Electrical resistance of films composed from filled single-wall carbon nanotubes or doped graphene

E.D. Obraztsova[1*], A.A.Tonkikh[1], V.I. Tsebro[2], D.V. Rybkovskiy[1], M.G. Rybin[1], E.A. Obraztsova[1,3], E.I. Kauppinen[4], A.S. Orekhov[1], A.L. Chuvilin[5]

[1]A. M. Prokhorov General Physics Institute, RAS, 38 Vavilov street, 119991 Moscow, Russia
[2] P.N. Lebedev Physical Institute, RAS, Leninskiy prosp., 53, 119991 Moscow, Russia
[3] M.M. Shemyakin and Yu.A. Ovchinnikov Institute of Bioorganic Chemistry, RAS, Moscow, Russia
[4] Department of Applied Physics, Aalto University, FI-00076 Espoo, Finland
[5] CIC NanoGUNE Consolider, San Sebastian 20018, Spain

Gas phase filling of inner space of single-wall carbon nanotubes integrated into thin films by donor or acceptor molecules or covering graphene by a thin film of such molecules allow to form a new prospective material for transparent conductive electrodes with characteristics comparable with those of indium-tin oxide (ITO). The HRTEM images of such nanotubes reveal formation of one-dimensional crystals inside (Fig.1). The optical spectroscopy confirms a Fermi level shift into a valence band and a complete metallization of the nanotubes [1]. To confirm metallization we have measured the electrical resistance of filled SWNT films of different transparency and registered a big drop of electrical resistance (of one order of magnitude) after filling. The best values were about 50 Ohm/square at 90% transparency. The temperature dependence of resistance (R(T)) demonstrated two contributions – from the inter-tube interactions and from the filled nanotubes by themselves (Fig.2). For the stronger acceptor (CuCl instead of iodine) the minimum value of R(T) shifted toward low temperatures. The mechanisms of electron-phonon interactions in doped materials are discussed.

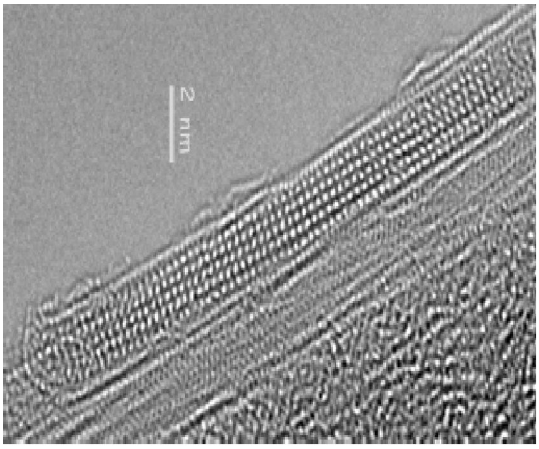

Fig.1. One-dimensional crystals formed inside SWNTs from donor or acceptor molecules.

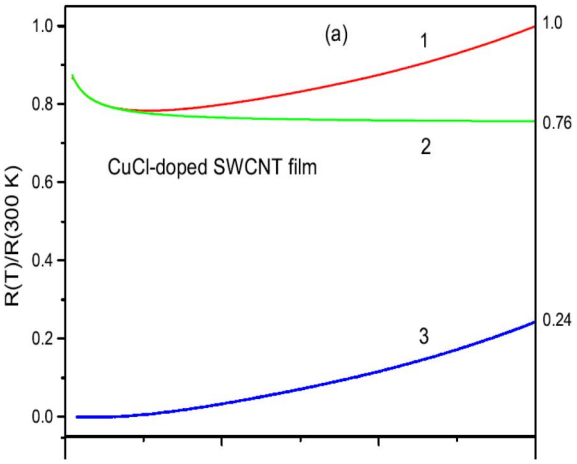

Fig.2. The electrical resistance of CuCl@SWNT film. (1) experimental data, (2) tunneling between nanotubes, (3) nanotube contribution.

The work was supported by RSF project 15-12-30041 and RFBR project 15-32-20941.

[1] A.A. Tonkikh, V.I. Tsebro, E.A. Obraztsova, et al., C*arbon 94, 768-774, (2015).*