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Humidity detection using chitosan film based sensor

T I Nasution[1,3,4*], I Nainggolan[1,3], D Dalimunthe[2], M Balyan[1,4], R Cuana[2], S Khanifah[2]

[1]Centre of Excellence for Sensor Systems and Technology, Universitas Sumatera Utara, Medan 20155, Sumatera Utara, Indonesia
[2]Physics Department, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan 2055, Sumatera Utara, Indonesia
[3]Chemistry Department, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan 2055, Sumatera Utara, Indonesia
[4]Integrated Laboratory, Universitas Sumatera Utara, Medan 20155, Sumatera Utara, Indonesia

*E-mail: ikhsan_05@yahoo.com

Abstract. A humidity sensor made of the natural polymer chitosan has been successfully fabricated in the film form by a solution casting method. Humidity testing was performed by placing a chitosan film sensor in a cooling machine room, model KT-2000 Ahu. The testing results showed that the output voltage values of chitosan film sensor increased with the increase in humidity percentage. For the increase in humidity percentage from 30 to 90% showed that the output voltage of chitosan film sensor increased from 32.19 to 138.75 mV. It was also found that the sensor evidenced good repeatability and stability during the testing. Therefore, chitosan has a great potential to be used as new sensing material for the humidity detection of which was cheaper and environmentally friendly.

1. Introduction

The humidity sensor has a very important role in many aspects in our daily life such as meteorology, agriculture, medicine, biology, and others. Because of the various characteristics of humidity, humidity sensors are usually applied in industrial processes, environment monitoring, and equipment maintenance, all of which require accurate humidity control. Due to many fields involve humidity sensors, so it is necessary to make continuous improvements to the sensor performance, especially on the selection of sensor-making materials [1,2]. MOFs are rarely applied as a material for humidity sensor fabrication because MOFs framework structure can collapse in high humidity. Even if some MOFs are used, it still produces a low sensitivity because its limited specific surface [5,6]. In this study, humidity sensor is based on chitosan. When compared to MOFs then chitosan has several advantages as a sensor material. Chitosan is one of the natural biopolymers derived from chitin, as well as an abundant natural polymer on earth after cellulose [7]. Chitosan is also non-toxic, renewable, environmentally friendly, and doesn't have a bad effect on humans and the environment [8,9]. Chitosan has very high sensitivity to humidity because it has hydrogen bonds that is formed when the process of absorption of

water molecules and hydrophilic groups in chitosan [10]. The hydrogen bond serves as the transport of protons in chitosan [11], thus making chitosan become a good conductor [12]. Chitosan which is a natural polymer material has amino groups acting as active sites that can interact with water vapor [13]. Besides that, chitosan has unique characteristics that can be formed into a film [14]. Therefore, these characteristics makes chitosan can be used as a humidity sensor designed to work with some advantages such as cheaper, accurate and practice.

2. Methodology

Chitosan powder with medium molecular weight (85% distillation rate) was purchased from Sigma-Aldrich Chemical. Chitosan powder was dissolved using a magnetic stirrer with the rotation speed of 300 rpm for 6 hours at 30oC. The chitosan solution was then tested first using a particle size analyzer (PSA) to determine its particle size and homogeneity. In this work, the chitosan film was formed by a solution casting method in which the chitosan solution was put in a glass petri dish and followed by drying it at 65oC. Furthermore, the film was characterized by using scanning electron microscopy (SEM) to observe its surface morphology and chemical cluster analysis of chitosan film using FTIR. To test the electrical properties of chitosan film as humidity sensor, the film was placed in a cooling machine room model KT-2000Ahu equipped with two electrodes (positive and negative). The humidity level in the room was set from 30 to 90%. Both electrodes function to connect chitosan film sensor to an Arduino-based electronic readout system that was interfaced to the computer via USB TTL and PLX-DAQ software.

3. Results and Discussion

Figure 1 shows that the chitosan particles are evenly distributed. This is indicated by the same diameter value of 562.49 nm. This value also indicates good homogeneity of chitosan solution. In addition, the particle size obtained at 562.49 nm is a fairly small particle size in which a small particle size determines the stability of the chitosan solution and the smoothness of the chitosan film surface produced from the drying process.

