REFERENCES

Boudghene, S., and A.,Traversa, E. (2002). Fuel cells, an alternative to standard sources of energy. Renewable and Sustainable Energy Reviews, 6, 297- 306.

Minh, N.Q. (2004). Solid oxide fuel cell technology-features and applications. Solid State Ionic, 174, 271-277.

Vielstich, W., Lamm, A., and Gasteiger, H.A. (2003). Automotive development. Handbook of FuelCells-Fundmentals, Technology and Applications, 4, 1217-1223.

Dimitrava, P., Friedrich, K.A., stimming, U., and Vogt, B. (2002). Modified Nafion®-based membranes for use in direct methanol fuel cells. Solid State Ionics, 150, 115-122.

Mikhailenka, S.D., Zaidi, S.M.J., and Kaliaguine, S. (2001). Sulfonated polyether ether based composite polymer electrolyte membranes. Catalyst Today, 67, 225-236.

Vallejo, E., Pourcelly, G., Gavach, C., Mercier, R., and Pineri, M. (1999). Sulfonated polyimides as proton conductor exchange membranes. Physicochemical properties and separation H^+/M^{Z+} by electrodialysis comparison with a perfluorosulfonic membrane. Journal of Membrane Science, 160, 127-137.

Fang, J., Guo, X., Harada, S., Watari, T., Kita, H., and Okanoto, K. (2002). Novel sulfonated polyimides as polyelectrolytes for fuel cell application. 1. synthesis, proton conductivity, and water stability of polyimides from 4,4'-diaminodiphenyl ether-2,2'-disulfonic acid. Macromolecules, 35, 9022-9028.

Woo, Y., Oh, S.Y., Kang, Y.S., and Jung, B. (2003). Synthesis and characterization of sulfonated polyimide membranes for direct methanol fuel cell. Journal of Membrane Science, 220, 31-35.

Zhai, F., Gou, X., Fang, J., and Xu, H. (2007). Synthesis and properties of novel sulfonated polyimide membranes for direct methanol fuel cell application. Journal of Membrane Science, 296, 102-109.

Li, Q., Xu, Z., and Yi, C. (2008). Preparation of poly(amic acid) and polyimide derived from 3,3',4,4'-benzophenonetetracarboxylic dianhydride with different diamines by microwave irradiation. Journal of Applied Polymer Science, 107, 797-802.

Matasuguchi, M., and Takahashi, H. (2006). Methanol permeability and proton conductivity of a semi-interpenetrating polymer networks (IPNs) membrane composed of Nafion® and cross-linked DVB. Journal of Membranes Science, 281, 707-715.

Okamoto, K., Yan, Y., Yamada, O., Islam M.N., Honda, T., Mishima, T., Suto, Y., Tanaka, K., and Kita, H. (2005). Methanol permeability and proton conductivity of sulfonated co-polyimide membranes. Journal of Membranes Science, 258, 115-122.

Wang, Z., Li, X., Zhao, C., Ni, H., and Na, H. (2006). Synthesis and characterization of sulfonated poly(arylene ether ketone ketonesulfone) membranes for application in proton exchange membrane fuel cells. Journal of Power Sources, 160, 969–976.

Le, X., Bai, H., and Ho, W., (2006). Synthesis and characterization of new sulfonated polyimides as proton-exchange membranes for fuel cells. Journal of Membrane Science, 279, 570-577.

Lee, C., Park, C., and Lee, Y., (2008). Sulfonated polyimide membranes grafted with sulfoalkylatedside chains for proton exchange membrane fuel cell (PEMFC) applications. Journal of Membrane Science, 313, 199-206.

Deligöz, H., and Yılmazoğlu, M., (2011). Development of a new highly conductive and thermomechanically stable complex membrane based on sulfonated polyimide/ionic liquid for high temperature anhydrous fuel cells. Journal of Power Sources, 196, 3496-3502.

Deligöz, H., Vantansever, S., Koç, S.N., Öksüzömer, F., Özgümüş, S., and Gürkaynak, M.A. (2008). Preparation of sulfonated copolyimides containing aliphatic linkages as proton-exchange membranes for fuel cell applications. Journal of Applied Polymer Science, 110(2), 1216-1224.

Yin, Y., Fang, J., Cui, Y., Tanaka, K., Kita, H., and Okamoto, K. (2003). Synthesis, proton conductivity and methanol permeability of a novel sulfonated polyimide from 3-(2',4'-diaminophenoxy)propane sulfonic acid. Polymer, 44, 4509-4518.

García, M.G.,Marchese, J., and Ochoa, N.A. (2010). Aliphatic-aromatic polyimide blends for H_2 separation. International Journal of Hydrogen Energy, 35, 8983-8992.

Huang, Y.J., Ye, Y.S., Yen, Y.C., Tsai, L.D., and Hwang, B.J. (2011). Synthesis and characterization of new sulfonated polytriazoleproton exchange membrane by click reaction for directmethanol fuel cells (DMFCs). International Journal of Hydrogen Energy, 36, 15333-15343.

Guo, X., Fang, J., Watari, T., Tanaka, K., Kita, H., and Okamoto, K. (2002). Novel sulfonated polyimides as polyelectrolytes for fuel cell. Macromolecule, 35, 6707-6713.

Ye, X., Bai, H., and Ho, W.S.W. (2006). Synthesis and characterization of new sulfonated polyimides asproton-exchange membranes for fuel cells. Journal of Membrane Science, 279, 570-577.

Pan, H., Zhu, X., and Jian, X. (2010). Synthesis and properties of sulfonated copoly(phthalazinone ether imides) aselectrolyte membranes in fuel cells. ElectrochimicaActa, 55, 709-714.

Asano, N., Aoki, M., Suzuki, S., Miyatake, K., Uchida, H., and Watanabe, M. (2006). Aliphatic/aromatic polyimide ionomers as a proton conductive membrane for fuel cell applications. Journal of the American Chemical Society, 128(5), 1762-1769.

Genies, C., Mercier, R., Sillion, N., Cornet, G. G, and Pineri, M. (2001). Soluble sulfonated naphthalenic polyimides as materials for proton exchange membranes. Polymer, 42, 359-373.

Park, H.B., Lee, C.H., Sohn, J.Y., and Lee, Y.M. (2006). Effect of crosslinked chain length in sulfonated polyimide membranes on water sorption, proton conduction, and methanol permeation properties. Journal of Membrane Science, 285, 432-443.

Wu, D., Fu, R., Xu, T., Wu, L., and Yang, W. (2008) A novel proton-conductive membrane with reduced methanol permeability prepared from bromomethylated poly(2,6-dimethyl-1,4-phenylene oxide) (BPPO). Journal of Membrane Science, 310, 522-530.

Li, Q., Jensen, J.O., Savinell, R.F., and Bjerrum, N.J. (2009). High temperature proton exchange membranes based on polybenzimidazoles for fuel cells. Progress in Polymer Science, 34, 449-477.

Blázquez, J.A., Iruin, J.J., Eceolaza, S., Marestin, C., Mercier, R., Mecerreyes, D., Meguel, O., Vela, A., and Marcilla, R. (2005). Solvent and acidification

method effects in the performance ofnew sulfonated copolyimides membranes in PEM-fuel cells. Journal of Power Sources, 151, 63-68.

Li, L., Zhang, J., and Wang, Y. (2003). Sulfonated poly(ether ether ketone) membranes for direct methanol fuel cell. Journal of Membrane Science, 226, 159-167.

Kang, S., Zhang, C., Xiao, G., Yan, D., and Sun, G. (2009). Synthesis and properties of soluble sulfonated polybenzimidazoles from3,3'-disulfonate-4,4'- dicarboxyl biphenyl as proton exchange membranes. Journal of Membrane Science, 334, 91-100.

Zhu, X., Pan, H., Liang, Y., and Jian, X. (2008). Synthesis and properties of novel sulfonated polyimides containing phthalazinone moieties for PEMFC. European Polymer Journal, 44, 3782-3789.

Lee, C.H., and Wang, Y.Z. (2007). Synthesis and characterization of epoxy-based semi-interpenetrating polymer networks sulfonated polyimides proton-exchange membranes for direct methanol fuel cell applications. Journal of Polymer Science Part A: Polymer Chemistry, 2263-2276.

Stambouli, A., and Traversa, E. (2002). Fuel cells, an alternative to standard sources of energy. Renewable Sustainable Energy, 6, 295–304.

Doyle, M., and Rajendran, G. (2003). Handbook of fuel cells.England: Wiley.

Xu, H., Chen, K., Guo, X., Fang, J., and Yin, J. (2007). Synthesis of novel sulfonated polybenzimidazole and preparation of cross-linked membranes for fuel cell application. Polymer, 48, 5556-5564.

Han, S.I., Im, S.S., and Kim, D.K. (2003). Dynamic mechanical and melt rheological properties of sulfonated poly(butylene succinate) ionomers. Polymer, 44, 7156-7173.

Yeager, E. (1986). Presentation at DOE Contractors Meeting (Technology Base Research Project), Cleveland, Ohio, The United States.

Solomon, F. (1985). Electrochemical Society Spring Meeting, Toronto, Canada.

Srinivisan, S., Dav, B., Murugesamoorthi, K.A., Parthasarathy, A., and Appleby, A.J. (1993). Fuel Cell Systems. Plenum Press, New York, The United States.

Tsai, C.L., and Schmidt, V.H. (2011). Tortuosity in anode-supported proton conductive solid oxide fuel cell found from current flow rates and dusty-gas model. Journal of Power Sources, 196, 692-699.

Kim, Y.S., Hickner, M.A., Dong, L., James, Pivovar, B.S., and McGrath, J.E. (2004). Sulfonated poly(arylene ether sulfone) copolymer proton exchange membranes: composition and morphology effects on the methanol permeability. Journal of Membrane Science, 243, 317-326.

Liu, Y., Yu, Q., and Wu, Y. (2007). More studies on the sulfonated poly(phenylene oxide)+imidazole brønsted acid–base polymer electrolyte membrane. Journal of Physics and Chemistry of Solids, 68, 201-205.

Li, N., Cui, Z., Zhang, S., and Wei, X. (2007). Synthesis and characterization of rigid-rod sulfonated polyimides bearing sulfobenzoyl side groups as proton exchange membranes. Journal of Membrane Science, 295, 148-158.

Qing, S., Huang, W., and Yan, D. (2006). Synthesis and properties of soluble sulfonated polybenzimidazoles. Reactive & Functional Polymer, 66, 219-227.

Andronie, A., Antohe, S., Iordache, S., Cucu, A., Stamatin, S., Ciocanea, A., Emandi, A., and Nan, G. (2010). Study of the conduction mechanisms in poly-perfluoro-sulfonated membranes impregnated with intrinsic semiconducting polymers. Journal of Optoeletronics and Advanced Materials, 12(11), 2288-2295.

APPENDICES

Appendix A Fourier Transform Infrared Spectrometer (FTIR)

FTIR spectrometer (Thermo Nicolet, Nexus 670) was used to study structures of 4,4'-diaminodiphenylmethane (DDM), 4,4'-diaminodiphenylmethane-2,2'-disulfonic acid disodium salt (SDDM), 3,3',4,4'-benzophenonetetracarbolylic dianhydride (BTDA). The spectrometer was operated in the absorption mode with 64 scans and a resolution of 4 cm^{-1} in the wave number range 400-4000cm^{-1}. Optical grade KBr was used as the background material. DDM, SDDM, BTDA and HDA were mixed with KBr before the measurement. FTIR-ATR was used to measure the spectra of sulfonated poly(aromatic imide-co-aliphatic imide). ZeSe was used as a background material.

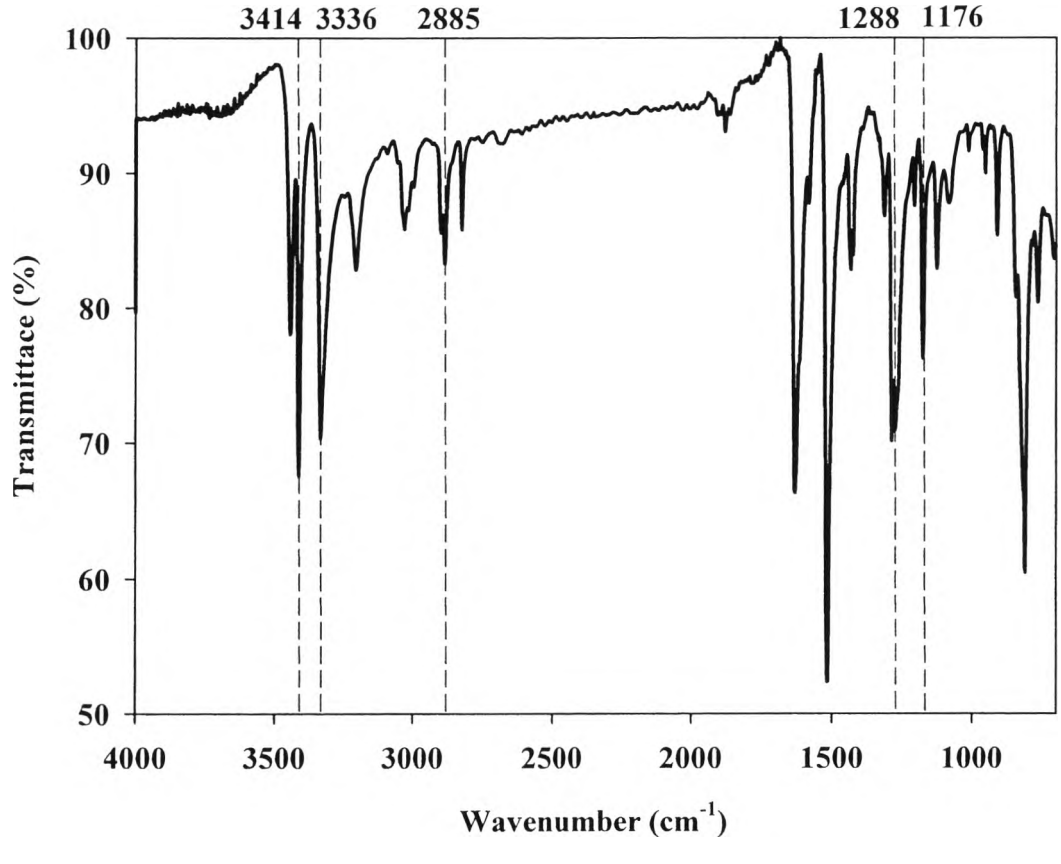


Figure A1 FTIR spectrum of 4,4'-diaminodiphenylmethane (DDM).

