INVESTIGATION ON THICKNESS OF THIN FILM GAS SENSOR FOR HIGH SENSITIVITY GAS SENSOR

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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DEDICATION

I specially dedicated to my supervisors, lecturers, family and friends, who always guide and support me to complete my final year project successfully.

ABSTRACT

VOC gas is a colourless and flammable gas. Hence, it is one of the main sources that causes combustion in high-temperature conditions. Besides, it is harmful to the health of living things. It will induce dizziness, headaches, vomiting, nose, eye, and throat irritation in the short term. In the long term, it will cause central nervous system damage, cancer, liver and kidney damage. As a result, a thin film gas sensor is used to detect the presence of VOC gases in the environment, although in a small region. A thin film gas sensor works on the premise of converting chemical quantities contained in gas into an electrical signal, such as current. The purpose of this project is to investigate the high sensitivity of thin film gas sensors at various thicknesses of the fabricated thin film. The substrates used are glass and Kapton film. There are several types of solutions used which consist of three different types of solvent (acetone, ethanol, and DI water) and three different concentrations of graphene power (0.01 g, 0.02 g, and 0.05 g of graphene power). The thickness of the thin film can be variable through different amounts of graphene power used in the solutions. All the prepared solutions are sonicated for 30 minutes to ensure they are well mixed. First, the electrode is screen-printed onto the substrates before being annealed at 150 degrees Celsius for 10 minutes. After that, a thin film is deposited on the substrate that contain

electrode by applying the dropping process with one drop of solution and undergoing annealing at 150 degrees Celsius for 10 minutes. The resistance-containing thin film gas sensor will next be used to test the target VOC gases. The VOC gases used are acetone and ethanol. Finally, the results of the gas test are used to perform further research. The gas sensors that are fabricated on the Kapton film substrates with 0.01 g graphene and 10 g DI water have high sensitivity to acetone and ethanol, where sample D1a has a sensitivity of 3.24% and D1b has a sensitivity of 7.02%. Sample E5b has the shortest response time (1 s), whereas sample D-5b has the quickest response time (5 s) of all the samples. The majority of fabricated gas sensors are more sensitive to acetone than to ethanol gas.

ABSTRAK

Gas VOC adalah gas tanpa warna dan mudah terbakar. Oleh itu, ia adalah salah satu sumber utama yang menyebabkan pembakaran dalam keadaan suhu tinggi. Selain itu, ia berbahaya kepada kesihatan makluk hidup. Ia akan menyebabkan pening, sakit kepala, muntah, hidung, mata dan kerengsaan tekak dalam jangka masa pendek. Dalam jangka masa Panjang, ia akan menyebabkan kanser, kerosotan system saraf pusat dan buah pinggang. Oleh itu, sensor gas filem nipis digunakan untuk mengesan kehadiran gas VOC di alam sekitar walaupun di Kawasan kecil. Sensor gas filem nipis berfungsi di premis menukar kuantiti kimia yang terkandung dalam gas menjadi isyarat elektrik, seperti arus. Tujuan projek ini adalah untuk menyiasat sensitivity tinggi sensor gas filem nipis pada pelbagai ketebalan filem nipis yang dibuat. Substrat yang digunakan adalah kaca dan filem Kapton. Terdapat beberapa jenis larutan yang digunakan, ia terdiri daripada tiga jenis pelarut yang berbeza (aseton, etanol, dan air DI) dan tiga kepekatan graphene yang berbeza (0.01g, 0.02g dan 0.05g graphene). Ketebalan filem nipis boleh berubah-ubah melalui jumlah kuasa graphene yang berbeza yang digunakan dalam larutan. Semua larutan yang disediakan akan menjalani sonikasi selama 30 minit untuk memastikan ia bercumpur dengan baik. Dalam proses pertama, elektrod dicetak skrin ke substrat sebelum dilil pada 150 darjah Celsius

selama 10 minit. Selepas itu, filem nipis disimpan pada substrat yang mengandungi elektrod dengan proses “dropping” dengan satu titisan larutan dan menjalani penyepulindapan pada 150 darjah Celsius selama 10 minit. Sensor gas filem nipis yang mengandungi rintangan akan diguji dengan gas VOC. Gas VOC yang digunakan adalah aseton dan etanol. Akhirnya, keputusan ujian gas digunakan untuk melakukan penyelidikan selanjutnya. Sensor gas yang dibuat pada substrat filem Kapton dengan 0.01 g graphene dan 10 g air DI mempunyai sensitivity yang tinggi terhadap aseton dan etanol, di mana sampel D1a mempunyai sensitivity 3.24% dan D1b mempunyai sensitivity 7.02%. Sampel E5b mempunyai masa tindak balas terpendek ketika gas disalurkan (1 s), manakala sampel D-5b mempunyai masa tindak balas terpantas ketika pelepasan gas (5 s) berbandingkan semua sampel. Sebilangan besar sensor gas yag dibuat lebih sensitive terhadap aseton daripada etanol.

