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Fabrication, Characterization and Applications of Multiwall Carbon Nanotubes-Aluminium oxide (MWCNTs-Al_2O_3) Ceramic Composites

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ABSTRACT.

The rapid evolution of electronic and wireless communication technology has given rise to a growing demand for dielectric substrate materials that possess specific properties. Despite its potential, carbon nanotubes (CNTs) have not been extensively used in the development of useful composite substrate materials. This paper showcases the outcomes and practical uses of synthetically produced multiwall carbon Nanotube-Al_2O_3 ceramic composites (MWCNTs-Al_2O_3). Through careful characterization, these materials exhibit great potential for employment in electronic devices, including but not limited to microwave absorbers, insulators, capacitors, and patch antenna substrates.

Keywords: Fabrication, Characterization, Application, Multiwall, Aluminium, Composite.

1.0 Introduction

The branch of technology that studies different materials at a nanometric scale is referred to as nanotechnology and it is also defined as science of production, manipulation and use of materials at subatomic level that finds its application in various disciplines [1]. In 1991, Iijima discovered carbon nanotubes (MWCNTs) using arc-evaporation of graphite in a helium atmosphere [2-7]. Multi-wall nanotubes can be classified as either the Parchment model, which is a single graphene sheet folded repeatedly, or the Russian Doll model, which contains a carbon nanotube of smaller diameter inside [8,9]. While multi-walled and single-walled carbon nanotubes share similar properties, the outer layers of multi-wall nanotubes provide protection for the inner carbon nanotubes against chemical reactions with external substances [9]. Notably, multi-wall nanotubes boast a greater tensile strength than their single-walled counterparts [10]. When designing broadband-absorbing or functional materials at higher microwave frequencies, nanostructure carbon materials like carbon nanotubes (CNTs) provide a wealth of design possibilities due to their exceptional mechanical strength, quality electromagnetic compatibility, and quality frequency-dependent relation [11-14]. However, their application in fabricating dielectric composite substrates has been underutilized.

As electronic and wireless communication technology continues to advance, there arises a demand for dielectric substrate composites that possess a variety of characteristics. These include being lightweight, electromagnetic compatible, having frequency-dependent permittivity and permeability, exhibiting excellent microwave absorptiveness, and having extremely low dielectric and magnetic losses. Additionally, there is a need to develop dielectric composite substrates with custom-tailored dielectric properties in order to improve the performance of existing dielectric substrates.

2.0 Formation of Multiwall Carbon Nanotube Aluminium Oxide

2.1 Aluminium Oxide

Alumina which is another name for aluminium oxide, is an inert, white, odourless material commonly used in various industries as ceramics due to its exceptional properties. It has been extensively applied in electronics, clinical, and biomedical applications and can serve as a starting material for many ceramic products. For this experiment, we prepared 100 grams of aluminium oxide with a maximum impurity limit of 1% and divided it into five equal portions.

2.2 Synthesis of Multiwall Carbon Nanotube

For the synthesis of the multiwall carbon nanotube, the chemical vapor deposition technique was used in this research. The synthesis MWCNT was then purified and functionalized using H_2SO_4 and methanol respectively.

