



Functional Groups and Ionic Conductivity of Chitosan/LiOH/ZnO Membranes for Secondary Batteries

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Abstract

The development of solid-state electrolytes with high ionic conductivity and structural stability is crucial for advancing secondary battery technologies. Solid electrolytes play a critical role in facilitating ion transfer between electrodes, directly impacting battery efficiency. Solid electrolyte polymer membranes can be manufactured for use in secondary batteries as electrical energy storage devices. In batteries, solid electrolytes act as a medium for ion transfer. The polymer membrane was modified by incorporating Zinc Oxide (ZnO) into the chitosan/LiOH polymer membrane using the solution casting method. Fourier Transform Infrared (FTIR) and Electrochemical Impedance Spectroscopy (EIS) tests were conducted. The FTIR analysis of the polymer membrane revealed the presence of functional groups such as OH stretching, -NH stretching, -NH bending, -CO stretching, -CH stretching, and -ZnO stretching. The EIS results demonstrated that the ionic conductivity of the 3% chitosan/LiOH/ZnO membrane was higher at 1.4821×10^{-6} S/cm compared to the 2% chitosan/LiOH/ZnO membrane at 3.6893×10^{-7} S/cm. This study suggests that chitosan/LiOH membranes doped with Zinc Oxide (ZnO) are a promising option for solid electrolyte membranes in secondary batteries.

Keywords: Functional Groups, Ionic Conductivity, SPE, Chitosan, LiOH, ZnO.

INTRODUCTION

Globalization has increased societal needs, shifting focus from tertiary to primary needs. The demand for electronic goods is evolving rapidly (Sari et al., 2020). Most electronic devices rely on batteries for power. Batteries convert chemical energy into electrical energy through electrochemical reactions. They consist of a positive electrode, a negative electrode, a separator, and an electrolyte (Shi et al., 2021).

The positive electrode (cathode) is where reduction reactions occur, accepting electrons from the external circuit. The negative electrode (anode) is where oxidation reactions occur, releasing electrons into the external circuit. The separator is a porous material that prevents short circuits and contact between the cathode and anode (Kartika

et al., 2019). The electrolyte commonly used is liquid. Liquid electrolytes ionize more quickly than solid electrolytes. However, they have disadvantages such as the risk of leakage and flammability. As a result, solid electrolytes were developed. Solid electrolytes are in solid form, typically in the form of membranes or layers made of polymer materials. (Sari et al., 2022). Due to their solid form, they are leak-resistant, safer, more practical, and can be manufactured in smaller and thinner sizes; however, they possess a lower capacity compared to their liquid counterparts (Rajeev et al., 2020).

One of the polymer materials used as an electrolyte component is chitosan, an organic compound widely utilized in the development of solid electrolytes. Its amine and hydroxyl functional groups enable chemical modifications to tailor



its physical and chemical properties as desired (Syifaurrehman et al., 2021). Such modification efforts have been explored in previous studies, including the fabrication of polymer membranes using chitosan as the base material combined with the addition of lithium hydroxide (LiOH) salt (Han et al., 2020).

Lithium hydroxide is an inorganic compound that appears as a white crystalline solid with the chemical formula LiOH, consisting of hydroxide ions (OH⁻) and lithium ions (Li⁺). As a strong base, lithium hydroxide undergoes complete ionization in solution, a property that underlies its suitability as an electrolyte source (Bi et al., 2020). Research on polymer membranes composed of chitosan and LiOH revealed that the interaction between these components resulted in the formation of a new -OH functional group at a wavelength of approximately 3500 cm⁻¹, and bending vibrations involving -OH and -NH₃⁺ functional groups were observed in the range of 1500–945 cm⁻¹. Moreover, the resulting polymer membrane exhibited improved flexibility and reduced hygroscopicity (Sari et al., 2024). Modifications to enhance the quality of the polymer film can be achieved through the incorporation of oxide fillers, such as lithium salts and zinc oxide (ZnO).

Furthermore, zinc oxide (ZnO), when integrated into the polymer matrix, functions as an inorganic filler that significantly improves thermal and mechanical stability, imparts antimicrobial activity, and enhances ionic conductivity by promoting more efficient ion transport pathways through the membrane. This study aims to develop chitosan/LiOH-based polymer membranes with ZnO filler to enhance their ionic conductivity and structural stability as solid-state membrane. The characterizations employed include Fourier Transform Infrared Spectroscopy (FTIR) to identify the functional groups

and vibrational modes within the membrane, and Electrochemical Impedance Spectroscopy (EIS) to measure the ionic conductivity, thereby assessing the membrane's potential as a solid polymer electrolyte for battery applications.

