Flexible microstrip antenna based on carbon nanotubes/ (ethylene–octene copolymer) thin composite layer deposited on PET substrate

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Abstract. A most of portable devices, such as mobile phones, tablets, uses antennas made of cupper. In this paper we demonstrate possible use of electrically conductive polymer composite material for such antenna application. Here we describe the method of preparation and properties of the carbon nanotubes (CNTs)/ (ethylene–octene copolymer) as flexible microstrip antenna. Carbon nanotubes dispersion in (ethylene–octene copolymer) toluene solution was prepared by ultrasound finally coating PET substrate by method of dip-coating. Main advantages of PET substrate are low weight and also flexibility. The final size of flexible microstrip antenna was 5 x 50 mm with thickness of 0.48 mm (PET substrate 0.25 mm) with the weight of only 0.402 g. Antenna operates at three frequencies 1.66 GHz (–6.51 dB), 2.3 GHz (–13 dB) and 2.98 GHz (–33.59 dB).

1. Introduction

Electronic devices use mainly copper based microstrip antenna for communication between each portable devices in network [1-3]. In many fields of science, carbon nanotubes are one of the most promising materials. Gradually, there are increasing possibilities for the use of carbon nanotubes in electronics. The main reasons for employing these materials are their characteristics, which are, for instance, good conductivity (after complex adjustments), or great potential for miniaturization. As the composite materials can perform several functions simultaneously, they can be applied to various products and surfaces not only in the ICT field. This contribution is focused on the use of carbon nanotubes in the passive antenna, which consists of a layer of carbon nanotubes and (ethylene–octene copolymer), applied to PET substrate. The antenna described in this article operates at three frequencies 1.66 GHz (–6.51 dB), 2.3 GHz (–13 dB) and 2.98 GHz (–33.59 dB).

Nevertheless, the aim of the research is to produce the layer with the lowest possible resistivity. The low resistivity ensures a better suitability for the material for the construction of the antenna. This characteristic can be influenced by the use of specific chemicals and by the type of carbon nanotubes. The produced specimen of the antenna employs multi-walled carbon nanotubes (MWCNTs) (Figure 3). The main reason for choosing MWCNTs is the fact that the composite does not have to be perfectly pure; for the pure composite it would be more appropriate to use the single-walled carbon nanotubes (SWCNTs). In addition, the final price of the subsequent applications to the devices plays an important role. Therefore, the price is an important criterion. However, this would lead to the price of the final product being much higher than in the case of multi-walled carbon nanotubes (MWCNTs).

2. Experimental methods

Carbon nanotubes and (ethylene–octene copolymer) EOC was used as an electrically conductive polymer base for preparation of conductive antenna layer. Engage (ethylene–octene copolymer) is a new elastomer produced by DuPont Dow Elastomers. By bridging the gap between rubber and plastic, versatile engage polymers inspire new design possibilities. The flexibility and mechanical properties of synthetic rubbers combined with the process ability of plastics make engage a great material. Low hardness and low viscosity are the advantages for easy thermoplastic processing as well as in solution state. EOC copolymer was dissolved in toluene to reach 16% wt polymer solution. Multiwall carbon nanotubes supplied by Sunnano china was treated by sonication in toluene by using sonication horn UZ Sonopuls HD 2070 kit for 15 minutes to disperse carbon nanotubes. Obtained dispersion was mixed together with (ethylene–octene copolymer) solution and stirred for two hours. The resulting dispersion contains 30% wt% of carbon nanotubes. PET substrate was dipped in the carbon nanotubes/ (ethylene–octene copolymer) dispersion in toluene for 10 s to reach the resulting active layer. The composite was kept at room temperature for 48 hours [4-6].

