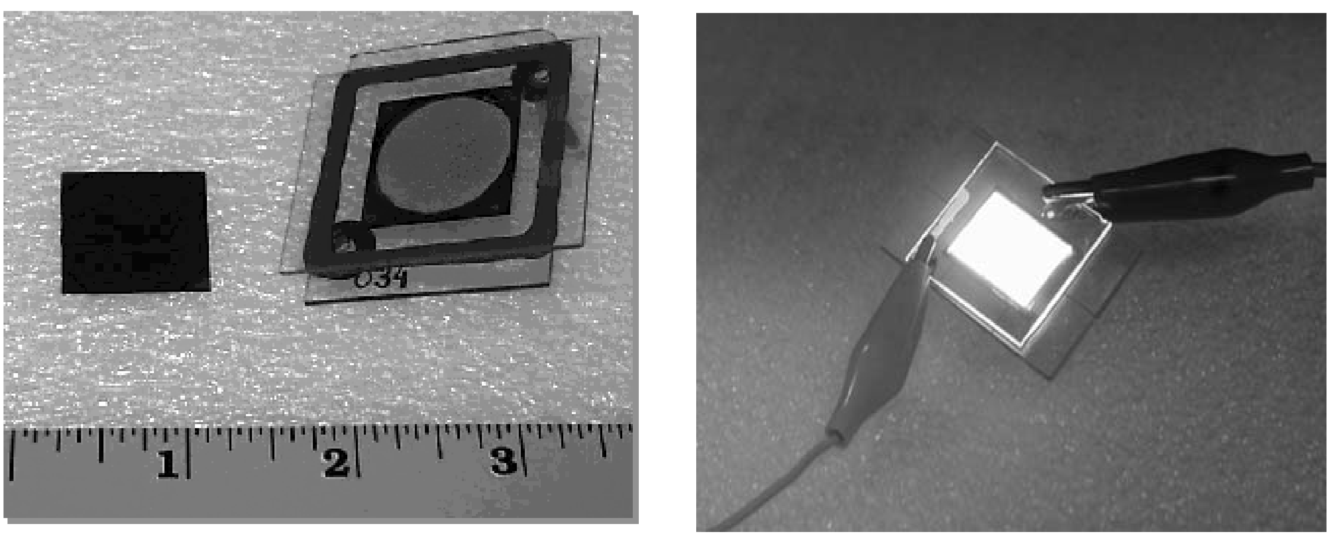


Fig. 2 A prototype sealed device and a cathode plate (left), and a device during operation (right).

Turn-on electric field for diode test packages varied from 0.8 to 2 V per micron. A typical I/V characteristic of a diode test device is shown in Fig.3. Curve 1 corresponds to the measurements with no ballast resistor; curves 2 and 3 were taken with serial resistors of 1.1 to 8.8 MΩ. Figure 4 shows brightness of the phosphor screen with and without resistive loading.

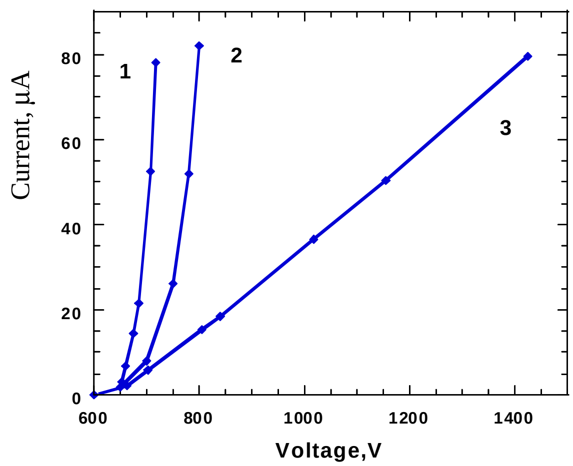



Fig. 3 Left: A current-voltage characteristics of the sealed diode test device (1) no ballast resistor; (2) of 1.1 MΩ resistor, (3) 8.8 MΩ.

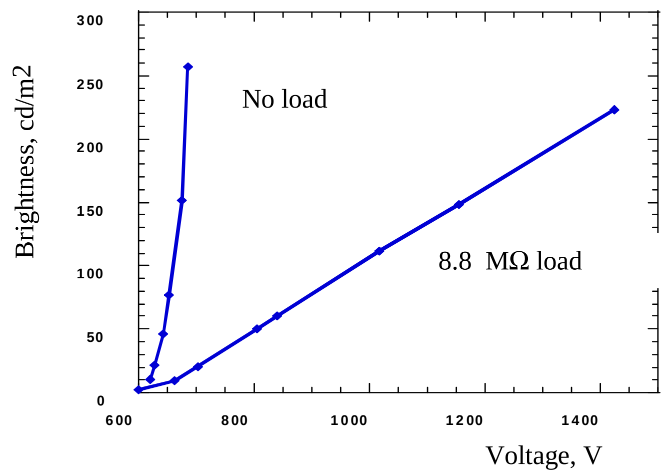



Fig 4. Brightness of the test device with no resistive loading and with 8.8 MΩ serial resistor

**Conclusion**

Oriented carbon nanoflake field-emission cathodes were fabricated on silicon and molybdenum substrates. Field emission currents up to 100 µA is observed under electric field strength 3-3.75 V/µm. Cathodes were tested in the sealed prototype devices compatible with flat panel display manufacturing requirements.

**References**


1. A.N.Obraztsov, I.Yu.Pavlovsky, A.P.Volkov, V.L.Kuztetsov, A.L.Chuvilin. MRS 1999 Spring Meeting, San Francisco, CA, April 1999, p.B.4.9/C.2.9.
2. A.N.Obraztsov, I.Yu.Pavlovsky, A.P.Volkov Low-voltage electron emission from chemical vapor deposition graphite films. JVST B 17(2) Mar/Apr 1999, pp.674-678.

3. H.Kim, J.W.Huh, M.J.Kim, J.Y.Oh, Y.R.Cho, H.S.Jeong and S.Ahn Development of a Diamond-like Carbon Based Field Emission Display. IVMC'98 Technical Digest, Asheville, NC, USA, 1998, p.193.
4. O.M.Kuttel, O.Groning, Ch.Emmenegger, E.Maillard, and L.Schlapbach Electron Field emission from Nanotubes and Other Carbon Containing Films. IVMC'98 Technical Digest, Asheville, NC, USA, 1998, pp.194-195.
5. R.A.Tuck Printable Large-Area FEDs. Information display. Vol. 16, #6, June 2000, pp. 14-16.
6. A.G.Chakhovskoi, C.E.Hunt Abstracts of MRS Spring'2000 Meeting, San Francisco, 2000, R.5.8., p.286.
7. Chubun N.N., Chakhovskoi A.G., Hunt C.E., Obraztsov A.N., Volkov A.P., Emission Characterization of Nanostructured Carbon Field-Emission Cathodes, Technical Digest of 2000 International Vacuum Electron Sources Conference, Orlando, FL, 2000, paper H-7.