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Effect of TiO_2 Addition on The Electrical Conductivity of Nylon-TiO_2 Hybrid Membrane

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Abstract. Current membrane technology has developed rapidly in industrial commercial interests. This has led to various studies, especially on membrane raw material innovation. Research on the measurement of electrical conductivity on nylon-TiO_2 hybrid membranes has been carried out. This study aims to determine the addition of the right TiO_2 mass fraction based on the electrical conductivity value. The variations in the concentration of TiO_2 used were 0.5%, 1%, 3%, 5%, and 7% (w/v). The nylon-TiO_2 hybrid membrane was prepared using the phase inversion method. The measurement of the electrical conductivity of the hybrid membrane was carried out using the parallel plate method. The measurement results of the nylon-TiO_2 hybrid membrane showed that the electrical conductivity of the hybrid membrane increased with the addition of the mass fraction of TiO2, from $(0.66 \pm 0.04) \times 10^{-9}$ S / cm for nylon membrane to $(9.15 \pm 5.71) \times 10^{-9}$ S / cm for additionalmass fraction of TiO_2 5% (w/v). Meanwhile, onadditionThe mass fraction of TiO2 7% (w/v) causes the electrical conductivity of the hybrid membrane to decrease, by obtaining an electrical conductivity value of$(2.31 \pm 0.45) \times 10^{-9}$ S / cm

Keywords: Hybrid Membrane, Nylon, TiO_2, Electrical Conductivity

Introduction

In recent years membrane technology has developed rapidly, both on a laboratory scale and on a commercial scale. The synthesis and characterization of membranes continues to progress, especially in terms of making synthetic membranes which are expected to replace the function of natural membranes.

Synthetic membranes can be made from ceramic or polymer materials. Ceramic membranes generally have chemical, physical, and thermal properties that are superior to polymer membranes. However, ceramic membranes are relatively expensive, brittle, and difficult to manufacture. Meanwhile, polymer membranes are cheaper, flexible, easy to form, and are widely used in industry [1].

Nylon is a polyamide compound, which is a type of polymer compound that has an amide group in each repeating unit [2]. In addition, nylon is a thermoplastic polymer that has flexible properties and can be recycled (recycling) so it is widely used in various applications. Nylon is widely chosen as a polymer matrix and can be used as a membrane because it is cheap, has good mechanical and physical properties, which is stretchable up to 8%, is resistant to extreme pH, is resistant to high temperatures, is resistant to corrosion, and forms a homogeneous mixture when combined with suitable solvent [3-4].

One way to improve the performance of polymer membranes is to add inorganic materials to the membrane, which is commonly known as a mixed matrix membrane (MMM). Hybrid membrane is a membrane made from a mixture of polymer and inorganic materials which aims to

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overcome the weaknesses of each raw material [5]. TiO_2 is an inorganic material that can be mixed into polymer membranes.

TiO_2 is widely used as a photo catalytic material because it is very stable, resistant to corrosion, non-toxic, and high resistance to bacteria, has a high refractive index [6-7]. In addition, TiO_2 has high oxidizing ability and can conduct electricity [8].

One of the characteristics of the membrane can be determined physically by measuring its electrical properties. Measurement of the electrical properties of the membrane to observe the ion transport mechanism and as a fuel cell material has been widely used. Research on the electrical properties of hybrid membranes using TiO_2 has been carried out. reported that the TiO_2 material added to the polysulfan polymer membrane caused the conductance and capacitance values conductance to increase, but the loss coefficient decreased [9]. Research [10], also states that the cellulose acetate membrane with TiO_2 added causes the conductance to increase. The best electrical properties resulted from the addition of 5 wt% TiO_2 concentration. Juliandri has successfully synthesized a fuel cell membrane from PVDF doped with TiO_2 [11]. The highest electrical conductivity was obtained at the addition of 3 wt% TiO_2 concentration. Based on these studies, measurements of the electrical properties of several TiO_2-polymer hybrid membranes have been carried out before. However, there is still little information regarding the electrical properties of the nylon-type polymer added with TiO_2.
This study is expected to provide information related to the addition of the right TiO_2 mass fraction to the nylon-TiO_2 hybrid membrane to obtain the best membrane results measured from its electrical properties.

