Kompozitų su daugiasieniais anglies nano vamzdeliais žemo dažnio triukšmo charakteristikos

Low frequency noise characterisation of multi-walled carbon nanonubes composites

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Composite materials with carbon nanotubes (CNTs) attract great attention as novel electromagnetic material. CNTs have a number unique structural and physical properties, what makes them a promising candidate for various applications: nanoscale bioelectronic devices, nano-sized FETs, nanoscale terahertz devices, micro-scale inductors, sensors, etc. [1-3].

Carbon nanotube composites can be seen as conductive particles in dielectric matrix, and they are disordered materials. Electromagnetic properties of such materials are greatly dependent on nanotubes dimensions, density, orientation and distribution in the matrix [4]. Electrical conductivity studies in disordered solids are a topic of considerable interest. Noise spectroscopy is an informative method that reveals physical processes in various materials and structures and provides valuable information on charge carrier transport and conduction mechanisms. In this work, we present comprehensive investigation of low frequency noise and resistivity characteristics in composite materials with multi-walled carbon nanotubes (MWCNTS) with different surface treatment. The aim of the investigation was to determine the charge carrier transport mechanisms in such materials and to clear up the influence of the MWCNT's surface treatment to the material conduction.

Investigated materials were composed from multi-walled CNTs in polymer matrix. Two types of materials were investigated: epoxy-grafted (MWCNTs were mechanically dispersed in liquid epoxy resin (D.E.R. 321 (Dow Chemical) was chosen as polymer matrix)) and amino-grafted (MWCNTs were dispersed in polyethylene polyamine (PEPA) hardener) [5]. Solid composites were then fabricated by curing of the irradiated dispersions with the addition to them of the appropriate amount of the second component (hardener and epoxy resin, respectively) at the molar ratio 70:30 (D.E.R.321:PEPA). The percolation threshold of the obtained materials is in the range of 0.03-0.05 wt.% for epoxy-grafted, and 0.05-0.08 wt.% for amino-grafted samples [5]. Results for materials with 0.08 wt.% and 0.3 wt.% of MWCNTs are presented here.

The low-frequency noise characteristics were measured under constant current operation in frequency range from 10 Hz to 20 kHz and temperature range from 73 K to 380 K.

As expected for the materials with conductive fillers the resistivity of the investigated materials is Ohmic at low electrical field (in the voltage range 10 mV – 0.1 V at room temperature), but starts to decrease at higher voltage (above 1 V). Conduction mechanisms that can be found in composite materials are tunneling, transport through defects' centers, and hopping. It is found that the resistivity of epoxy-grafted materials is larger comparing to the amino-grafted ones: amino-grafted MWCNTs have larger density of charge carrier states at the nanotube's surface, what increases probability of electron tunneling. Below ~275 K the resistivity is proportional to the reciprocal cube root of temperature. Therefore, at low temperature the carrier transport occurs due to electrons hopping inside MWCNTs cluster and tunneling between clusters.

The low frequency noise spectra are $1/f^{\alpha}$-type at room temperature and slightly deviates from this proportionality - influence of individual Lorentzians is noted - at particular temperatures for both types of the investigated materials. The spectral density of voltage fluctuation is proportional to the squared voltage, what is characteristic for resistance fluctuations caused by the charge carrier capture and release processes in localized states. The Mott's hopping between carbon nanotubes controlled by the charge carrier capture in localized states between them determines the conductivity in investigated materials and leads to the observed noise characteristics.

The spectral density of voltage fluctuations for amino-grafted material is about an order of magnitude larger comparing to epoxy-grafted one: CNTs' surface treatment with polyethylene polyamine leads to the larger number of charge carrier capture centers.

MWCNTs' surface treatment with liquid epoxy resin and polyethylene polyamine hardener does not change the dominant conduction mechanisms in the investigated composites. But this treatment influences the density of the MWCNTs' surface states, what leads to the different value of resistivity and different low frequency noise intensity.

Key words: carbon nanotube, composite, fluctuation, noise.

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