TRANSPARENT CONDUCTIVE CARBON NANOTUBES / BINDER HYBRID THIN FILM

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"I declare that this report entitle "Transparent Conductive Carbon Nanotubes / Binder Hybrid Thin Film" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree"

Signature: …………………………………….

Name: ………………………………………

Date: ………………………………………..

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To beloved my father and mother, Syed Zainal Abidin bin Syed Mahdzar and Sharifah Zaharah Bt Syed Ibrahim

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ABSTRACT

The aims of this project to study design transparent conductive carbon nanotubes / binder hybrid thin film of conjugated polymer and polyelectrolyte using single walled carbon nanotube (SWCNT) network films by loaded in software CST. The development of this gas sensor able to detect the food that is not in a good condition. Furthermore the use of carbon nanotube as the main material because the properties of the carbon nanotubes which has the most extremely good in thermal conductivity. Furthermore carbon nanotube also is a good gas absorber since it has a smaller volume to ratio. To construct or to design this gas sensor, using the CST software by consider each of material of the gas sensor which are the copper, silicon oxide and carbon nanotubes. This gas sensor consists of three layer of sensor. The bottom layer which is the copper layer with 0.035mm thickness. Meanwhile the second layer act as insulator which electrically insulating with SiO (silicon oxide) layer which lossly in characteristics. Beside this second layer consists of a printed RLC circuit. The third layer which is the top layer is the layer of the carbon nanotube. The printed RLC circuit is design in the ADS software, construct the RLC circuit, by fixed the value of inductor able to design the suitable RLC fir this gas sensor. With this gas sensor user able to detect food either it is in good condition or not. Furthermore the new invention for material carbon nanotubes which is low cost able to produce a product such as this gas sensor.

ABSTRAK

Tujuan projek ini untuk mengkaji *transparent conductive carbon nanotubes / binder hybrid thin film of conjugated polymer and polyelectrolyte using single walled carbon nanotube (SWCNT) network films* dengan dimuatkan dalam CST perisian. Perkembangan ini sensor gas dapat mengesan makanan yang tidak berada dalam keadaan yang baik. Selain penggunaan *carbon nanotube* sebagai bahan utama kerana sifat-sifat nanotube yang *good in thermal conductivity*. Tambahan pula *carbon nanotube* juga merupakan penyerap gas yang baik kerana ia mempunyai size yang lebih kecil . Untuk membina reka bentuk gas sensor ini , dengan menggunakan perisian CST, bahan-bahan yang harus digunakan ialah tembaga, silikon oksida dan *carbon nanotube*. Gas sensor ini terdiri daripada tiga lapisan. Iaitu lapisan bawah yang merupakan lapisan tembaga dengan ketebalan 0.035mm. Selain itu, lapisan kedua bertindak sebagai penebat dimana *electrically* SiO (silikon oksida) lapisan kedua ini mempunyai sifat *lossly*. Lapisan kedua juga mempunyai litar RLC dicetak. Lapisan ketiga yang lapisan atas adalah lapisan nanotube karbon. Litar RLC bercetak adalah reka bentuk dalam perisian ADS, untuk membina litar RLC, dengan tetap nilai *inductor* supaya mendapat reka bentuk litar RLC yang sesuai untuk gas sensor ini. Dengan ini pengguna sensor gas dapat mengesan makanan sama ada ia berada dalam keadaan baik atau tidak. Tambahan pula penciptaan baru *carbon nanotube*, di mana mempunyai kos yang rendah dapat menghasilkan produk seperti ini sensor gas.

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LIST OF NOTATION AND SYMBOLS

CNT – Carbon nanotubes

SWCNT- Single-walled carbon nanotubes

MWCNT- Multi-walled carbon nanotube

CST- Computer Simulation Technology Suite 2011

ADS- Agilent Advanced Design System

CHAPTER 1

INTRODUCTION

In this chapter will discuss about the project background for this thesis. The problem statements have been analyzed in order to achieve the objective for this project. All the objectives in this project are achieved, so does the scope of works.

1.1 Project Background

Carbon nanotubes (CNTs) are allotropes of carbon alongside a cylindrical nanostructure. Nanotubes have been crafted alongside length-to-diameter ratio of up to 132,000,000: 1, considerably larger than for each supplementary materials science and technology. Nanotubes are associates of the fullerene structural family. Their term is deduces from long, hollow construction alongside the walls industrialized by one-atom-thick pieces of carbon, shouted graphene. CNTs are describes as piece of graphene rolled up as hollow cylinders. They basically can be categorized into two clusters single-walled (SWNTs) and multi-walled (MWNTs). Carbon nanotubes are an interesting new class of materials from both hypothetical and requested standpoints. There are lot of request of carbon nanotube for example the transmission of carbon nanotubes, nanoscale electronic mechanism on carbon nanotubes and countless more.

