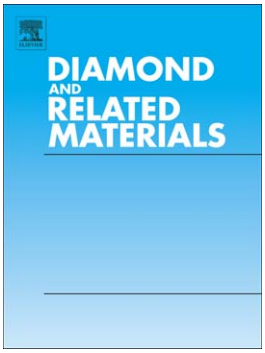

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Low-frequency electric noise spectroscopy in different polymer/carbon nanotubes composites

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Abstract

Carbon nanotubes addition to polymer and epoxy material allows to realize a large variety of new types of sensors and actuators. For the development of these devices, a deeper understanding of the basic charge carriers transport mechanisms is needed and low-frequency noise spectroscopy can effectively contribute to this task. The dc and electrical noise characteristics of different polymer/carbon nanotubes composites are analyzed at temperatures from 10 to 300 K. It has been found that a random tunnel junctions resistive networks model describes all the systems under test. A crossover from a two-level tunneling mechanism, at low temperatures, to resistance fluctuations induced by percolative paths, in the high-temperature region, has also been observed. This behavior of the 1/f noise is a general feature of the investigated highly conducting nanocomposites, independent of the specific polymer matrix and nanotube concentration.

Keywords: Polymer/carbon nanotubes composites, Electrical noise characterization, Sensors, Percolation

1. Introduction

Only few years after their discovery [1], carbon nanotubes (CNTs) have been used in a wide range of electrical applications. For the realization of CNT based transistors, single-wall carbon nanotubes (SWCNTs) are preferred [2], and recently thin film transistors (TFTs) made from parallel arrays [3] or networks [4] of semiconductor-enriched SWCNTs have reached performances, that not only rival, but outperform the commercial state-of-the-art thin film transistor technologies. Multi-wall carbon nanotubes (MWCNTs), on the other hand, generally have metallic character that play an important role in other applications with and without a polymeric matrix, as transparent conductive contacts for solar cells [5], for RF-shielding [6] and as sensors and actuators.

Electrical noise is generally considered as a limiting factor for the functionality of electronic devices and sensors. Therefore, the understanding of the underlying mechanisms, useful to lower the noise level, is of great interest. Moreover, noise can also be an additional critical criterion in sensing applications. This technique, called fluctuation induced sensing [7], has also been applied to carbon nanotube structures [8]. 1/f-type noise has been reported in SWCNTs based ballistic transistors and attributed to the intrinsic current fluctuations, due to the influence of nearby charge-traps [9]. Also for SWCNT network based transistors, the 1/f-type noise has been observed and has been related to the mobility change due to adsorption and desorption of gas molecules to the CNT surface [10]. While there are a series of studies regarding the noise behavior of devices prepared with SWCNTs [9–11], fewer reports on noise characteristics of MWCNT composites can be found. In this respect, it has been reported that the noise spectrum for metallic CNT based gated structures has also 1/f behavior, and its amplitude is up to 2 orders of magnitude lower than the one measured in semiconducting SWCNTs [12].

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