

Electronic Identification System of Volatile Organic Compound Gases using Roselle-chitosan Blend

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Abstract-This paper presents a study on design and fabrication of an electronic identification system (EIS) for some volatile organic compounds i.e. toluene, ethanol and methanol through vaporization technology. A new sensing material of roselle-chitosan blending thin film based on electrochemical deposition method was used to guarantee the differentiation and the accuracy of the identification system. Chitosan smart gel with 2% acetic acid was prepared and then roselle extract was blended to enhance the sensing properties of the chitosan film. Differentiation ability was studied by exposing 50ppm of toluene, ethanol and methanol vapor to the sensing material. The accuracy of the identification system was tested by IV electrical testing. The analyzed data demonstrated that the electronic identification system is capable of identifying different volatile organic compound gases at room temperature successfully. The roselle-chitosan film sensors showed the characteristic of a reliable sensor i.e. good sensitivity, selectivity, repeatability, recovery and stable.

I. Introduction

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors [1].

Intoxication problems including gas emission and inflammable gas leakages provide the impetus for fundamental and applied research in environmental areas. Moreover for the sake of environmental monitoring and control of chemical processes, many efforts to develop simple, inexpensive, and reliable sensors have been made [2]. It's also known that certain chemical species, even at low values can be toxic to humans, which leads to the need of an identification system, which reflects the often-enormous challenge of selectively detecting small numbers of a specified molecule in chemical industries and laboratories. For many years, high sensitivity/selectivity sensors and identification systems were limited to the laboratory. Conventional techniques used to

analyze VOC gases like metal oxide semiconductors have to deal with the problem of poor sensitivity at room temperature. Optical methods and carbon nanotubes techniques are also suffering from the disadvantages of high cost, the need for trained personnel, difficulties in fabrication and achieving the sensor properties [3]. There is increasing need for a reliable analysis of VOCs toxic gases in beverages, industrial and workplaces. High percentage of VOCs like ethanol and toluene in beverages and alcoholic are health risks. Furthermore there is pressure by media with regards to health risk and mental effect of toxic VOCs, which has led to stricter rules by governments.

Therefore there is a requirement for newer and effective methods which are reliable and cost-effective. Sol-gel method is a feasible option because it is both efficient and low cost. Compared to other conventional methods of VOCs detecting, electrochemical deposition or sol-gel process has the advantages of low cost operation, minimization of volume of chemicals and its high efficiency.

Gas sensors are used in many applications such as the detection of toxic and combustible gases, the monitoring of emissions from vehicles and other combustion processes, breath analysis for medical diagnosis and quality control in the chemical, food and cosmetics industries.

II. Experimental

a. Chitosan-roselle formation

Chitosan powder synthesized from crab shells was supplied from (Sigma-Aldrich, practical grade) and used as a sensing material. The medium grade chitosan powder 99% purity was dissolved in acetic acid 2% and stirred with distilled water using a magnetic bar for 24 hours at room temperature to prepare the transparent chitosan smart gel. The solution was then filtered through a sintered glass crucible to remove any undissolved matter. Fresh roselle flowers were harvested from

a farm in Perlis, Malaysia and cleaned. Then the unwanted seeds were removed to obtain a fresh roselle flowers. The roselle flowers were washed then dried in oven at 40°C to

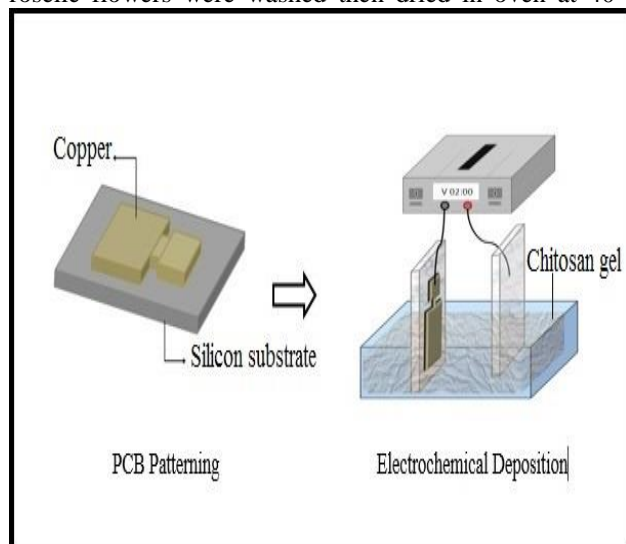


Fig. 1: (a) Fabrication process of chitosan-roselle blend thin Film.

