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Photo-thermal resistivity response of polyisoprene/nanographite composites

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In some recent reports authors have shown that the embedding of single wall carbon nanotubes (SWCNTs) in an insulating polymer matrix such as polycarbonate (PC) dramatically enhances the infrared (IR) photoresponse - the rise of electrical conductivity - of (SWCNTs) [1]. Authors stated that existence of tunnelling resistance of nanotube – polymer – nanotube (CNT-P-CNT) junctions plays a dominant role in the photoresponse enhancement and described the electrical conductivity by a thermal fluctuation-induced tunnelling (TFIT) model [2] adapted to CNT-P-CNT junctions in PC matrix [1]

In this work we found and described an opposite effect (to the previously mentioned photoresponse effect) in polyisoprene/nanographite composites (PNC) where the electrical resistivity rises under the influence of laser radiation (photo-thermal resistivity response (PTRR)).

The PNC composites were prepared as follows. High structure extra-conductive carbon black consisting of 0D carbon polyhedrons with graphitic panes (nanographite) was dispersed in SWR-3L natural rubber together with curing ingredients. The composition was vulcanized (323K, 3MPa, 15 min) using Rondol TM hot press.

The PNC resistivity increase with the incident light intensity demonstrates a linear relationship. To find out the mechanism of this PTRR effect the temperature dependence of the electrical resistivity of the PNC samples was investigated. All composites exhibit a negative temperature coefficient of resistivity (NTCR) at low temperature and show a positive temperature coefficient of resistivity (PTCR) above approximately 280 K. Coefficient of thermal expansion (CTE) of the PNC samples was measured to explain the coexistence of both NTCR and PTCR in the same sample in different temperature regions.

We proved that the decrease of tunnelling currents between nanographite aggregates with increasing temperature plays the main role in the conductivity mechanism of the PNC composites in the rubbery phase of the polymer matrix. However in our case the TFIT model is not applicable because of the large CTE of the polyisoprene matrix (in comparison with the CTE of nanographite) which causes sufficient broadening of the tunnelling junctions in the composite with increasing temperature and a subsequent exponential rise of resistivity. A numerical model of temperature dependence of electrical resistivity of PNC with PTCR has been developed.

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