The PET substrate strip (5 × 50 mm) was coated by dip coating method on the following scheme (Figure 1) is demonstrate the process of dip coating of PET substrate by CNTs and (ethylene–octene copolymer) dispersion. First step: Dip a specimen into Dip Coat dispersion; second step: Wait for a dispersion surface to become the stationary state after dipped a specimen perpendicularly; third step: Raise a specimen up perpendicularly by optional speed; forth step: Available to control film thickness with raise-up speed for specimen and by the density of particle in solution.
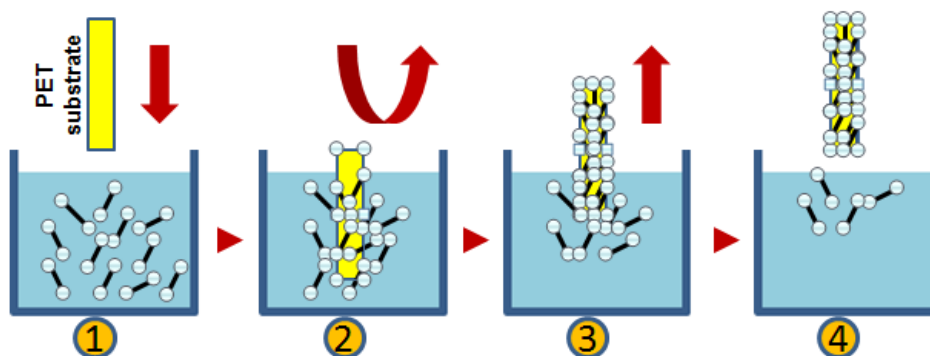

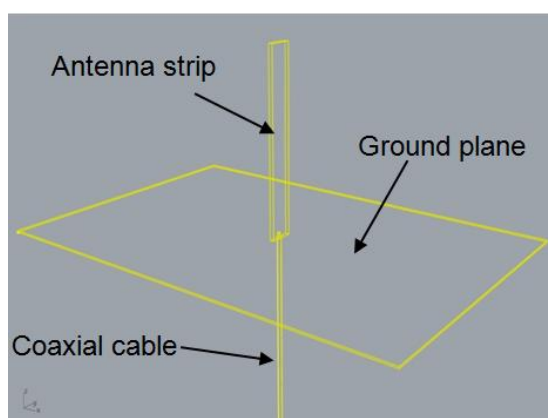**Figure 1.** Preparation of electrically conductive layer by dip coating process.

Figure 2. Construction of the antenna with antenna strip (coated PET), ground plane and coaxial cable.
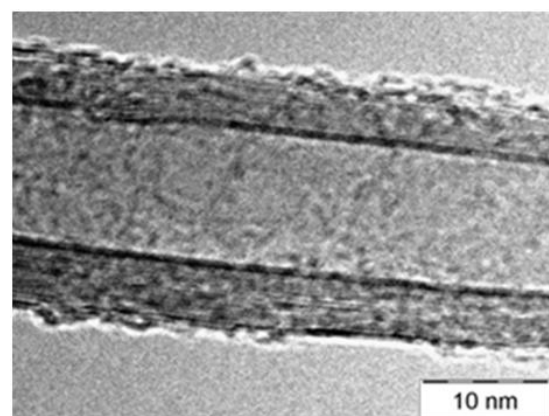

Figure 3. HRTEM detailed view of the structure of the MWCNT nanotube (scale of 10 nm).

3. Results

All measurements of the prepared antenna were performed in the anechoic chamber using the N9912A FieldFox Handheld RF spectrum analyzer with a measuring range within 2 MHz to 4 GHz. By means of this spectrum analyzer the parameter S11 was measured; this parameter determines the best frequencies of impedance matching for the antenna. The dimensions of the coated PET substrate are 5 × 50 mm. The total weight of the coated antenna is 0.402 g. The final size of flexible microstrip antenna was 5 x 50 mm with thickness of 0.48 mm (PET substrate 0.25 mm) The ground plane of the antenna is made of FR-4 copper substrate sized 65 × 75 mm (Figure 2). All measured values (Figure 4) show that the PET substrate and carbon nanotubes/ (ethylene–octene copolymer) in combination with dip coating technology proved to be very promising materials. By combining these materials a very efficient design of the microstrip antenna was achieved. Micrographs (Figure 5) obtained by scanning electron microscopy (FEI Nova NanoSEM 450) showed MWCNTs/ (ethylene–octene copolymer) conductive structure on the PET substrate.
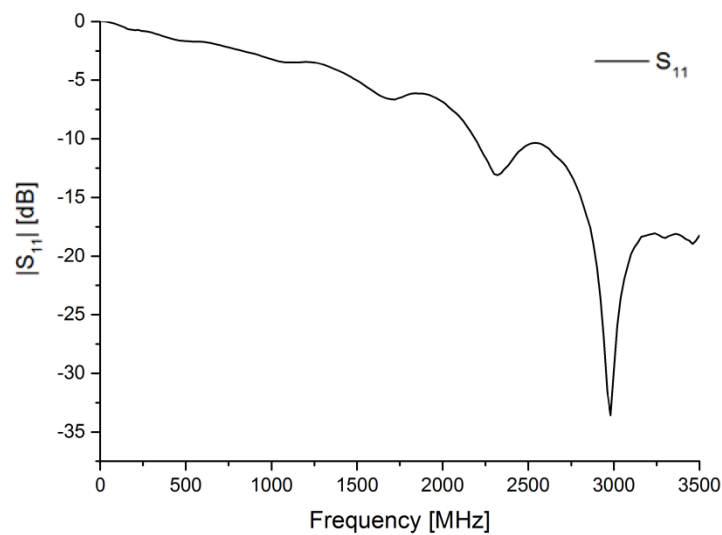