One of the most momentous request of carbon nanotubes is carbon nanotubes established by transparent conductive film (TCF) technologies have possible request in electrostatic dissipation (ESD), electromagnetic interference (EMI) protecting, and transparent film warming, as well in the progress of alternative electrode materials. This new conception employing the single-walled carbon nanotube (SWCNT) web films have been intensively learned for the progress of alternative transparent conductive electrodes. For such request of multifunctional electronic mechanism that is the most momentous one is sensor.

Carbon nanotubes have tremendously desirable mechanical and thermal properties have been believed for their applicability in sensor design. In addition to the exceptional mechanical properties of carbon nanotubes, their brilliant thermal conductivity, elevated mechanical robustness, and extremely colossal external to volume ratio create them superior materials for fabrication of electromechanical and electrochemical sensors alongside higher sensitive, lower limits of detection, and faster reply time. A good example is the carbon nanotubes based mass sensor that can notice adjustments in mass provoked by solitary gold adsorbing on its surface.

1.2 Problem Statement

Sensors tolerate to create momentous encounter in everyday important as from biomedical to automotive industry. This has managed to intensive scrutiny hobbies across the globe in growing new detecting materials and technologies.

Miniaturized sensors can lead to decreased heaviness, lower manipulation consumption, and low cost. Materials such as inorganic semiconductor are utilized in creating nanosensors. Momentous trials to this knowledge remain. Early to minimizing the junction confrontation in a random web construction have to be industrialized for request such as elevated presentation CNT- based TCFs.

Secondly, enhanced hybridization method employing assorted ceramic oxides or metal oxides such as silicon oxide and many more that are demanded to use these films in multifunctional electronic mechanisms such as sensors.

1.3 Objective

- To study design transparent conductive carbon nanotubes / binder hybrid thin film of conjugated polymer and polyelectrolyte using single walled carbon nanotube (SWCNT) network films by loaded in software CST.
- To study design RLC circuit of sensors using Agilent Advanced design System (ADS) software.
- To provide multifunctional electronic device which is the most significant one is sensor.
- To analyze electronic devices characteristic sensor such as miniaturized sensors can lead to reduced weight, lower power consumption, and low cost, after adding the carbon nanotubes (CNT) using single walled carbon nanotube (SWCNT) network films.

1.4 Project Scope

- Design wireless gas sensor with the mixture of inorganic material mixture with single and multi-walled carbon nanotube network films
- Stimulate the RF signal of this thin film in CST software.
- Stimulate RLC circuit of sensors in Agilent Advance design Systems.
- Analyze electronic sensors can lead to reduced weight, lower power consumption, and low cost, after adding the carbon nanotube.

CHAPTER 2

LITERATURE REVIEW

In this chapter will explain the material that used in this project. The characteristic of single, multi-wall carbon nanotubes, properties each gas involve in this gas sensor are explained in this section. Besides, the explanation about the RLC circuit and operation of the gas sensor also has been clarified in this section.

2.1 Reviews from Research Paper

2.1.1 Introduction

Carbon nanotubes (CNTs) have drawn a lot attention as the detecting agent in sensor knowledge because of their exceptional electronic properties and remarkable mechanical properties. CNTs tremendously elevated surface-to-volume ratio create an extremely good nominee for the adsorption of gas molecules. Gas sensors are divided into two kinds, namely physical gas sensor and chemical gas sensors. Physical gas sensor that work by ionization mechanism or fingerprinting or detection of the characteristics of different gases. Carbon nanotubes have discovered request as earth emission mechanism [1], electronic switches [2] [3], actuators, and random admission recollection. Recently, request of carbon nanotubes as oxygen and methane gas sensors has been reported, as nanotubes are vitally external, they proposal the potential of brilliant sensitivity and rapid response times. Gas sensors are utilized in countless manufacturing, health, and business applications. For example, oxygen sensors are utilized in the monitoring of combustion engine nature to raise engine presentation and cut emission of greenhouse gases. [4] Ammonia sensors are vital for monitoring ambient ammonia compression as it is connected to countless environment subjects such as acidification, human condition, and meteorological conditions change across particle formation. [5] In addition to manipulating manufacturing procedures and monitoring air quality, CO sensors are extensively utilized in food and medicine packages as a way noticing spoilage [6]. Most gas sensor obtainable on the marketplace nowadays work by computing the impedance of coated with a gas-responsive polymer or ceramic such as heteropolysioxane, BaTio Ceo/ BaCO / CuO, Ag SO, Na CO and SnO [7] [8] .

