Computer and experimental study of field-induced conductivity modulation in liquid crystal – carbon nanotubes system

Yu.I. Olenych[1], I.B. Olenych[1], Yu.Yu. Horbenko[1], O.I. Aksimentyeva[1], I.D. Karbovnyk[1], B.R. Tsizh[2,3]

[1] Ivan Franko National University of Lviv, Ukraine, e-mail: igor.olenych@lnu.edu.ua

[2] Stepan Gzytsky Lviv National University of Veterinary Medicine and Biotechnologies, Ukraine

[3] Kazimierz Wielki University, Bydgoszcz, Poland

Introduction

The electrical charge in the dielectric matrix–CNTs composites is transferred mainly through a percolation network of conductive nanotubes. The study of percolation phenomena in the CNTs system shows a significant influence of the nanotube predominant orientation on the threshold value of percolation. The effect of the orientational ordering of liquid crystal (LC) makes it possible to manipulate CNTs and control their orientation by the electrical field application. Therefore, we studied the possibility of controlling the electrical properties of the LC–CNTs nanocomposite.

Methods

Nanocomposites based on LC mixture KET90700 and single-walled CNTs were deposited to a prepared substrate with silver contacts. For computer simulation of percolation phenomena, it was used a model in which a system of chaotically arranged CNTs was in a volume element in the shape of a parallelepiped. The introduction of anisotropy into the system was carried out by limiting the angles α and β between the axis of the nanotube and the normal to the electrodes (Fig. 1).

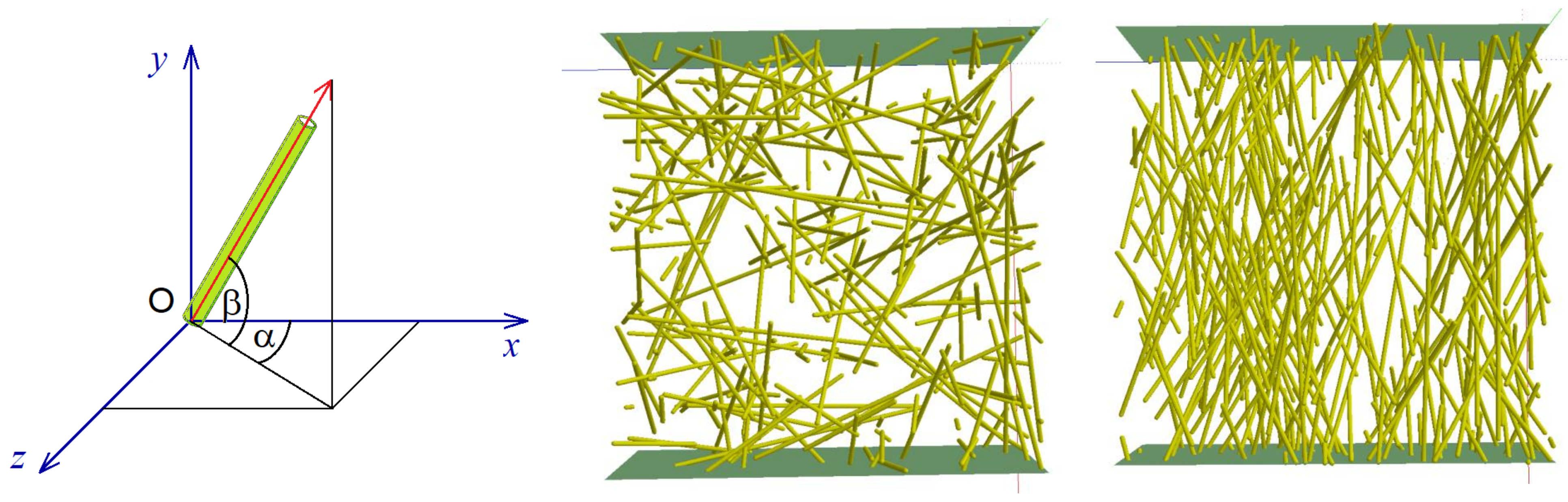

Fig. 1. Determination of the nanotube orientation in 3D space (*a*) and nanotubes distribution with angular dispersion limitation: $-90^o < \alpha < 90^o$, $-90^o < \beta < 90^o$ (*b*); $-35^o < \alpha < 35^o$, $-35^o < \beta < 35^o$ (*c*).

Results

The electrical resistance of the LC–CNTs nanosystems decreases with increasing applied voltage. The field-induced reorientation of LC molecules leads to a partial reorientation of nanotubes dispersed in the host medium, which changes the structure of the percolation network.

In the proposed model, we assume that the modulus of the boundary angles α and β, which limit the orientation of nanotubes, decreases linearly from 90 to 35 degrees with increasing applied voltage from 0 to 10 V, as shown in [1].