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LIST OF SYMBOLS AND ABBREVIATIONS

DI water	:	Deionized water
Gr	:	Graphene
IDEs	:	Interdigitated electrodes
IPA	:	Isopropyl alcohol
SEM	:	Scanning electron microscope

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Volatile organic compounds (VOCs) are emitted as colourless gases from certain liquids or solids. VOC gas covers a wide range of chemical substances that are naturally occurring or man-made. There are common types of VOC gas, including acetone, acetic acid, acetylene, benzene, ethanol, formic acid, methanol, isopropanol, and toluene. VOC gases come from building materials (such as carpet, paint, and composite wood products), personal care products (like cosmetics, nail removers, and hand sanitizers), and daily used equipment (like cooking gas, fuel oil, and dry cleaning). VOC gas has a high vapour pressure and is flammable. So, it is one of the main causes of firebreaks. Moreover, VOC gases will have a negative effect on living things' health. If we are exposed to VOC gas in the short term like hours to days, we might experience headaches, vomiting, dizziness, worsening of asthma symptoms,

eye, nose, and throat irritation. But chronically exposed to it might cause cancer, central nervous system damage, liver and kidney damage. A gas sensor is an electronic device to identify and detect different types of gases. A thin film gas sensor has a very fine layer of around 10 nm to 1µm deposited on a substrate. Therefore, this project will fabricate thin film gas sensors with varying thicknesses, test them with several types of VOC gases, and investigate the results.

1.2 Problem Statements

Volatile organic compounds (VOCs) are flammable gases, so it is easy to cause combustion when exposed to high temperatures. According to ACS' Environmental Science and Technology researchers, they have analysed the level of particulate matter and VOCs surrounding firefighters actively fighting fires, finding the highest exposures among hotshot teams and those establishing firebreaks [1]. Moreover, VOC gas will affect living things' health. According to the Minnesota Department of Health, exposure to high levels of VOC gas in acute terms (hours to days) may cause us headaches, dizziness, worsening of asthma symptoms, vomiting, eye, nose and throat irritation [2]. While we exhibit VOC gas at a high percentage chronically (years to a lifetime), we might have some symptoms like cancer, central nervous system damage, liver and kidney damage [2]. Moreover, some VOC gases cause cancer in animals, according to the United States Environmental Protection Agency [3].

1.3 Objectives

i. To fabricate the thin film gas sensor on different substrates using the dropping technique.

ii. To investigate the various thicknesses of thin film gas sensors for the target VOC gases.

iii. To analyse the performance of the fabricated thin film gas sensors in terms of sensitivity, response time, and recovery time.

1.4 Project Scopes

The substrates used in this project are glass and Kapton film. The substrate is coated with various types of solutions with three different types of solvent (acetone, ethanol, and DI water) and several amounts of graphene. The different amounts of graphene power (0.01g, 0.02, and 0.05g) are used to obtain various thicknesses of thin film. All the measurements of the samples are done on an analytical balance. Then, the solutions are sonicated using an ultrasonic cleaner for 30 minutes. First, the screen-printing technique is used to fabricate an electrode on the substrate with silver paste. Besides, the dropping method is used to form thin film layers on the substrates. A scanning electron microscope (SEM) is used to observe the structure of crystalline graphene in the thin films on the substrates, which are glass and Kapton film. Silver paste is pasted with 2.5cm of copper wire. It acts as a connecter to make the thin film have a connection to become a gas sensor. A picoammeter is a tool used to check the current contained in the gas sensor by applying a certain voltage to it. The well-performed thin film gas sensors are tested with the targets of VOC gases, which are acetone and ethanol. Finally, analyse the sensitivity, response time, and recovery time of the thin film gas sensor through the graph and some calculations.