CONDUCTIVITY OF POLYMER COMPOSITES WITH NANOCARBON FILLER

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Objective: to investigate the electrical conductivity of composites based on nanocarbon fillers with different types of polymer matrix and to establish the factors causing the specific type of conductivity temperature dependence

Composites

Filler

Graphite nanoplatelets (GNPs)
Thermoexfoliated Graphite (TEG)
Thermoexfoliated Graphite dispersed (TEGd)
Carbon Fibers (CFs)
Multiwall Carbon Nanotubes (MWCNTs)

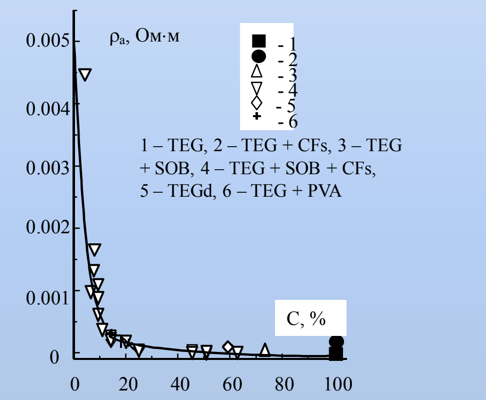
Polymer matrix

Polyvinyl acetate (PVA)
phenol-formaldehyde resin (PFR)
epoxy resin (ER)
silicon -organic binder (SOB)

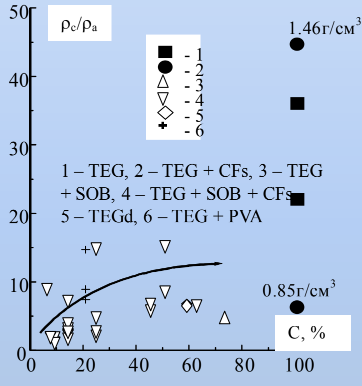
Concentration of filler:
(0.1 – 95.0)% mass

Resistance measurement
Four-probe DC compensation method, temperature range (77 -293)K

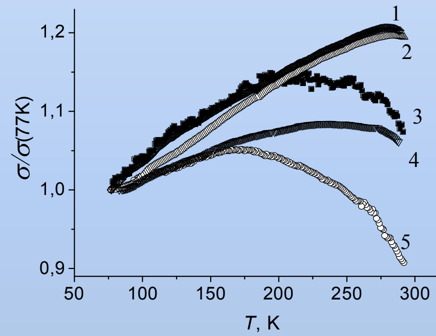
Bulk specimens:
cold pressing in rectangular and in round molds with a diameter of 10 mm and 13 mm



Dependence of the resistivity perpendicular to the compression axis (ρ_a) on filler's concentration at room temperature



Dependence of ρ_c/ρ_a on filler's concentration at room temperature



Dependences $\sigma/\sigma_{77}(T)$ for polymer composites based on PFR with different nanocarbon fillers 1 TEG (7.8%); 2 TEG (10%); 3 GNPs (8.5%); 4 TEG(2) (10%); 5 GNPs (10%).

Conclusions. The main factors that determine the character of the temperature dependence of the electrical conductivity of polymer composites

Nanocarbon filler type / Parameters determining resistivity	Cylindric (MWCNTS, CFs) *aspect ratio* ~ 1000	Vermicular (TEG) *aspect ratio* ~ 100	Vermicular (TEGd) *aspect ratio* ~ 10-50	Platelet (GNPs) *aspect ratio* ~ 10
Resistivity of nanocarbon filler, R_{cf}	Decreases with temperature due to increase of charge carriers' concentration at temperature independent scattering of charge carriers			
Electro-conducting structure	Branched sceleton	Branched sceleton	Small current conductive clusters	Separate current conductive clusters
Quantity of contact between filler particles	Relatively high	High	Substantial	Very high
Relation between linear temperature expansion coefficient (LTEC) of polymer α_p and nanocarbon filler α_{cf}	$\alpha_p \sim \alpha_{cf}$	$\alpha_p \sim \alpha_{cf}$	$\alpha_p > \alpha_{cf}$	$\alpha_p >> \alpha_{cf}$
Contact resistance, R_k	Changes with temperature proportionally to the change of resistance of the filler particles	Changes with temperature proportionally to the change of resistance of the filler particles	Increases with temperature due to decrease of the sizes of contact area	Significantly increases with temperature due to decrease of the sizes of contact area and increase of thickness of the polymer interlayers between separate nanoparticles
Quantity of current conductive channels, N_{cf}	High, quantity is almost temperature independent	High, quantity changes weakly with temperature	Limited, quantity decreases with temperature due to elimination from the conductive net of separate chains, polymer interlayer between which is higher than crytical size ~2 nm	
Relation between factors determining resistance	$R_{cf} > R_k$ within the whole investigated temperature interval	$R_{cf} > R_k$ within the whole investigated temperature interval	$R_{cf} > R_k$, at T< 240K $R_{cf} < R_k$, at T< 240K	$R_{cf} > R_k$, at T< 150K $R_{cf} < R_k$, at T< 150K