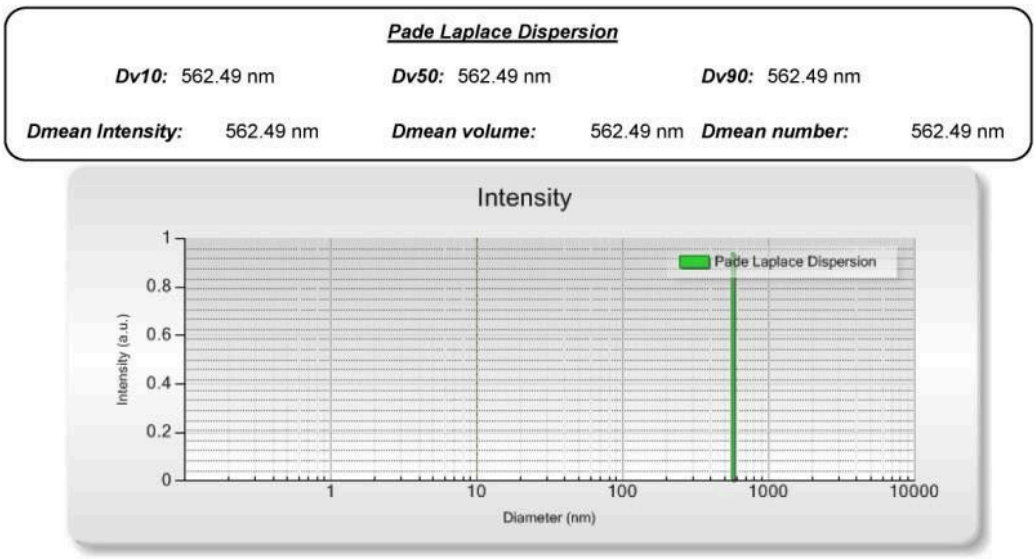

Figure 1. Particle size distribution of chitosan solution.

The surface morphology of the chitosan film was tested using a Scanning Electron Microscopy (SEM). Figure 2 shows the surface morphology of the chitosan film. The smooth surface morphology

of the chitosan film shows the distance between the chitosan particles are tightly. The smooth surface of the chitosan film allows the chitosan film to be strongly bonded to the electrode surface during the humidity detection process. This strong bond between the layers of chitosan and the electrode is important to avoid the swelling of the chitosan film layer due to the absorption of water molecules after exposure to humidity.

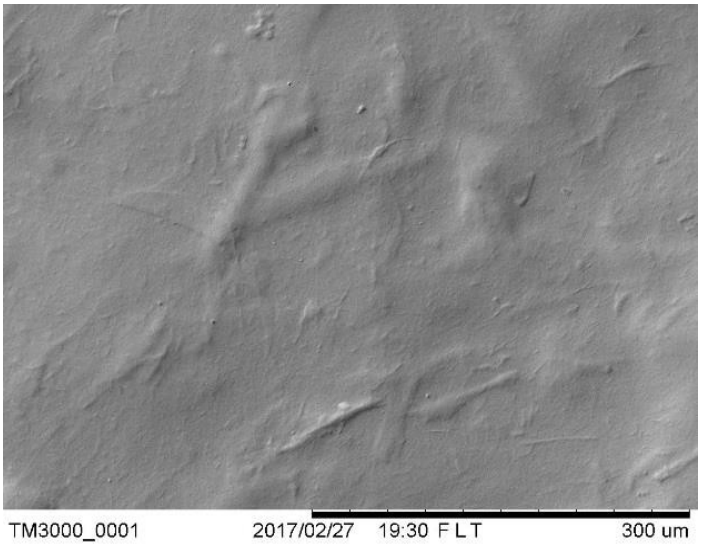

Figure 2. Analysis of chitosan film surface using Scanning electron microscope

The FT-IR spectrum (Figure 3) shows the OH groups at absorption band of 3614 cm^{-1} and NH_2 groups at the absorption band of 3001 cm^{-1}. The absorption peak at 1681 cm^{-1} indicates conjugated ketone C=O. Meanwhile, the peaks at 1593 cm^{-1} and 1438 cm^{-1} show the existence of N-H and –OH. This indicates both peaks are functional groups of chitosan which is having an important role as active sites to react with water vapor to generate electrical energy. It is also found that the C-N, C-O-C and C-O absorption groups appear at peaks of 1172, 1126 and 1045 cm^{-1}, respectively.