Table A1 Characterization of FTIR spectrum of 4,4'-diaminodiphenylmethane (DDM)

Wavenumber (cm^{-1})	Mode of vibration
3414	The primary amine group
3336	The primary amine group
2885	C-H stretching of the methylene group

The FTIR spectrum indicates functional groups of DDM as shown in figure A1. The band around 3414 cm^{-1} and 3336 cm^{-1} are assigned to the primary amine group. The band at2885 cm^{-1} is assigned to the C-H stretching of the methylene group of DDM.(Vora *et al.*, 2006 and Zhu *et al.*, 2008)

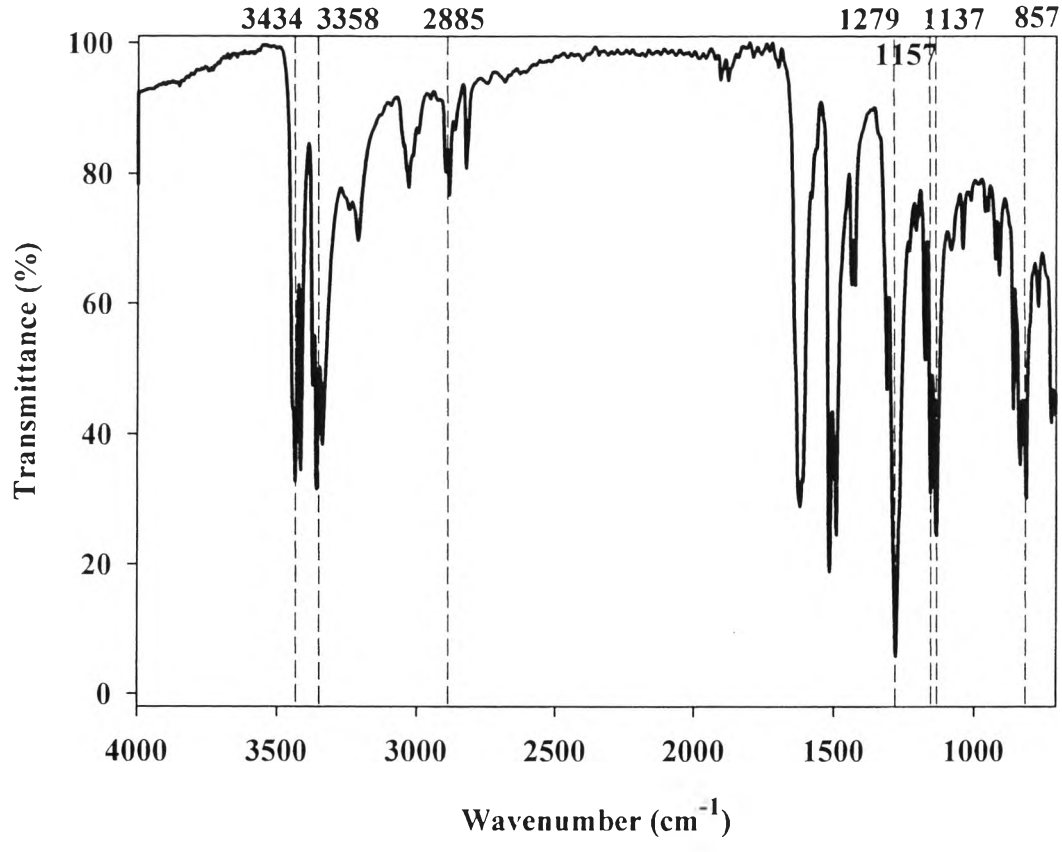


Figure A2 FTIR spectrum of 4,4'-diaminodiphenylmethane-2,2'-disulfonic acid disodium salt (SDDM).

Table A2 Characterization of FTIR spectrum of 4,4'-diaminodiphenylmethane-2,2'-disulfonic acid disodium salt (SDDM)

Wavenumber (cm^{-1})	Mode of vibration
3434	The primary amine group
3358	The primary amine group
2885	C-H stretching of the methylene group
1279	S=O of the sulfonic group
1157	S=O of the sulfonic group
1137	S-O stretching vibration of sulfonic group
857	S-O stretching vibration of sulfonic group

The FTIR spectrum indicates functional groups of SDDM as shown in figure A2. The band around 3434 cm^{-1} and 3358 cm^{-1} are assigned to the primary amine group (Vora *et al.*, 2006 and Zhu *et al.*, 2008). The band at2885 cm^{-1} is assigned to the C-H stretching of the methylene group (Vora *et al.*, 2006 and Zhu *et al.*, 2008). A band at 1279 $cm^{-1}$and 1157 cm^{-1} are attributed to S=O of the sulfonic group (Lee *et al.*, 2007). The S-O stretching vibration of sulfonic group appears at 1137 and 857 cm^{-1} respectively (Li *et al.*, 2008). These sulfonic peeks are not present in the DDM spectrum.

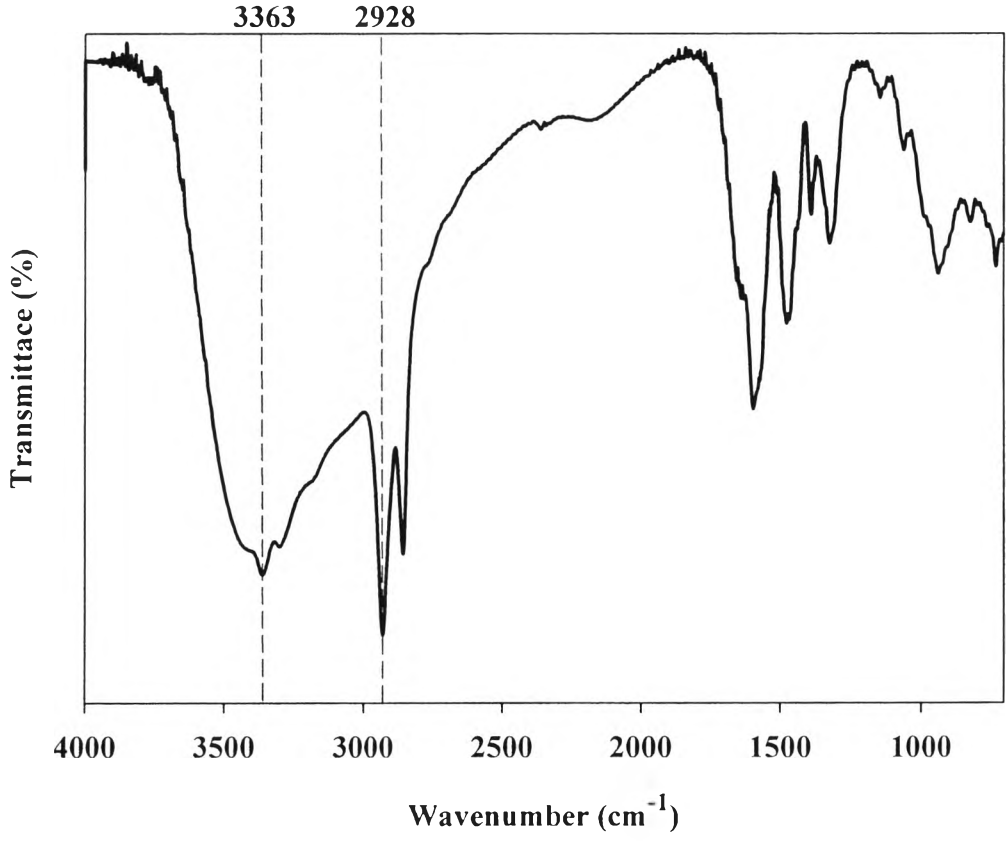


Figure A3 FTIR spectrum of hexamethylenediamine (HDA).

Table A3 Characterization of FTIR spectrum of hexamethylenediamine (HDA)

Wavenumber (cm^{-1})	**Mode of vibration**
3363	The primary amine group
2928	C-H stretching of the methylene group

The FTIR spectrum indicates functional group of HDA as shown in figure A3. The band around 3363 cm^{-1} is assigned to the primary amine group. The band at2928 cm^{-1} is assigned to the C-H stretching of the methylene group of HDA. (Vora *et al.*, 2006 and Zhu *et al.*, 2008)

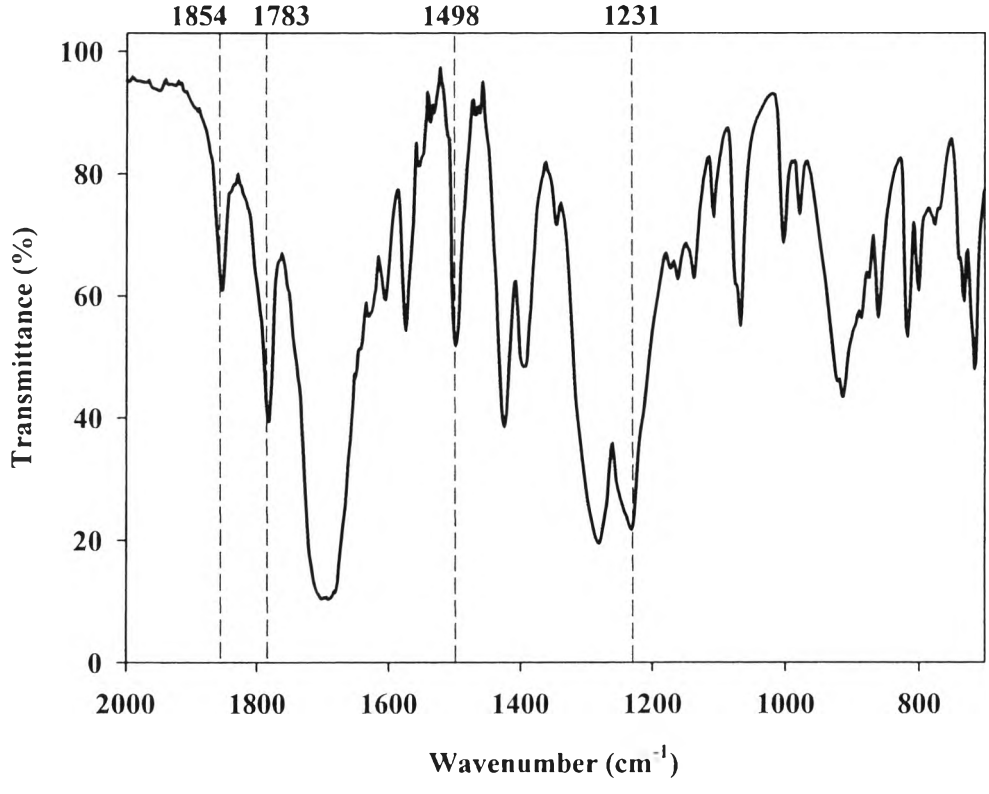


Figure A3 FTIR spectrum of 3,3',4,4'-benzophenonetetracarboxylic dianhydride (BTDA).

Table A3 Characterization of FTIR spectrum of 3,3',4,4'-benzophenonetetracarboxylic dianhydride (BTDA)

Wavenumber (cm^{-1})	**Mode of vibration**
1854	C=O asymmetric stretching of the carbonyl group
1781	C=O symmetric stretching of the carbonyl group
1486	C=C stretching of aromatic ring
1231	C-O stretching of anhydride

The FTIR spectrum indicates functional group of BTDA as shown in figure A4. The band around 1854 cm^{-1} is assigned to the C=O asymmetric stretching of the carbonyl group. The band at 1781 cm^{-1} is assigned to the C=O symmetric stretching of the carbonyl group. A band at 1486 cm^{-1} is attributed to C=C stretching vibration of aromatic ring. The C-O stretching of anhydride appears at 1231 cm^{-1} (Vora *et al.*, 2006 and Zhu *et al.*, 2008)

