International Journal of Synergy in Engineering and Technology Vol.4 No.1 (2023) 7 – 12

International Journal of Synergy in Engineering and Technology IJSET

# Effects of crosslinking agent for PVA base membrane

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KEYWORDS
Solid Polymer electrolyte
Polyvinyl Alcohol
Conductivity

ABSTRACT

Currently, electrochemical devices are widely used as power sources in portable consumer electronic devices. However, these electrochemical devices which composed of liquid electrolyte has a limited lifespan with environmental issues. Thereby, solid polymer electrolyte (SPE), is promising candidate to replace conventional liquid electrolyte due to that improved conductivity, more stable and reduce risk of leakage. This study was conducted to investigate crosslinking effects on Polyvinyl Alcohol (PVA) based membrane in order to make a high-performance Solid Polymer Electrolyte. So, different polymer such as of poly (vinyl alcohol) (PVA), polyethylene glycol (PEG), with additives such as graphene (Gr), and graphene oxide (GO) were chemically crosslinked using glutaraldehyde (GA). Electrochemical Impedance Spectroscopy (EIS) and Differential Scanning Calorimetry (DSC) were used for each step to characterize the PVA based membrane. According to this study, the conductivity of PVA base membrane was increased 2 times after adding crosslinking agent. In summary, from data taken it can be finalizing that crosslinked PVA and PEG have bright potential to produce high performance SPE.

## 1.0 INTRODUCTION

The use of portable electronics devices such as smartphones, notebooks, and tablets has become increasingly important in daily life as the internet and wireless technology communications have grown in popularity. This portable electronic equipment is an electrochemical device that needs to be powered by a portable power source such as a battery. Nonetheless, most portable power sources, such as lithium-ion batteries, are created with high-cost fabrication and are not environmentally friendly. Many environmental concerns have arisen as a result of the widespread usage of electrochemical devices, such as hazardous metal pollution. The electrolyte used in battery manufacturing costs resources and frequently contains toxic substances. Despite, the electrolyte in today's modern gadgets has a high conductivity, it is hazardous and no recyclable, posing a threat to the environment as well as humans. Other than that, liquid electrolyte has a high ion conductivity, it has a number of drawbacks, including leakage, electrode reactivity, and low electrochemical stability, making it unsuitable for long-term use in electrochemical devices [1]. Studies on the conduction mechanism of these SPEs systems are, therefore of particular importance. It was widely believed that ionic conductivity of solid polymer

Received 7 December 2022; Revised 2 March 2023; Accepted 26 March 202; Accepted 1 April 2023.

electrolytes occurred predominantly in the amorphous phase above the glass-transition temperature ($T_g$) was driven by the local random Brownian motion of amorphous polymer chains.

Solid polymer electrolytes (SPE) are gaining a lot of attention due to their potential usage to replace conventional liquid organic variants, which is fundamentally made up from dissolved conducting salt within the polymer host [2]. SPE has a number of advantages, including ease of fabrication, reduce risk of leakage, and durable construction. SPE are substantially more stable than liquid electrolytes and have a much longer life span. Compared liquid electrolyte, the SPE polymer matrix functions as ion solvation, where it provides segmental polymer sites for mobility ions.

Ramaswamy et al., [3] investigated the effect of magnesium ion conducting solid polymer electrolyte base PVA and they found the highest conductivity is $1.0 \times 10^{-4}$ S/cm at room temperature. Fan L et al. [4] investigated the potential of bamboo charcoal as filler in PVA membrane based. They found adding the filler significantly increased the conductivity value of membrane up to $6.63 \times 10^{-2}$ $Scm^{-1}$. A group of researchers explored the potential of biopolymer based SPE by incorporating PVA/Cellulose acetate with potassium carbonate as salt [5]. They found the conductivity value of $5.30 \times 10^{-4}$ S/cm. With the remarkable potential of PVA as matrix, this research was conducted to investigate the conductivity value of incorporating potassium hydroxide, KOH as a salt and polyethylene glycol as plasticizer. Moreover, graphene and graphene oxide potential were explored by adding onto polymer PVA matrix.

## 2.0 EXPERIMENTAL PROCEDURE

### Materials

Polyvinyl alcohol (PVA), Hydrochloric acid, acetone,glutaraldehyde (GA, 25 wt.-% content in distilled water) were supplied by Sigma-Aldrich Handels GmbH, Austria, and were used without further purification. PVA had a degree of polymerization of 1600 and a hydrolysis degree of 97.5–99.5 mol%.

