Electrical Properties of Nanostructured ZnO Thin Film Prepared by Sol-Gel Method for Humidity Sensor Applications

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Abstract – **the humidity sensor is produce by zinc oxide thin film by using sol-gel. These projects focus on the effect electrical properties of ZnO thin film for Humidity sensor. The effect of zinc oxide concentration to the electrical properties is measure by I-V measurement. The sol-gel method is use to produce the zinc oxide nanostructured that have the single nanorods particles mixed with some cluster of rods. The I-V measurement studies that the 0.05M of concentration having higher sensitivity Humidity sensor than 0.025M and 0.01M of concentration.**

Keywords: Nanostructured ZnO; Sol-gel Method; Electrical Properties; Humidity Sensor.

I. INTRODUCTION

Humidity is the amount of water vapor in the air. There are several types of humidity. The types of humidity are absolute humidity, mixing ratio, relative humidity, humidity during rain, specific humidity, and dew point and frost point. Sensing of relative humidity plays important role in various fields especially for human life. Therefore, humidity sensors had been studied and used intensively. For example, a humidity sensor was fabricated to equip a multi-sensor Microsystems for pulmonary functions diagnosis and in food industry, the humidity sensors had been used to control and monitor the process environment [1]. Other applications of humidity sensors including the meteorological services, chemical and food industry, civil engineering, air conditioning, agriculture and electronic processing. Humidity sensors are having increased the interest in electronic control systems [2].

Humidity sensor is a device consisting of a special material whose electrical characteristics change according to the amount of humidity in the air. There are three main operating principles of humidity sensors that are capacitive, resistive and thermal conductive. There are having been rapid developments of new materials for usage in humidity sensor. Porous ceramics, polymers, and electrolytes are the most commonly used hygroscopic sensing elements in modern devices. Porous ceramics of $Al2O3$, $TiO2$, and $MgCr2O4$ are examples that have been used in humidity sensors. The electrolyte such as polyvinyl acetate/LiCl has also been utilized. However, all the available materials that use show some limitations. For example, polymer films cannot operate at high temperatures or high humidity, and they show hysteresis and slow response time. Ceramics have shown advantages in terms of the mechanical strength, the resistance to chemical attack and the thermal and physical stability but still do not have high sensitivity for humidity [1, 3].

From the literature review, as the size became smaller the sensitivity is increase. So, that the sensor have greatly improve in the nanoscale size. Recently, a higher sensitivity of humidity sensor has been obtained from feather-like Zinc Oxide (ZnO) nanostructures. The response time and recovery time are 40–70 and 80–150 s, respectively with the change of RH from 5% up to 95%. While, humidity sensitive characteristic of a sensor fabricated from flower-like ZnO nanorods with surface modified by a protective layer of OH rich ethyl cellulose show higher humidity sensitivity that the impedance of the sensor decreases by about five orders of magnitude with increasing relative humidity (RH) from 11 to 95%. The response and recovery time of the sensor is about 5 and 10 s, respectively. From the overview of recent humidity sensitivity investigations, we have found that humidity sensors with high sensitivity are made from a simple oxide of ZnO [4].

The Zinc Oxide is a chemical compound that is nearly insoluble in water but soluble in acid and alkalis. It occurs in nature as the mineral zincates. The ZnO has direct band gap around 3.4eV and large energy of about 60meV [5]. ZnO also is a high means bright light emission characteristic for ultraviolet (UV) light emitters, gas sensors, transparent electronics and surface acoustic wave devices applications [6, 7]. This shows that ZnO is a semiconductor with numerous applications ranging from optoelectronics to chemical sensors [1, 5]. In recent years, one dimensional (1D) ZnO nanostructures such as nanowires, nanorods, nanobelts and nanotetrapod have attracted much attention since the dimension or the surface to volume has great influence to the material performance [1]. Nanostructured ZnO is believe to be a good sensor material due to the high specific area that facilities the absorption of water vapor [1, 7].

