TRANSPORT PROPERTIES OF SURFACE MODIFIED SINGLE-WALLED CARBON NANOTUBES

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Objectives

- **to establish the possibility of surface modification of SWCNTs by cobalt-containing complexes;**
- **to identify the structural and morphological state of cobalt on the surface of SWCNTs;**
- **to study the electrical magneto-electrical conductivity of modified SWCNTs;**
- **to determine the mechanisms of charge transfer in modified SWCNTs**

The structure and phase composition

X-R diffraction, Electron microscopy, Thermomagnetometry

Specimens

Source SWCNTs: have been produced by catalytic decomposition of acetylene with use yttrium and nickel as catalysts. The mean diameter of carbon nanotubes <d> = 1.4 nm , the packed density is 15 mg/cm^3.

Modification:

scheme 1. SWCNTs → H_2O_2(100^{0}C,18 hrs.+10 hrs.) → HCl (100^{0}C) → MEA (t^{0}C) → $CoCl_2$ (60^{0}C)

scheme 2 SWCNTs → H_2O_2(100^{0}C,18 hrs.+10hrs.) → HCl (100^{0}C) → 1,3DAP (t^{0}C) → benzophenone → $CoCl_2$(t^{0}C)

Transport properties

Standard four-zond technique
Temperature: (4,2-293)K
Magnetic field up to 2T

Structure and phase composition

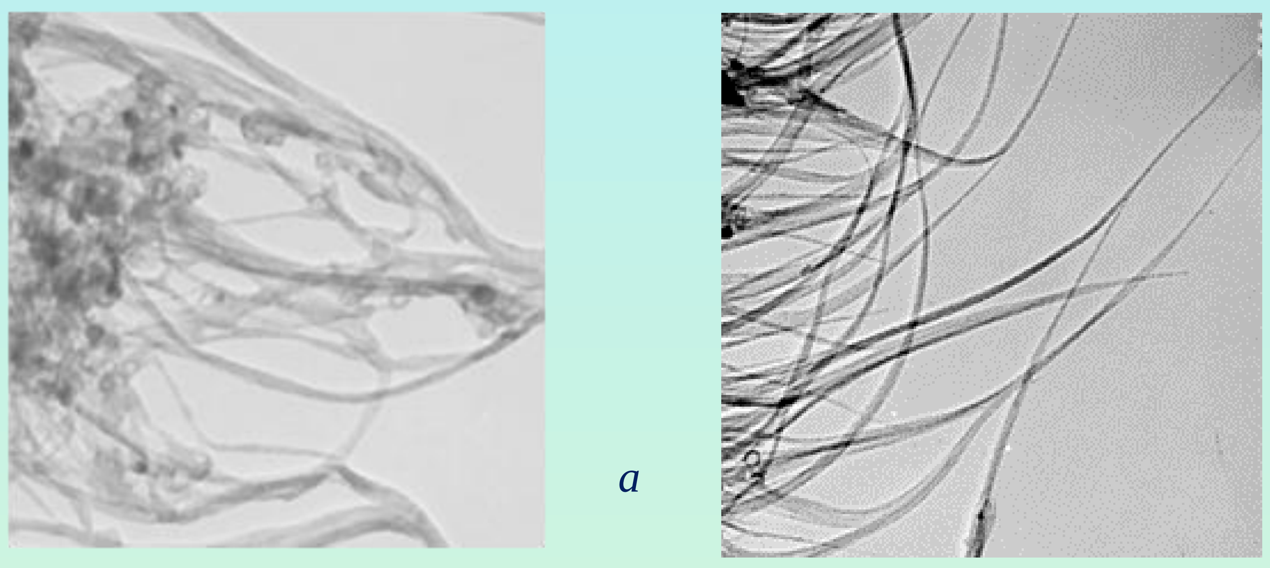

Figure 1. Fragments of TEM imagines of source (*a*) and modified with scheme 2 (*b*) SWCNTs