This gas sensor offer a high degree of accuracy and reliable performance, but need hard-wire connections between the sensor head, power supply, and data processing electronics that preclude countless monitoring applications. Thus, the application of multiwall carbon nanotubes (MWNTs) for remote query detection of carbon dioxide, oxygen, and ammonia established on the measured adjustments in MWNT permittivity and conductivity alongside gas exposure.

2.2 Multi/Single-Walled Carbon Nanotubes

A single-walled carbon nanotube (SWNT) is a nanoscale tube formed by a cylindrical shell of single atomic layer of carbon atoms. Nanotubes have diameter of a few nanometer and length up to 100μm so that they form extremely thin wires. The atomic structure of SWNT can be industrialized by cloaking a stripe of solitary atomic layer of graphite piece alongside a precise association, and this association determines the diameter and chirality of the nanotubes. Experimental and theoretical studies have found that these nano-meter sized CNTs have novel electronic properties, which can be metallic or semiconducting, depending on their radius or chirality. Nanotubes can be utilized as electronic wire between two metal electrodes as shown in Figure 2.1 and the conductance amid the electrodes can measured as a purpose of the gate bias voltage. As the nanotube electronic property is a forceful purpose of its atomic construction, mechanical deformations or chemical doping can instigate forceful adjustments in conductance. Such adjustments can facilely noticed by electron present signals, and these properties make CNTs extremely small sensors sensitive to their chemical and mechanical environments [9].

Figure 2.1 Schematic of a nanotube-based chemical sensor. This schematic diagram shows similar concept in carbon nanotube gas sensor [9]

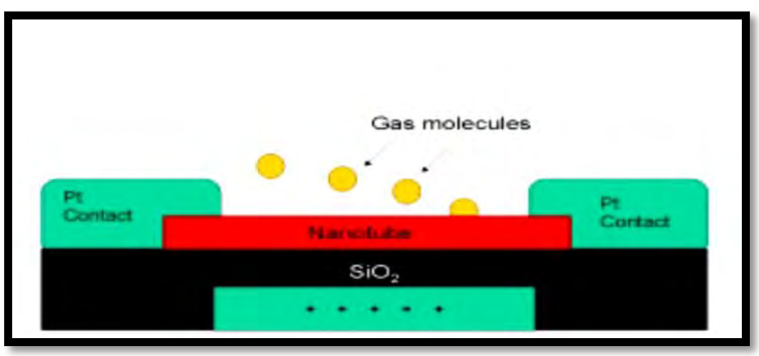
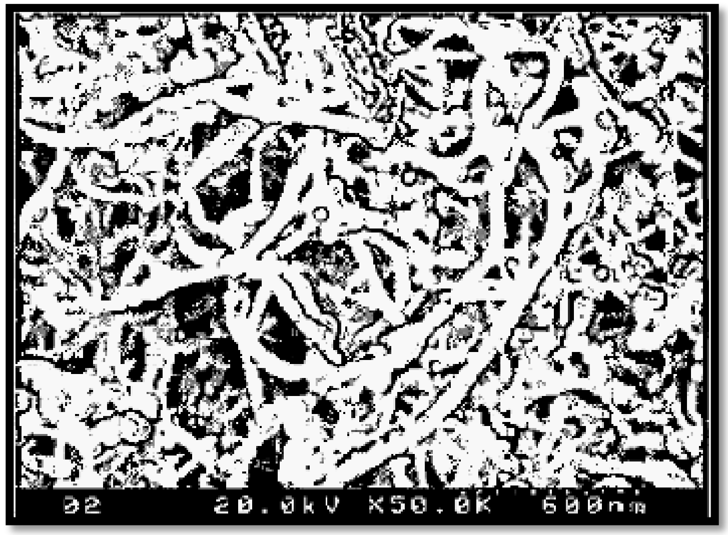


