A Robust Optimization for Zinc Oxide - Graphene Composite Sensor Electrode Utilization in Biodegradable Environment

Rajesh Kumar, Sunita Mishra

Abstract**:** ***In this paper, the emphasis is made on sensor electrodes using Zinc Oxide and Graphene based composites. A robust optimization for ZnO - Graphene composite sensor electrode and its possible application as sensor in the potential field of biodegradable environment is explored. It is explored that the Graphene conductivity dependence on the geometrical structure of nanotubes. The reaction time and decomposition rate along with other properties at low temperatures are discussed along with the result and analysis. These composite based sensor devices can be very useful in the potential field of harmful environment and its effective utilization are analyzed and characterized.***

Keywords **:** ***Chemical sensors, Composite Materials, Graphene, Nano sensor, Nanomaterials, Nanotube, Radiation.***

I. INTRODUCTION

The nanotechnology is a research hot spot in modern materials science [2]. This technology is capable of providing miscellaneous novel applications that range from innovative fabric compounds, food processing, and agricultural production to sophisticated medicinal techniques [1]. It is considered as the synthesis, characterization, and exploration of materials in the nanometer region of 1 nm to 100 nm. At this level, the properties and functions of living and anthropogenic systems are defined [6]. In this technology, the pertinent materials are those whose structures exhibit new and considerably enhanced physicochemical and biological properties as well as distinct phenomena and functionalities as a result of the nanoscale size [3]. This nanoscale size generally confers larger surface areas to nanoparticles (NPs) compared with macro-sized particles [4]. NPs are known as controlled or manipulated particles at the atomic level of 1nm to 100 nm. They show size-related properties significantly different from bulk materials [5].

The surprising physio-chemical properties of fullerenes and Zinc Oxide and Graphene composites offer new prospects for the development of nanotechnologies. The range of nanoclusters applications is very wide.

Revised Manuscript Received on December 30, 2019.
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We aim at considering only a part of the problem, namely, analyzing the state-of-the-art in the nanotube electronics and, first of all, showing the actual devices. We have been engaged in Graphene electronics, in particular, field emission of carbon nanoclusters films, for almost 10 years [18]. Given their small size, NPs have larger structures in comparison with their counterparts. This distinct property allows their possible applications in many fields such as biosensors, nano-medicine, and bio-nanotechnology [16].

The intrinsic properties of metal NPs such as zinc oxide (ZnO), TiO_2, and silver are mostly characterized by their size, composition, crystallinity, and morphology. Reducing the size to nanoscale can modify their chemical, mechanical, electrical, structural, morphological, and optical properties [10-14]. These modified features allow the NPs to interact in a unique manner with cell bio molecules and thus facilitate the physical transfer of NPs into the inner cellular structures [6].

Nanostructure materials have a larger percentage of atoms at their surface which lead to high surface reactivity. Thus, nanomaterials have witnessed recently significant importance in the basic and applied sciences as well as in bio nanotechnology [9-10]. Nano - sized ZnO exhibits varying morphologies and shows significant antibacterial activity over a wide spectrum of bacterial species explored by a large body of researchers [7,8]. ZnO is currently being investigated as an antibacterial agent in both micro scale and nanoscale formulations [11]. ZnO exhibits significant antimicrobial activities when particle size is reduced to the nanometer range, then nano-sized ZnO can interact with bacterial surface and/or with the bacterial core where it enters inside the cell, and subsequently exhibits distinct bactericidal mechanisms [12]. The figure 2 below shows the photograph of strip of oriented Zinc Oxide and Graphene composites nano-electrodes. These strips are synthesized on a substrate with the dimensions, width 2 mm : 6 mm with depth of 23 nm.

The interactions between these unique materials and bacteria are mostly toxic, which have been exploited for antimicrobial applications such as in food industry. Interestingly, Zinc Oxide and Graphene (ZnO-GR) are reported by several studies as non-toxic to human cells [14]. This aspect necessitated their usage as antibacterial agents, noxious to microorganisms, and hold good biocompatibility to human cells [17]. The various antibacterial mechanisms of nano-materials are mostly attributed to their high specific surface area-to-volume ratios [15], and their distinctive physicochemical properties [16]. However, the precise mechanisms are yet under debate, although several proposed ones are suggested and adopted.