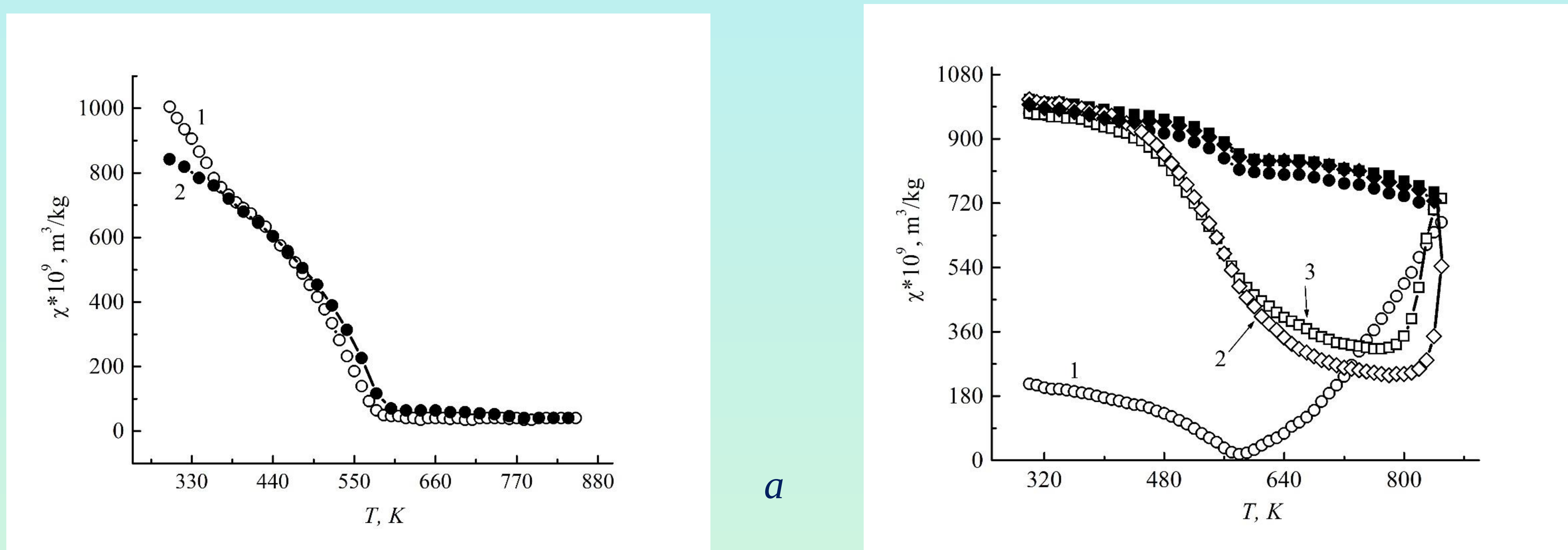

Figure 2. Temperature dependences of magnetic susceptibility χ(T) for source (*a*) and modified by cobalt containing complexes (scheme 1) (*b*) SWCNTs for the sequenced heating-cooling cycles, the curve number corresponds to the cycle number, the open labels are heating, the closed ones are cooling.

Resistivity

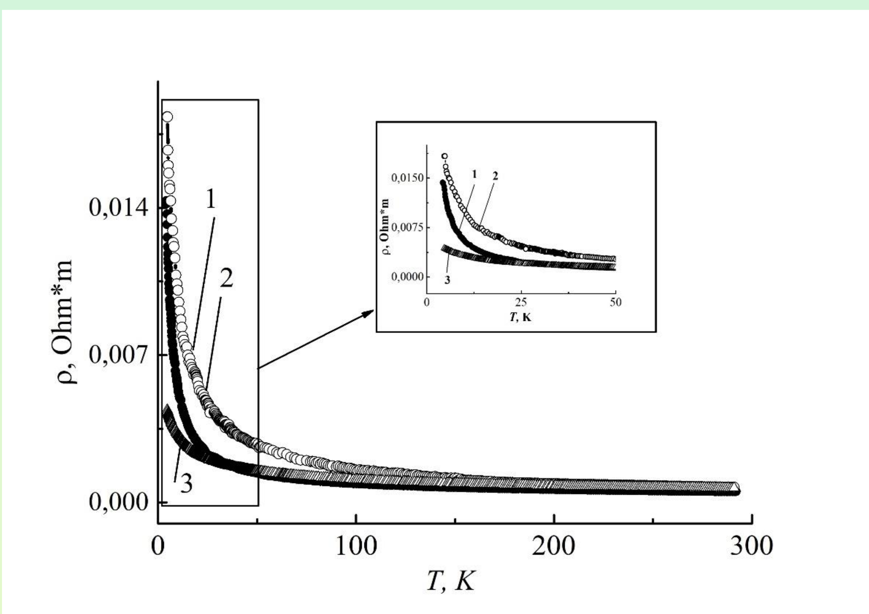

Figure 3. Dependences ρ(T) for bulk specimens of source SWCNTs (1) and modified SWCNTs according scheme 1 (2) and scheme 2 (3)