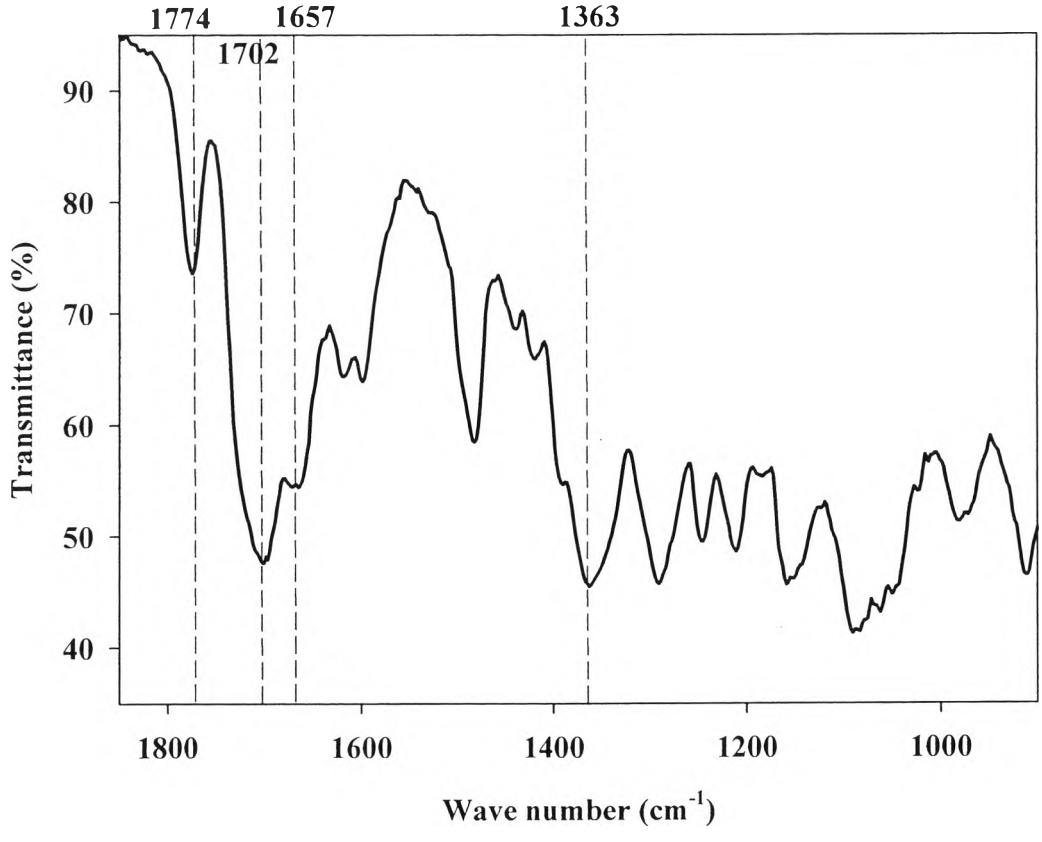


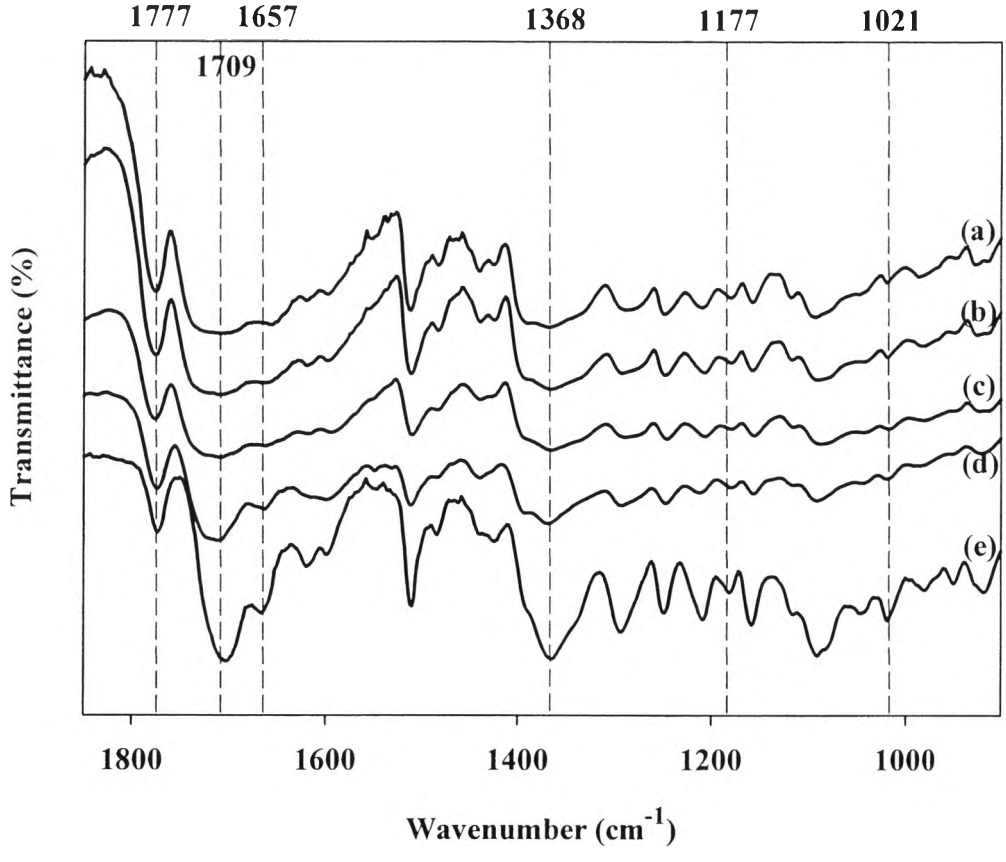
Figure A4 FTIR spectra of unsulfonated copolyimide SDH 0

SDDM: DDM: HDA = 0: 5: 5.

Table A4 Characterization of FTIR spectrum of unsulfonated copolyimide SDH 0 SDDM: DDM: HDA = 0: 5: 5

Wavenumber (cm^{-1})	Mode of vibration
1774	C=O imide carbonyl group (Lee *et al.*,2008)
1702	C=O symmetric stretching vibration of imide carbonyl group (Genies *et al.*, 2001)
1657	C=O asymmetric stretching vibration of imide carbonyl group (Genies *et al.*, 2001)
1368	C-N-C stretching vibration of imide ring (Lee *et al.*,2007)

The FTIR spectrum indicates functional group of the unsulfonated poly(aromatic imide-co-aliphatic imide) membrane as shown in figure A4. The band around 1774 cm^{-1} is assigned to the C=O imide carbonyl group (Lee *et al.*, 2008). The band at 1702 cm^{-1} and 1657 cm^{-1} are assigned to the symmetric and asymmetric stretching of the carbonyl group of polyimide (Genies *et al.*, 2001). A band at 1368 cm^{-1} is attributed to the C-N-C stretching vibration of the imide ring (Lee *et al.*, 2007).



(a) SDDM: DDM: HDA (1:4:5) (b) SDDM: DDM: HDA (2:3:5)

(c) SDDM: DDM: HDA (3:2:5) (d) SDDM: DDM: HDA (4:1:5)

(e) SDDM: DDM: HDA (5:0:5)

Figure A4 FTIR spectra of sulfonated copolyimide: (a) SDH 1; (b) SDH 2; (c) SDH 3; (d) SDH 4; and (e) SDH 5.

Table A4 Characterization of FTIR spectra of sulfonated copolyimide (a) SDH 1, (b) SDH 2, (c) SDH 3, (d) SDH 4 and (e) SDH 5

Wavenumber (cm^{-1})	Mode of vibration
1777	C=O imide carbonyl group (Lee *et al.*,2008)
1709	C=O symmetric stretching vibration of imide carbonyl group (Genies *et al.*, 2001)
1657	C=O asymmetric stretching vibration of imide carbonyl group (Genies *et al.*, 2001)
1368	C-N-C stretching vibration of imide ring (Lee *et al.*,2007)
1177	SO_3 asymmetric stretching vibration of hydrated sulfonic acids (Genies *et al.*, 2001)
1021	SO_3 symmetric stretching vibration of hydrated sulfonic acids (Li *et al.*, 2008)

The FTIR spectra indicate functional group of sulfonated poly(aromatic imide-co-aliphatic imide) membrane as shown in figure A4. The spectra of sulfonatated copolyimide copolymer with all ratio of sulfonation are interpreted in table A4. The band around 1777 cm^{-1} is assigned to the C=O imide carbonyl group (Lee *et al.*, 2008). The band at 1709 cm^{-1} and 1657 cm^{-1} are assigned to the symmetric and asymmetric stretching of the carbonyl group of polyimide (Genies *et al.*, 2001). A band at 1368 cm^{-1} is attributed to the C-N-C stretching vibration of the imide ring (Lee *et al.*, 2007). And the characteristic peak that represents the sulfonated of copolyimide is the SO_3 asymmetric and symmetric stretching vibration of the hydrated sulfonic acid which appears at 1182 and 1019 cm^{-1} respectively (Li *et al.*, 2008). These sulfonic peak are not present in the unsulfonated copolyimide SDH 0.

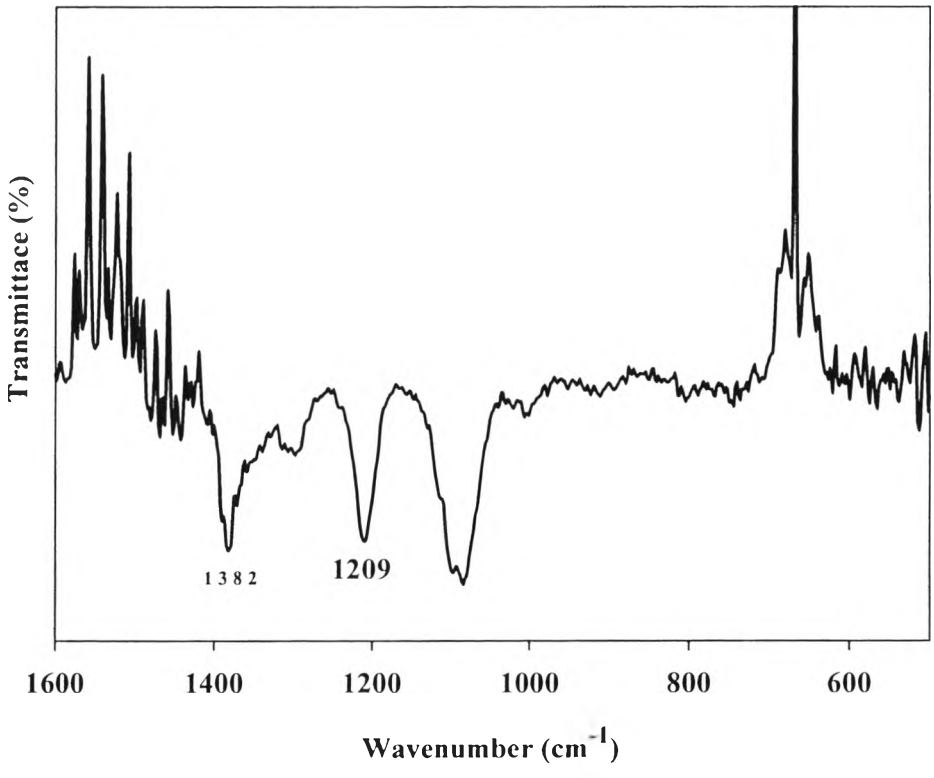


Figure A5 TGA-FTIR spectrum of sulfonated copolyimide membranes SDH 3 at degradation temperature of 193 °C.

Table A5 Characterization of TGA-FTIR spectrum of sulfonated copolyimide membranes at degradation temperature of 193 °C

Wavenumber (cm^{-1})	**Mode of vibration**
1382	SO_2 asymmetric stretching vibration
1209	SO_2 symmetric stretching vibration

The TGA-FTIR spectrum of sulfonated copolyimide is shown in figure A5. At the degradation temperature of 193 °C, the peaks at 1382 cm^{-1} and 1209 cm^{-1} appear which can be attributed to the asymmetric stretching vibration and the symmetric stretching vibration of sulferdioxide, respectively.

Appendix B Thermogravimatric Analysis (TGA)

Thermogravimatric analysis (Parkins Elmer, Pyris Diamond TG/DTA) was used to investigate the thermal stability of the polymer membranes using the TGA technique. The membranes were dried in vacuum for 24 hours. The experiment was carried out by weighting a membrane sample of 2-4 mg and placed it in an alumina pan. The sample pan was heated under nitrogen atmosphere at heating rate 20 °C/min. The temperature range was 50-900 °C.

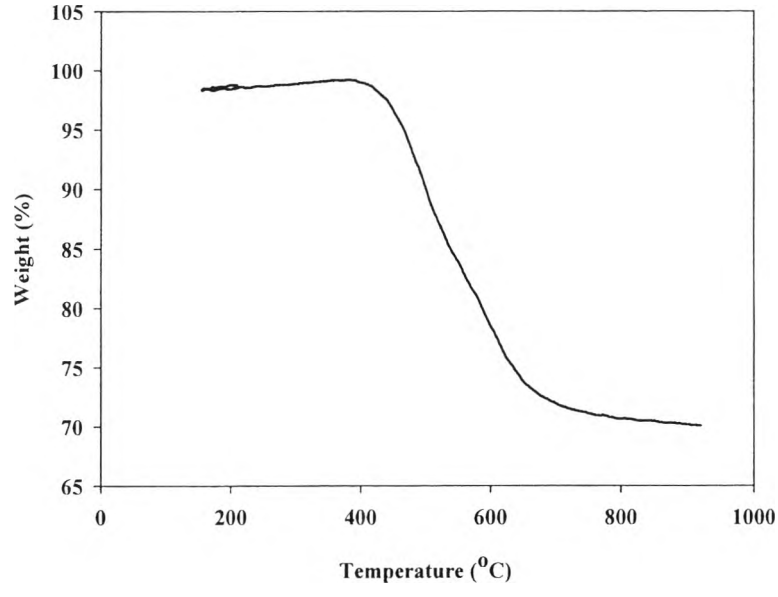


Figure B1 TGA curve of sulfonated copolyimide membranes SDH 0 SDDM: DDM: HDA (0:5:5).

Table B1 Characterization of TGA curve of sulfonated copolyimide membranes SDDM: DDM: HDA (0:5:5)

Temperature (°C)	**Characterization**
451	The degradation of polymer main chain (Genies *et al.*, 2001)

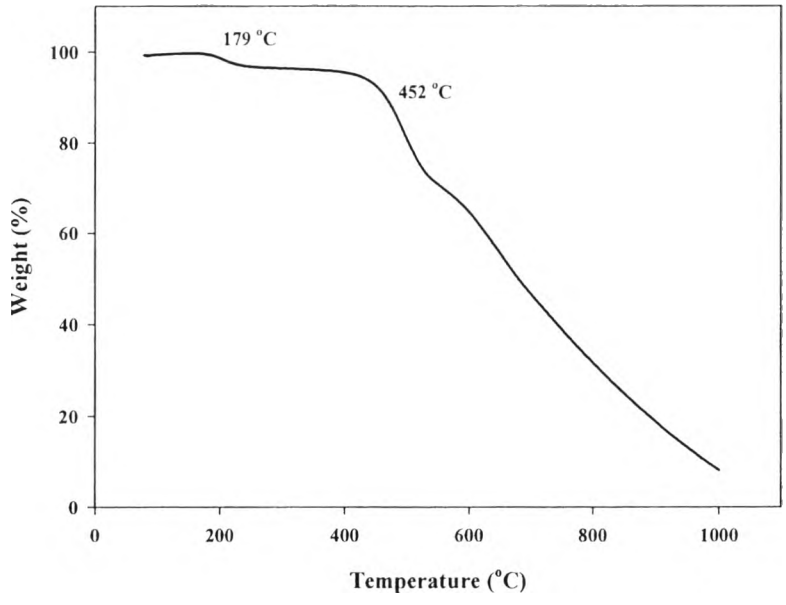


Figure B2 TGA curve of sulfonated copolyimide membranes SDH 1 SDDM: DDM: HDA (1:4:5).