Figure 4. This graph represents the reflection coefficient S11 (expressed in dB) with dependence on the frequency with impedances to 1.66 GHz (–6.51 dB), 2.3 GHz (–13 dB) and 2.98 GHz (–33.59 dB).
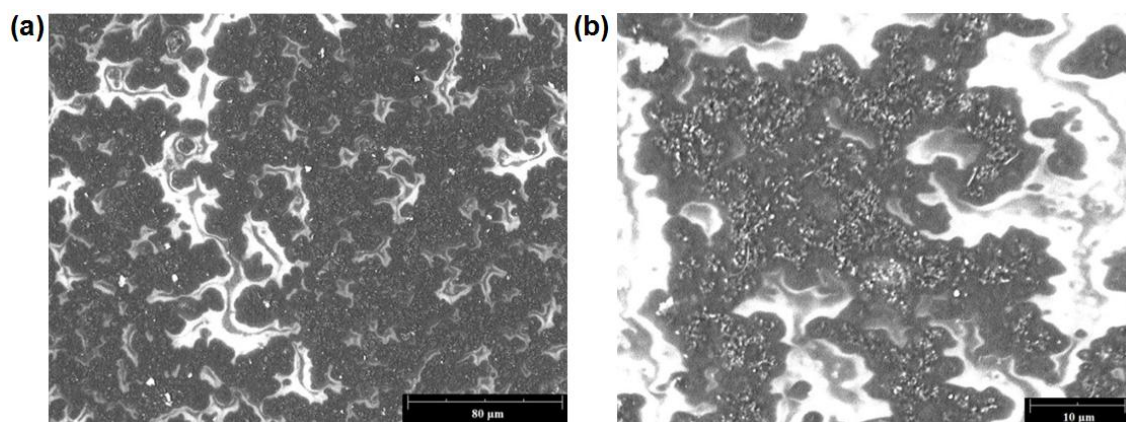

Figure 5. (a) SEM microscopy of the conductive structure on the PET substrate (scale of 80 μm), (b) SEM microscopy of the conductive structure on the PET substrate (scale of 10 μm).

4. Conclusion

Multiwall carbon nanotubes and (ethylene–octene copolymer) were used to prepare conductive antenna layer. The antenna works at three frequencies 1.66 GHz (–6.51 dB), 2.3 GHz (–13 dB) and 2.98 GHz (–33.59 dB) and could be used in telecommunication field. Main advantages are light weight and the possibility to be incorporated to a mobile phone cover. The carbon nanotubes and (ethylene–octene copolymer) network as an antenna could replace commonly used materials in the future.

The main advantages of the antenna are low weight and the possibility for applying to plastic covers of portable telecommunication devices and wearable electronics. Portable telecommunication devices, such as mobile phones, use for communication antennas made of copper foils and strips, which could be replaced by the developed antenna. The majority of widespread technologies, e.g. GSM, UMTS, or LTE operate at frequencies for which it is possible to produce a customized antenna made of carbon nanotubes and (ethylene–octene copolymer) deposited on the PET substrate, because PET substrate is mostly used for next generation of the flexible antenna [7-15].

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