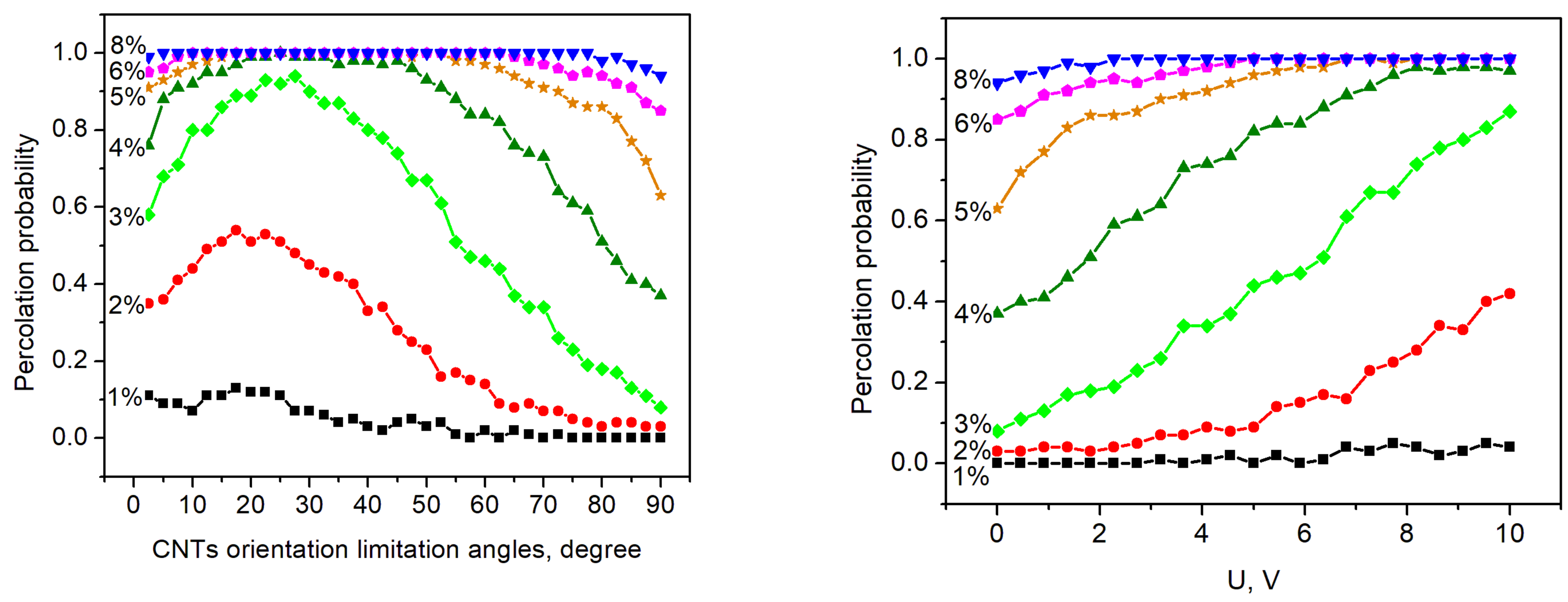

Fig. 2. Percolation probability as function of the CNTs orientation limitation angles (*a*) and applied voltage (*b*) for different nanotubes concentration.

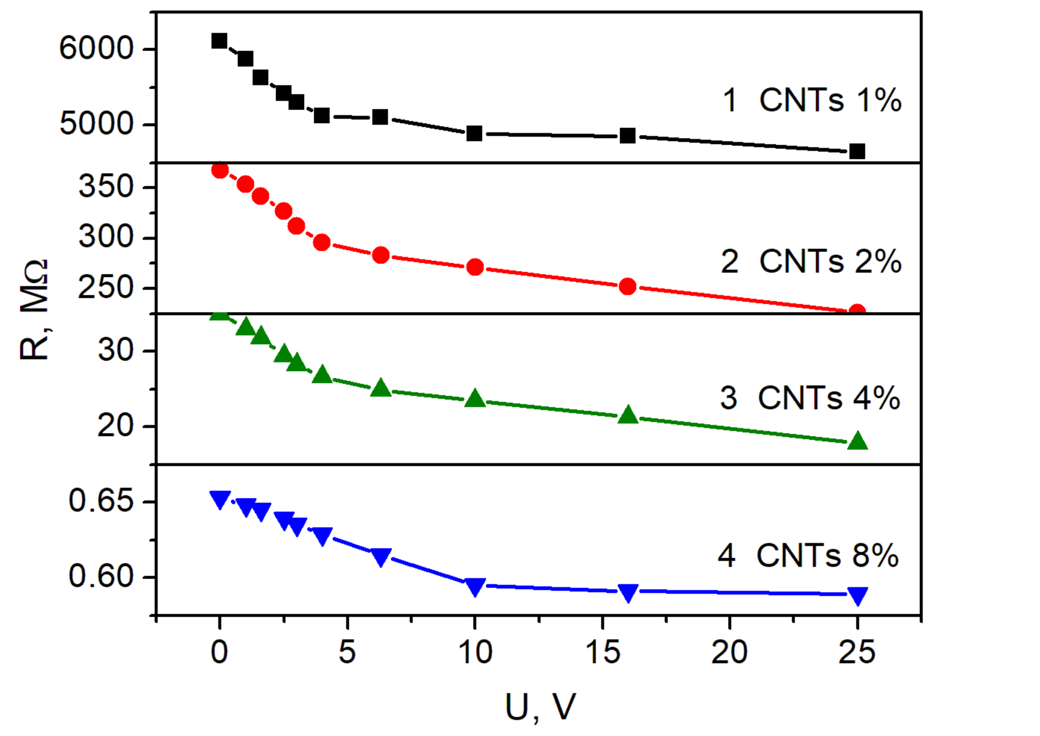

Fig. 3. Dependence of electrical resistance of the LC–CNTs nanocomposite on the applied voltage.

Conclusions

The change in the percolation probability was revealed in the case of the limitation of nanotube orientation angles that are controlled by the electrical field. The relative change in the resistance of the LC–CNTs nanocomposite under the influence of an external electric field is 24, 38, 49 and 10 % for experimental samples with a mass content of single-walled nanotubes of 1, 2, 4 and 8 %, respectively.

[1] *Massey M.K., Kotsialos A., Volpati D., Vissol-Gaudin E., Pearson C., Bowen L., Obara B., Zeze D.A., Groves C., Petty M.C.* Evolution of Electronic Circuits using Carbon Nanotube Composites // Sci. Reports.-2016.-**6**.-32197.