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POLYMER ELECTROLYTE MEMBRANE BEHAVIOR UNDER AN APPLIED ELECTRIC FIELD

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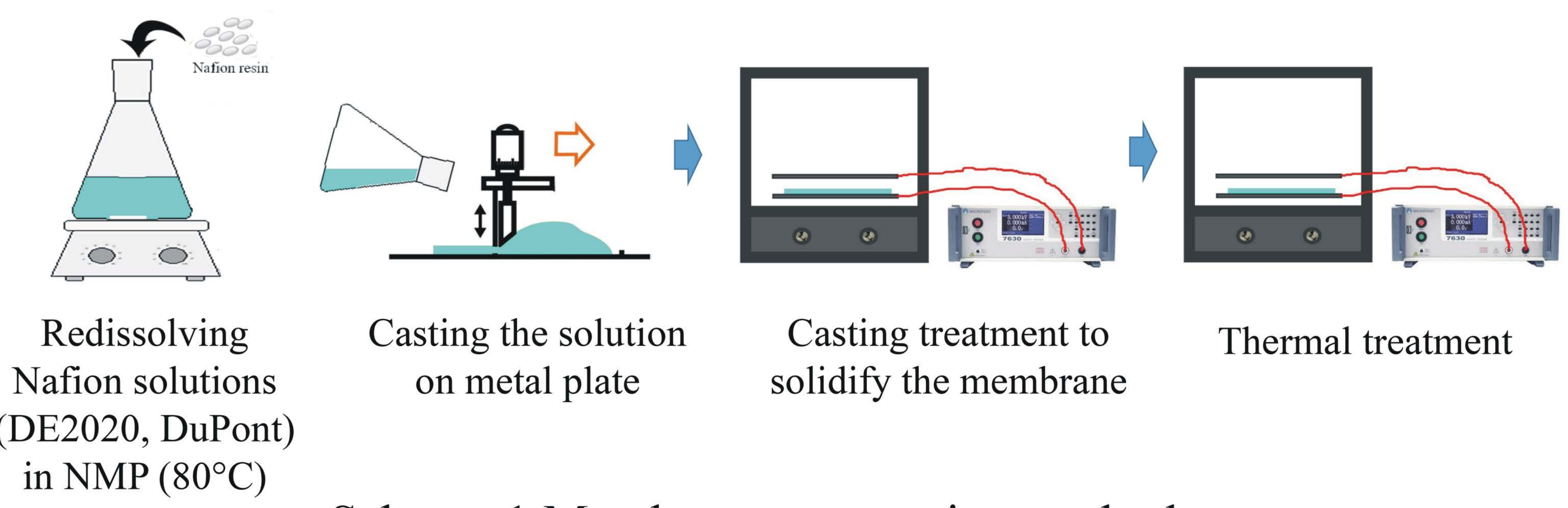
INTRODUCTION

Polyelectrolyte membrane separating both electrodes is the heart of fuel cell since their ability to transport ion from cathode to anode determines the overall device performance [1]. The high ionic conductivity of the newly developed membranes is often attributed to membrane morphology at the molecular level [2]. Currently, nafion membranes are the most widely used polyelectrolyte in commercial fuel cell products. The polymer exhibits excellent ion-conductivity due to microphase separation between hydrophobic polyfluoroethylene backbone and ionic perfluorosulfonic side chain [3]. However, random ionic clusters in untreated nafion membranes favor inefficient ion transport which has downgraded its ion-conductive properties [4].

As a part of the bottom-up approach, the electric field has been developed to arrange bulk, solution, or thin membrane polymer into higher-order structure[5]. Electrostatic energy in an electric field is capable of inducing polarization in molecules, including long polymer chain, in which it initiates polymer chain to arrange, therefore creating unique morphology and yields superior performances [6]. The intense interaction between polymer molecules and applied electric field can be exploited to modify membrane morphology in order to improve the proton transport performances. Our previous result shows that electric pooling during membrane preparation results in a membrane with a more balanced property where high ion conductivity and low alcohol (methanol and ethanol) permeability co-existed [7]. Despite exciting novel results, a comprehensive study revealing the relationship between membrane morphology and the applied electric field has not been published. Addressing these issues becomes the primary motivation for the thesis and will be addressed clearly in this research.