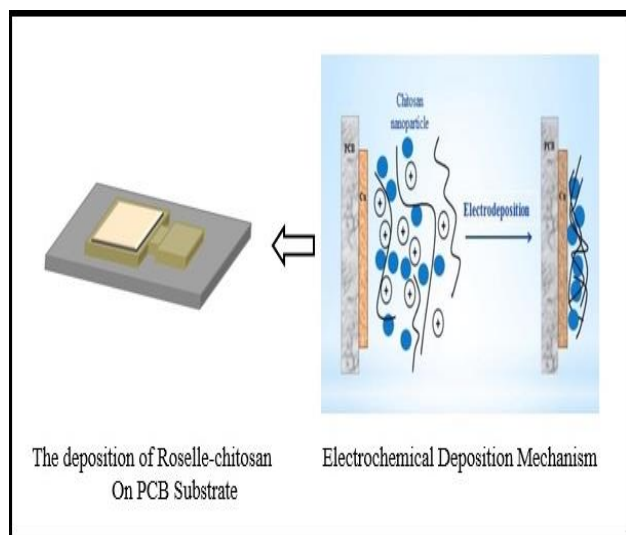


Fig. 1: (b) Fabrication process of chitosan-roselle blend thin Film.

remove water spots then blended after that squeezed and filtered using a cheesecloth bag. To get the extract roselle, a specific amount of methanol was stirred using magnetic stirrer for 3 hours at speed of 400 rpm [4]. Final extracted roselle solution was blended with chitosan gel with a percentage of 5% v/v. The blended chitosan-roselle solution was stirred using magnetic bar for 30 minutes to get homogenous chitosan-roselle blended solution. The electronic identification system was mad by the following process which includes printed circuit board pattern, chitosan-roselle blend deposition finally, testing chamber designing.

b. PCB patterning and electrochemical deposition process

PCB patterning involved several steps. It begun with Cu patterned then PCB substrate cutting with size of 10mm by 20mm, followed by PCB polishing using sand paper to soften the copper surface and remove any particles that may affect

the conductivity and deposition process. After that PCB cleaned using acetone then dried.

The chitosan-roselle blend gel was coated onto the patterned copper surface using an electrochemical deposition technique as it shown on figure 1. The technique was selected because it costs less compared to other techniques. Chitosan-roselle blend deposition onto the electrode is in response to the potential voltage it's a combination of two effects. First chitosan has a positive charge in acidic conditions, which will force it to assemble onto cathode electrode surface [5]. Second it's known that chitosan is insoluble under basic form and water-soluble in acidic form, hydrogen evolution reaction of the cathode surface will increase, if the local pH increases, and as a result of that chitosan will become insoluble then deposited on the surface of the electrode [6].

2.3 Testing chamber designing

I-V testing chamber was designed as it shown in Figure 1, the targeted PCB was equipped with positive and negative contacts and placed in the chamber then connected to voltage resource. The supplied voltage was fixed at 2 volts. The output voltage was displayed as mV at a high resolution voltmeter. Reading was recorded every 30 seconds, for three minutes continuously. Developed exposing technique will be used to expose different VOC gases to roselle-chitosan film in order to determine the sensor performance and its properties such as sensitivity, recovery, repeatability and stability. The electrical testing of the EIS properties is in accordance to the experimental setup diagram as shown in Fig. 2.

