STUDY OF HUMIDITY SENSING BEHAVIOR OF AN ORGANIC COMPOSITE VOPCPHO: P3HT PREPARED BY ELECTROSPINNING TECHNIQUE

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Abstract- We report on study of the applications of electrospun organic composite materials for humidity sensing measurements. For the purpose, the humidity sensing properties of VOPcPhO:P3HT electrospun based humidity sensing devices has been investigated. A 5 wt% of the polymer composites undergone electrospinning process that subsequently forming novel structured thin film composite to serve the active sensing layer of the device. The presence of highly porous microbeads and fiborous microstructure has provided an effective base for the entrapment of water molecules amid the high humidity surrounding. By the virtue of this novel structured composite layer, further investigation of these sensor devices would be very interesting, and hopefully to be able to overcome the limitations possessed by the organic polymer based sensing device.

Keywords- Humidity Sensor, Electrospinning, Thin Film, Organic Polymer, Composite, Semiconductor.

I. INTRODUCTION

Presently the struggle has always been about utilizing the right materials which bear excellent properties of higher sensitivity to suit with sensing applications while retaining low production cost, relatively simple processing method, and environmental friendly. Hence, by the virtue of its simple fabricating process, couple with the physical flexibility of the polymer organic based humidity sensors, mass productions for this type of sensing devices seem promising once we manage to overcome their other limitations. On that account, rigorous efforts to optimize these limitations possessed by polymer organic based sensor have lead researchers into introducing several fabrication methods as an alternative in order to further improve the performance of this sensor type. One of the most intriguing is electro spinning deposition method.

The performance of the sensor can be manipulating accordingly simply by adjusting the pores shape, size of the active sensing layer, and in effect prompting a better response behaviour towards relative change in surrounding humidity [1]. Nonetheless, it is noteworthy that an increase in pore size would reduce the sensitivity of the device. However still, this sensitivity issue can simply be resolved by introducing organic multilayer structure [2]. Furthermore, the addition of secondary component of the sensing layer would significantly boost sensing properties of the device. As compared to its separated component, polymer in composite form typically possesses rather good stability, shorter response and recovery time, smaller hysterisis, and higher sensitivity when being put into sensing applications [3-5]. In this study we investigate the potential application of organic composite electrospun structure into the fabrication of humidity sensing device. Due to this application of novel electrospun fibre-structured composite active layer of the device, we expect an improvement of the sensing properties of the composite in term of their sensitivity, stability, hysteresis and response-recovery behaviour.

II. DETAILS EXPERIMENTAL

In order to fabricate the humidity sensor, first, the glass substrate was thoroughly cleaned using sonication bath and later soaked with acetone, ethanol, and distilled water, subsequently. Afterwards the substrates were then allowed to get dried by blowing them with nitrogen gas. Next, the deposition of the aluminium (Al) electrodes was done on the cleaned surfaces of the glass substrate. Then a gap of 40 μm was made across the width of the Al film. Both the VOPcPhO and P3HT were purchased from Sigma Aldrich and used without any further purification. VOPcPhO solution with concentration of 5wt% with solution of 5wt% P3HT were prepared separately in chloroform. Later the prepared solutions were mixed together at volume ratio of (1:1). The composite solution was then deposited by the process of electro spinning in between the gap of the electrodes. During the electro spinning process, the factors such as applied voltage (20 kV), flow rate (2.0 ml/h) and the distance between nose and substrates (15cm) were set constant. The spincoating was done at 2000 rpm. The morphological study of film was performed by Field Emission Scanning Electron Microscopy (FESEM). The measurements setup consisted of the Nitrogen (N₂) gas source, humidity meter, LCR meter, and the humidity chamber containing check valves, exhaust check valve and the sample holder. The influence of humidity on the
capacitance and the resistance of the sensors were recorded using the LCR meter.