Theoretical Background

The membrane is a thin layer that can act as a filter or barrier (barrier) that limits the two phases [12]. The first phase is known as the feed or feed solution, which is the component that is separated and the second phase is the permeate, which is the component of the separation. The ability of a membrane to pass a component or molecule is influenced by differences in physical and chemical properties between the membrane and the components [13].

One of the properties possessed by the membrane is electrical conductivity. Conductivity arises due to the interaction between the ion and the membrane. Electrical conductivity is a measure of a material's ability to conduct electric current. If there is an electric potential difference at the ends of the conductor, the charges will move to produce an electric current. The electrolyte membrane is influenced by two things, namely the concentration of ions as charge carriers and the mobility of these ions [14].

The conductivity (σ) is inversely proportional to the resistivity value (ρ). The conductivity value of a material depends on the properties of the material. The equation for calculating electrical conductivity is:

$$\sigma \frac{1}{\rho} = \frac{L}{AR} \quad (1)$$

Where σ is electrical conductivity (S/cm), ρ is electrical resistivity (Ohm.cm), R is polymer membrane resistance (Ohm), L is membrane thickness (cm), A is the cross-sectional area of the

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electrode (cm^2) [14]. Electrical conductivity arises due to the interaction between ions and the membrane [15].

Materials and Methods

a.) Membrane Synthesis
The nylon-TiO_2 hybrid membrane was prepared using the phase-to-solid phase inversion method. The membrane in this study used a nylon mass of 6 grams. The mass variation of TiO_2 which was mixed was respectively 0.030 gram (0.5 wt%); 0.061 gram (1 wt%); 0.186 gram (3 wt%); 0.316 gram (5 wt%); and 0.450 grams (7 wt%).

The membrane was made by mixing nylon thread and TiO_2 into 20 ml of 25% HCl and 2 ml of acetone. Then stirred using a magnetic stirrer for ± 1 hour until the solution is homogeneous. The membrane was then printed on a glass plate and immersed for 10 minutes in distilled water to facilitate the removal of the membrane from the glass plate. The formed membrane was dried for ± 12 hours.

b.) Electrical conductivity test
The electrical conductivity test was carried out at room temperature using a Lutron 9183 LCR meter. Measurements using a two-plate parallel system method. The chip plate parallel to the capacitor is made of PCB plates measuring 2.5 2.5 cm. Then the membrane that has been cut is adjusted and placed between the PCB plates. The plate is then connected to the LCR Meter tool to measure its resistance value. The electrical conductivity measurement scheme is shown in Figure 2. For each variation, 3 test samples were taken as repetition. ×

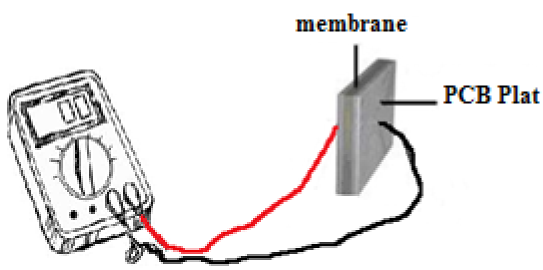

Figure 1. Electrical conductivity measurement scheme

Results and Discussion

The nylon-TiO_2 hybrid membrane is a membrane made of nylon polymer material added with the inorganic TiO_2 material. In this study, the addition of TiO_2 mass fraction into nylon polymer to obtain the best nylon-TiO_2 hybrid membrane based on electrical measurements. Membrane manufacturing in this study uses the phase inversion method. Phase inversion is a method of making a membrane from a polymer in the form of a solution to a solid [5]. The process of mixing nylon solution with variations in the addition of TiO_2 mass fraction in this study resulted in 6 membrane samples.

Electrical conductivity is a measure of the ability of a material to conduct electric current [14]. The electric current in the material is carried by the ions contained in the material. Electrical

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conductivity measurements were carried out directly using the parallel plate method, from copper PCB plates carried out at room temperature. This test aims to determine the best nylon-TiO_2 mass fraction based on the measured electrical conductivity of the membrane. The measured electrical conductivities for the membrane are shown in Table 1.

