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Alignment of Reduced Graphene Oxide on Interdigitated Electrode by Dielectrophoresis Method for Hydrogen Gas Sensor

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Abstract— — **Graphene is a popular 2D material that has been explored to improve the performance of many devices due to its unique properties. Nowadays, reduced graphene oxide (rGO) has been used in many application because the surface defect density can be controlled compare to pristine graphene. It also has a band gap which makes it easier to integrate with any technologies. In semiconductor fabrication, a simple process and large scale device fabrication is needed to decrease the complexity of fabrication process. In this work, dielectrophoresis (DEP) technique has been used to deposit the rGO accurately on a substrate. The rGO was dropped on top of the 5 µm gap interdigitated electrodes, where the DEP technique was utilized afterwards for the deposition purposes. The electrical conductivity increases due to the percolation threshold effect. Raman spectroscopy confirmed the presence of rGO in between the channel of electrodes. This is a simple and less complex technique which suitable for large scale device fabrication.**

Keywords— reduced graphene oxide; Interdigitated; dielectrophoresis; electrical property; hydrogen gas sensor

I. INTRODUCTION

Currently, hydrogen gas is widely used in automotive industrials and researches purposes because it exhibits excellent properties such as clean and renewable gas. However, hydrogen gas is highly flammable and easily explosive in air at a concentration of approximately 4%. Therefore, high sensitivity of hydrogen gas detection at low concentration is required.

Over the past decade, graphene is one of the popular 2D materials that has been used for many devices because of its 2D hexagonal honeycomb structure with sp^2-hybridization which give excellent electrical, mechanical, structural and thermal properties [1-3]. However, graphene is a zero bandgap material and it is quite a challenge to open and tune the bandgap of this material to integrate with any technologies.

Reduced graphene oxide (rGO) has been chosen as a sensing material due to its large surface area. Besides that, rGO has a band gap approximately about 1.19 – 1.58 eV which is very suitable for mechanical, electronics and optical devices [4]. In order to get high density of rGO bridging between the electrodes, proper alignments of the rGO is necessary. In this paper, we report the alignment of randomized rGO on interdigitated electrodes (IDEs) by using dielectrophoresis method (DEP).

II. MATERIALS AND METHODS

A. Materials

Reduced graphene oxide with concentration of 0.2 mg/ml.

B. Methodology

The IDEs were fabricated by using a standard photolithography process as shown in Figure 1. First, the substrates were cleaned with acetone, methanol and DI water (5:5:5). The substrates (SiO_2) were spin coated by using spin coater at 3000 rpm for 40 sec with positive photoresist (Futurrex PR1-1000A). It was followed by soft baking process at 120°C for 120 sec, then, the UV lithography was take placed where the IDEs patterns were transferred from a chrome photomask to the samples by exposed to ultraviolet light with an intensity of 2.41 mW/cm2 for 40 sec.

An IDE has been designed with 5 um gap between fingers. For the fabrication, a thin layer of chromium was first deposited as adhesive layer and followed by a platinum layer. This has formed a Cr/Pt layers with thickness of 10 nm and 100 nm respectively. Finally, the samples was annealed at 400℃ for 20 min in N2 ambient after the lift-off process.

Then, a drop of solution (~0.15 µl) containing rGO with the concentration of 0.2 mg/ml was dropped on the IDE. DEP process was continued to position the rGO in between of the IDE finger until it dried. The frequency and peak to peak voltage are set up to 2 MHz and 15 V respectively. The samples were then rinsed with deionized water (DI) for 30 sec and dried it with nitrogen gas. This step is very important to remove any dispersion residual of rGO from the samples which can improve the electrical contact between rGO and electrodes [5]. The experiment is repeated with different frequency and voltage.

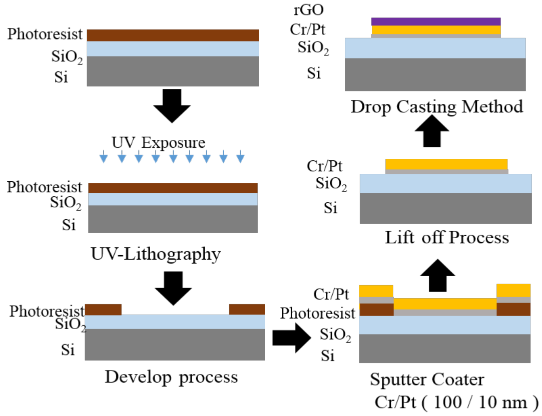

Fig. 1. Fabrication process of Hydrogen Gas Sensor

C. Characterizations

Electrical characterization was carried on to monitor the resistance changes at different number of drops. The current-voltage (I-V) characteristics were measured from -3 to 3 V by using Keithley 2400 source measurement unit. Meanwhile, Raman Spectroscopy with a wavelength of 532 nm had been used to identify the presence of rGO on the samples. SEM images also have been acquired to study the morphology of the rGO.

III. RESULTS AND DISCUSSION

A. Electrical characteristics

I-V characteristics were measured by sweeping the bias voltage from +3 to -3 V. I-V shows current enhancement with applied voltage.

B. Raman Spectroscopy Analysis

Raman Spectroscopy is required to identify the presence of rGO on the samples. Figure 2 shows the Raman spectra of rGO on the IDEs. Two Raman peaks (G and 2D bands) at around 1580 cm-1 and 2670 cm-1 indicate the existence of rGO on top of the IDEs.

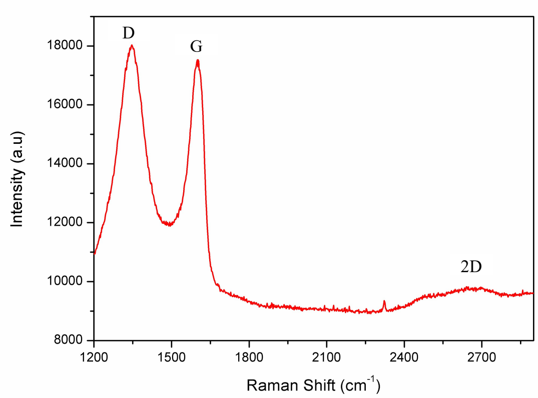

Fig. 2. Raman Spectra of rGO on IDEs

C. Scanning Electron Microscopy Analysis.

Scanning Electron Microscopy (SEM) have been acquired to study the morphology of rGO. Percolation network pathway effect is attributed to the sensitivity enhancement, based on SEM images.

IV. CONCLUSIONS

In conclusion, we have done the I-V characterization of rGO drop-casted on the IDEs pattern. Ohmic contact has been obtained between the rGO and Cr/Pt electrodes. An IDEs with finger gap of 5 µm was designed for the DEP process to enable a high concentrated of electric fields for alignment of rGO to form a percolation network pathway. The DEP method has simplified the alignment process for the fabrication of these sensing devices. Future works can be continued by using different gap size of IDEs for better DEP alignment process

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