Investigations on antibacterial nano-materials, mostly ZnO-NP's, would enhance the research area of nano-materials, and the mechanisms and phenomenon behind nano-structured materials [18]. The minimum threshold electric field for the film samples which we consider to be good is from 0.5 to 1 V/µm, the operating field is from 5 to 10 µV, the current density reaches 0.5 A/cm2 and 2 A/cm2 in the direct-current and pulsed regimes, respectively, and the cathode life exceeds 2000 hours [19-20].

II. OBSERVATIONS

Despite recent progresses on the mechanical and electro-chemical characterization of the zinc oxide-graphene based composites, no results have been published yet regarding the electro-chemical response of the zinc oxide-graphene reinforced polymer composites under compressive loading conditions. The present study focuses on the electro-chemical response of the zinc oxide-graphene reinforced epoxy under variable compressive loading. A modified probe measurement system was used to measure the bulk resistance change of the nanocomposite material through a series of well designed experiments. Variable experiments were performed to investigate the electro-chemical response of the zinc oxide-graphene reinforced epoxy composite samples. A screw driven testing machine and a drop weight tower were utilized to load the nanocomposite. In the two methods, different technologies yield films of both well oriented and strongly entangled tubes. The general procedure of material fabrication is shown in figure 1. High surface energy of carbon nanotubes causes the agglomeration of nanotubes when dispersed, adversely affecting the electro-chemical transport properties of the material in a defective manner [18]. In order to address the agglomeration issue and effectively disperse the Zinc oxide-graphene, the present work implemented high-intensity ultrasonication and high-speed shear mixing. Pre-measured amounts of Epothin Part A Resin and carbon nanotubes were mechanically stirred for 5 min in a copper beaker. The mixture was then placed into a shear mixer outfitted with a 3-blade propeller stirrer and shear-mixed at 600 RPM for 30 min. Following shear mixing, the ultrasonication process was applied for one hour on pulse mode, 4.5 on 9 s off, with 100 kHz. The mixture was then placed into a vacuum chamber to remove any trapped air bubbles generated during the mechanical mixing process.

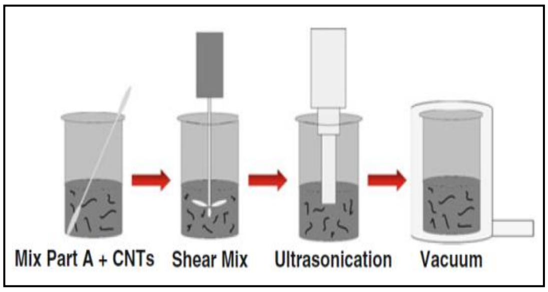

Figure 1: Schematic of nanocomposite fabrication procedure

A pre-measured amount of part B epoxy hardener, in a separate container, was also placed inside the vacuum chamber. Both solutions were placed under a vacuum for 1 h. Once all air was removed from both solutions, they were combined and mechanically stirred for 2 min. The mixture was once again placed back into the vacuum chamber for 5 min. The catalyst, the so-called ink was applied to the stamp surface. The ink was a solution containing from 1 to 50 mm of Fe (NO_3) and $9H_2O$. The composite are created utilizing numerous means in succession. The chemical process is as follows:

$$Zn\,(CH_3CO_2)_2 + 2NaOH \rightarrow Zn\,(OH)_2 + 2NaCH_3CO_2 \quad (1)$$

$$Zn\,(OH)_2 \rightarrow ZnO + H_2O \quad (2)$$

The equation 1 and 2 shows the precipitation of zinc oxide through the chemical processing using sodium hydroxide, methanol arrangement. At first, the Zinc acetic acid derivation of 0.325 M and 0.25 M sodium hydroxide arrangement were broken down in progression into methanol warmed to 65°C under persistent mixing. At that point, 50 mL of the sodium hydroxide - methanol arrangement was gathered in a 20 mL syringe and infused into a response container containing 10 mL zinc acetic acid derivation. The flow rate was 320 µL/min (kept up by the syringe siphon). The arrangement was blended at 800 rpm and kept up at a temperature of 65°C as appeared in the stage 1 beneath.