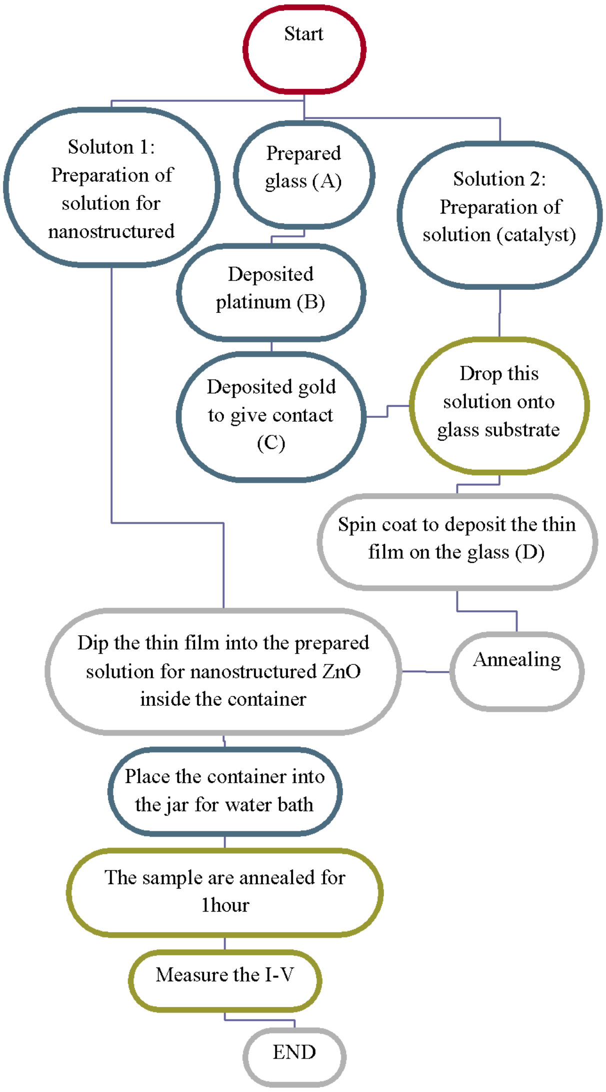
ZnO can be prepared with many techniques, such as reactive evaporations, sputtering, thermal oxidation, chemical vapor deposition and sol gel method [7, 8]. The sol gel method has many advantages over the other technique due to excellent compositional control, homogeneity on the molecular level due to the mixing of the liquid precursors, lower crystallization temperature , simple and cheap[7,9]. Besides that, the micro structural properties such as the pore size pore volume and surface area of the film can be tailored by the control of sol gel variables [7]. Due to the advantages of the nanostructured ZnO for humidity sensor and sol gel method discuss above, the electrical properties of this material should be investigate. This investigation is very important to fulfill the fabrication of the humidity sensor device and the application in the future.

II. METHODOLOGY

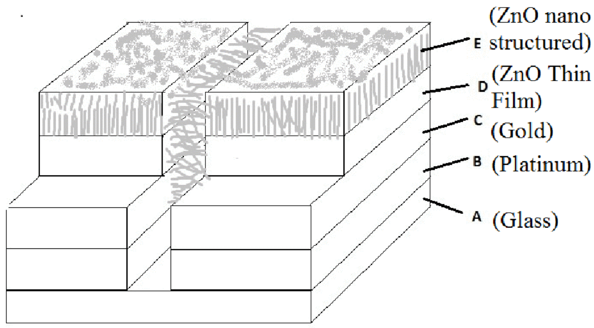
This experiment involved eleven steps which is likes as figure 1.

The glass (A) is use as substrate in this experiment. The glass is cleans with acetone methanol and deionized water in the ultrasonic device for five minutes and dry it with nitrogen gas, nitrogen is for dry a glass. The alcohol and ultrasonic is use to clean all the stain, oily and other that attach to the glass. Then, the glasses will deposit with platinum (B) and follow by gold (C). The platinum is use to stick the glass with the gold contact and for the gold is for electrode to make contact so it easily to measure the I-V.

These project use 2 solutions need to use, one is for the growth of ZnO nanostructures and the second solutions used for this project are for the thin film. The ZnO nanostructures were grown from aqueous solutions prepared using zinc nitrate hexahydrate as the starting material, deionized water as the solvent, and HMT (Hexamethylenetetramine) as stabilizer. Each concentration was mixed thoroughly with a hotplate magnetic stirrer for 2 hours in 60°C and then the solutions are further stirred for another 24 hours in the room temperature. For the second solutions, Zinc acetate-dhydrate was mixed with the MEA that is Ethanolamine and dissolved in Methoxyethanol as the solvent in the room temperature. This solution was stirred by using hotplate magnetic stirrer at 60°C for 2 hours and then stirred again for another 24 hours aging period in room temperature.This solution (2) will be the catalyst for the ZnO growth. The solution for thin film (D) was dropped onto the surface of glass substrate and the thin film was deposited by using the spin coating technique with 3000rpm for 3 minutes. This thin film (D) then was annealed for 1 hour with 550°C in the electric furnace. ZnO nanostructures (E) were grown on the thin film by immerse process.



(a)



(b)

Figure 1: (a) Flow chart of the experimental procedure for the project. (b) Layer diagram of the sample.

thin film into the container that was filled with the ZnO solution that has been prepared earlier. Then this container was dipped into the water bath jar with 95°C for 24 hours. Then the glass was annealed again for 1 hour each with several temperatures.