### Preparation of PVA Membrane

PVA solution was prepared by adding 5g,10 g of PVA was mixed with 200 ml water. The solution was stirred and heated until the mixture was thoroughly combined. The PVA membrane was formed using solution casting method. It was dried in the oven for 24hours. For different types of membrane, the PVA solution was added with polyethylene glycol (PEG), Graphene (Gr) and Graphene Oxide (GO) respectively.

### *Crosslink Immersion Solution*

The crosslinking agent was prepared by adding water ($H_20$), Glutaraldehyde 2%, Hydrochloric acid (HCl), and pure acetone in a beaker. The PVA membrane was immersed in the crosslink solution in a sealed container for 40 minutes.

### *Bath of Potassium Hydroxide (KOH)*

Potassium hydroxide (KOH) solution was prepared by adding 5g, 10g and 15g in 100 ml water. The PVA membrane was immersed in the KOH solution and was heated in oven for 3 hours at $60^{O}C$.

### *Characterization of Membrane*

Membrane was characterized using Electrochemical impedance spectroscopy (EIS), Autolab PGSTAT128N from Metroohm for conductivity measurement. Differential Scanning Calorimetry (DSC) from Metler Teledo for glass transition temperature measurement.

## 3.0 RESULTS AND DISCUSSION

### a) Conductivity value for PVA base membrane.

Conductivity values for PVA, PVA/PEG, PVA/PEG/Gr and PVA/PEG/GO matrix composite was observed as indicated in Figure 1. The conductivity value of PVA matrix alone is 1.5 x $10^{-3}$mS/cm. It was depicted in the graph that adding PEG increased the conductivity value by a fold. This can be represented from Figure 2, where DSC measurement shows the glass transition temperature Tg of PVA/PEG is shifted from 85°C to 56°C, amorphous phase, where allow the movement of electron where increase the conductivity [2]. However, adding the Graphene (Gr) or Graphene Oxide (GO) were not significantly affecting the conductivity value.

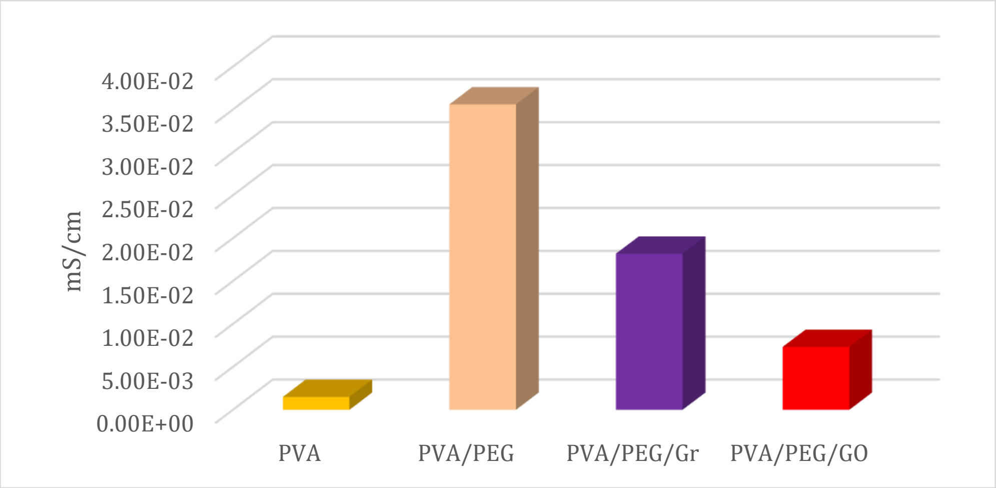

**Figure 1:** Conductivity value of PVA based membrane at room temperature.

### b) Conductivity value of PVA base membrane with crosslinking agent.

Figure 2 obviously shown the significant effect of crosslinking agent, gluteraldehyde (GT) in order enhance the conductivity value of PVA membrane base. The figure shows the conductivity value of PVA, PVA/PEG, PVA/PEG/Gr and PVA/PEG/Go were increased to 2 times, compared the conductivity value without crosslinking. Crosslinking a polymer, is making it thermoset, is a way to reduce the possibility of crystallization. The crystalline phase was considered as insulator that will reduce the ionic conductivity that obstruct the movement the ions [6]. The adding of GT increasing the conductivity of PVA membrane base due to increase the porosity membrane. The proton hopping mechanism is directly dependent on the amount of free space available which influenced overall proton conductivity [7].