Figure 2.2 Multi-walled carbon nanotubes in microscope with 600 nanometer



Multi-walled nanotubes (MWNT) encompass of several rolled layers (concentric tubes) of graphene. There are two models that can utilize to delineate the constructions of multi-walled nanotubes. In the Russian Doll ideal, piece of graphite are coordinated in concentric cylinders. The single-walled (SWNT) size is between 0-8 nanotubes meanwhile MWNT have a large size compare to SWNTs. The inside size of MWNT is 0-17 nanotubes than SWNTs. Meanwhile in Parchment ideal, a solitary piece of piece of graphite is rolled in concerning itself, resembling a scroll of parchment or a rolled newspaper. The interlayer distance in multi-walled nanotubes is close to the distance amid graphene layers in graphite. The Russian Doll structure is observed more commonly. Its individual shells can be described as SWNTs, which can metallic or semiconducting. Because of statistical probability and limits on the comparative diameters of the individual pipes, one of the shells, and therefore the finished MWNT, is normally zero-gap metal [9] .

2.2.1 Electrical Properties of carbon nanotubes

Carbon nanotubes (CNTs) are macromolecular one dimensional system with unique physical and chemical properties. The chemical properties are derived of that all chemical bonds are satisfied and they are very strong, which also leads to total mechanical, thermal and chemical stability. The electronic structure and electrical properties of CNTs are derived from those of a layer of graphite (graphene sheet). The specific electrical properties of the carbon nanotubes are obtained as result of their particular band structure and the hexagonal shape of its first Brillouin zone. CNTs can carry out high electrical current densities at low electron energies. When high electron energies are injected in CNTs, this quantity of energy destroys the CNT structure, and become other structure for example zigzag structure [10] .

Among physical variables of the carbon nanotube related with the electrical performance are diameter, chirality, length, position, and orientation. Each graphene sheet is wrapped in accordance with a pair of indices (n, m), which represents the number of unit vectors along two directions in the honeycomb crystal lattice of graphene. If $m = 0$, the nanotubes are called zigzag nanotubes, if $n = m$, the nanotubes are called armchair nanotubes and otherwise, they are called chiral nanotubes. Two physical properties of the graphene modify its electrical properties: symmetry and electronic structure. There are three types of electrical behaviour as shown in Figure 3: 1) if = m, the nanotube is metallic; 2) if n-m is equal to 3j, where j is a positive integer ("3j" rule),then the nanotube is semiconducting with a very small band gap, and 3) otherwise, the nanotube is a moderate semiconducting [10].

The 3j rule has exceptions due to the curvature effects in carbon nanotubes with small diameter, which can influence in the electrical properties. A metallic carbon nanotube can present semiconducting behaviour and vice versa.

Figure 2.3 Fullerene CNT structure [10]

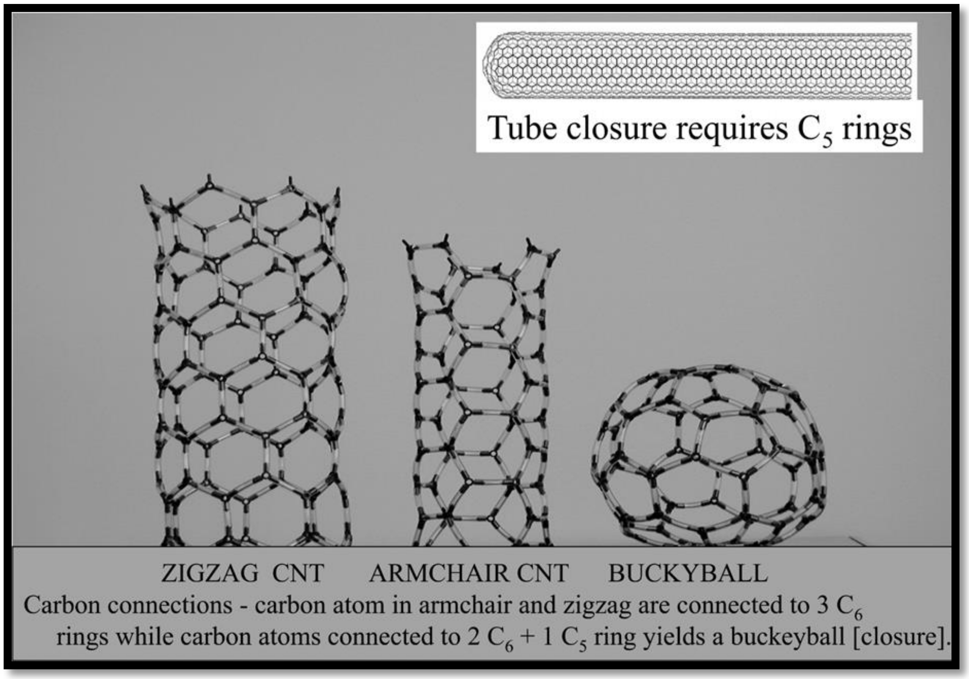
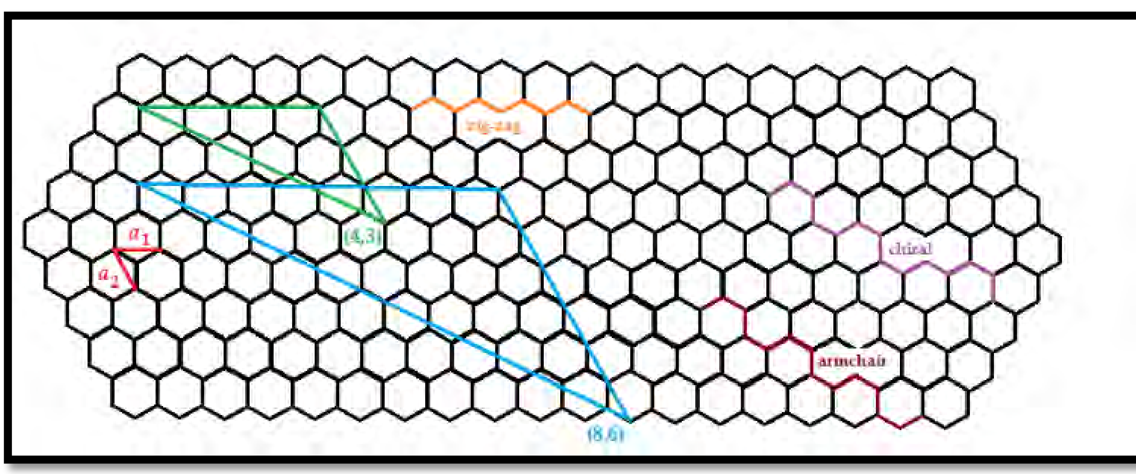


