CNT-Ni-Pd-C nanocomposite films for terahertz applications

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In this invited paper, we propose carbon nanotubes (CNTs) films as a material for some nano-electronic devices, e.g. THz nanoantennas. Carbon nanomaterials— single-wall carbon nanotubes (SWCNTs) and multiwall carbon nanotubes (MWCNTs) — have recently emerged as novel terahertz (THz) systems, offering new opportunities for basic research and device applications in THz science and technology. SWCNTs are cylinders are built of a sheet of graphene rolled up into a tube and have a radius of a few nanometers and a length up to centimeters. MWCNTs are made by SWCNTs nested concentrically inside one another. It is known that CNTs can be either metallic with excellent conductivity or semiconducting with a band gap inversely proportional to the diameter of the tube, depending on their different chirality. Depending on their electric character they can be applied in many electronic nano-devices. It was recently proposed [1, 2] an effective circuit model for the ac impedance of a capacitively contacted nanotube, and a dc contacted nanotube. It was also recently demonstrated [3] - the operation of carbon nanotube transistors at microwave frequencies (2.6 GHz). In [4] it was discussed a circuit models of the ac performance of active 1d transistor structures, leading to the prediction that THz cutoff frequencies should be possible. Such circuit models are also applied for modeling nano- antennas properties. In paper [5], the mathematical framework for the analysis of carbon nanotubes as potential dipole antennas was developed. The authors of various simulations shows that it is possible to obtain THz antennas built of single SWCNT, two parallel SWCNTs or bundle of SWCNT. Such antennas give a electromagnetic radiation within THz region.

Many proposals exist for using carbon nanotubes for THz devices such as THz sources based on ballistic quasi-metallic SWCNTs [6] and THz nano-antennas with plasmons in armchair SWCNTs [7-10]. Some THz and infrared spectroscopy experiments on SWCNTs have shown various results and interpretations on an origin of the absorption peak observed around 4THz [11-14]. Most of these results cannot be compared because the samples were prepare with different methods and placed in a variety of THz-transparent polymer films, but also most samples consisted of randomly-oriented bundles of both semiconducting and metallic nanotubes with a wide distribution of lengths and diameters. In paper [15] it was show that for highly-aligned SWCNT samples indicating the high uniformity of the nanotube lengths (~75 μm) studied by polarization dependent THz time domain spectroscopy and Fourier-transform infrared spectroscopy in the low-frequency THz regime (<3 THz), there is virtually no absorption when the THz polarization is perpendicular to the nanotube axis. The attenuation for both parallel and perpendicular polarizations increases with increasing frequency, exhibiting a pronounced and broad peak around 10 THz in the parallel case.

The main features in electrical and optical properties of terahertz radiation for single- and double-walled CNTs are similar [16]. Terahertz measurements are suitable for investigation of membrane and aligned nanotubes films as well as polymer composites containing CNTs [17]. Recently, it was found that stretched polymer filled by MWCNTs exhibits anisotropic absorption in the gigahertz region (26–37 GHz) [18]. It was demonstrated [19] that MWCNTs interact with light in the same manner as simple dipole radio antennas. In particular, they show both the polarization and the length antenna effect. The first effect is characterized by a