EMISSION PROPERTIES OF CARBON NANOTUBES

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Introduction

High emission characteristics of carbon nanotubes have attracted attention of researchers for about 10 years. Considerable effect of enhancement of electric field near the tip of a nanotube and good conductance have allowed electron emitters based on nanotubes to compete noticeably with traditional commercial devices that use metal and semiconductor sources of electrons. This allows the development of high effective low voltage and low temperature emitters based on nanotubes, and also field devises to create bright and economic plane displays, light sources, vacuum pressure transducers [1].

Stringent requirements are made to the matrix emitters created from the nanotube mass. The nanotubes must be straight, located perpendicular to the site where they form and have the same length and diameter. Bending and non-perpendicularity are responsible for instability of emission current what often makes increase spacing between a control electrode and an emitter.

Discussion

The problem on achieving high spatial homogeneity of emission characteristics of carbon nanotubes (CNT) and reducing threshold intensity of electric field remains in the case of practical applications of CNT. Different groups of development engineers have the approaches to solving this problem that differ by the method for CNT production and the type of substrate.

Chemical precipitation of hydrocarbons over the nanoporous surface in which pores are filled with metal-catalyst particles are applied to form large matrixes of CNT. Researchers at Pekine University [2] have used substrates from anodized aluminium prepared in a special manner. The nanotubes growing from the pores of anodized aluminium had open ends and a rather large internal diameter. Field electron emission of the prepared matrixes has been investigated in a vacuum chamber at a pressure of residual gases 10^{-8} Torr and a voltage of 1100 V. An aluminium sheet 5 mm in diameter was an anode. The area of the emitting surface was 2 mm^2, the electrode spacing was 300 μm. At intensity of 3.6 V/μm density of emission current reaches 0.08 mA/cm^2 and remains stable during 150 hours.

The group of Japanese and American researchers [3] has performed measurements of the work function of monolayer nanotubes using the method of photoelectron emission. The nanotubes were prepared by laser ablation, purified by filtration using ultrasonic irradiation and deposited on the GaAs substrate by sputtering. Pressure in the chamber of an analyzer was $2\cdot10^{-9}$ Torr. Voltage, about 9 V, was applied to a sample. The work function was about 4.8 eV for graphite and monolayer nanotubes.

Measurements of field emission [4] have been performed in conditions of ultrahigh vacuum. Small diameter and high aspect ratio make CNT prospective to create low voltage field emitters. The performed investigations have shown that density of emission current is about 1 mA/cm^2 at average electric field intensity E = 2.5÷3.0 V/μm.

Field emission properties of autocathodes from CNT doped with barium and without it have been studied in [5]. The studies have been conducted in a diode probe located in the vacuum camera ($5\cdot10^{-7}$ Torr). The values of electric field intensity are 4.45 V/μm and 3 V/μm for pure nanotubes and for nanotubes doped with barium, respectively. The latter is less by 30%. In this case the glass plate covered with a conducting layer of ITO and a layer of phosphor was used as an anode. The electrode spacing was about 300 μm. The achieved working function is 0.77 eV.

At the Lukin Research Institute for Semiconductors Physics the plane cathodes were prepared from nanotube powders by stenciling. Field emission properties of the above cathodes have been measured in the diode probe. The investigations have shown that at the intensity of the applied field equal 5 V/μm spread of emission currents is ±0.25 μA at the average current density of 4.25 $\mu A/mm^2$. In the diode design the important characteristic of emission emitters is direct current to back current ratio that is over 10^5 for the prepared samples and far exceeds the analogous value in semiconductive devices.

The laboratory of Institute for Problems of Materials Science of NAS of Ukraine gained wide experience in synthesis of carbon nanotubes, new carbon compounds, exo- and endofullerenes, and composites based on them. The carbon nanostructures in the form of cylindrical tubes with cut tips, and the nanotubes with pointed tips produced by electric arc method in the liquid phase are of interest. The synthesized carbon nanostructures are prospective for application in autocathodes. Needle-like and pointed forms are known to be good electron sources what greatly affects operating characteristics of field emission cathodes. At present the regimes for synthesis of new carbon nanostructures and composites based on them by different methods are being refined, i.e. quantitative and qualitative compositions of electrodes, chemical composition of liquid phase, and catalysts are being selected.

The special vacuum setup to measure emission properties of carbon nanostructures has been created in the laboratory. Field emission of the materials has been investigated in the vacuum chamber at vacuum of 10^{-6} mm of mercury in the diode design. The glass plate covered with a conducting layer of ITO and a layer of phosphor was used as an anode. The electrode spacing was 200 μm. Optimum compositions are used in cathodoluminescent light sources. Variety of forms and modifications of CNT produced in the laboratory makes it possible to hope for success in searching materials with optimum parameters.

Conclusions

The review of some methods for producing and possible variants of using nanostructures as emission materials is given in the report. Application of nanotubes is considered for field, photoelectron and autoelectron emission.

It has been shown that application of carbon nanotubes instead of metal or semiconductive emitters allows the significant improvement of operating characteristics of such devices.

References

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