Table B2 Characterization of TGA curve of sulfonated copolyimide membranes SDDM: DDM: HDA (1:4:5)

Temperature (°C)	**Characterization**
179	The degradation of sulfonic group (Genies *et al.*, 2001)
452	The degradation of polymer main chain (Genies *et al.*, 2001)

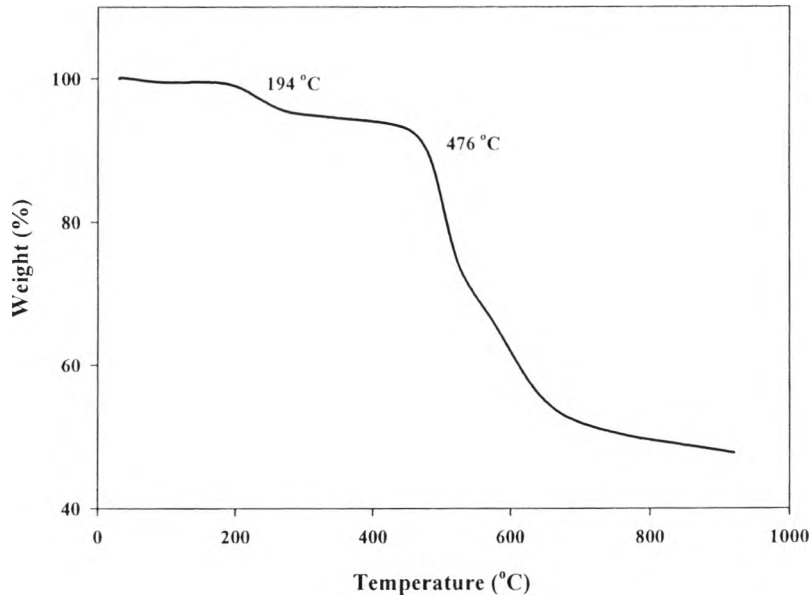


Figure B3 TGA curve of sulfonated copolyimide membranes SDH 2 SDDM: DDM: HDA (2:3:5).

Table B3 Characterization of TGA curve of sulfonated copolyimide membranes SDDM: DDM: HDA (2:3:5)

Temperature (°C)	Characterization
194	The degradation of sulfonic group (Genies *et al.*, 2001)
476	The degradation of polymer main chain (Genies *et al.*, 2001)

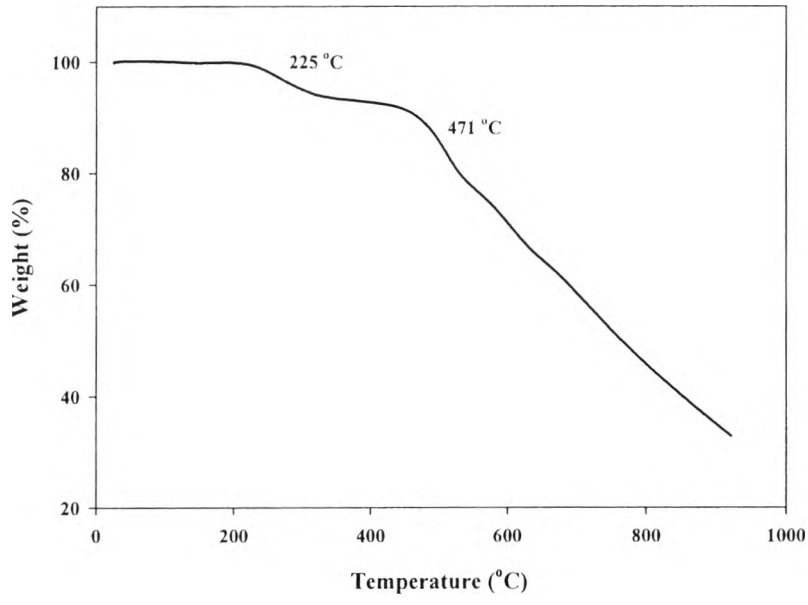


Figure B4 TGA curve of sulfonated copolyimide membranes SDH 3 SDDM: DDM: HDA (3:2:5).

Table B4 Characterization of TGA curve of sulfonated copolyimide membranes SDDM: DDM: HDA (3:2:5)

Temperature (°C)	Characterization
225	The degradation of sulfonic group (Genies *et al.*, 2001)
471	The degradation of polymer main chain (Genies *et al.*, 2001)

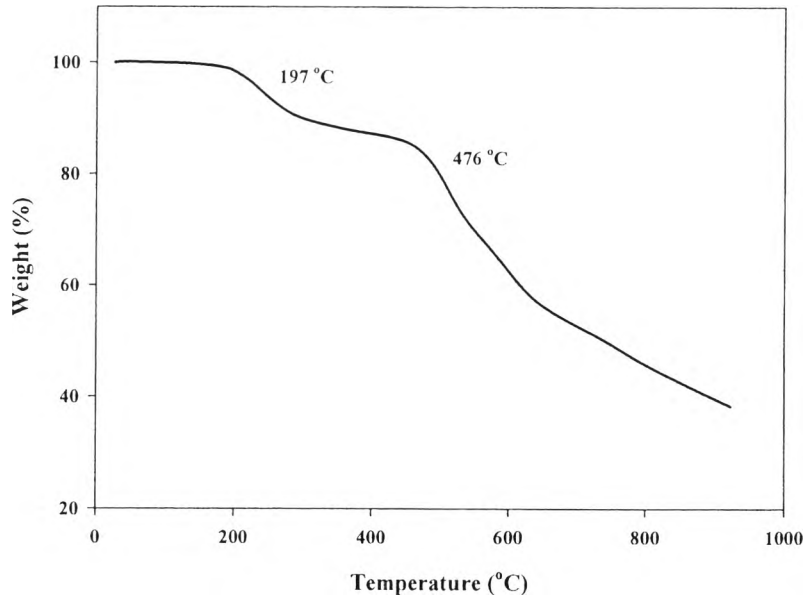


Figure B5 TGA curve of sulfonated copolyimide membranes SDH 4 SDDM: DDM: HDA (4:1:5).

Table B5 Characterization of TGA curve of sulfonated copolyimide membranes SDDM: DDM: HDA (4:1:5)

Temperature (°C)	Characterization
197	The degradation of sulfonic group (Genies *et al.*, 2001)
476	The degradation of polymer main chain (Genies *et al.*, 2001)

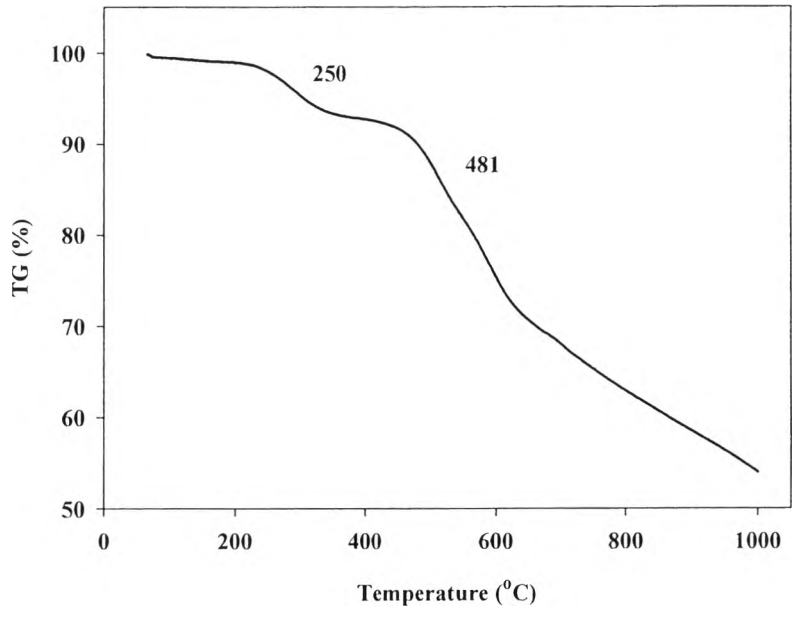


Figure B6 TGA curve of sulfonated copolyimide membranes SDH 5 SDDM: DDM: HDA (5:0:5).

Table B6 Characterization of TGA curve of sulfonated copolyimide membranes SDDM: DDM: HDA (5:0:5)

Temperature (°C)	Characterization
250	The degradation of sulfonic group (Genies *et al.*, 2001)
481	The degradation of polymer main chain (Genies *et al.*, 2001)

The thermal property of sulfonated copolyimide at all ratios of sulfonation are shown in figure B1 to figure B6; the weight loss at about 200 °C is assigned to the decomposition of the sulfonated groups The weight loss due to degradation of the polymer backbone structure appears at nearly 500 °C.

Appendix C Ion Exchange Capacity

Ion exchange capacity of the sulfonated polyimide membranes was measured by a titration. The membranes were cut into small pieces. Then the membranes were immersed into 1 M NaCl solution and stirred for 2 days. The solution was titrated with a 0.01N NaOH solution. Phenolphthalein was used as an indicator in the titration. Ion exchange capacity was calculated from following equation:

$$IEC\ (meq/g) = \frac{\text{Consumed NaOH (ml)} \times \text{molarity NaOH (M)}}{W_{dry}\ (mg)} \qquad (C1)$$

(Deligöz *et al.*, 2008).

Table C1 Ion exchange capacity of sulfonated copolyimide membranes

Sample	Ratio	Weight (mg)	Consume NaOH (ml)	Molarity of NaOH (M)	IEC (meq/g)	Average IEC (meq/g)	SD
SDH 0	0:5:5	0.1052	0	0.01165	0	0	0
		0.0977	0	0.01165	0		
SDH 1	1:4:5	0.0571	4.3	0.01125	0.85	0.84	0.02
		0.0571	4.2	0.01165	0.82		
SDH 2	2:3:5	0.0451	5.4	0.01125	1.35	1.28	0.10
		0.0576	6.0	0.01165	1.21		
SDH 3	3:2:5	0.0679	13.0	0.01125	2.15	2.20	0.06
		0.0679	13.5	0.01125	2.24		
SDH 4	4:1:5	0.0782	18.6	0.01125	2.68	2.82	0.20
		0.0550	14.0	0.01165	2.96		
SDH 5	5:0:5	0.1052	28.2	0.01165	3.12	3.12	0.01
		0.1052	28.3	0.01165	3.13		

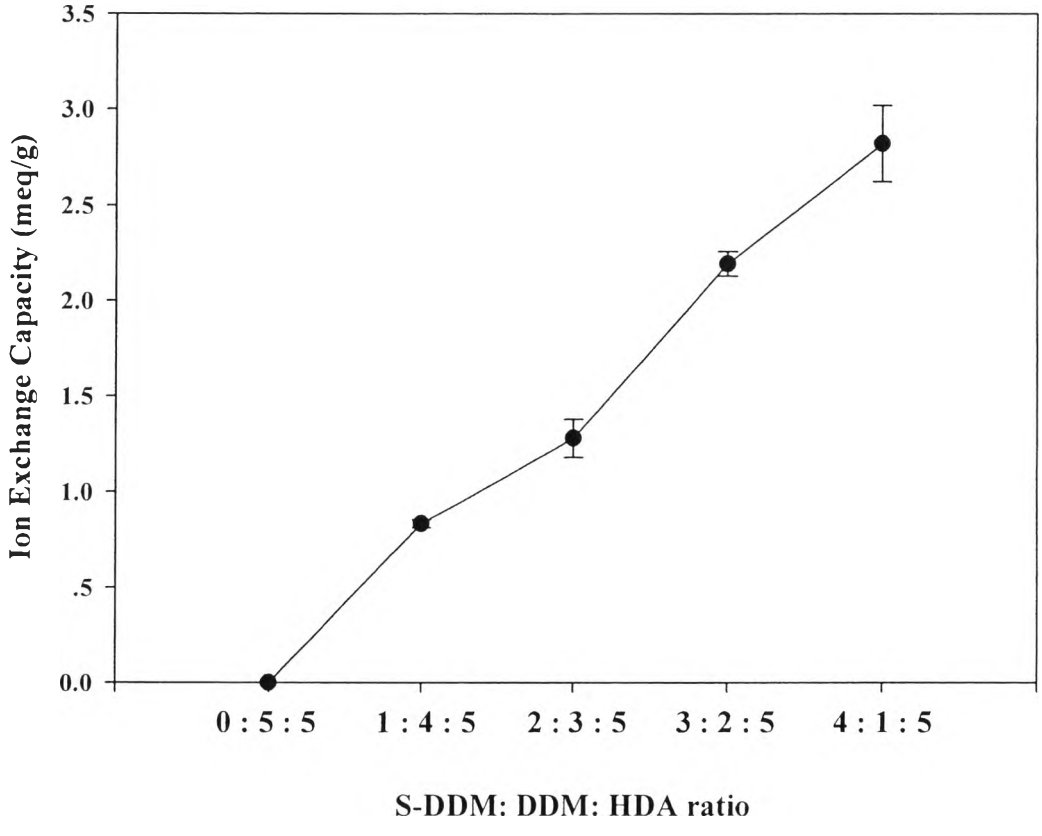


Figure C1 Ion exchange capacity of sulfonated copolyimide.

Appendix D Degree of Sulfonation (DS)

The polymer membranes were acidified by a 0.1 M HCL solution at room temperature for 24 hours. Then the membranes were washed with DI water and dried at 80 °C for 24 hours. After that the membranes were placed in a NaCl solution for 24 hours. The degree of sulfonation of solution was determined by the titration with 0.01 M NaOH using phenolphthalein as an indicator. Degree of Sulfonation of sulfonated copolyimide was calculated by following equation:

$$DS(\%) = \frac{(V_{NaOH}(ml) \times M_{NaOH}(Molar))/1000}{\text{Mole of polymer membrane}} \times 100 \qquad (D1)$$

where V_{NaOH} is volume of NaOH consumed and M_{NaOH} is molarity of NaOH.

