UNIVERSITI PUTRA MALAYSIA

ELECTRICAL PROPERTIES OF NAFION 117 MEMBRANE AT VARIABLE TEMPERATURES AND SOLUTION UPTAKES

RAJA IBRAHIM PUTERA BIN RAJA MUSTAPHA

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Thesis submitted to the School of Graduate Studies, University Putra Malaysia, In Fulfillment of the Requirements for the Degree of Master of Science

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Chair : **Professor Elias bin Saion, PhD**

Faculty: **Faculty of Science**

Nafion being among the best proton exchange membrane for the use of Fuel Cell was studied to find the best parameters to be used to increase conductivity. Currently Nafion exhibits high rates of methanol crossover in the application of Direct Methanol Fuel Cell which occurs at high pressure and high temperature that lowers the power output of the system. This work studies the Nafion membrane at relatively low temperatures up to the boiling point of methanol (28^{o}C to 65^{o}C) and at atmospheric pressure. Nafion membrane is investigated when it is dry, in deionized water, pure methanol, pure ethanol and in different solution ratios of deionized water to methanol (1:3, 1:1, 3:1) and different solution ratios of deionized water to ethanol (1:3, 1:1, 3:1). Nafion is also observed at different solution uptakes, first being at fully saturated, at 5% solution uptake and at 10% solution uptake. The main interest in this study to optimize power output is to look into the conductivity values obtained from the given

environments. It was observed that conductivity increases with increasing thickness of the membrane as a result of absorption of the solution introduced where the best obtained values for alternating current conductivity is obtained for Nafion in 50% methanol and 50% ethanol solutions. While for the direct current conductivity, the best was obtained at 75% methanol and 75% ethanol solutions. From other studies, Nafion's conductivity was supposed to increase with increasing water content but here the opposite is true because deionized water was used where all the impurities usually present in water is discarded as well as the fractionation effect. The results obtained were attributed to proton tunneling mechanism and also plasticization effect of alcohol on the membrane. For Nafion at room temperature, the ac conductivity when dry, in deionized water, pure methanol and pure ethanol were in the range of 3.12×10^{-8} - 1.52×10^{-4} S m^{-1}, 2.76×10^{-5} - 6.33×10^{-3} S m^{-1}, 6.83×10^{-6} - 6.92×10^{-3} S m^{-1} and 1.05×10^{-5} – 4.74×10^{-3} S m^{-1} respectively. While for dc conductivity for Nafion when dry, in deionized water, pure methanol and pure ethanol were in the range of 4.31×10^{-4} – 5.90×10^{-4} S m^{-1}, 1.14×10^{-2} – 1.72×10^{-2} S m^{-1}, 1.36×10^{-3} – 1.87×10^{-3} S m^{-1} and 7.20×10^{-4} – 8.82×10^{-4} S m^{-1} respectively. Whereas for the conduction activation energy of Nafion when dry, in deionized water, pure methanol and pure ethanol were 5.72×10^{-1} eV, 1.06 eV, 1.05 eV and 2.32 eV respectively. With the thickness being the difference between the 5%, 10% and fully saturated Nafion membrane, the conductivity from fully saturated to 5% solution uptake shows a 53-96% decrease. While from fully saturated to 10% solution uptake shows a 71-98% decrease. The conduction activation energy for the 5% solution uptake is 52-98% less than for the saturated membrane. And for the membrane with 10% solution uptake is 68-81% less.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