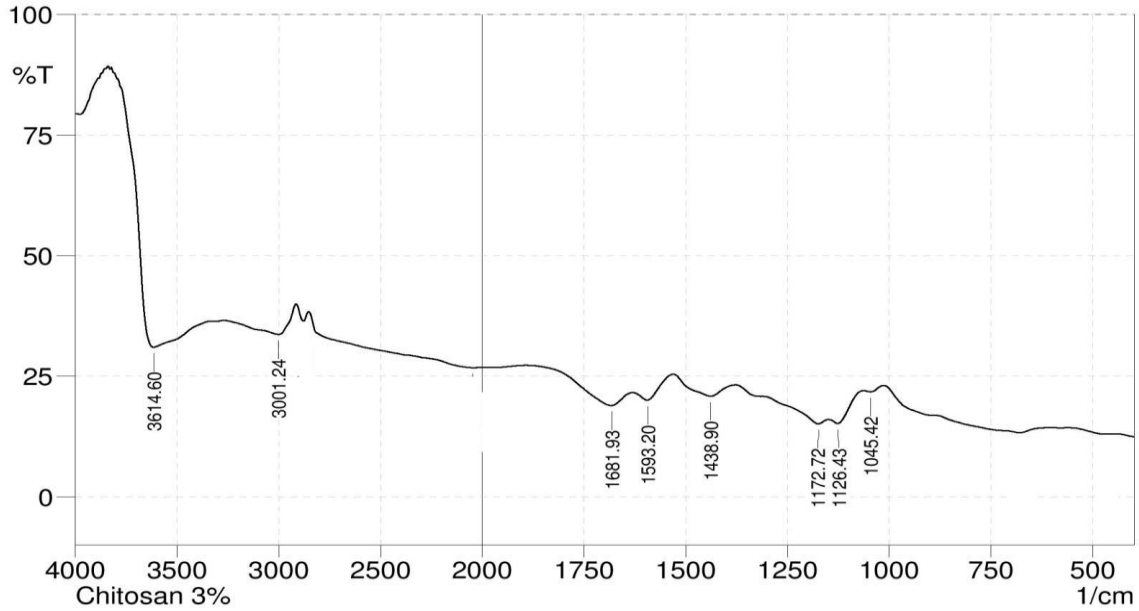

Figure 3. Chemical cluster analysis of chitosan film using FT-I

The ability of chitosan film sensors to detect humidity is shown in Fig. 3. It is obtained that there is an increase in the output voltage of chitosan film along with the increase of humidity in the cooling machine. This linear value can be explained because there is an interaction between the chitosan film sensor with water vapor that results in the output voltage of chitosan film.