Table D1 Degree of sulfonation of sulfonated copolyimide membranes

Sample	ratio	Weight (mg)	Mole of polymer	Consumed NaOH (ml)	Molarity of NaOH (Molar)	DS (%)	Average DS (%)
SDH 0	0:5:5	0.0977	0.0003174	0	0.01165	0	0
		0.0977	0.0003174	0	0.01165	0	
SDH 1	1:4:5	0.0571	0.0002474	4.3	0.01125	19.55	19.32
		0.0571	0.0002474	4.2	0.01165	19.09	
SDH 2	2:3:5	0.0451	0.0001676	5.4	0.01125	36.25	34.46
		0.0576	0.0002140	6.0	0.01165	32.66	
SDH 3	3:2:5	0.0679	0.0002525	13.0	0.01125	57.92	58.94
		0.0679	0.0002525	13.5	0.01125	59.97	
SDH 4	4:1:5	0.0782	0.0002903	18.6	0.01125	72.08	75.96
		0.0550	0.0002042	14.0	0.01165	79.87	
SDH 5	5:0:5	0.1052	0.0003418	28.2	0.01165	96.12	96.29
		0.1052	0.0003418	28.3	0.01165	96.46	

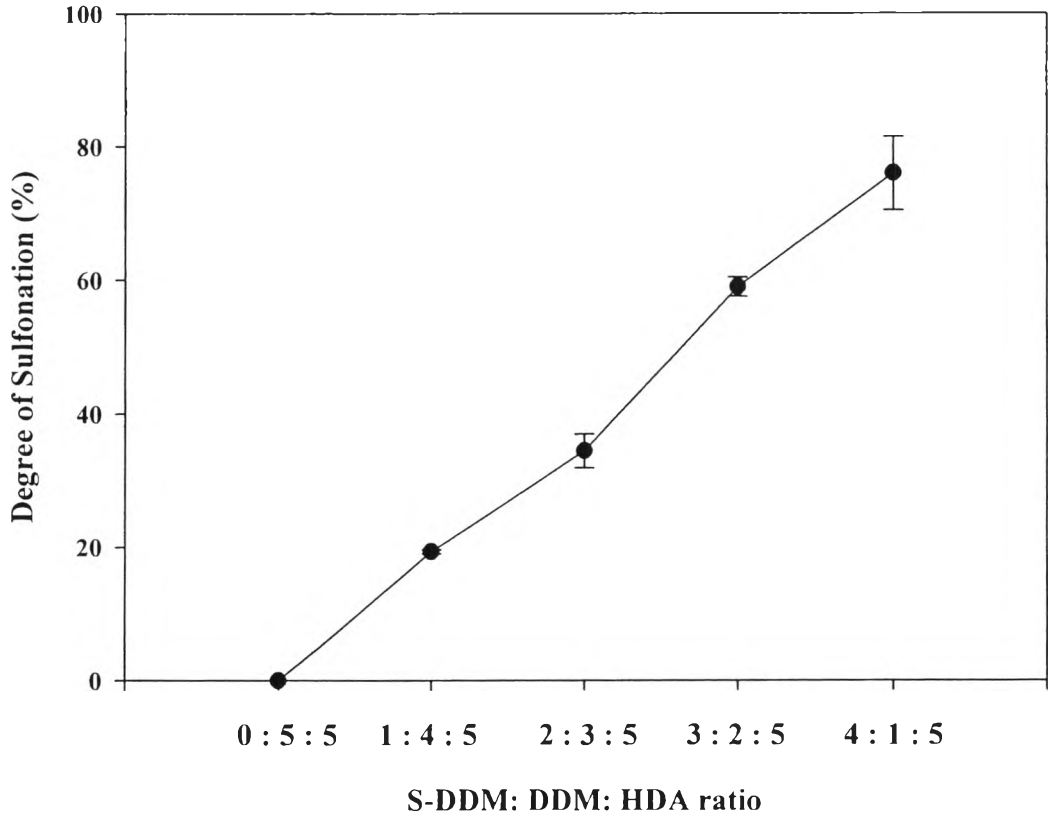


Figure D1 Degree of sulfonation of sulfonated copolyimide.

Appendix E Water Uptake

Water sorption was measured by placing several polyimide membranes into distilled water at 80 °C for 5 hours. Then the membranes were taken out, quickly wiped with a tissue paper and weighted on a microbalance. The water uptake of sulfonated copolyimide film was calculated form following equation:

$$\text{Water uptake} = \frac{W_s - W_d}{W_d} \times 100\% \quad \text{(E1)}$$

where W_s and W_d refer to the weights of the wet and dry samples, respectively (Pan *et al.*, 2010).

Table E1 Water uptake of sulfonated copolyimide membranes

Sample	Ratio	Weight (mg)		Water uptake		Av.Water uptake (%)
		W_s	W_d	(mg)	(%)	
SDH 0	0:5:5	0.0988	0.0977	0.0011	1.12	2.18
		0.1086	0.1052	0.0034	3.23	
SDH 1	1:4:5	0.0635	0.0623	0.0012	1.93	2.34
		0.0448	0.0436	0.0012	2.75	
SDH 2	2:3:5	0.0796	0.0782	0.0014	1.79	2.18
		0.1045	0.1072	0.0027	2.58	
SDH 3	3:2:5	0.0618	0.0597	0.0021	3.52	3.82
		0.0655	0.0682	0.0027	4.12	
SDH 4	4:1:5	0.0826	0.0797	0.0029	3.64	3.20
		0.0560	0.0545	0.0015	2.75	
SDH 5	5:0:5	0.0461	0.0448	0.0013	2.90	1.99
		0.0560	0.0554	0.0006	1.08	

Appendix F Proton Conductivity

The proton conductivity of the films was recorded on an Agilent E4980A LCR meter. The fully hydrated films was cut to 0.5 cm× 0.5 cm pieces and coated with silver. The coated film was measured at a 1V potential using the alternating current in the frequency range of 20 Hz – 2 MHz. The graph shows relationship between the radian and the impedance. The conductivity σ was calculated from the impedance as follow:

$$\sigma(Scm^{-1}) = \frac{d}{R \times A} \qquad (F1)$$

where σ is the proton conductivity, d is the thickness of the membrane, S is the area of the interface of membrane in contact with the electrodes, and R refers to the measured resistance of the membrane – derived from the low frequency semicircle on the complex impedance plane with the Z axis (Park *et al.*, 2006).

Table F1 Proton conductivity of sulfonated copolyimide membranes

Sample	ratio	Proton Conductivity (S cm^{-1})		
		No.1	No.2	Average
SDH 0	0:5:5	0.001603	0.001603	0.001603
SDH 1	1:4:5	0.001868	0.001864	0.001866
SDH 2	2:3:5	0.002734	0.002711	0.002723
SDH 3	3:2:5	0.002793	0.002826	0.002810
SDH 4	4:1:5	0.002991	0.002991	0.002991
SDH 5	5:0:5	0.003241	0.003241	0.003241
Nafion®	-	-	-	0.00683*

* Matsuguchi*et al.*(2006)

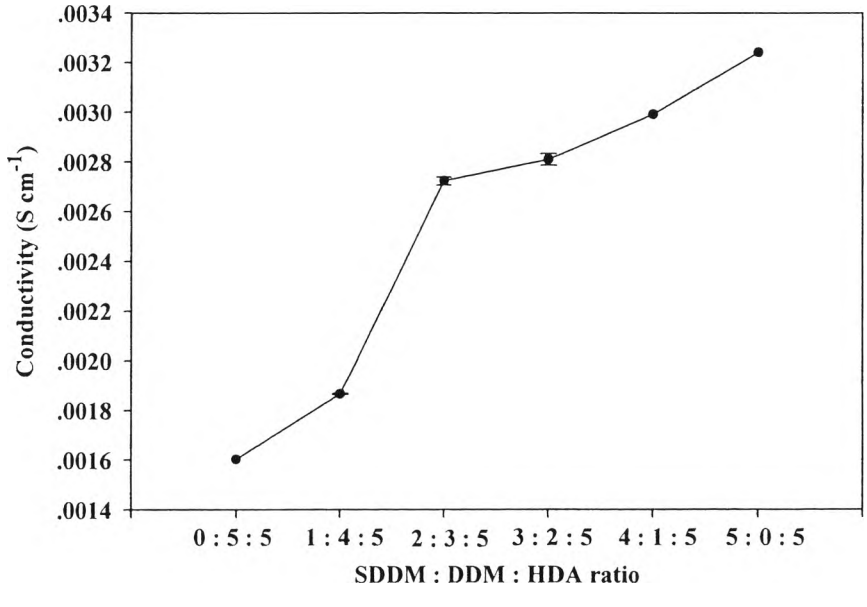


Figure F1 Proton conductivity of sulfonated copolyimide.

Table F2 Proton conductivity raw data of SDH 0 (1) SDDM: DDM: HDA (0:5:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
400000	27.4093	-0.0108	27.4077	-0.2956
600000	27.4021	-0.0162	27.3985	-0.4430
800000	27.3890	-0.0215	27.3826	-0.5898
1000000	27.3740	-0.0269	27.3641	-0.7363
1200000	27.3659	-0.0322	27.3517	-0.8813
1400000	27.3538	-0.0376	27.3345	-1.0272
1600000	27.3456	-0.0428	27.3205	-1.1706
1800000	27.3220	-0.0482	27.2903	-1.3151

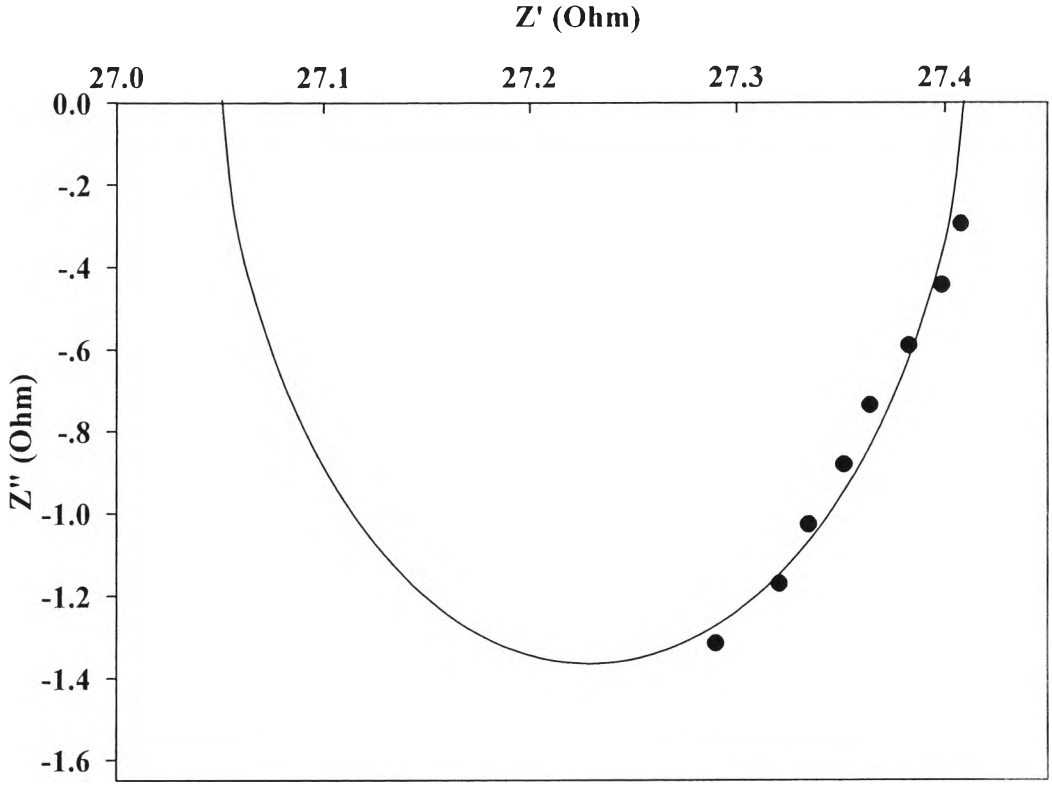


Figure F2 Nyquist plot of SDH 0 (1).

Table F3 Proton conductivity raw data of SDH 0 (2) SDDM: DDM: HDA (0:5:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
400000	27.4057	-0.0108	27.4041	-0.2957
600000	27.3982	-0.0162	27.3946	-0.4431
800000	27.3825	-0.0216	27.3761	-0.5901
1000000	27.3706	-0.0269	27.3607	-0.7362
1200000	27.3640	-0.0322	27.3498	-0.8804
1400000	27.3554	-0.0376	27.3361	-1.0274
1600000	27.3439	-0.0428	27.3188	-1.1709
1800000	27.3223	-0.0481	27.2907	-1.3146

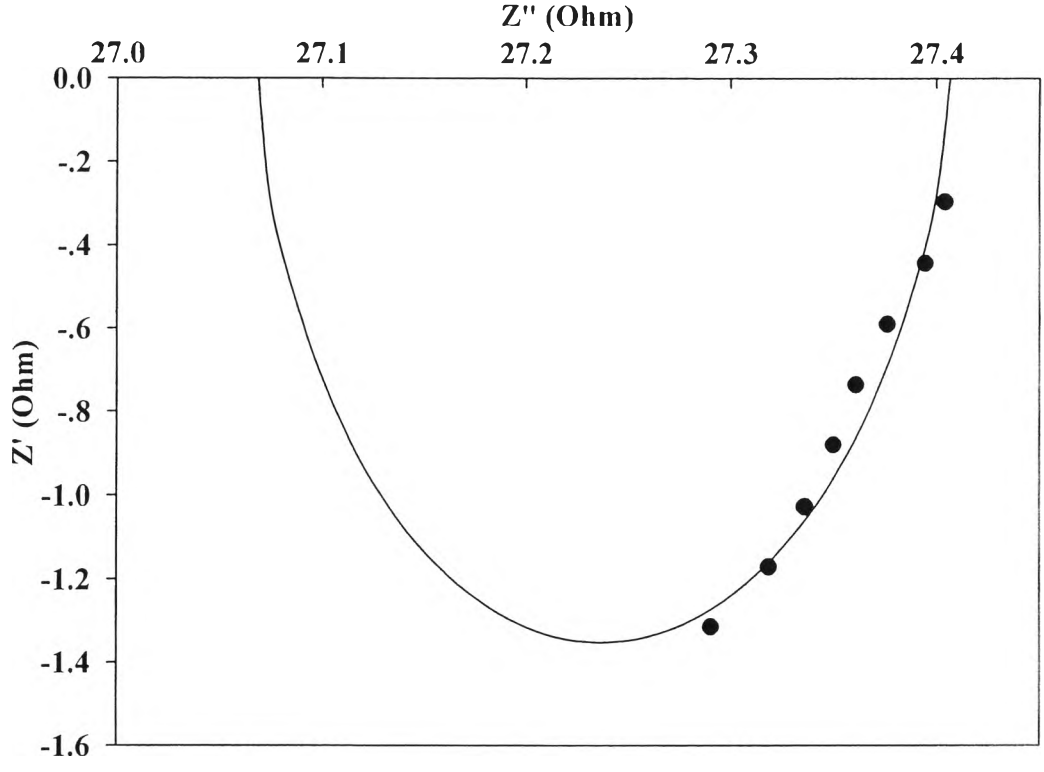


Figure F3 Nyquist plot of SDH 0 (2).