Table 1. The value of the electrical conductivity of the nylon-TiO_2 hybrid membrane

TiO_2 concentration (wt%)	**Electrical Conductivity $\bar{\sigma} \pm \Delta\sigma$ (S / cm)**
0	$(0.66 \pm 0.04) \times 10^{-9}$
0.5	$(1.21 \pm 0.02) \times 10^{-9}$
1	$(2.79 \pm 0.38) \times 10^{-9}$
3	$(4.23 \pm 0.39) \times 10^{-9}$
5	$(9.15 \pm 5.71) \times 10^{-9}$
7	$(2.31 \pm 0.45) \times 10^{-9}$

The measurement results show that the addition of TiO_2 mass fraction increases the electrical conductivity of the membrane. The electrical conductivity of the nylon-TiO_2 membrane obtained in this study was around 0.66×10^{-9} S/cm to 9.15×10^{-9} S/cm. The greater the electrical conductivity indicates that the material is better at conducting electricity [14]. Based on Table 4.2, it can be seen that the lowest electrical conductivity value is obtained in the membrane sample A which is a nylon membrane without the addition of TiO_2, which is equal to $(0.66 \pm 0.04) \times 10^{-9}$ S/cm. According to pure nylon-6 has an electrical conductivity value of 10^{-14} S/cm [16]. Meanwhile, the electrical conductivity value of a pure nylon-6 membrane using the electrospinning method was 2.7×10^{-9} S/cm [17]. The different results from the electrical conductivity obtained may be due to the use of nylon raw material and the membrane fabrication method used. However, the results obtained from the measurement of the electrical conductivity of the nylon membrane were not much different.

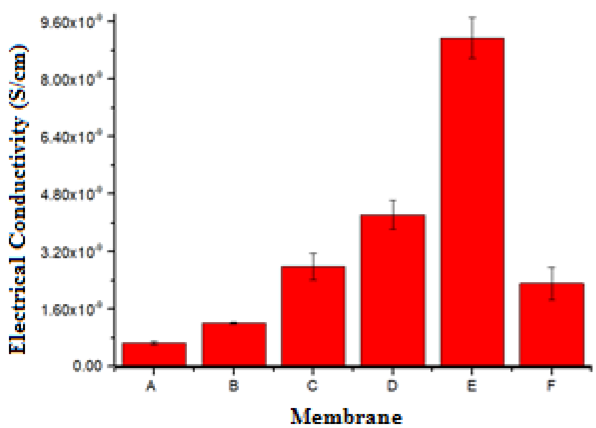

Figure 3. Graph of the electrical conductivity of the nylon-TiO_2 hybrid membrane by measuring the parallel plate method

The value of the electrical conductivity increases due to the increasing density and mobility of the charge carriers along with the addition of the mass fraction of TiO_2 into the nylon-TiO_2 hybrid

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membrane [18]. In this study, the electrical conductivity value increased starting from the addition of TiO_2 mass fraction 0.5% (membrane B), 1% (membrane C), 3% (membrane D), up to 5% (membrane E), respectively. Then the electrical conductivity value decreased when the mass fraction of TiO_2 was 7% (membrane F).The tendency of decreasing electrical conductivity is made possible by the existence of a maximum limit of the ratio between nylon and the addition of the mass fraction of TiO_2 to the membrane.The value of the largest electrical conductivity of the nylon-TiO_2 hybrid membrane was obtained at the addition of the mass fraction of TiO_2 5% (membrane E), which was $(9.15 \pm 5.71)\times10^{-9}$ S/cm. The greater the electrical conductivity of the membrane, the better the characteristics of the membrane in conducting ions. Based on the research results, the best nylon-TiO_2 hybrid membrane was found in the addition of 5% TiO_2 mass fraction (membrane E).

Conclusions

The best membrane is obtained when the electrical conductivity value is greatest. The greater the electrical conductivity value indicates that the ability of the membrane ion transport mechanism is getting better. The greatest electrical conductivity was obtained at the addition of 5 wt% TiO_2 mass fraction.

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