MATERIALS AND METHODS

The tools used in the research included a digital balance, beaker, measuring cylinder, petri dish, sieve/mesh, magnetic stirrer, magnetic bar, oven/dryer, spatula, FTIR tester, SEM tester, and EIS tester. The materials used were chitosan, zinc oxide (ZnO), lithium hydroxide (LiOH), sodium hydroxide (NaOH), distilled water, 1% CH₃COOH, parchment, plastic wrap, plastic clips, aluminum foil, and silica gel. The synthesis and testing of the chitosan/LiOH/ZnO polymer electrolyte membrane were conducted at the Physics Laboratory of the Materials Core of the Faculty of Mathematics and Natural Sciences, Jenderal Soedirman University, the Engineering Materials Laboratory of Gadjah Mada University, and the National Research and Innovation Agency (BRIN).

A. Synthesis Stage of Polymer Electrolyte Membrane

The synthesis design for the chitosan/LiOH/ZnO polymer electrolyte membrane in Figure 1 represents the synthesis process for the chitosan/LiOH/ZnO polymer electrolyte membrane using the solution casting method.

The synthesis stage of the chitosan/LiOH polymer membrane with ZnO begins by dissolving ZnO at varying concentrations of 2% and 3% in 100 ml of 1% CH₃COOH in a beaker. The dissolution process is carried out using a magnetic stirrer at 600 rpm at 60 °C for 1 hour until a homogeneous solution is



Figure 1 Research Design of Synthesis Chitosan/LiOH/ZnO Membrane

obtained. Then, 4 grams of chitosan are added to the solution and stirred for 1 hour. Next, 2% LiOH by weight is added to the solution and stirred for 3 hours. The homogeneous chitosan/LiOH/ZnO solution is poured into a Petri dish and dried until the membrane is dry. The chitosan/LiOH/ZnO polymer membrane formed was then characterized.

B. Characterization of Polymer Electrolyte Membrane

1. Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR characterization aims to identify the presence of functional groups in the chitosan/LiOH/ZnO polymer electrolyte membrane with varying concentrations of 2% and 3% (w/w) over a wavelength range of 4000–400 cm⁻¹. FTIR spectra of the samples were recorded on Shimadzu 8201 PC with 1 cm⁻¹ resolution with the wavenumber 400 to 4000 cm⁻¹. The sample was blended as a KBr pellet and scanned into a blank KBr pellet before measurement.

2. Electrochemical Impedance Spectroscopy (EIS)

This test uses an LCR meter to determine the ionic conductivity of the polymer electrolyte membrane. LCR Meter type Hioki 3532-50 LCR HITESTER. The data results obtained for the ionic conductivity. The test was conducted at the Advanced Materials

Research Center (PRMM) Laboratory of the National Research and Innovation Agency (BRIN).

RESULTS AND DISCUSSION

This study presents the characterization results of solid polymer electrolyte membranes composed of chitosan/LiOH/ZnO with ZnO concentrations of 2% and 3%. The characterization techniques employed include Fourier Transform Infrared Spectroscopy (FTIR) and Electrochemical Impedance Spectroscopy (EIS). FTIR characterization was conducted to identify the functional groups present in the polymer membranes. The absorption peaks observed in the FTIR spectra correspond to the specific chemical bonds formed within the membrane structure. Figure 2 presents the FTIR spectra of the chitosan/LiOH polymer membrane incorporated with ZnO, highlighting the vibrational modes associated with the functional groups resulting from the interaction among the components.

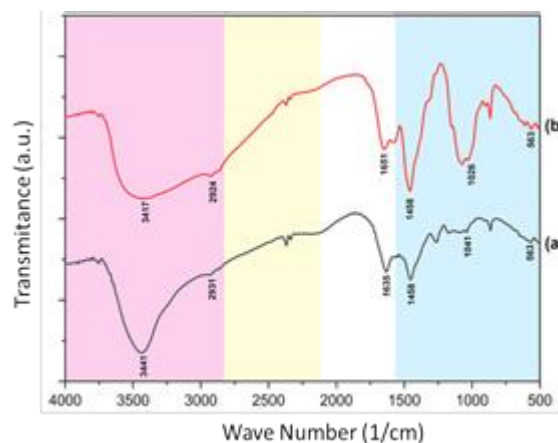


Figure 2. FTIR spectra of polymer electrolyte membranes (a) chitosan/LiOH/ZnO 2%, (b) chitosan/LiOH/ZnO 3%