Table F4 Proton conductivity raw data of SDH 1 (1) SDDM: DDM: HDA (1:4:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
1000	23.5529	-0.000070	23.5529	-0.0017
2000	23.5542	-0.000084	23.5542	-0.0020
4000	23.5875	-0.000156	23.5875	-0.0037
6000	23.6098	-0.000224	23.6098	-0.0053
8000	23.6259	-0.000284	23.6259	-0.0067
10000	23.6431	-0.000347	23.6431	-0.0082
20000	23.6578	-0.000625	23.6578	-0.0148
40000	23.6734	-0.0011	23.6734	-0.0255
60000	23.7412	-0.0014	23.7412	-0.0341
80000	23.7550	-0.0018	23.7550	-0.0420
100000	23.7889	-0.0021	23.7888	-0.0495

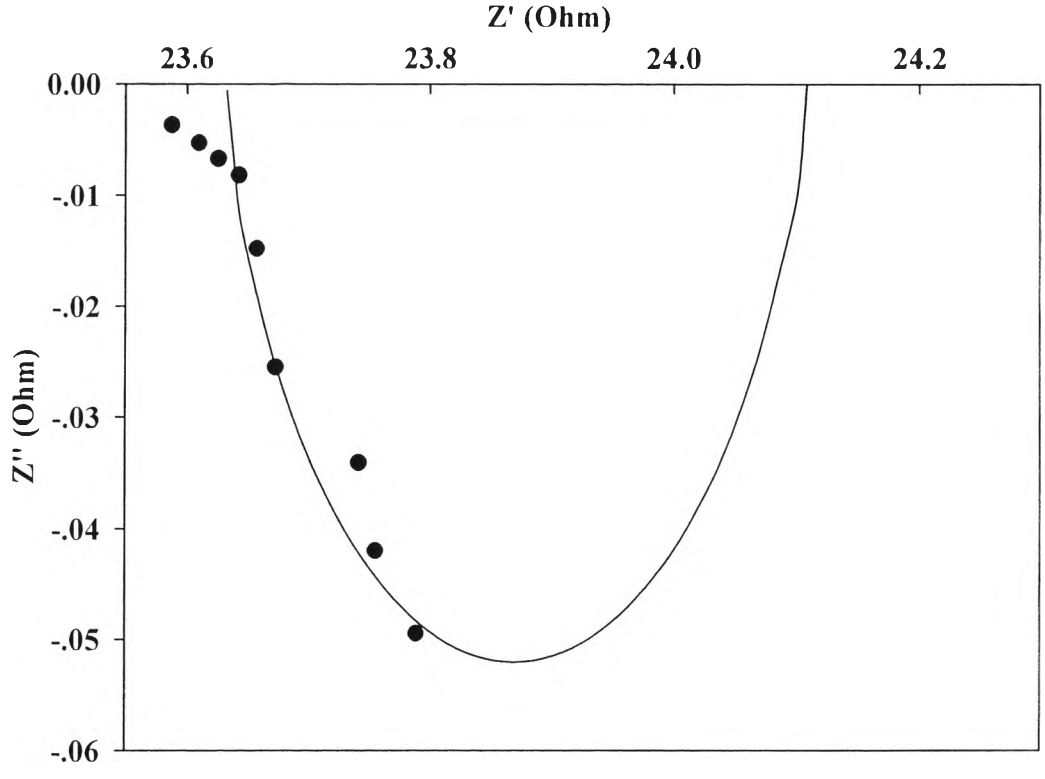


Figure F4 Nyquist plot of SDH 1 (1).

Table F5 Proton conductivity raw data of SDH 1 (2) SDDM: DDM: HDA (1:4:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
8000	23.6094	-0.000286	23.6094	-0.0068
10000	23.6423	-0.000345	23.6423	-0.0082
20000	23.6583	-0.0006	23.6583	-0.0147
40000	23.6717	-0.0011	23.6717	-0.0254
60000	23.7101	-0.0014	23.7101	-0.0342
80000	23.7518	-0.0018	23.7518	-0.0422
100000	23.7589	-0.0020	23.7588	-0.0494

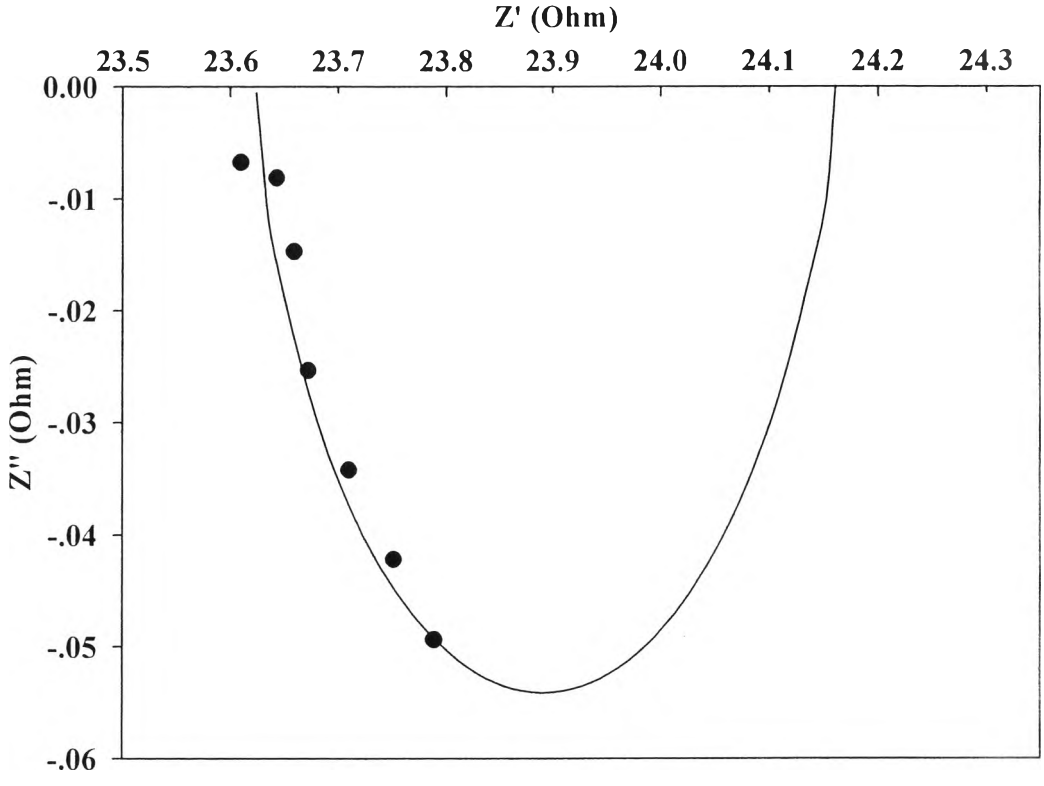


Figure F5 Nyquist plot of SDH 1 (2).

Table F6 Proton conductivity raw data of SDH 2 (1) SDDM: DDM: HDA (2:3:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
200000	6.6341	-0.0068	6.6339	-0.0452
400000	6.6763	-0.0132	6.6757	-0.0886
600000	6.8582	-0.0197	6.8568	-0.1349
800000	6.8645	-0.0261	6.8621	-0.1791
1000000	7.0733	-0.0323	7.0696	-0.2283
1200000	7.0695	-0.0384	7.0643	-0.2712
1400000	7.2388	-0.0444	7.2316	-0.3213
1600000	7.7580	-0.0501	7.7482	-0.3883
1800000	7.4605	-0.0461	7.4526	-0.3442

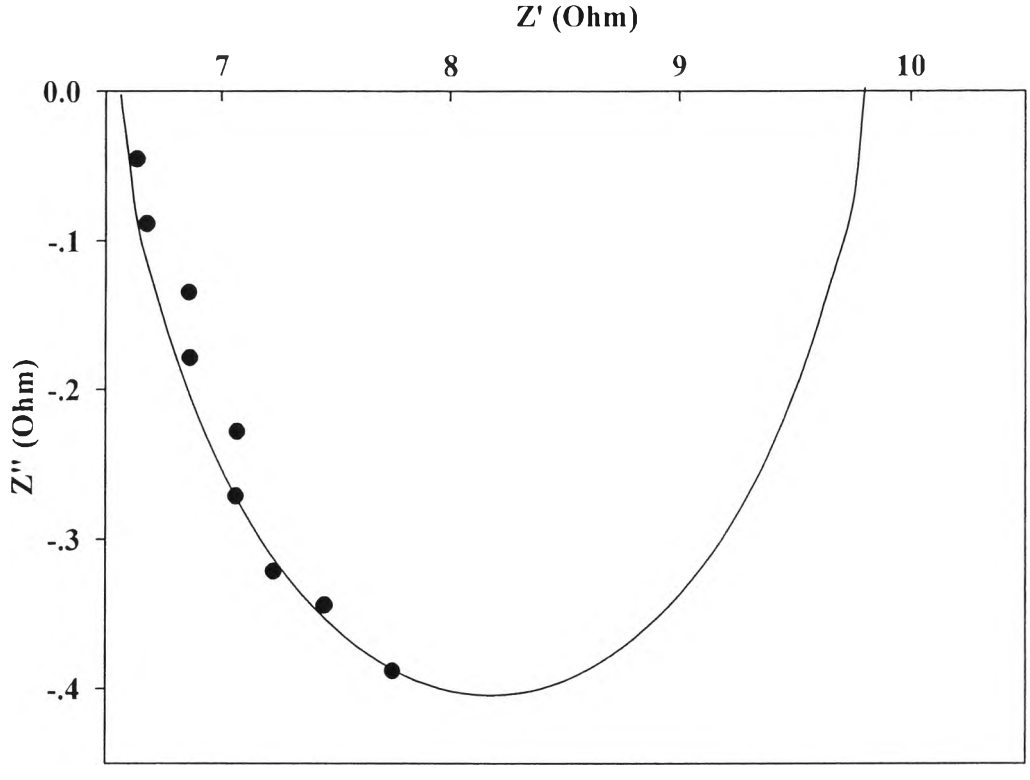


Figure F6 Nyquist plot of SDH 2 (1).

Table F7 Proton conductivity raw data of SDH 2 (2) SDDM: DDM: HDA (2:3:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
200000	6.5734	-0.0068	6.5732	-0.0450
400000	6.6171	-0.0133	6.6165	-0.0878
600000	6.8303	-0.0197	6.8290	-0.1345
800000	6.9262	-0.0260	6.9239	-0.1801
1000000	7.0350	-0.0323	7.0314	-0.2271
1200000	7.0521	-0.0384	7.0469	-0.2709
1400000	7.2252	-0.0445	7.2180	-0.3212
1600000	7.4984	-0.0504	7.4889	-0.3777
1800000	7.8979	-0.0558	7.8856	-0.4408

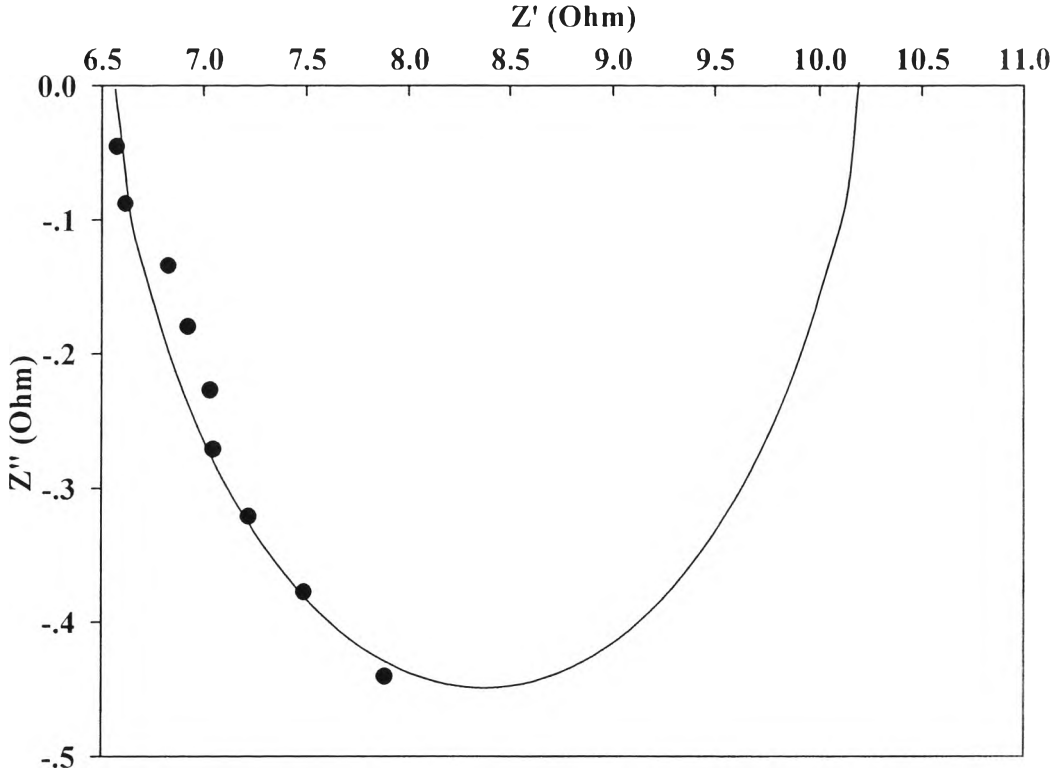


Figure F7 Nyquist plot of SDH 2 (2).