METHODOLOGY

1) Membrane Preparation



Scheme 1 Membrane preparation method

Table 1 Sample casting and thermal treatment condition

Samples	Casting condition	Thermal treatment condition
N-100C-0kV	80°C, 45 min, 0 kV/cm	100°C, 3 hours, 0 kV/cm
N-120C-0kV	80°C, 45 min, 0 kV/cm	120°C, 3 hours, 0 kV/cm
N-140C-0kV	80°C, 45 min, 0 kV/cm	140°C, 3 hours, 0 kV/cm
N-100C-6kV	80°C, 45 min, 6 kV/cm	100°C, 3 hours, 6 kV/cm
N-120C-6kV	80°C, 45 min, 6 kV/cm	120°C, 3 hours, 6 kV/cm
N-140C-6kV	80°C, 45 min, 6 kV/cm	140°C, 3 hours, 6 kV/cm

2) Characterization

Several analysis were employed in this research, including Electrochemical Impedence Spectroscopy (EIS), X-ray diffraction (XRD), Differential Scanning Calorimetry (DSC), water uptake, and ion exchange capacity.

Results and Discussions

1) Effect of applied electric field on water uptake and ion conductivity

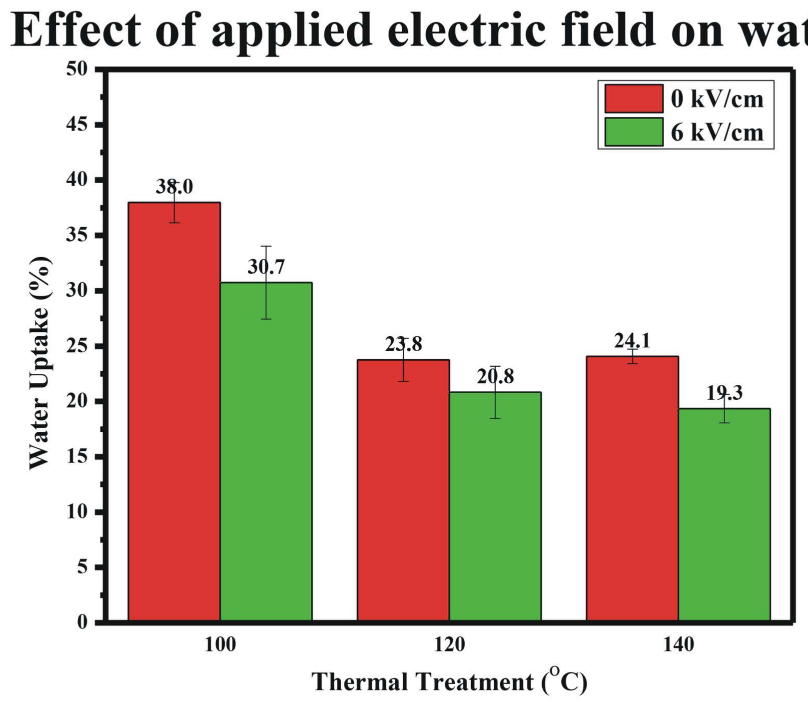


Figure 1:
Water uptake of all samples

Applied electric field decreases water uptake on nafion membrane.