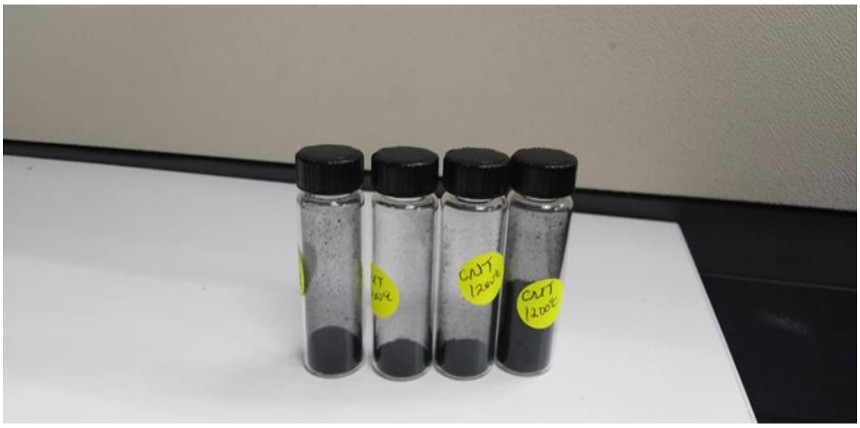

Fig. 1. Sample of MWCNTs produced

The synthesized MWCNTs were been investigated with an EDS, XPS, FESEM, XRD, and RAMAN spectroscopy. The particle shapes and sizes, microstructure characteristics, defects and geometrical properties of the grown Multiwall Carbon Nanotubes were studied using FESEM. The structural strain, impurities, and interlayer spacing were all determined using XRD. Raman scattering was used for the quick and reliable screening for the presence of the desired MWCNT. Chemical structure of the grown CNT was observed with the aid of XPS while the elemental and quantitative composition of the synthesized CNT were identified and obtained through EDS analysis. The synthesized MWCNTs were been investigated with an EDS, XPS, FESEM, XRD, and RAMAN spectroscopy. The particle shapes and sizes, microstructure characteristics, defects and geometrical properties of the grown Multiwall Carbon Nanotubes were studied using FESEM. The structural strain, impurities, and interlayer spacing were all determined using XRD. Raman scattering was used for the quick and reliable screening for the presence of the desired MWCNT. Chemical structure of the grown CNT was observed with the aid of XPS while the elemental and quantitative composition of the synthesized CNT were identified and obtained through EDS analysis.

3.0 Fabrication of carbon nanotube aluminium oxide ceramic composite

Samples of MWCNT-Al_2O_3 composites substrates were made by mixing different quantities of the synthesized and characterized samples of MWCNTs with powder samples of Al_2O_3 at different concentration to form the MWCNT-Al_2O_3 composite substrates. Five portions of Al_2O_3 powder each weighing 20g were mixed proportionately with 9.1wt% (2.0g), 11.1wt% (2.5g), 13.04wt% (3.0g), 14.89wt% (3.5g) and 16.67wt% (4.0g) of the total 15g of the MWCNTs produced. After proper mixing, closed moulding technique was adopted to prepare moulded samples of MWCNT-Al_2O_3 composite substrate to the desired shapes

4.0 Characterization of carbon nanotube alminium oxide

Further analysis was carried out to examine and obtain the properties of the developed MWCNTs-Al_2O_3 composite substrates at higher microwave frequency between 8.2 GHz and 12.4GHz using key sight vector network analyzer. Real relative permittivity and permeability, imaginary relative permittivity and permeability, bulk conductivity, dielectric loss tangent, Magnetic loss tangent and Microwave absorptiveness of each sample were obtained.

5.0 Application of carbon nanotube aluminium oxide ceramic composite

The table below shows different MWCNT-Al_2O_3 ceramic composite samples and their propose area of suitable application that was deduced from their various properties

Table 1. . MWCNT-Al_2O_3 Ceramic Composites Propose Applications

MWCNT-Al_2O_3 Ceramic Composite	Properties						
	Relative Permittivity	Relative Permeability	Microwave AbsorptiveNess	Bulk Conductivity (Siemens/m)	Dielectric Loss Tangent	Magnetic Loss Tangent	Propose Area of Suitable Application
9.1wt%	7.857463	0.792592	0.013879	27.21	0.12487	0.180115	Microwave absorber, RF integrated devices, Electromagnetic compatibility devices, HF Transmission Line
11.1wt%	9.26239	0.913588	0.029587	0.00	0.14216	0.076483	Insulator, Ferroelectric Devices, Ultrasonic, Microphones, Loudspeakers, Ceramic condensers, RF integrated devices
13.01wt%	9.805718	1.231225	0.036546	0.85	0.10359	0.099757	Ferroelectric Devices, Microphones, Loudspeakers, Ceramic condenser, Generator
14.89wt%	8.428757	1.215763	0.017184	29.50	0.09771	0.102992	Ferroelectric Devices, Microphones, Loudspeakers, Ceramic condensers
16.67wt%	8.836543	2.090033	0.010777	0.00	0.02954	0.076483	Biomedical Application, Insulator, Patch Antenna, Capacitor, Wireless Technology
16.67wt%	8.836543	2.090033	0.010777	0.00	0.02954	0.076483	Biomedical Application, Insulator, Patch Antenna, Capacitor, Wireless Technology

5.0 Conclusion

In this study, MWCNTs were produced via chemical vapor deposition at various temperatures, the samples were characterized and used to doped five different samples of Al_2O_3 at various concentrations to create a ceramic composite of MWCNTs and Al_2O_3. The composites samples obtained were further characterized to realize some properties such as relative permittivity and permeability, microwave absorptiveness, bulk conductivity, dielectric and magnetic loss tangent. The properties obtained showed that the composite materials formed can be suitably used as microwave absorber, electromagnetic compatibility devices, insulator, ferromagnetic devices, capacitor and patch antenna substrate which are essential components of solid state electronic devices.

Disclosure of Interests. There is no conflict of interest among the authors of this paper.

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