Figure 2 reveals the presence of distinct vibrational peaks corresponding to various functional groups within the polymer membranes. The FTIR analysis of chitosan/LiOH/ZnO membranes with 2% and 3% ZnO concentrations indicates

the existence of several characteristic functional groups, confirming the chemical interactions among chitosan, LiOH, and ZnO within the membrane matrix. Chitosan exhibits characteristic absorption bands at 3441 cm^{-1} , corresponding to overlapping O–H and N–H stretching vibrations; at 2931 cm^{-1} , attributed to C–H stretching; at 1635 cm^{-1} , associated with N–H bending; and at 1041 cm^{-1} , corresponding to C–O stretching vibrations. The interaction between ZnO and the chitosan/LiOH matrix is evidenced by an increase in the intensity of the N–H stretching band in the $3441\text{--}3425\text{ cm}^{-1}$ region, which overlaps with the O–H absorption band. This enhancement is attributed to the bonding of N–H groups with ZnO. Additionally, ZnO exhibits a characteristic absorption band at 563 cm^{-1} , confirming its presence within the polymer matrix. The FTIR spectra of the chitosan/LiOH/ZnO polymer membrane, as shown in Figure 2, display prominent absorption bands in the wavenumber range of cm^{-1} . The presence of amine groups in chitosan is confirmed by strong absorption bands at 3441 cm^{-1} and 1635 cm^{-1} , corresponding to N–H stretching and N–H bending vibrations, respectively.

The Electrochemical Impedance Spectroscopy (EIS) characterization was employed to evaluate the ionic conductivity of the polymer electrolyte membranes, which reflects their ability to facilitate the transport of lithium ions within battery components. The EIS analysis yielded the ionic conductivity values of the membranes. The observed enhancement in ionic conductivity is attributed to the transition of the polymer matrix toward a more amorphous (non-crystalline) state, which promotes the mobility of charge carriers particularly ammonium ions resulting in an increased concentration of mobile ions and improved ion transport.

Ionic conductivity refers to the electrical conductivity that arises from the effortless flow of charged particles. Figure 3 shows the ionic conductivity graphs produced by chitosan/LiOH polymer membranes with 2% and 3% ZnO addition. The calculation of ionic conductivity is performed utilizing equation 1.

$$\sigma = G \times \frac{l}{A} \quad (1)$$

Where σ is the ionic conductivity (S/cm), l is the sample thickness (cm), A is the outer surface of the material (cm), and G is the conductance (S). The conductivity obtained is the AC conductivity, whose value increases as the frequency used increases.

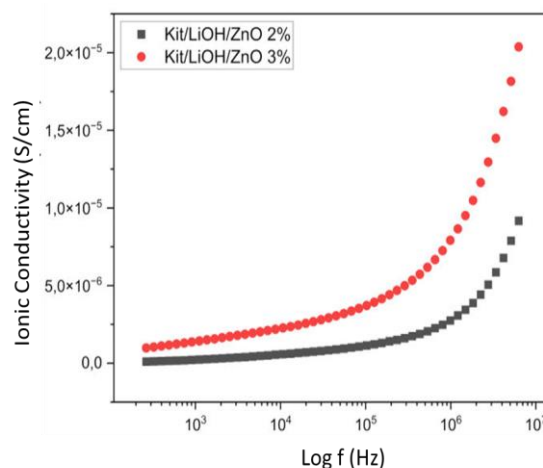


Figure 3. Ionic conductivity graph of membranes (a) chitosan/LiOH/ZnO 2%, (b) chitosan/LiOH/ZnO 3%

Figure 3 illustrates that the chitosan/LiOH/ZnO polymer membranes exhibit ionic conductivity values of $3.6893 \times 10^{-7}\text{ S/cm}$ and $1.4821 \times 10^{-6}\text{ S/cm}$ for ZnO concentrations of 2% and 3%, respectively, indicating a significant enhancement in ionic conductivity with increasing ZnO content. The incorporation of 3% ZnO filler results in

a greater increase in ionic conductivity compared to the addition of 2% ZnO. This enhancement in conductivity suggests stronger interactions between Li^+ ions and the functional groups within the membrane matrix, particularly the hydroxyl ($-\text{OH}$) and amine ($-\text{NH}_2$) groups from chitosan, as well as zinc (Zn) from ZnO. These functional groups can serve as hopping sites that facilitate the migration of Li^+ ions within the polymer electrolyte membrane matrix. The increased mobility of Li^+ ions through these sites contributes to the enhancement of the membrane's ionic conductivity.