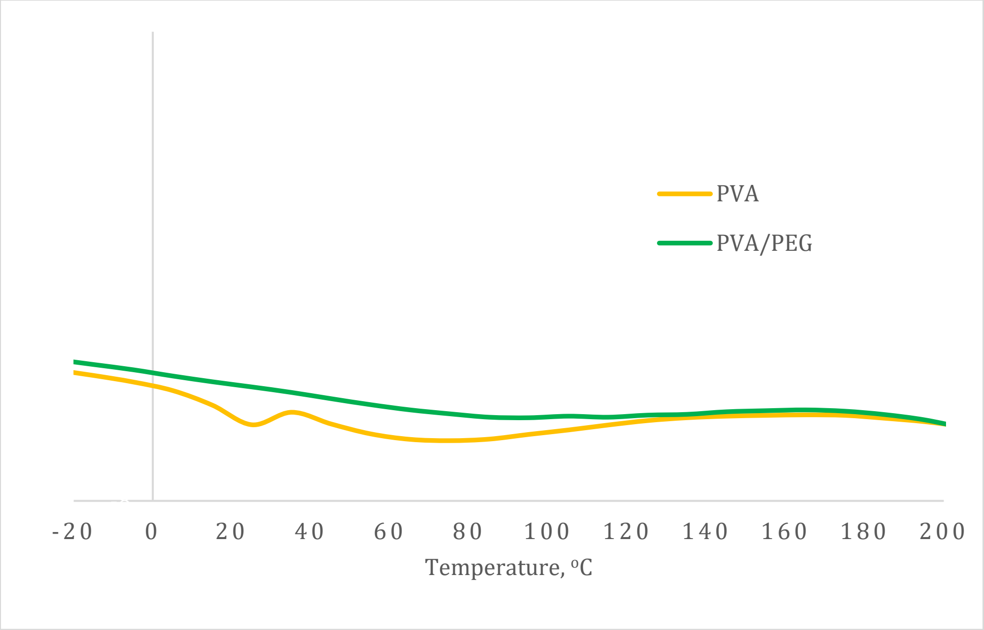

**Figure 2:** DSC measurements of PVA and PVA/PEG membrane at room temperature.

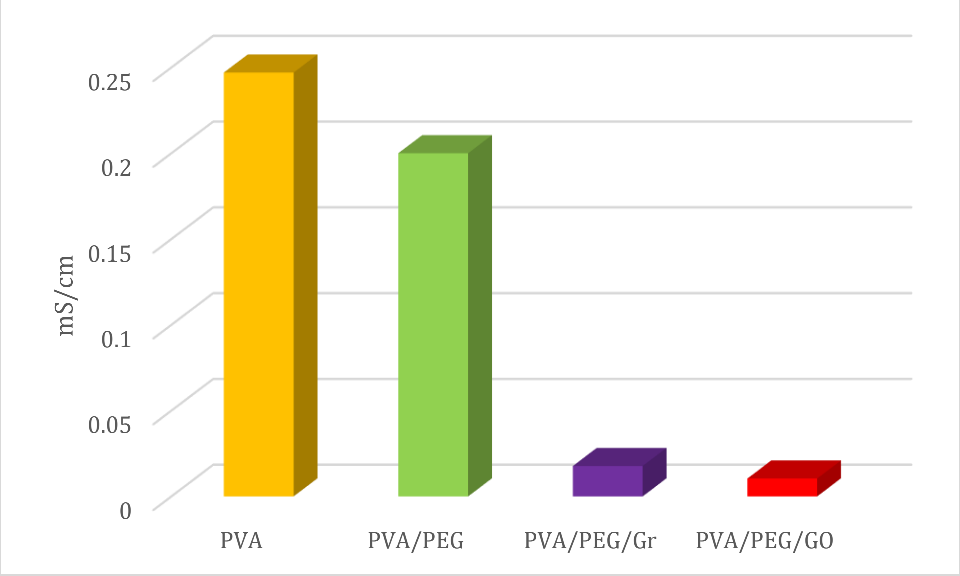

**Figure 3**: Conductivity value of PVA based membrane with crosslinking at room temperature.

## 4.0 CONCLUSION

It can conclude that conductivity of PVA membrane-based increase after crosslinking. For PVA, the best conductivity gains from sample 5g PVA which is conductivity increase from 1.5x $10^{-6}$s/cm to 1.33 x $10^{-3}$s/cm after crosslinking. For PVA/PEG, the best conductivity gains from sample 4g PEG which is conductivity increase from 3.56 x $10^{-5}$s/cm to 2.13 x 10-$4^{4}$s/cm after crosslinking. It can be finalizing that crosslinked PVA has better conductivity than PVA/PEG. For conclusion for this study, crosslinking PVA with GT can improve the conductivity of membrane in order to make a high performance SPE.

## ACKNOWLEDGEMENT

The authors gratefully acknowledge UC TATI for providing laboratory facilities and financial support from Short Term Grant (STG) 9001-2003 which makes this work possible.

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