Persiskirstymo efektai kompozituose su nanodariniais

Redistributions effects in composites with nanoinclusions

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Nowadays polymer composites with nanoiclusions are very attractive due the possibility to manipulate with polymer properties adding a very small amount of nanoparticles. Here can be mentioned polymer composites with carbon nanotubes, grafene, onion like carbon, feromagnetic and ferroelectric nanoinclusions. Although electromagnetic properties of all these inclusions are quite different, some general tendency for broadband electrical behaviour of composites can be drawn. First of all for composites of electrical conductive particles/insulator matrix for some certain concentration (called as the percolation threshold) occurs the electrical percolation (i. e. transition from electrically insulator to electrically conductive state). Although according to the excluded volume theory the percolation threshold is mainly determined by geometrical parameters of nanoparticles (like length or diameter) such correlation was never observed experimentally [1]. This suggests that other things: the distribution of nanoparticles inside polymer matrix and electrical contacts between nanoparticles are the most important factors for composites electromagnetic propeties. Secondly, the electrical percolation occurs at relatively low concentrations of nanoparticles and the tunneling conductivity is very important in this case. Also usually the properties of polymer matrix is strongly temperature dependent (especially close to the glass transition and melting temperatures), while properties of nanoinclusions are stable in much wider temperature range. Therefore in composites is possible to observe a lot of temperature dependent phenomena, which are closely related with so called positive and negative (for resistivity) temperature effects. In this presentation the broadband electromagnetic properties of polymer composites with various nanoinclusions are considered as the model of infinite RC circuit connected in serial. According to this model the complex impedance spectra can be presented as

$$Z(\nu) = Z_\infty + \Delta Z \int_{-\infty}^{\infty} \frac{f(\tau) d\lg\tau}{1+i\omega\tau} \qquad (1)$$

where f(τ) is the distribution function and τ=RC.

For example, the calculated distributions of relaxation times for Onion Like Carbon (OLC)/Polyurethane (PU) composites are presented in Fig. 1. In the not annealed sample on heating the distributions of relaxation times exhibit pronounced temperature dependence, the maximum of distributions shifts from milliseconds to several tens of microsecond and distributions become narrower. After the annealing the position of maximum of distributions of relaxation times shifts by two orders of magnitude. In contrast on cooling the distributions of relaxation times are only very weak temperature independent. Considering, the physical interpretation of distribution of relaxation times in composites, the relaxation time τ=RC=C/σ, where C is the capacitance of one OLC cluster, R is the resistivity and σ is the conductivity inside one OLC cluster or between neighborhood OLC clusters. The capacitance of OLC clusters is dependent only from geometrical parameters of OLC clusters, for example if we assume spherical OLC clusters its capacitance is proportional to effective radius of carbon clusters.

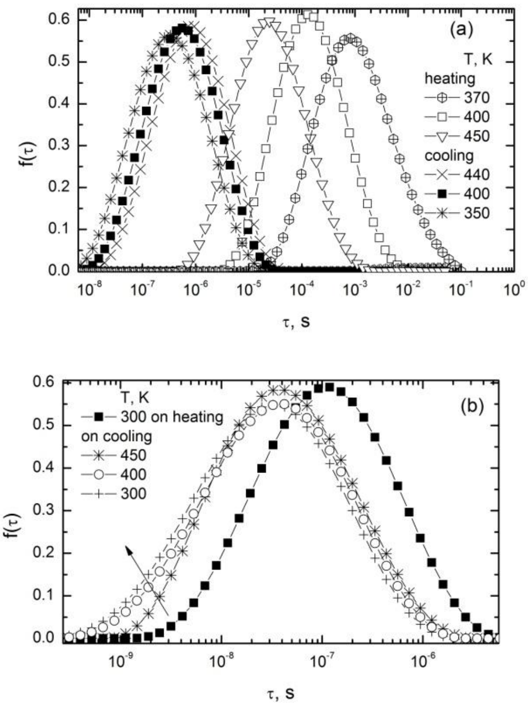

Fig. 1 Temperature evolution of the distribution function a) not annealed OLC/PU, b) annealed OLC/PU composites

Keywords: nanoparticles, composites, polymers.

Literatūra

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