III. Results and discussion

In this study, electrochemical deposition was used since it offers a simplified fabrication process. Patterning was determined by the trace created by the copper electrode, using conventional fabrication techniques. The copper electrode was negatively biased to draw the chitosan (with a net positive charge due to the amine groups) out of the gel. The current flowing through the electrolyte raised the pH at the cathode, allowing chitosan particles to be electrodeposited, chitosan is positively charged in acidic conditions, and it will assemble onto the PCB surface, which formed roselle-chitosan film.

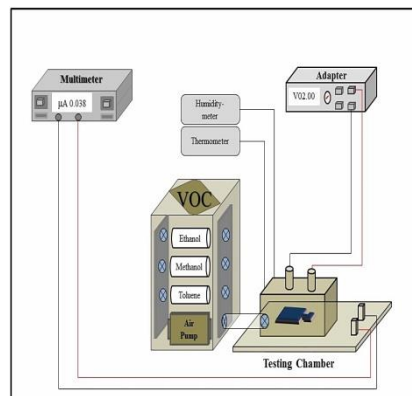


Fig. 2. The electronic identification system (EIS) setup.

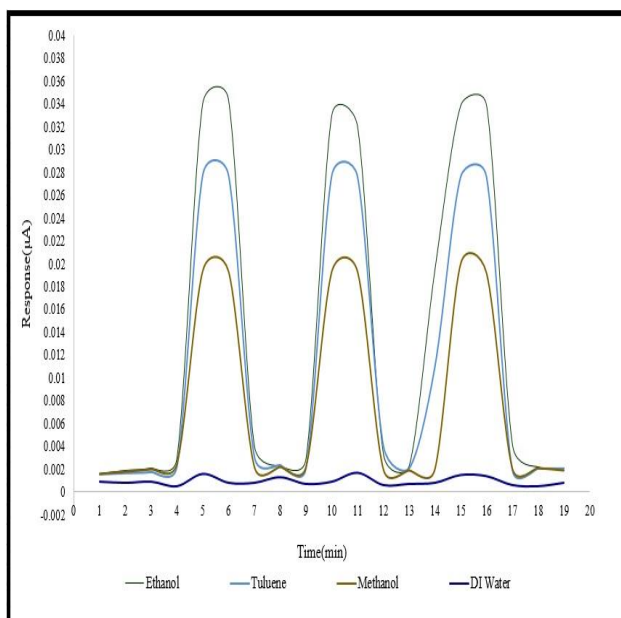


Fig. 3. The response of EIS exposed to normal air and VOC gases.

Fig. 3 shows the response of EIS exposed to normal air and VOC contaminated air. The variations of VOC gases are Ethanol, toluene and methanol. As can be clearly seen EIS exhibited very small response when its surface is exposed to normal air where the average response values for five times measurements are within the range of 0.0014 A to 0.0016A. However, good response is observed when the sensor is exposed to different VOC gases.

When the exposures are removed, the electrical response values for all different exposure conditions decrease to the original value in 4 min, as shown by the drop in the graph. This implies that the roselle-chitosan sensors produced in this work does show a good response, also exhibit a fast recovery. The response time of a roselle-chitosan film sensor defined as the initial time that required by the sensor to sense the presence of the target molecules on its surface, is approximately less than four minutes for each gas.

EIS showed good stability as the measurements were taken. Stability is indicated by the ceaseless increase in response without a significant signal fluctuation in the graph. EIS also exhibited excellent repeatability. Although the measurements were repeated three times uninterruptedly, the roselle-chitosan film sensors showed almost the same maximum response values for each exposure time of 4 min/measurement. Good response, recovery, stability and repeatability. The other important property is selectivity. Fig. 3 shows that the roselle-chitosan film sensor is selective to ethanol gas over toluene and methanol gases.

IV. Conclusion

This study has shown the effectiveness of roselle-chitosan sensor using electronic identification system. The roselle-chitosan film is capable to detect VOC particle and become selective to different types of VOC gases. Roselle-chitosan

film has good response time, excellent recovery and repeatability properties.

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