Carbon Nanotubes Emission Electronics – New Direction in Vacuum Microwave Microelectronics

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Abstract

Carbon Nanotubes Emission Electronics is advanced direction in Vacuum Microwave Microelectronics in the World. Arrays of Carbon Nanotubes (CNT) as cathodes for Microwave devices are experimentally obtained. A new types of efficient displays using CNT cathodes are demonstrated. Many other applications of CNT autoemission cathodes in vacuum microelectronics are suggested. Some results by the authors in theoretical and experimental study of CNT structures are presented.

1 Introduction

Vacuum electronic devices are still widely used in the industry especially in high power radars and high current electronics. Miniature vacuum electronic devices: BWT, Δf = 1÷4 GHz, weight < 0.1 kg, BWT, Δf 36 - 300 GHz, weight < 1 kg, are widely used in the ground, plane, spacecraft equipment, in the radiometers as heterodynes for various radars, in navigation devices etc. Very important applications of vacuum electronic devices are X-Ray sources (in particular, in medicine), cathode – ray tubes, super high quality audio amplifiers, plasma TV displays, electron and scanning tunnel microscopy, etc. The advantages of vacuum electronic devices are the following:

- high work temperatures (up to 800°K),
- high resistance to radiation (up to 10^{15} n/cm^2 and 10^{17} R/sec),
- high resistance with respect to electromagnetic fields, etc.

The results obtained by the authors under investigation of new electron autoemission materials, carbon nanotubes and nanostructures as well as its properties, were presented at URSI AP-RASC 2019 [1].

2 Theoretical and experimental study of CNT structures

During latest three decades a new direction is being developed - vacuum microelectronics, which is based on the phenomenon of auto electron emission (or field electron emission), the emission of electrons from solid or liquid conductors or semiconductors to vacuum under the influence of strong electric field (usually <10^7 v/cm).

The main goals of vacuum microelectronics development are the following: new electron emission guns for microwave devices, new types of efficient displays (in particular for TV) with higher brightness and less energy consumption, new types of X-Ray tubes operating at low voltage with high efficiency, new types of special processors, working with super high speed under the conditions of high temperatures and high level of radiation and electromagnetic surroundings, new efficient and harmless sources of light etc.

Here we present the theoretical an experimental study of CNT structures including doping and technology methods of growing regular bundles of CNT for CNT cathodes. Electron field emission from carbon films containing nanotubes and nanostructures was firstly predicted and experimentally observed in 1993 at Saratov Branch of the Kotelnikov IRE RAS. The results were presented at the 7th International Vacuum Microelectronics Conference IVMC'94 at Grenoble, France. [2]. Transmission electron microscope image of carbon nanotube and Carbon film with pattern through catalytic lithography (electron-scan microscope are presented at Figure 1.

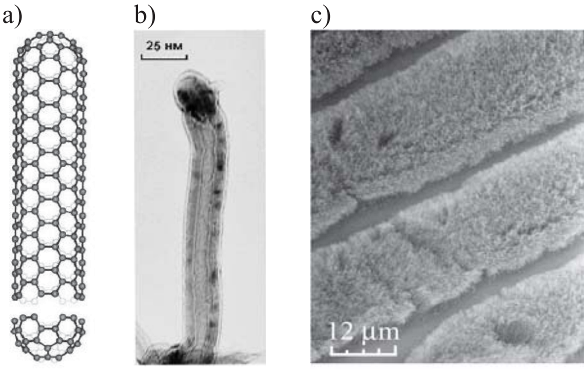

Figure 1. a), b) Transmission electron microscope image of carbon nanotube, c) Carbon film with pattern. Catalytic lithography (electron-scan microscope)

Doping of CNT by IV group elements leads to essential reduction of work function [3] as it presented at Figure 2.

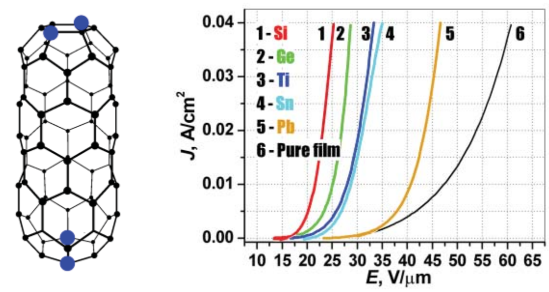

Figure 2. Doping of CNT by IV group elements leads to essential reduction of work function.

Some technologies for synthesis of Carbon Nanotubes at Saratov Branch of Kotelnikov IRE RAS are applied: cathalytic plasmochemical vapor deposition method (PCVD), catalytic high temperature pyrolysis and magnetron sputtering from graphite target.
Digital diode type indicators with field-emission cathode based on carbon nanotubes (Anod-cathod gap - 200 мкm and brightness ~ 20 000 kJ/m^2) has been developed by Saratov Branch Kotelnikov IRE RAS in collaboration with industry and now matrix display based on triod carbon nanostructure is developed.
Principal Scheme of the Pixel from CNT Field Emission Display (YOS: Eu-Red, ZnS: Cu, Al-Green, ZnS: Ag,Cl-Blue) is presented at Figure 3.

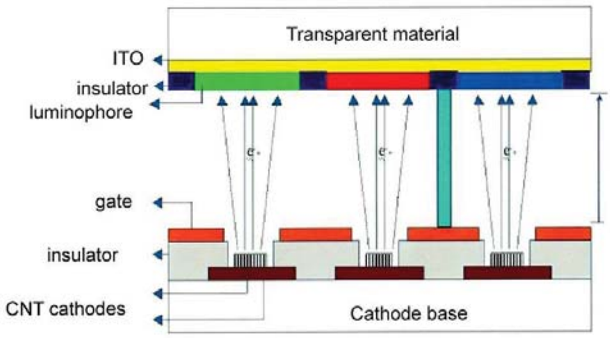

Figure 3. Principal Scheme of the Pixel from CNT Field Emission Display

First Color TV-set with 38 inches CNT Display was produced by Samsung Electronics in 2011. Unfortunately, it was not widely used because of the high cost of the screen namely. Nevertheless, the advantages of CNT field emission displays in comparison with traditional liquid crystal displays are low energy consumption, good visibility of the images even at bright lighting. So, probably, first of all, CNT displays could find applications in mobile devices like video camera. CNT displays also strongly demanded for the different devices inside the cabin of airplane, car, high-speed train, ship, etc.

3 Conclusion

At present, the development and practical implementation of the Carbon Nanotubes Emission Electronics is significantly demanded because the developing devices could provide transmission, receive, storage and real time processing of the data under environment extremal impacts (initial radiation, high and low temperatures, large light energy fluxes, etc.).
Some other applications of CNT, investigated in Russia and elsewhere are: Transducers of physical values: Sensors of pressure acceleration, etc; Active electronics components: Diodes and triodes, etc; EMI screens, microwave filters, antennas, etc.; Accumulators 3D Circuits and interconnections etc.

4 References

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