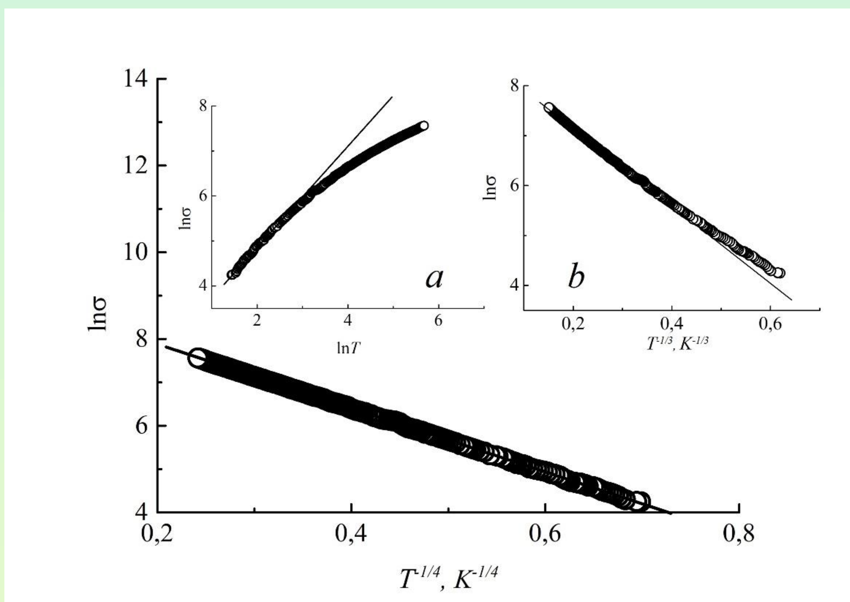

Figure 4. Temperature dependences of conductivity for bulk specimen of source SWCNTs in coordinates lnσ(T$^{-1/4}$), lnσ(lnT) (inset 1), lnσ(T$^{-1/3}$) (inset 2)

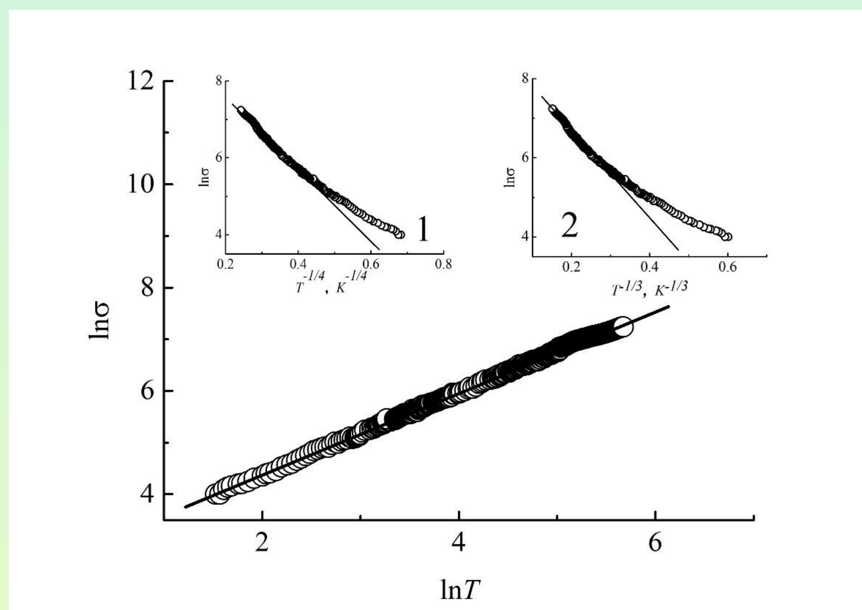

Figure 5. Temperature dependences of conductivity for bulk specimens of modified SWCNTs according to scheme #2 in coordinates lnσ(lnT), lnσ(T$^{-1/4}$) (inset 1), lnσ(T$^{-1/3}$) (inset 2)