The electrical properties were measured by using current-voltage (I-V) measurement. The surface morphologies and electrical measurement were carried out for the structures prepared at different Zinc oxide concentration. The I-V measurement are taken while the samples was supplied by the water vapor to studies the effect of humidity for the nanostructured ZnO. The water vapor is supplier by a moisturizer inside the transparent box and the relative humidity is measure using the sensor that was place near to the sample.

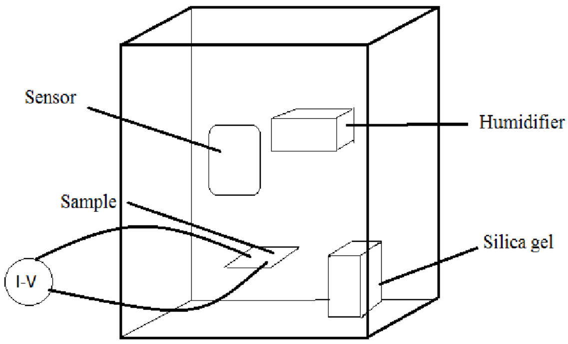


Figure 3: Box for measure the humidity

III. RESULTS AND DISCUSSION

Comparison

Figure 4 show the picture of sample for each concentration. The 0.05M concentration have thick layer for zinc oxide nanostructured compare 0.025M and 0.01M. This is because the higher concentration, the zinc oxide nanorods will growth more and it easily to combine others ZnO.

(a)

(b)

(c)

Figure 4: sample for concentration a) 0.01M, b) 0.025M, c) 0.05M

I-V Measurement

The I-V measurement is to check the I-V characteristic at a certain relative humidity. The relative humidity, RH% is ratio of the partial pressure of water vapor in the mixture to the saturated vapor pressure of water at a prescribed temperature. The current value was increase proportionally with humidity. This is because of changing in resistance. Form the I-V, the resistance and conductance can be determined. By using the formula:

$$G = \frac{I}{V} = \frac{1}{R}$$

$$R = \frac{V}{I} = \frac{1}{G}$$

Figure 5, 6 and 7 show the graph current vs. voltage for 0.01M, 0.025M and 0.05M concentration. As the percentage of relative humidity is increase, the current also increase. At the 85%Rh the value for current is greater than other percentage of relative humidity. The higher percentage of relative humidity so, the current value also increase.

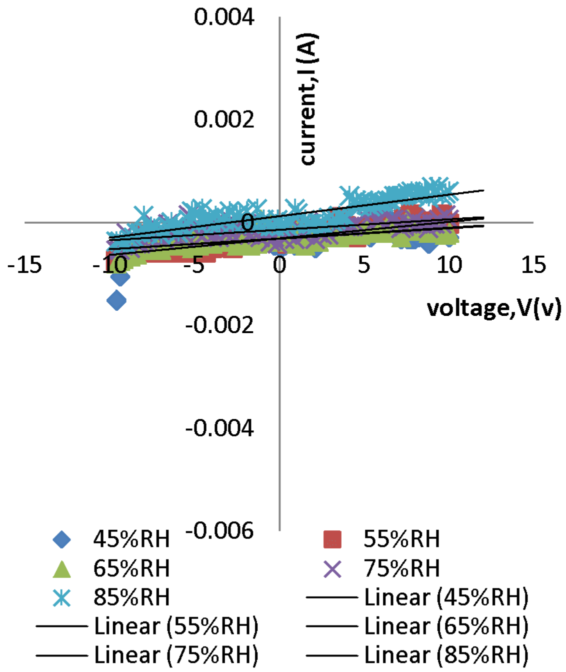


Figure 5: Current vs. voltage Graph for 0.01M of concentration and comparison between different relative humidity.

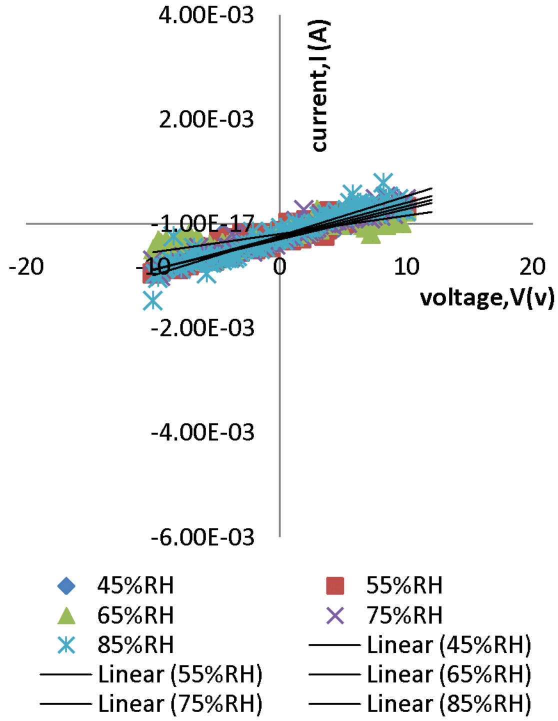


Figure 6: Current vs. voltage Graph for 0.025M of concentration and comparison between different relative humidity.

