Paper

Correlation between electric parameters of carbon layers and their capacity for field emission

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Abstract— The aim of this work is to study a possibility of field electron emission from carbon layers produced by radio frequency plasma chemical vapor deposition (RF PCVD) method. A correlation between electric parameters of the layers and the ability to produce electron emission is also studied through material (AFM) and electrical (*C-V*, *I-V*) characterization of the obtained layers. It is demonstrated that the layers deposited with the highest self-bias exhibit the highest capacity for electron emission.

Keywords— carbon layers, diamond-like carbon (DLC), field emission, RF PCVD, AFM, capacitance-voltage (C-V), current-voltage (I-V).

1. Introduction

The phenomenon of the electron cold emission has been extensively investigated recently. A number of applications based on this effect may be found in microelectronics, biology, chemistry and medicine. While technologies of emitter fabrication have been developed for production purposes, they are expensive and complicated. Therefore many laboratories are interested in new and competitive methods and materials suitable for field electron emitters. Carbon layers produced with radio frequency chemical vapor deposition (RF CVD) method seem to be very promising as a field emitting material.

2. Experimental details and results

The deposition processes were carried out on p-type silicon < 100 > substrates (5 – 7 Ωcm resistivity). Carbon layers deposition process parameters are shown in Table 1.

Table 1
Parameters of carbon film deposition

Sample	Self-bias voltage [V]	Pressure [Pa]	Time [min]	Flow of gases CH_4/Ar [ml/min]
Z1	350	41.1	10	20/5
Z2	280	41.1	10	20/5
Z3	250	41.1	10	20/5

The electronic properties of carbon layers were calculated from the results of metal-insulator-semiconductor (MIS) capacitor high-frequency capacitance-voltage (*C-V*) and current-voltage (*I-V*) measurements. The carbon layers played the role of gate insulator in the investigated MIS structures.

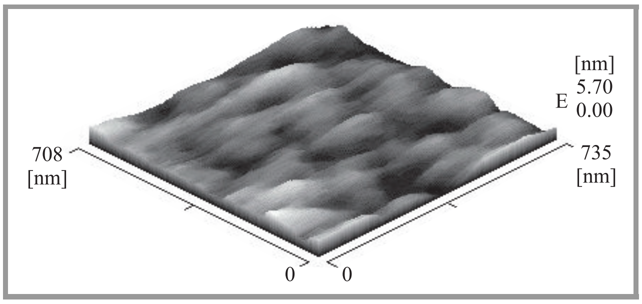

Fig. 1. AFM image of carbon layer surface after deposition, sample Z3.

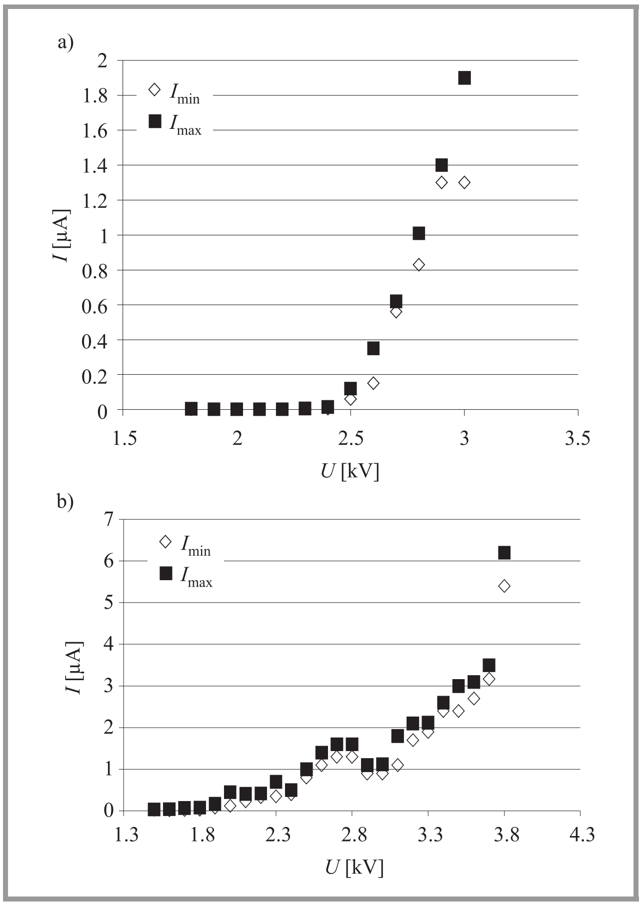

Fig. 2. Field emission current versus voltage: (a) Z2 sample; (b) Z3 sample.

The surfaces of carbon layers was investigated with atomic force microscope (AFM) (Fig. 1). The field emission was measured under the following conditions: voltage ranging from 0 to 4 kV, distance between electrodes in the range of $0-1$ mm and chamber pressure of 1 mPa. The results of emission current measurements are shown in Fig. 2.

3. Discussion and conclusions

Sample Z3 exhibits the highest capacity for field emission. Sample Z2 on the other hand has better electrical parameters and higher breakdown voltage than other samples. The results indicate that carbon layer of sample Z3 has higher content of graphite phase and less ordered carbon structure. The sample has higher capacity for field emission of electrons, but its breakdown voltage is low (Table 2).

Table 2

Electrical parameters of MIS Al/C/Si/Al capacitors

Parameters	Sample Z1	Sample Z2	Sample Z3
Thickness of carbon layer [Å]	2610	2380	2300
U_{FB} [V]	0.26	0.48	6.9
U_{MB} [V]	-4.6	-1.55	-2.13
Q_{eff} $[\mathrm{C \cdot cm^{-2}}]$	$-4.600 \cdot 10^{-8}$	$-4.572 \cdot 10^{-8}$	$-1.312 \cdot 10^{-7}$
D_{it}	$6.71 \cdot 10^{12}$	$7.42 \cdot 10^{11}$	$1.63 \cdot 10^{12}$

The literature reveals the two major factors supporting field emission from carbon layers: irregularity of the surface and profusion of sp^2 phase in layer [1, 2]. The surface of deposited carbon layers is smooth (Fig. 1), therefore we believe that a better field emissivity from sample Z3 is caused by amorphous structure and profusion of sp^2 phase in the layer, rather than by irregularity of the surface or nanocrystalline diamond (NCD) forms. While the electrical quality of the layers is poor, our experiment has shown that they could be applicable in micro and nanoelectronics structures and devices.

Acknowledgements

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Jan Szmidt – for biography, see this issue, p. 36.