Electrical and electrodynamic properties of polymer composites with nanocarbon filler

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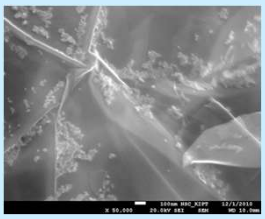
Aim of work: Determination of the effect of thermal loading and temperature stability limits of electrical and electrodynamic properties of polymer composites with nanocarbon filler

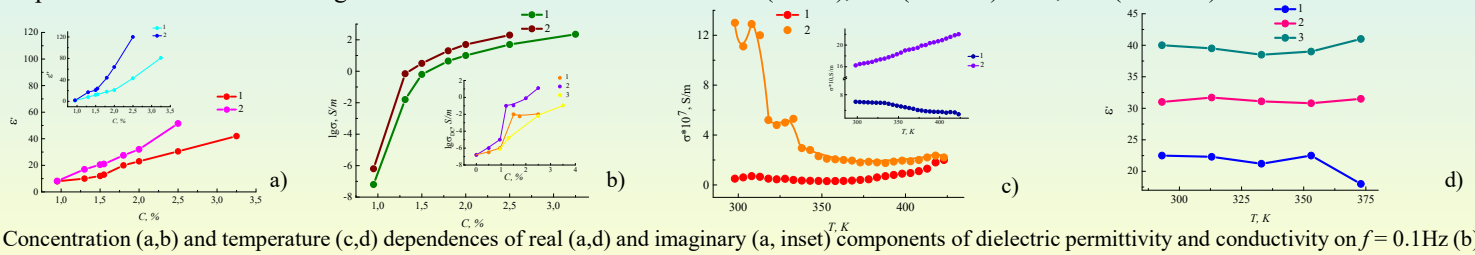
Specimens: Polymer composites**. Polymer:** Polychlorotrifluoroethylene (Fluoroplast – 3).
Nanocarbon filler: TEG, TEG modified with SiO_2, MWCNTs
Modification of TEG with SiO_2: From a hydrosol colloidal solution (20%) with sonication into an ethyl alcohol medium followed by heating to 90^0C
Obtaining of Polymer composites: Two-stage method. 1). Sonication of nanocarbon filler in an alcoholic medium (ethyl alcohol). 2). Heating of mixture of powdered polychlorotrifluoroethylene (spherical aggregates with a diameter of d ~ 200 nm) with the dispersion of ethyl alcohol - nanocarbon with constant stirring up to 640 K .
Bulk specimens: - method of thermal pressing



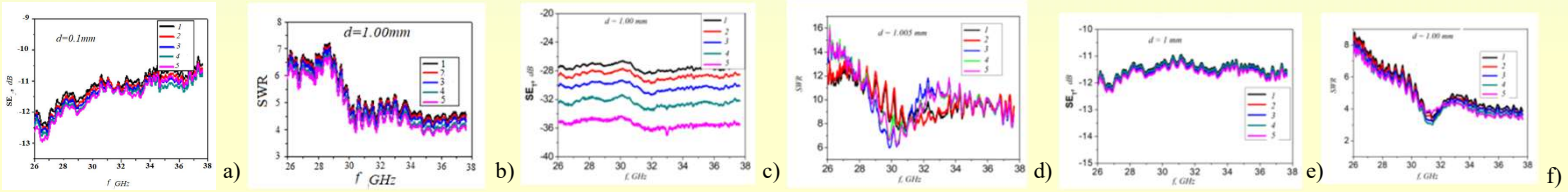
Fragment of an electron microscopic image of the surface of TEG modified with 30% SiO_2.

Measurements:

1. The real (ε') and imaginary (ε") components of the complex dielectric constant have been studied using an ultra-high-frequency interferometer, ν = 10 GHz, T = 295 K.
2. Temperature dependence of electrical conductivity σ(T): automated installation for measuring electrical resistance by two- and four-probe methods on direct current.
3. Temperature dependence of EMR reflection and absorption spectra and dielectric constant: experimental installations based on panoramic meters of standing wave coefficient and EMF attenuation (P2-65), ν = (26-37.5) GHz, T = (293-373) K.



Concentration (a,b) and temperature (c,d) dependences of real (a,d) and imaginary (a, inset) components of dielectric permittivity and conductivity on $f = 0.1$Hz (b) and at direct current (inset b, c). Fillers: 1 – TEG, 2 – TEG modified with SiO_2, 3 – CNTs. For Fig. (c) filler content is 0.95% mass and 1.5% mass (inset)



Frequency dependences of the EMR attenuation coefficient (a,c,e) and SWR (b,d,f) for composites with 2.5% mass TEG (a,b), with 2.5% mass TEG modified by SiO_2 (c,d) and with 3.5% mass CNTs (e,f)

Conclusions

- The use of TEG and modified with SiO_2 TEG as filler allows to obtain electrically conductive composites with high electrophysical properties and a low percolation threshold (~ 0.955% mass), preserving the unique properties of the polymer (chemical, thermal and radiation resistance, plasticity, manufacturability, etc).
- At concentrations of nanofiller in the composites below the percolation threshold, the main contribution to the electrical conductivity is made by the relaxation component. which is determined by the processes of interphase polarization at the polymer-filler interface. The contribution of interphase polarization increases in composites with modified by SiO_2 TEG.
- A slight improvement in the shielding characteristics, mainly due to an increase in the EMR absorption coefficient, has been detected at heating of all the studied composites up to 373 K. Moreover, the largest changes in the EMR attenuation coefficient have been observed for composites with modified by SiO_2 TEG. Thus, the EMR attenuation coefficient for a composite with 2.5% mass TEG, on average, is equal to ~ -12 dB. For composites with the same content of modified by SiO_2 TEG, the EMR attenuation coefficient increases to -27 dB, and heating these composites up to 373 K increases the value of the EMR attenuation coefficient to (-35÷-36) dB. At the same time, the value of the SWR does not change on average, indicating an increase in the absorption of EMR energy by the investigated composites.
- The changes in the effective dielectric constant ε' for all composites in the temperature interval from 293 K up to 373 K are no more than (10 ÷ 15)%, which does not significantly affect the shielding characteristics of composites.
- Thus, the developed polymer composites with different types of nanocarbon fillers are characterized by stable electrodynamic characteristics in the temperature range (293 – 373) K.

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