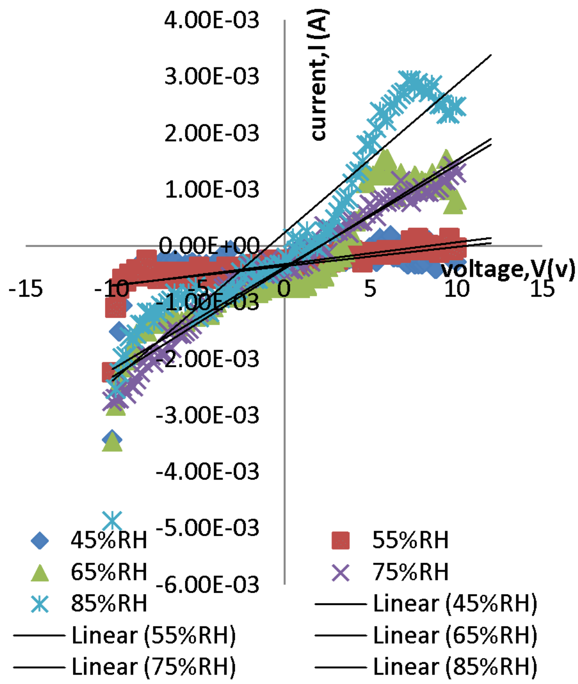


Figure 7: Current vs. voltage Graph for 0.05M of concentration and comparison between different relative humidity.

Figure 8 show the graph current vs relative humidity for different concentration of zinc oxide. The difference of zinc oxide has much effected on the current follow. The graph is like straight line graph. The concentration, the less concentration has lower current follow. The high concentration make the zinc oxide is grow more in one places and the growth of zinc oxide is constantly. When the concentration is higher, the layer of zinc oxide nanostructured is thicker. When the ZnO is thicker, the sensor can capture more water vapor, so it make the resistance become less and current flow is increase.

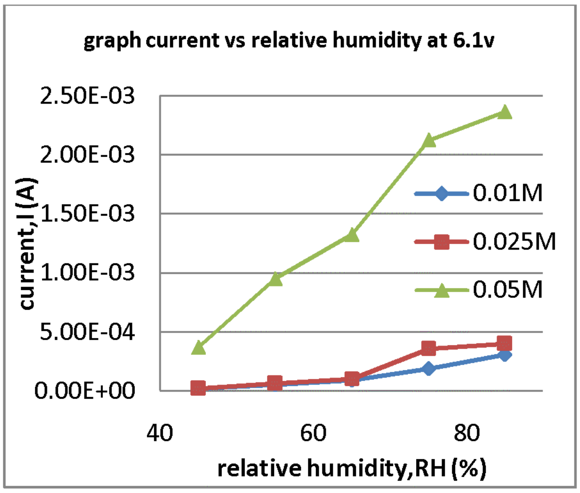


Figure 8: Current vs. relative humidity at different concentration

Figure 9 show graph for sensitivity at certain concentration. The graph is in straight line. This is show, when the concentration is increase, the sensitivity also increase. This is because when the concentration is high, the zinc oxide nanorod that growth are more, so this make more water vapor are easily to capture into it. Therefore, it makes the resistance is become decrease.

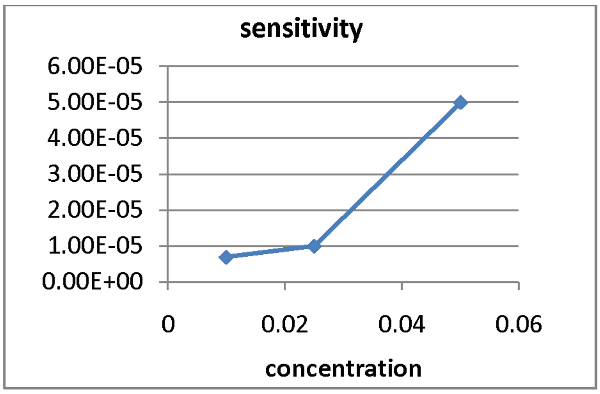


Figure 9: show the sensitivity for at certain concentration.

IV. CONCLUSION

The nanostructured are successful growth by using the sol-gel method with difference concentration. The electrical property is investigated by using the I-V measurement. From the I-V measurement shows that the sensitivity is high when the concentration at 0.05M than 0.025M and 0.01M. The high concentration give the zinc oxide nanorod to growth more, so it makes the sensor is more sensitive. The concentration 0.05M is suggested of use in the applications as a sensor compare to 0.01M and 0.025M.

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