SIFAT ELEKTRIK MEMBRAN NAFION 117 DENGAN PERUBAHAN SUHU DAN PENYERAPAN CECAIR

Oleh

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Nafion sebagai antara calon terbaik untuk membran penukaran proton untuk kegunaan Sel Bahan Api telah diselidik untuk mencari parameter terbaik untuk meningkatkan konduktiviti. Dengan keadaan sekarang, Nafion menunjukkan kebarangkalian tinggi berlakunya pindah-silang metanol dalam penggunaan Sel Bahan Api Metanol Terus yang berlaku pada tekanan tinggi dan suhu tinggi yang mengurangkan pengeluaran kuasa sistem tersebut. Di dalam kerja ini, Nafion diselidik pada suhu rendah sehingga takat didih metanol (28^{o}C sehingga 65^{o}C) dan pada tekanan atmosfera. Membran Nafion diselidik apabila ia kering, di dalam air dinyahion, metanol tulin, etanol tulin dan di dalam nisbah air dinyahion kepada metanol (1:3, 1:1, 3:1) dan di dalam nisbah air dinyahion kepada etanol (1:3, 1:1, 3:1). Nafion juga diperhatikan pada penyerapan berbeza, mulanya apabila penyerapan penuh, pada 5% penyerapan cecair danpada 10% penyerapan cecair. Kepentingan yang diselidik ialah untuk meningkatkan

pengeluaran kuasa oleh itu nilai konduktiviti pada persekitaran yang disebut. Daripada keputusan yang diperolehi, konduktiviti meningkat dengan peningkatan ketebalan membran yang berlaku apabila membran menyerap cecair yang diberi dan dimana nilai konduktiviti terbaik untuk ac diperoleh pada campuran cecair 50% methnol dan 50% etanol. Manakala untuk dc pula diperoleh pada 75% metanol dan 75% etanol. Daripada penyelidikkan lain, konduktiviti sepatutnya meningkat mengikut peningkatan air tetapi sebaliknya berlaku kerana air dinyahion digunakan dimana bendasing yang biasanya hadir di dalam air, tidak wujud dan juga kesan penisbahan. Keputusan yang diperoleh disebabkan oleh mekanisma penerowongan proton dan kesan pemplastikkan akibat pendedahan alkohol kepada membran tersebut. Untuk Nafion pada suhu bilik, kekonduksian ac apabila kering, dalam air dinyahion, metanol tulin dan etanol tulin berada di dalam julat 3.12×10^{-8} - 1.52×10^{-4} S m^{-1}, 2.76×10^{-5} - 6.33×10^{-3} S m^{-1}, 6.83×10^{-6} - 6.92×10^{-3} S m^{-1} dan 1.05×10^{-5} – 4.74×10^{-3} S m^{-1}, masing-masingnya. Sementara untuk kekonduksian dc untuk Nafion apabila kering, dalam air dinyahion, metanol tulin dan etanol tulin berada dalam julat 4.31×10^{-4} – 5.90×10^{-4} S m^{-1}, 1.14×10^{-2} – 1.72×10^{-2} S m^{-1}, 1.36×10^{-3} – 1.87×10^{-3} S m^{-1} dan 7.20×10^{-4} – 8.82×10^{-4} S m^{-1} , masing-masingnya. Manakala untuk tenaga pengaktifan kekonduksian untuk Nafion apabila kering, dalam air dinyahion, metanol tulin dan ethanol tulin ialah 5.72×10^{-1} eV, 1.06 eV, 1.05 eV dan 2.32 eV, masing-masingnya. Dengan ketebalan merupakan perbezaan bagi 5%, 10% dan membran Nafion yang tepu, kekonduksian daripada tepu kepada 5% penyerapan cecair menunjukkan penurunan di antara 53-96%. Manakala daripada membran tepu kepada 10% penyerapan cecair menunjukkan penurunan sebanyak 71-98%. Untuk tenaga pengaktifan kekonduksian untuk membran yang mempunyai 5% penyerapan cecair

menunjukkan 52-98% penurunan daripada membran tepu. Dan untuk membran dengan 10% penyerapan cecair penurunan ialah 68-81%.

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I certify that a Thesis Examination Committee has met on 15 July 2011 to conduct the final examination of Raja Ibrahim Putera Bin Raja Mustapha on his thesis entitled "Electrical Properties Of Nafion 117 Membrane With Temperature Variable And Solution Uptake" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Masters of Science degree.

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Declaration

I declare that the thesis is my original work except for quotations and citations which has been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution

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