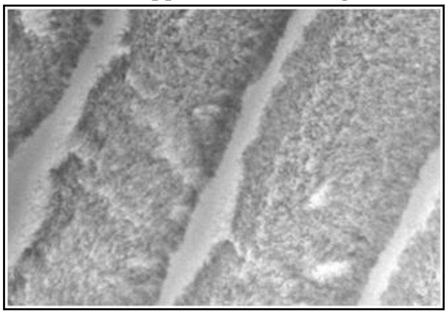

Figure 2. Photograph of strip of oriented Zinc Oxide and Graphene composites synthesized on a substrate. The strip dimensions, width 2 mm : 6 mm with depth of 23 nm.

The Zinc acetate is stirred at 65°C with the presence of NaOH. The process generates the tiny particles of Zinc-oxide, which in the solidification state behaves like a powered material. An extra 10 mol sodium hydroxide arrangement was added to the blend drop-wise, and mixing proceeded for 30 minutes. The subsequent white accelerate was isolated by means of centrifugation and washed multiple times with anhydrous ethanol in an ultrasonication shower. The arrangement containing ZnO particles was dried in a sight-seeing oven at 60°C for 24 hours.

The figure 3 below shows the differential conductivity dI/dV of a Zinc Oxide and Graphene composites as a function of V_{sd} for different temperatures. This application is favored by a strongly extended geometric shape and unique mechanical properties of Zinc Oxide and Graphene composites. The ratio of the nanotubes length to its diameter can exceed a thousand [6].

III. RESULT AND DISCUSSIONS

It is critically important to control the temperature of the mixture during the sonication process for the quality of the fabricated samples.

The sonication process generates substantial heat that may damage zinc oxide-graphene and deteriorate the electro-chemical properties of the final composite, which corresponds to semiconducting tubes. As we know that a finally, the zinc oxide-graphene/ epoxy solution was slowly poured into pre-manufactured wax molds and allowed to cure for 3 days under ambient conditions.

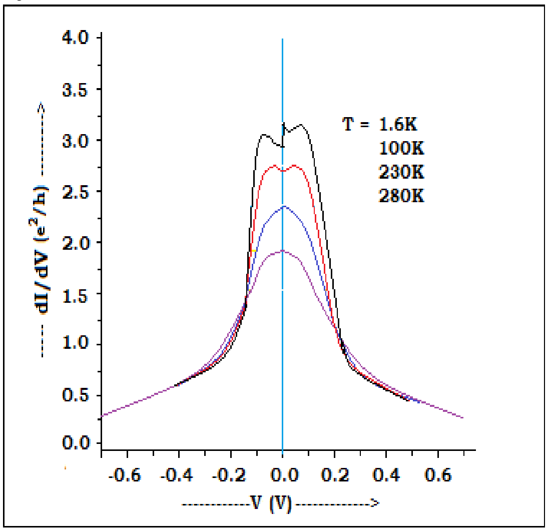

Figure 3. Differential conductivity dI/dV of a Zinc Oxide and Graphene composites as a function of V_{sd} for different temperatures.

The figure 4 below shows the relative comparison of pallet's chemical testing through chemical decomposition time for dimensions 2 mm: 6 mm and 2 mm: 10 mm. Finally it should be noted that a further effort in order to design and implement scaling and optimization techniques in quantum transport carriers requires stability analysis, which is necessary for a more efficient application of theoretical models over experimental data.

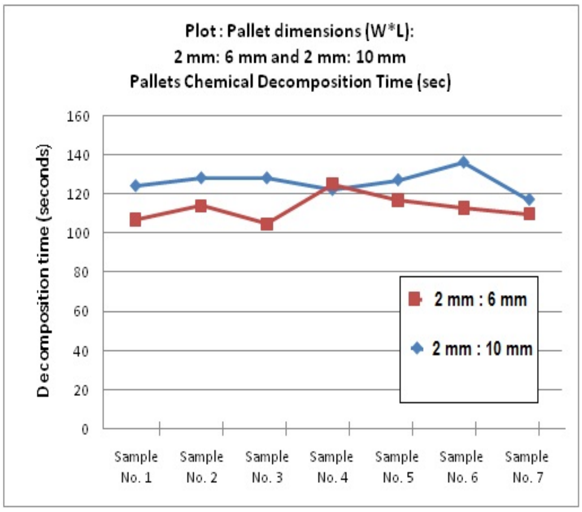

Figure 4. Relative comparison of pallet's chemical testing through chemical decomposition time for dimensions
2 mm: 6 mm and 2 mm: 10 mm.