CONCLUSION

This study concludes that FTIR characterization confirmed the presence of several functional groups, including O–H stretching, N–H stretching, N–H

bending, C=O stretching, C–H stretching, and Zn–O stretching vibrations. The results of the EIS characterization demonstrated that the chitosan/LiOH membrane incorporating 3% ZnO exhibited a higher ionic conductivity compared to the membrane with 2% ZnO, indicating that increased ZnO concentration enhances ion transport within the membrane matrix. In conclusion, ZnO demonstrates potential as an effective additive for the development of solid polymer electrolyte membranes in secondary battery applications.

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REFERENCE

- Bi, X., Li, M., Liu, C., Yuan, Y., Wang, H., Key, B., Wang, R., Shahbazian-Yassar, R., Curtiss, L. A., Lu, J., & Amine, K. (2020). Cation Additive-Enabled Rechargeable LiOH-Based Lithium–Oxygen Batteries. *Angewandte Chemie - International Edition*, 59(51), 22978–22982. <https://doi.org/10.1002/anie.202010745>
- Han, J. Y., Huang, Y., Chen, Y., Song, A. M., Deng, X. H., Liu, B., Li, X., & Wang, M. S. (2020). High-Performance Gel Polymer Electrolyte Based on Chitosan–Lignocellulose for Lithium-Ion Batteries. *ChemElectroChem*, 7(5), 1213–1224. <https://doi.org/10.1002/celec.20200007>
- Kartika, S., Edi, S., Roto, & Kamsul, A. (2019). Microstructures and functional group properties of nano-sized chitosan prepared by ball milling. *Materials Science Forum*, 948 MSF, 192–197. <https://doi.org/10.4028/www.scientific.net/MSF.948.192>
- Rajeev, K. K., Kim, E., Nam, J., Lee, S., Mun, J., & Kim, T. H. (2020). Chitosan-grafted-polyaniline copolymer as an electrically conductive and mechanically stable binder for high-performance Si anodes in Li-ion batteries. *Electrochimica Acta*, 333. <https://doi.org/10.1016/j.electacta.2019.135532>
- Sari, K., Haryadi, A. N. M., Khusaenah, N., Sudaryanto, Yulianti, E., & Utomo, A. B. S. (2024). Modification of Chitosan/PEG4000 dispersed with



- Lithium Triflate (LiCF_3SO_3) as a solid polymer electrolyte for the secondary battery. *Communications in Science and Technology*, 9(2), 243–251. <https://doi.org/10.21924/cst.9.2.2024.1496>
- Sari, K., Setiabudi, A., Halifah, R., A'yun, N. A. Q., & Sunardin. (2022). Gugus Fungsi, Struktur Morfologi dan Konduktivitas Ionik Membran Polimer Elektrolit Padat Kitosan/LiOH/ZnO. *Prosiding Seminar Nasional Fisika*, 1(1), 190–199.
- Sari, K., Sunardi, S., Utomo, A. B. S., Toruan, P. L., Yulianti, E., & Mashadi, M. (2020). Sifat Optik Dan Permittivitas Listrik Membran Polimer Padat Kitosan/Peo. *Sainmatika: Jurnal Ilmiah Matematika Dan Ilmu Pengetahuan Alam*, 17(2), 97. <https://doi.org/10.31851/sainmatika.v17i2.4987>
- Shi, X., Esan, O. C., Huo, X., Ma, Y., Pan, Z., An, L., & Zhao, T. S. (2021). Polymer Electrolyte Membranes for Vanadium Redox Flow Batteries: Fundamentals and Applications. *Progress in Energy and Combustion Science*, 85, 100926. <https://doi.org/10.1016/j.pecs.2021.100926>
- Syifaurrehman, A., Arnelli, & Astuti, Y. (2021). Lih/coconut shell activated carbon ratio effect on the conductivity of lithium ion battery anode active material. *Molekul*, 16(3), 233–241. <https://doi.org/10.20884/1.jm.2021.16.3.805>