Table F8 Proton conductivity raw data of SDH 3 (1) SDDM: DDM: HDA (3:2:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
80000	16.5991	-0.0094	16.6031	-0.0094
100000	16.4279	-0.0105	16.4252	-0.0105
600000	16.0569	-0.0258	16.1154	-0.0261
800000	15.8918	-0.0314	15.8358	-0.0312
1000000	15.6266	-0.0353	15.6221	-0.0353
1200000	15.1391	-0.0375	15.1719	-0.0377
1400000	15.1302	-0.0412	15.1386	-0.0413
1800000	14.9437	-0.0451	14.4988	-0.0426

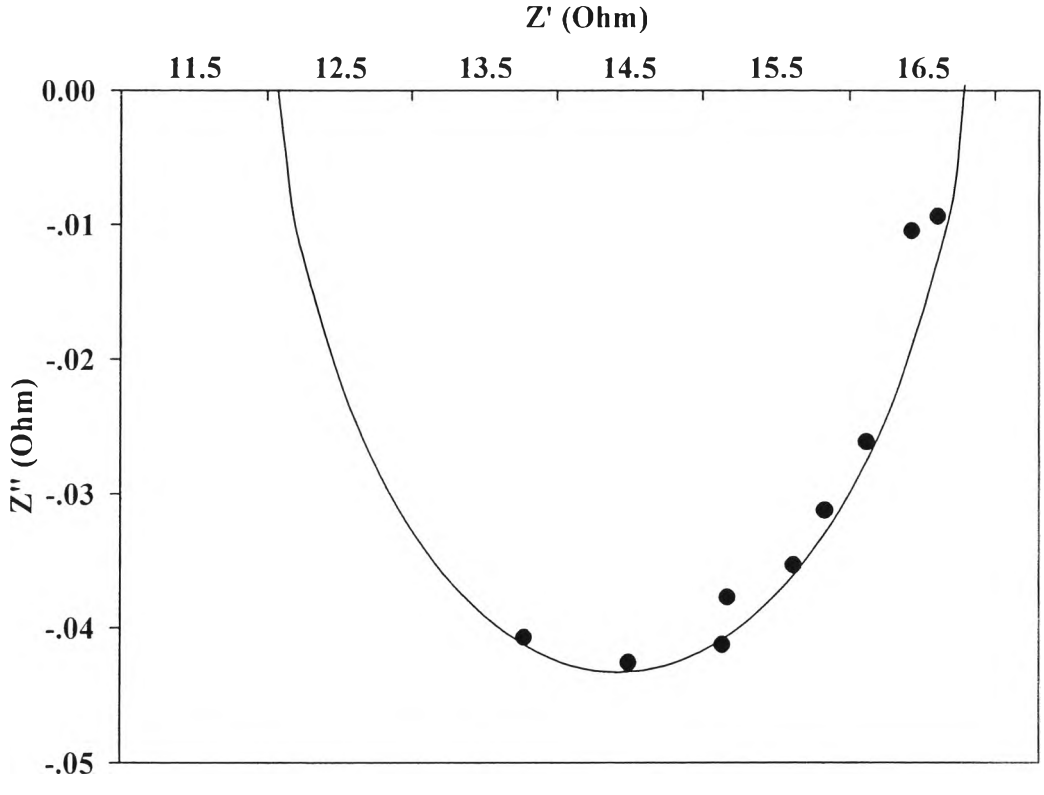


Figure F8 Nyquist plot of SDH 3 (1).

Table F9 Proton conductivity raw data of SDH 3 (2) SDDM: DDM: HDA (3:2:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
80000	16.5991	-0.0005	16.5991	-0.0094
100000	16.4279	-0.0006	16.4279	-0.0105
600000	16.0569	-0.0016	16.0568	-0.0258
800000	15.8918	-0.0020	15.8917	-0.0314
1000000	15.6266	-0.0022	15.6266	-0.0353
1400000	15.1303	-0.0027	15.1302	-0.0412
1600000	14.9438	-0.0030	14.9437	-0.0451

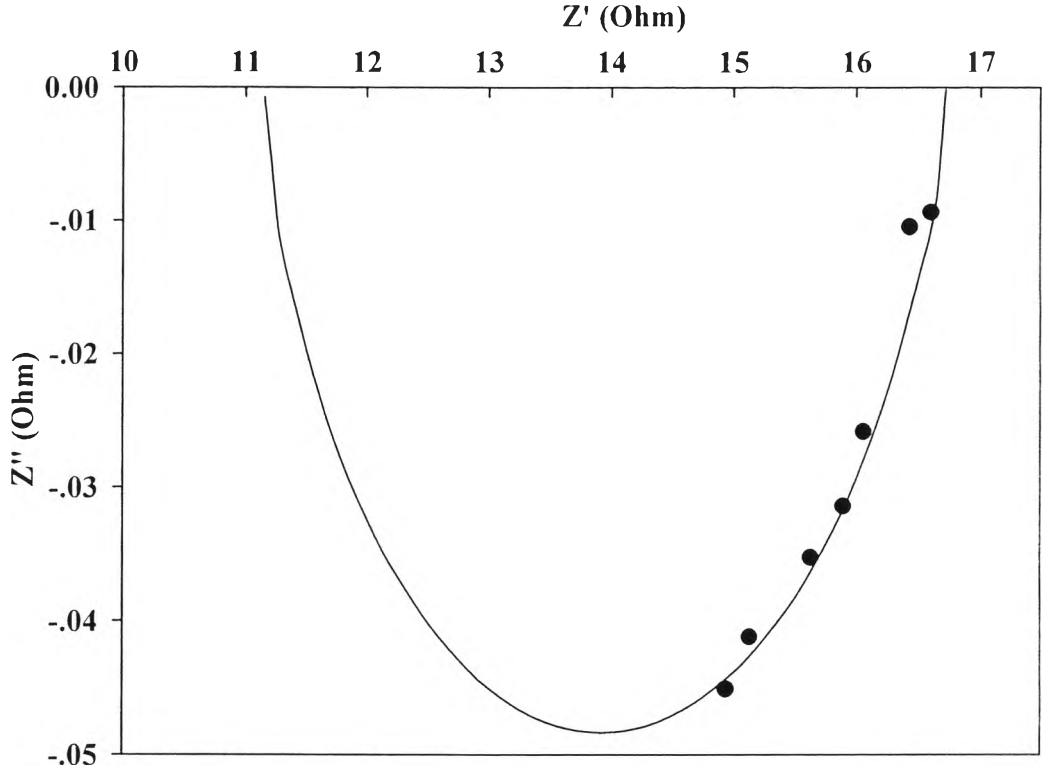


Figure F9 Nyquist plot of SDH 3 (2).

Table F10 Proton conductivity raw data of SDH 4 (1) SDDM: DDM: HDA (4:1:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
40	11.5126	0.000134	11.5126	0.0016
60	11.2351	0.000122	11.2351	0.0014
80	10.8804	0.000098	10.8804	0.0011
100	10.7383	0.000084	10.7383	0.0009
200	10.4734	0.000058	10.4734	0.0006
400	10.3447	0.000027	10.3447	0.0003
600	10.3017	0.000028	10.3017	0.0003

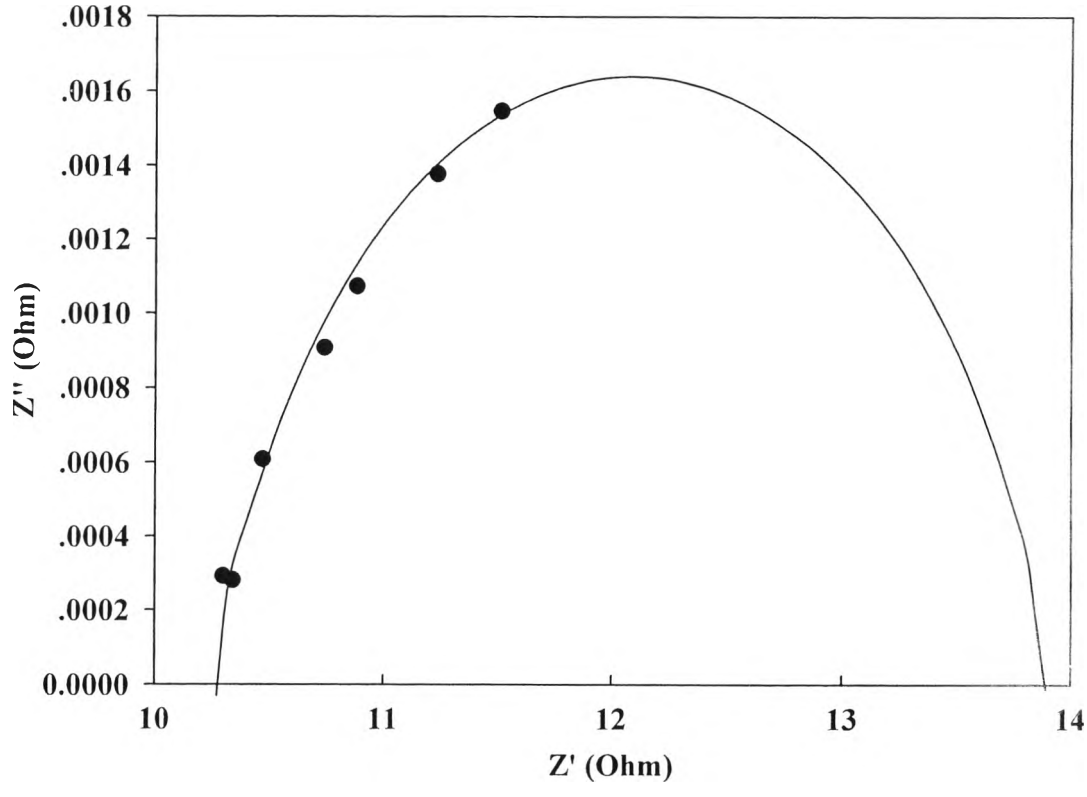


Figure F10 Nyquist plot of SDH 4 (1).

Table F11 Proton conductivity raw data of SDH 4 (2) SDDM: DDM: HDA (4:1:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
60	11.1399	0.000123	11.1399	0.001371
80	10.8079	0.000105	10.8079	0.001135
100	10.6268	0.000088	10.6268	0.000936
200	10.4462	0.000062	10.4462	0.000648
400	10.3314	0.000026	10.3314	0.000264
600	10.2364	0.000034	10.2364	0.000351
800	9.95371	0.000014	9.9537	0.000137

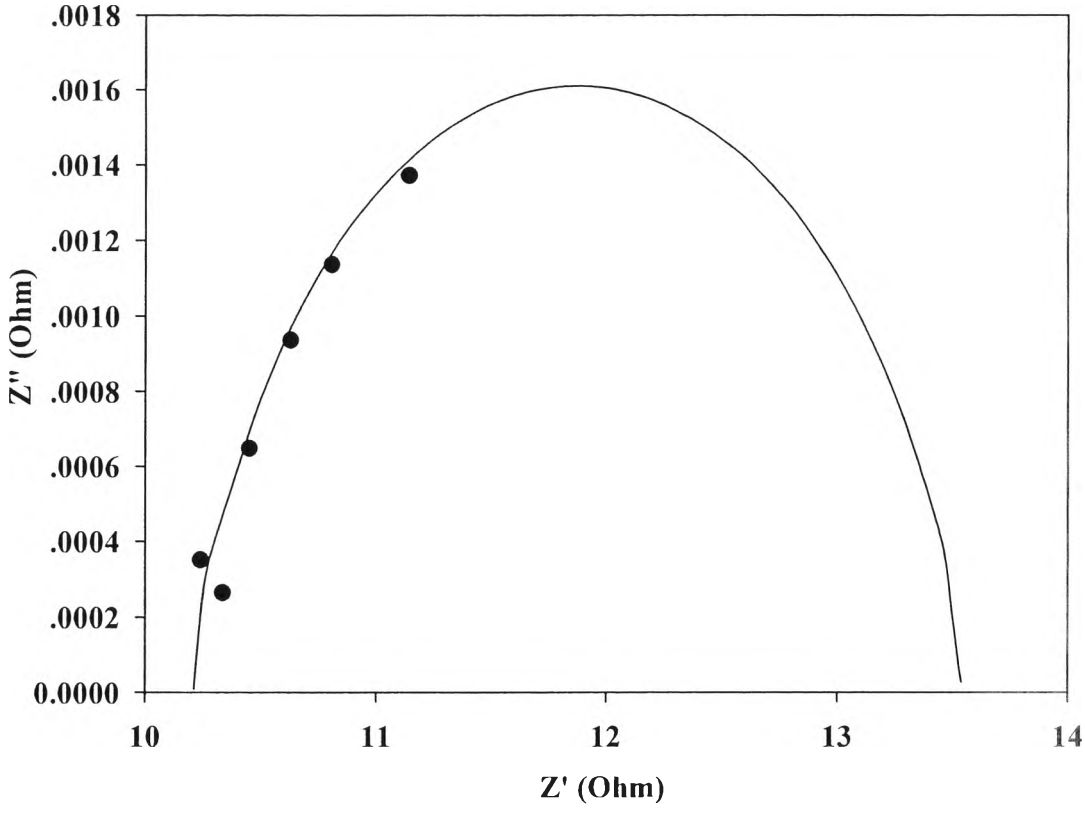


Figure F11 Nyquist plot of SDH 4 (2).