III. RESULTS AND DISCUSSION

The figure 1 above shows fesem image from the electrospun structure at of the 5wt% concentration as described. We have reported in [6] how the concentration factors would affect the eventual structure formation of polymer MEH-PPV:PVP composite following the electrospinning process. The same goes with the VOPcPhO:P3HT composite where at the lower concentration of 5wt%, coined like structures were formed instead of fibres. Clearly, the unprecedented application of this coined like structure into sensing measurement is the novelty of this research study. As can be seen in the figure, the presence of multi-sized and various dimensions of the highly porous structures was considered for the applications as we suspect that it would provide an effective base for both absorption and desorption process of water molecules during the measurement. Researchers has suggested how the presence of cross linked multi dimension porous structures may contribute to a better performing humidity sensing device [7, 8].

In the experiment, the organic composite is used as a dielectric sensing layer, whereby the unique morphological structure produced as in figure 1 above functioned by absorbing and releasing water molecules from the relative environmental humidity, and in turn changes the capacitance value of the device. At high humidity level, the sensor is exposed to the heavy presence of water vapour, consequently causing the clumps of water molecules to settle down in between the multi-dimension highly porous structures and changing both capacitive and resistive output the device as depicted in figure 2 and figure 3. Later, during the desorption process, water contents in the active layer get evaporated away by the blowing of nitrogen gas (N$_2$) thereby decreasing the net dielectric constant, while simultaneously increasing the resistance of the sensing film. This phenomenon forms the basis of the sensing mechanism of the humidity sensor.

As shown in figure 2, the correlation of the device sensitivity at different applied frequency of 10 kHz, and 100 kHz measure at relative humidity range at (10-95) %RH. As depicted in the figure above, the device sensitivity is inversely proportional to the increasing value of the applied frequency. The sensitivity values are as followed; 0.072 pF/RH% at 100 kHz, and 0.701 pF/RH% at 10 kHz. It has been known how the capacitive type humidity sensors would normally show a nonlinear response to the applied relative humidity [1, 9]. This capacitive type humidity sensor which pervading 75% of the total commercial market for humidity sensing device [10] posses several advantages including low power consumption and large output signals [11]. As in our case, the capacitance output of the sensor has yielded a capacitive output change even at low relative humidity value (%RH) with increasing sensitivity at lower applied frequency, even though a more linearly stable reading was obtained at higher frequency of 100 kHz.

In comparison, figure 3 below represents the relationship of the device resistance with the applied relative humidity (%RH). The resistive value of the material composite which act as an active layer were measured at applied frequency of 100 kHz in response to the increasing value of the %RH. Notice that the sensitivity of the device capacitive change is only apparent at higher humidity level of 30 up to 95 %RH, where the impedance values exponentially reduced once measured at the higher range of RH% values.
Despite of the sensitivity enhancement of the device which measured at roughly about 0.139 kΩ/RH%, this resistive type sensor has restricted %RH sensing range at particularly low humid environment. This could be due to the fact that the water polarization process that was not match with the rate and direction of electric field at high frequency, thus preventing the polarization at that present condition [12, 13].

A hysteresis effect can be observed when the device is exposed at an increasing and decreasing of humidity level accordingly. This hysteresis measurement can be associated with the structure and dimensions of the pores permeating the active sensing layer. It also indicates how effective the process of adsorption and desorption of water molecules which take place in between the voids of the film. Ideal hysteresis value for the humidity sensor should be approximately be lower than 3% [14], whereby organic polymer based humidity sensor would typically posses hysteresis value ranging up to 13% [15-17]. The humidity hysteresis property of the device from the composite is given in figure 4 above. It was found that the average hysteresis value was at 2.3%. This lower value for this type of sensing device indicates the effectiveness of water molecules entrapment by the novel structured composite sensing layer.

**CONCLUSIONS**

The innovation of this study is mainly contributed from the unprecedented application of the novel electrospun structure for humidity sensor device. The obtained highly porous multi dimensions coined structures from the organic semiconducting composite with high surface area and good electrical properties have enhanced the performance of the device in term of their hysteresis value, faster and repeatable response and recovery behaviour, with good sensitivity for over a very wide range of humidity level.

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REFERENCES


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