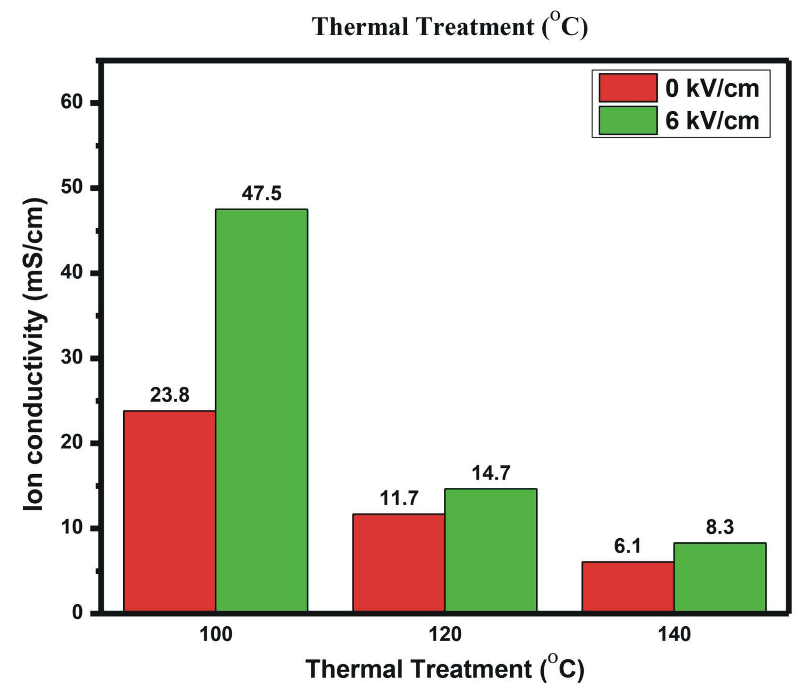


Figure 2 :
Ion conductivity of all samples

Despite water content on samples with applied electric field are lower, the ion conductivity are on those sample are remarkably higher.

Results and Discussions

2) Effect of applied electric field on morphology parameters

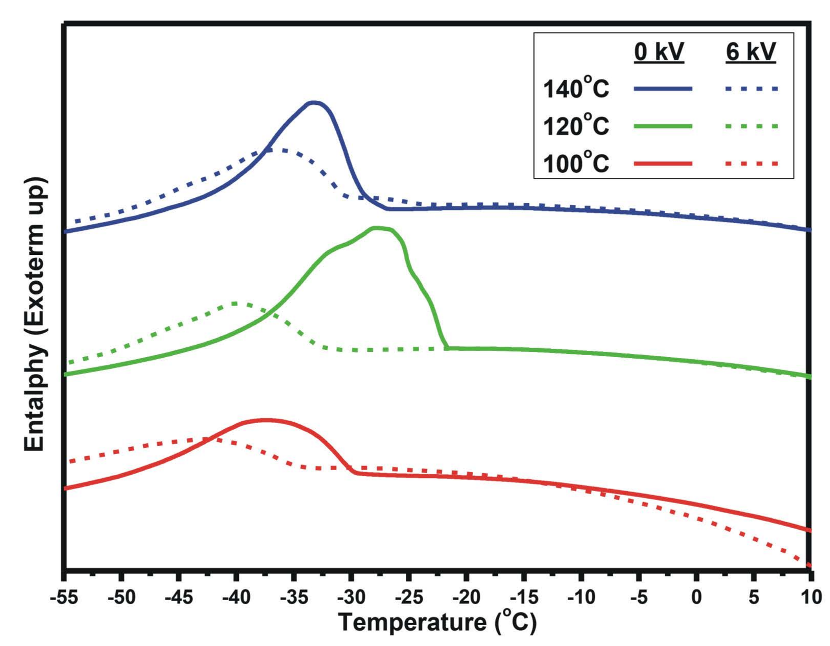


Figure 3 : Low temperature DSC

Table 2 :
Crystallinity and crystal size
(obtain from Deconvoluted XRD pattern)

Thermal treatment	Degree of crystallinity		Crystal size	
	0 kV/cm	6 kV/cm	0 kV/cm	6 kV/cm
100°C	25.26	29.26	5.82	5.52
120°C	20.62	23.71	6.41	5.75
140°C	31.08	39.86	4.91	3.93

The lower water freezing point in nafion membrane electric field treatment implied that water channel in Nafion become smaller. XRD reveal that it occur because the membranes have higher degree of crystallinity that contribute additional strain to nafion structure.

Conclusion

The results revealed that applied electric field improved nafion ion-conductive properties despite having low water uptake. The improved properties occurs due to the change in morphology parameter.

References

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