Figure 2.4 Classification of CNT by chiral, indices, zigzags and chiral [10]



2.2.2 Mechanical Properties of carbon nanotubes

SWNTs are strong and stiff. The Young's modulus of nanotubes, ~ 1TPa, is five times higher than that of steel. Their theoretically predicted tensile strength, the maximum tensile stress one material can sustain before failure, is 130GPa. A group measured this parameter of MWNTs and the largest observed value is about 63GPa. As a comparison, the tensile strength of steel is less than 1GPa. At the same time, SWNTs are extremely light [11].

These mechanical properties, coupled with electrical conductivity, also inspired people to integrate SWNTs into nano electromechanical systems. For example, an electrically actuated tunable oscillator using SWNTs has been demonstrated. A company is working toward commercializing large density and high speed random access memories based on suspended nanotubes that can be modulated by external voltages to switch between two states [11] .

2.3 Advantages Using Carbon Nanotubes in Gas Sensor

One should not be fooled by the width of nanotubes in AFM or SEM images. The convolution of nanotubes and the probing AFM tip or electron beams makes the lateral dimension much large than the nanotube diameter. AFM probes tube diameters by measuring how far the AFM tip lifts up from the substrate surface when it is on top of nanotubes. It is crucial to do it at small scanning range (~mm). Otherwise the diameter value will be underestimated. TEM can measure tube diameters too, but it is limited to suspended nanotubes. Raman spectroscopy is another tool to measure small SWNTs. The radial breathing mode (RBM) phonons, where all carbon atoms oscillate radially with the same phase, generate a strong peak in Raman spectroscopy at around 200 cm-1. The peak position is inversely proportional to tube diameters: w = 248 cm-1/ d [nm]. The RBM peak of large diameter tubes falls below the cut off frequency of typical instruments. The magnitude of Raman peak can be enhanced significantly when the excitation is in resonance with the nanotubes sample [10][11].

Due to the excellent and well-known properties of nanoscale materials, intensive research has been performed in various areas. The one-dimensional nanoscale structure of a nanowire or a nanotube is attractive for use in effective cold cathodes [1], field emitters, and vacuum microelectronic. Recently, silicide nanowire has shown the possibility of nanoscale interconnection with low resistance. Additionally, carbon nanotubes have been applied in various applications such as energy storage devices, sensors, and actuators. The electrical conductivity of carbon nanotubes (CNTs) is prominent (10^6 S m^{-2}), and thus CNT films also possess a low sheet resistance while holding an excellent optical transmittance in the visible spectrum comparable to that of commercial indium-tin-oxide (ITO); a transparent CNT film heater has been realized [10][11] .