MAGNETIC AND MAGNETOTRANSPORT PROPERTIES OF MODIFIED WITH COBALT CARBON NANOTUBES

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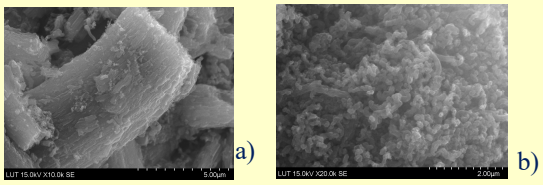
The aim: to establish the features of magnetic and magnetotransport properties of multiwall carbon nanotubes modified with cobalt nanoparticles

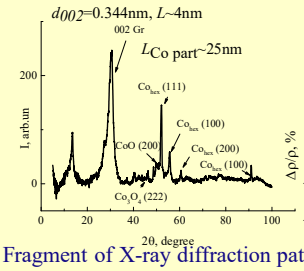
Specimens:
MWCNTs have been obtained by low temperature conversion of CO in the presence of catalyst.
Modification of MWCNTs: the method of reduction of metal from aqueous salt solution in a stream of hydrogen.
Bulk specimens of modified MWCNTs: the cold compacting of modified nanotubes with PVA as binder (25% mass).

Research methods and equipment.
Structure: PANalytical Empyrean 3 diffractometer (Co tube, λ=0.1789 nm), Scanning Electron Microscopy.
Magnetic properties: The hysteresis loops and temperature dependence of mass magnetization under FC and ZFC protocols in the in-plane orientation were measured using a SQUID magnetometer (Cryogenic S700X).
Magneto-transport properties: Magnetoresistance measurements were performed using the Pulsed Magnetic Field Setup (PMFS) technique, employing the standard four-probe.This configuration was used to investigate the magnetic field dependence of resistance across a range of temperatures (4.2–300 K) and in two distinct sample orientations: in-plane and out-of-plane. A pulsed magnetic field of 20 T, with a duration of 12 ms, was applied during the measurements.

Structure:

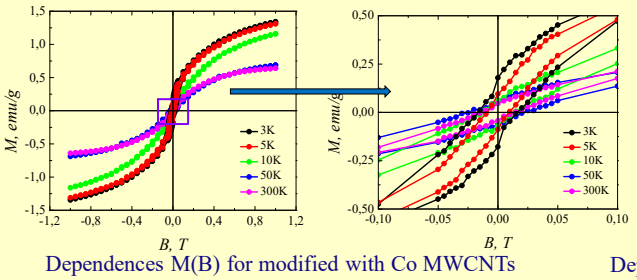


Fragments of SEM imagines of modified with Co MWCNTs, Figs. a) and b) are different magnifications

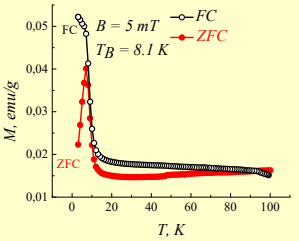


Fragment of X-ray diffraction pattern for modified with Co MWCNTs

Magnetic properties:

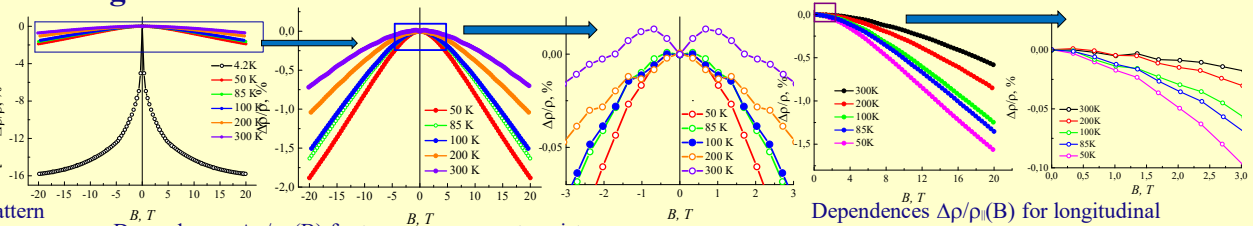


Dependences M(B) for modified with Co MWCNTs



Dependence M(T) under FC and ZFC for modified with Co MWCNTs

Magnetoresistance



Dependences Δρ/ρ⊥(B) for transverse magnetoresistance

Dependences Δρ/ρ∥(B) for longitudinal magnetoresistance

Conclusions

1. The magnetization of bulk specimens of modified MWCNTs reaches saturation in a magnetic field of 0.8 T at temperatures above 50 K. Saturation of magnetization is not observed in fields up to 1.2 T at lower temperatures.

2. The coercive force of bulk specimens of modified MWCNTs is at its lowest at a temperature of 5 K, and the hysteresis loop is slightly shifted relative to the center. This may be due to the effect of exchange bias caused by the presence of a small amount of cobalt oxides, which are antiferromagnets, in the specimens.

3. The magnetoresistance of the bulk specimens of modified MWCNTs is negative except in the region of small fields at a temperature of 300 K. Such a change in the sign of magnetoresistance in systems containing magnetic metal is associated with the manifestation of the anisotropic magnetoresistive effect.

4. The absolute value of the magnetoresistance increases as the temperature decreases to 50 K. The dependences $\Delta\rho/\rho_{\perp}(B)$ and $\Delta\rho/\rho_{\parallel}(B)$ are close to linear and saturation of the magnetoresistance is not observed.

5. A significant increase in the absolute value of magnetoresistance occurs at a temperature of 4.2 K, at which magnetoresistance also saturates in large magnetic fields.

Thus, the analysis of the features of the magnetic and magnetotransport properties of modified carbon nanotubes allows us to assume that the cobalt particles on/in the carbon nanotubes are mainly in a superparamagnetic state and weakly interact with each other.

Saturation magnetization (M_s), coercive force (H_c), transverse ($\Delta\rho/\rho_{\perp max}$) and longitudinal ($\Delta\rho/\rho_{\parallel max}$) magnetoresistance in maximum magnetic field

T, K	*M_s,(Mmax) emu/g*	*- H_c, kA/m²*	*- H_c, kA/m²*	$\Delta\rho/\rho_{\perp max}$, %	$\Delta\rho/\rho_{\parallel max}$, %
3	1.34	-13.5	11.9		
4.2				-15.7	
5	1.31	-7.9	7.9		
10	1.15	-13.5	11.9		
50	0.69	-19.9	17.5	-1.87	-1.57
85				-1.63	-1.35
100				-1.51	-1.25
200				-1.04	-0.85
300	0.64	-11.9	0.015	-0.70	-0.58

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