The figure 5 below shows the relative comparison of pallet's chemical testing through chemical decomposition time for dimensions 2 mm: 6 mm and 2 mm: 10 mm.

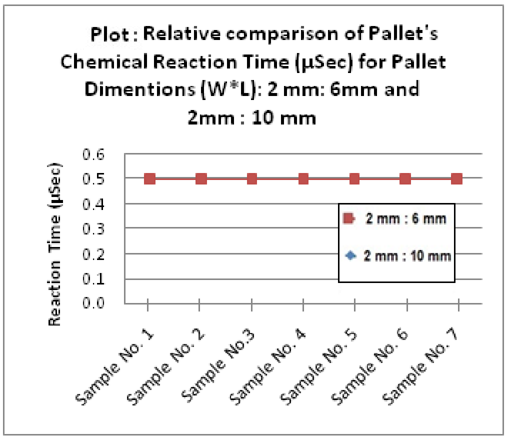

Figure 5. Relative comparison of pallet's chemical testing through chemical decomposition time for dimensions
2 mm: 6 mm and 2 mm: 10 mm.

The above graph shows the relative comparison of pallet's chemical testing through reaction time for dimensions 2 mm: 6 mm and 2 mm: 10 mm. The samples are compared here for different analysis and structural observations. Different values are observed during this testing. These values are shown in table 1 below. The sample which provides best pallet's chemical testing through reaction time, for dimensions 2 mm: 6 mm and 2 mm: 10 mm, has minimum and maximum values as 0.5 micro-seconds (µSec)./.

IV. CONCLUSION

The complete characterization is done with the development of Zinc Oxide and Graphene composite-based sensors. It is explored that these composites has tremendous scope in the future to come and is going to be a potential field to be explored further. This current review aimed to discuss and analyze research works that addressed the potential use of ZnO-NPs for antibacterial activity. The importance and significance of ZnO-GO in various areas has developed global interest to study their antibacterial activity. The documented reaction time and decomposition rate of ZnO-GO have stimulated a considerable range of biodegradable environment or antimicrobial applications. ZnO-GO possess unique properties and excellent stability with long life compared with organic- based disinfectants that stimulated its use as antibacterial agent. The table 1 below shows the relative comparison of different pallet's chemical decomposition (sec) for pallet dimensions (W*L): 2 mm: 6mm and 2mm: 10 mm. After the research is done in the field of device designing and fabrication using these compositions, the relative effect on the objects placed in biodegradable environment can be observed, analyzed and quantified. The measurements of the samples for both dye no. 206 and dye no. 210 are obtained and different values are observed during this testing. These values are shown in table 7.32 below. The samples which carry pallet's chemical decomposition and its values are tabulated in percentage. The sample no. 6 and sample no. 4 provides best sample values for chemical decomposition time, as 136 sec and 125 sec.

Table- I: Relative comparison of different Pallet's Chemical Decomposition (sec) for Pallet Dimensions (W*L): 2 mm: 6mm and 2mm: 10 mm.

Tested Sample	Pallet's Chemical Decomposition (sec)	
	*Dimensions (W*L): 2 mm : 6 mm*	*Dimensions (W*L): 2 mm : 10 mm*
1	124	107
2	128	114
3	128	105
4	122	125
5	127	117
6	136	113
7	117	110

The large surface area-to-volume ratio allows their use as novel antimicrobial agents, which are coming up as recent concern for researchers. In this field, expectations are very high due to their unique and robust nature. The development of Zinc Oxide and Graphene composite based integrated circuits and arrays are needed to be formulated. Nevertheless, we are sure that Zinc Oxide and Graphene composite electronics has great future and it is a potential field for the sensing antibacterial environment.

ACKNOWLEDGMENT

The author would like to present his deepest gratitude to Dr. Sunita Mishra for her guidance, advice, understanding and supervision throughout the development of this research paper and study. The author would also like to thank Lovely Professional University for their support on academic studies and letting research members to involve in research study. His special thanks to the research lab members for their valuable comments and discussions.

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