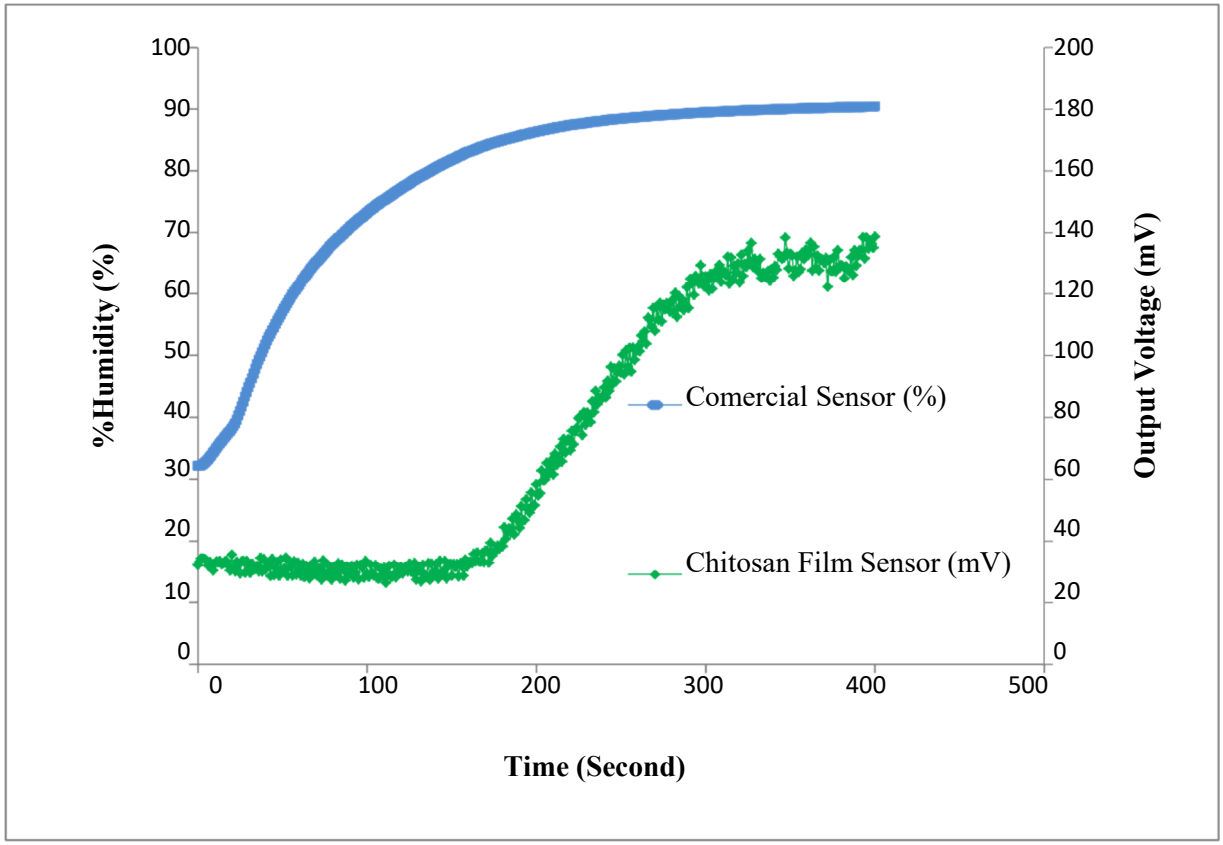

Figure 4. Comparation graph of output voltage from chitosan film and output value of commercial sensor

According to Ikhsan et al., chitosan film in the open air will absorb oxygen (O2). The absorbed oxygen trap electrons contained in chitosan and then form O- and O2- oxygen species as shown in the following reaction:

O_2 (gas) ↔ O_2 (absorbed) (1)

O_2 (absorbed) + e- ↔ O_2^- (2)

O_2 + e- ↔ $2O^-$ (3)

And when water molecules (H2O) stick on the surface chitosan film, the water molecules react with O- and produce O2 gases. This causes the release of electrons as described by the equation:

Chit-NH_2 + H_2O ↔ $2O^-$ + Chit-NH_2 + O_2+ H_2O + $2e^-$ (4)

This reaction raises the surface tension of chitosan film that helps the movement of electrons to escape the trap of oxygen species. The free electrons move randomly in the conduction band and increase the electrical conductivity of the chitosan film [14].

The graphs in Fig. 3 describe that the chitosan film sensor has good capability to detect different humidity level in the cooling machine. Besides that, it is also evidenced that sensors have as good characteristics which include short response time and good sensitivity. Even in terms of the range output voltage values, chitosan film sensor has a wide range of reading resolution, so the chitosan film sensor is excellent in terms of reading resolution. With a wide range of reading resolution, then the accuracy of reading humidity using chitosan film sensor is better than commercial sensor.

4. Conclusion

The chitosan film sensor shows the ability to detect air humidity. Humidity detection with chitosan film using this method has balanced the ability of general commercial sensor which has an expensive price. Then, the chitosan film sensor has potentially capability to detect humidity due to it is more accurate, cheaper, more durable and friendly environment.

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