Magnetoresistance

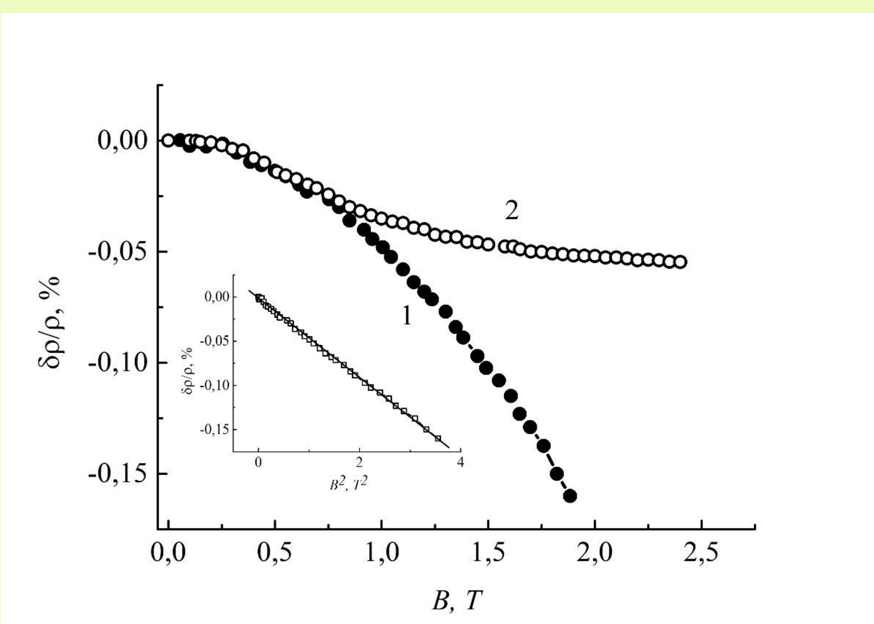

Figure 6. Dependences magnetoresistance δρ/ρ(B) for bulk specimens of as prepared (1) and modified (2) SWCNTs. Inset: dependence δρ/ρ(B^2) for as prepared SWCNTs, T = 77 K

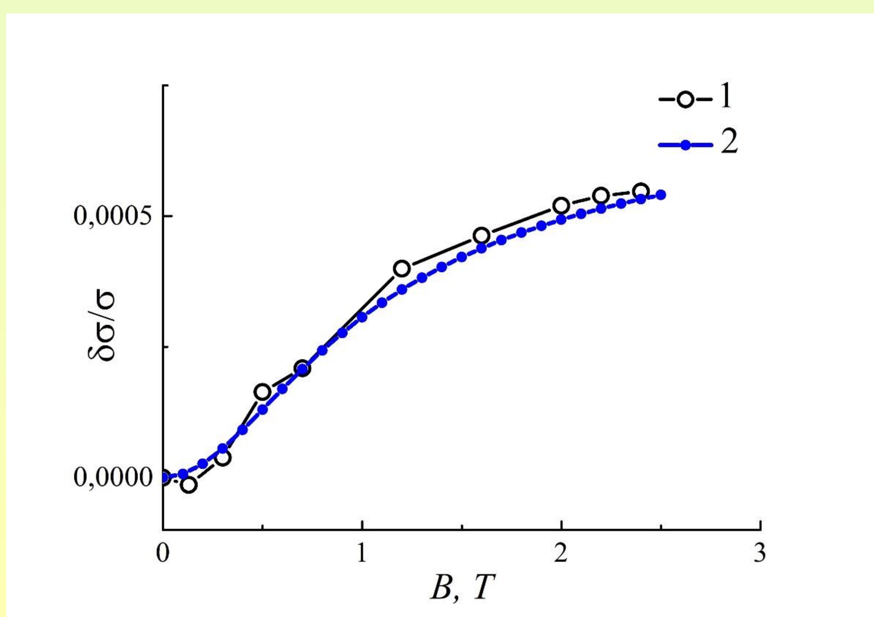

Figure 7. Experimental (1) and calculated (2) dependences δσ/σ(B) for modified SWCNTs

Hopping conductivity with the variable hopping length $\sigma(T) = \sigma_0 \exp\left(-\left(\frac{T_0}{T}\right)^{\frac{1}{d}}\right)$, where d is the dimensionality of the system

Conductivity in terms of power temperature law $\sigma(T) = \alpha T^{\beta}$, $\beta = \frac{g+\frac{1}{g}-2}{8}$

Magnetoconductivity in the model of 1-D weak charge carriers' localization $\sigma(B) = \sigma(0,T) - \frac{2e^2}{\hbar L} x \frac{1}{\sqrt{\frac{1}{L_{\varphi}^2} + \frac{e^2 B^2 \omega^2}{3\hbar^2}}}$,

ω is the tube's diameter

Conclusions

1. In modified SWCNTs attached to the tube's surface cobalt is a cation in the complicated complexes. These complicated complexes are destroyed when modified SWCNTs are heated. Due to the surface thermo-stimulated diffusion cobalt agglomerates and this leads to the formation of cobalt nanoparticles.

2. For source SWCNTs, the main mechanism of conductivity is the hopping conductivity with the variable hopping length and the source SWCNTs are considered as a 3-D system. This conduction mechanism is typical for disordered graphite materials, as well as for mats and binders of SWCNTs.

3. For modified SWCNTs conductivity is described in the terms of power temperature law, that is typical for individual SWCNTs. This is related with a significant increase in contact resistance between the individual tubes due to the modification of their surface. Surface modification of SWCNTs leads to the creation on the surface of CNTs small localized negative charge which acts as an electrostatic screen. The presence of such a charge makes it impossible to transfer charge between individual tubes and promotes the formation of a 1D conductive system of SWCNTs.