Table F12 Proton conductivity raw data of SDH 5 (1) SDDM: DDM: HDA (5:0:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
100000	18.7428	-0.003399	18.7426	-0.0637
200000	18.6756	-0.006761	18.6752	-0.1263
600000	18.4218	-0.019358	18.4184	-0.3566
800000	18.4057	-0.025534	18.3997	-0.4699
1000000	18.3340	-0.031588	18.3248	-0.5790
1200000	18.3030	-0.037678	18.2900	-0.6895
1400000	18.3119	-0.043911	18.2942	-0.8038
1600000	18.2959	-0.050088	18.2730	-0.9160
1800000	18.1896	-0.056338	18.1607	-1.0242
2000000	18.0945	-0.062527	18.0591	-1.1307

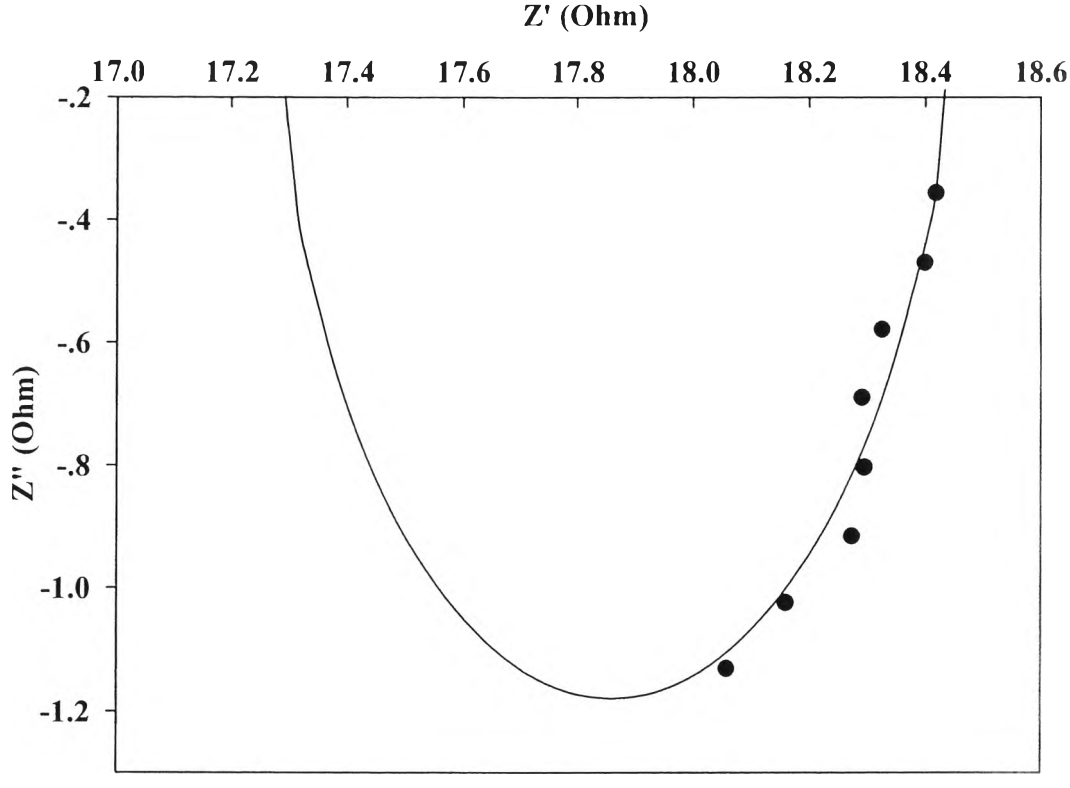


Figure F12 Nyquist plot of SDH 5 (1).

Table F13 Proton conductivity raw data of SDH 5 (2) SDDM: DDM: HDA (5:0:5)

Frequency (Hz)	Z (Ohm)	r (Radius)	Z'=Zcos r (Ohm)	Z''=Zsin r (Ohm)
100000	18.4920	-0.0067	18.4314	-0.2418
200000	18.4141	-0.0131	18.4235	-0.3569
400000	18.4139	-0.0193	18.3696	-0.4690
600000	18.3720	-0.0255	18.3051	-0.5783
800000	18.2992	-0.0315	18.3033	-0.6900
1000000	18.3360	-0.0376	18.2924	-0.8040
1200000	18.3039	-0.0439	18.2786	-0.9164
1400000	18.3025	-0.0500	18.1529	-1.0239
1600000	18.1184	-0.0562	18.0111	-1.1268
1800000	18.0290	-0.0624	17.9803	-1.1245

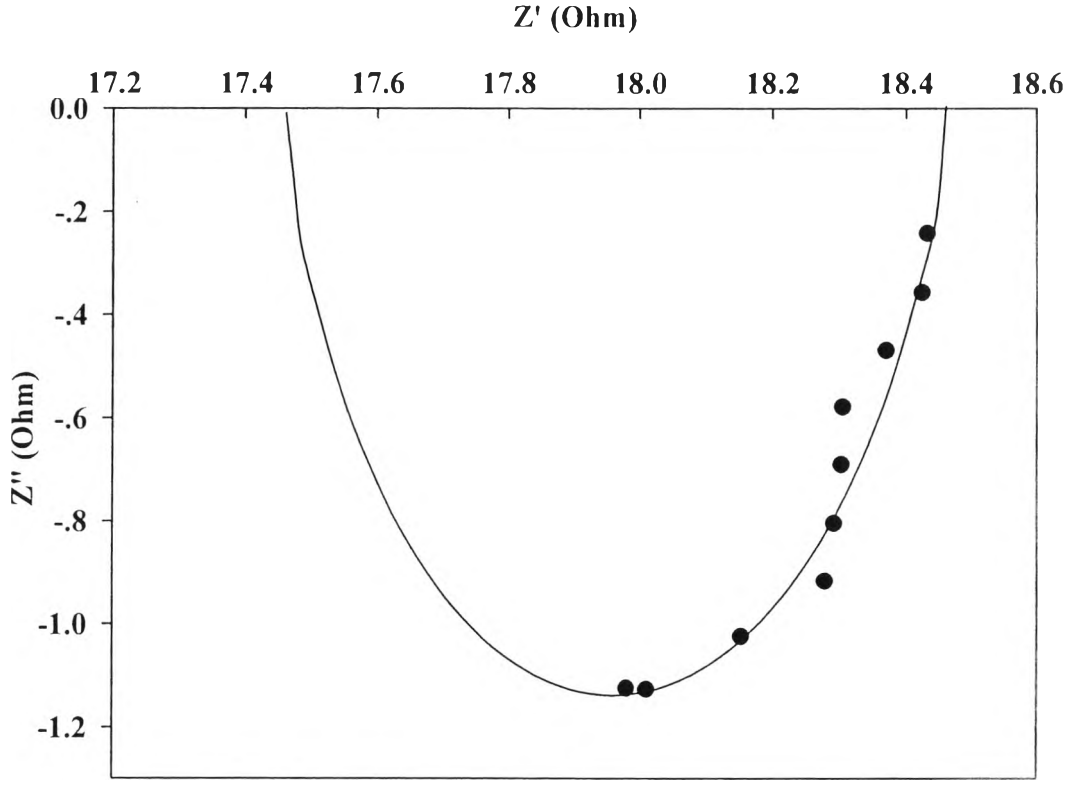


Figure F13 Nyquist plot of SDH 5 (2).

Appendix G Methanol permeability

The methanol permeability through the membrane was determined by a liquid permeation cell where the concentration of methanol that permeates the cell at 60 °C was measured. The liquid permeation cell is composed of two components. A compartment A contained methanol at 2.5 M 250 ml and a compartment B contained DI water 250 ml. The methanol concentration was determined using the gas chromatography. The methanol permeability coefficient was calculated from the following equation:

$$P\ (cm^2/s) = \frac{K_B V_B L}{A(C_A - C_B)} \qquad (G1)$$

where P = the methanol permeability

C_A = the methanol concentrations in the compartment A

K_B= the methanol concentration permeate per time of permeate (the slope of methanol concentration profile in the compartment B)

V_B = the solution volume of the permeate

L = the thickness of the membrane

A = the effective area of membrane

The methanol concentration profile was obtained by using a PR2100 gas chromatography fitted with a Thermal Conductivity Detector (TCD); 2.5 M of ethanol was used as the internal standard (Zhai *et al.*, 2007).

Table G1 Methanol permeability of the sulfonated polyimide membrane and Nafion®117 membrane at 60 °C

Sample	Ratio	Methanol permeability (cm^2/s)
SDH 0	0:5:5	1.5654×10^{-9}
SDH 1	1:4:5	1.6012×10^{-9}
SDH 2	2:3:5	1.6516×10^{-9}
SDH 3	3:2:5	1.7478×10^{-9}
SDH 4	4:1:5	1.0839×10^{-8}
SDH 5	5:0:5	2.7482×10^{-8}
Nafion®117	-	1.7400×10^{-6}

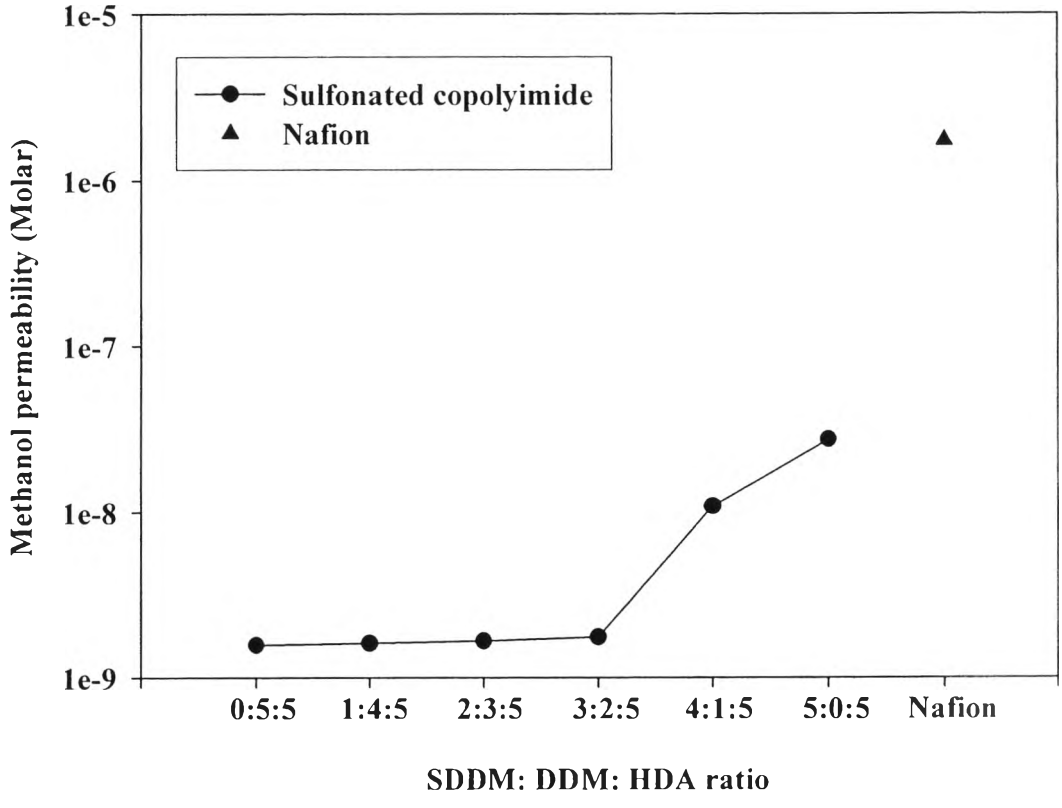


Figure G1 The methanol permeability of sulfonated copolyimide.

Table G2 Raw data of internal standard curve of methanol concentration

MeOH Concentration	Peak area of MeOH		Peak area of EtOH		Peak area ratio	
	No.1	No.2	No.1	No.2	No.1	No.2
0 M	0	0	1125.37	1178.84	0	0
0.1 M	32.06	21.49	1266.55	877.48	0.0253	0.0244
1.0 M	393.37	229.61	1535.81	806.50	0.2561	0.2846
1.5 M	647.14	470.07	1687.83	1082.86	0.3834	0.4341
2.0 M	750.88	530.89	1466.95	928.00	0.5118	0.5720
3.0 M	1109.34	569.73	1419.76	654.04	0.7813	0.8710

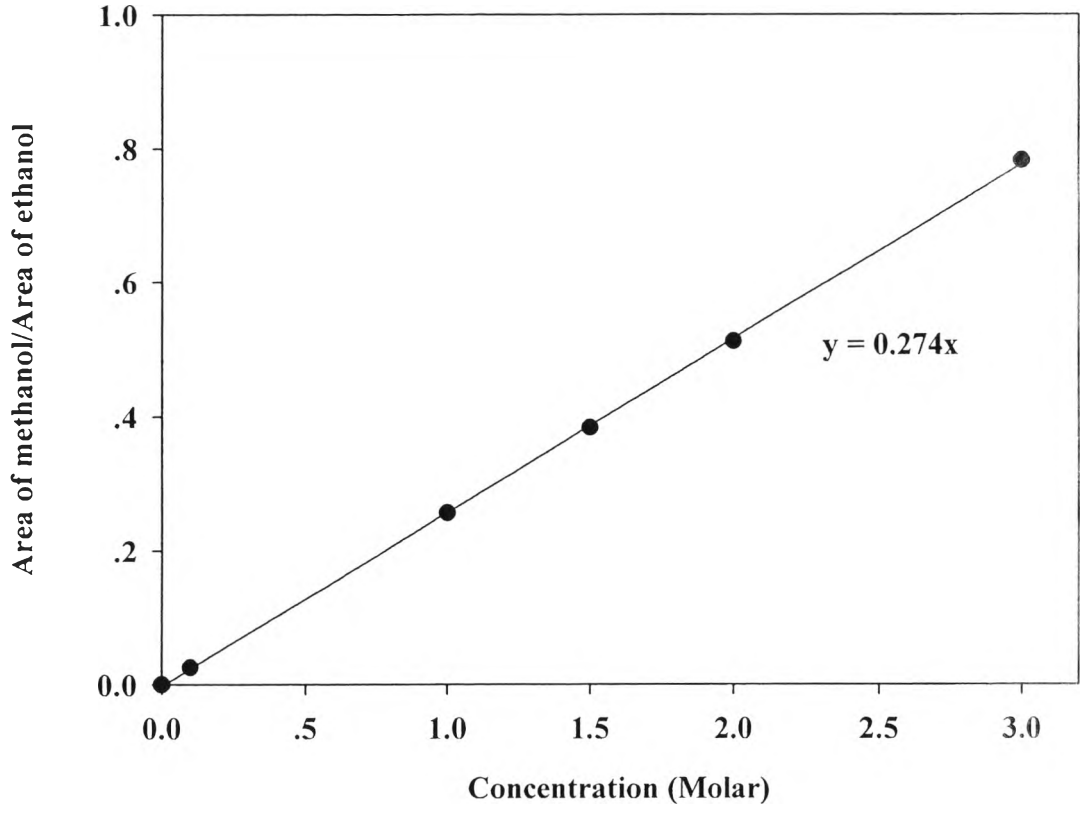


Figure G2 Internal standard curve of methanol concentration.

Table G3 Raw data of methanol permeability calculation of SDH 0

SDDM: DDM: HDA (0: 5: 5)

No.1 Thickness 0.156 mm		
Time	**MeOH concentration (M)**	
(second)	**Comp. A**	**Comp. B**
682200	2.4802	0.0066
702000	2.4401	0.0073
720000	2.4159	0.0079
770400	2.4083	0.0107
784800	2.3539	0.0112
806400	2.3673	0.0122
856800	2.3179	0.0153

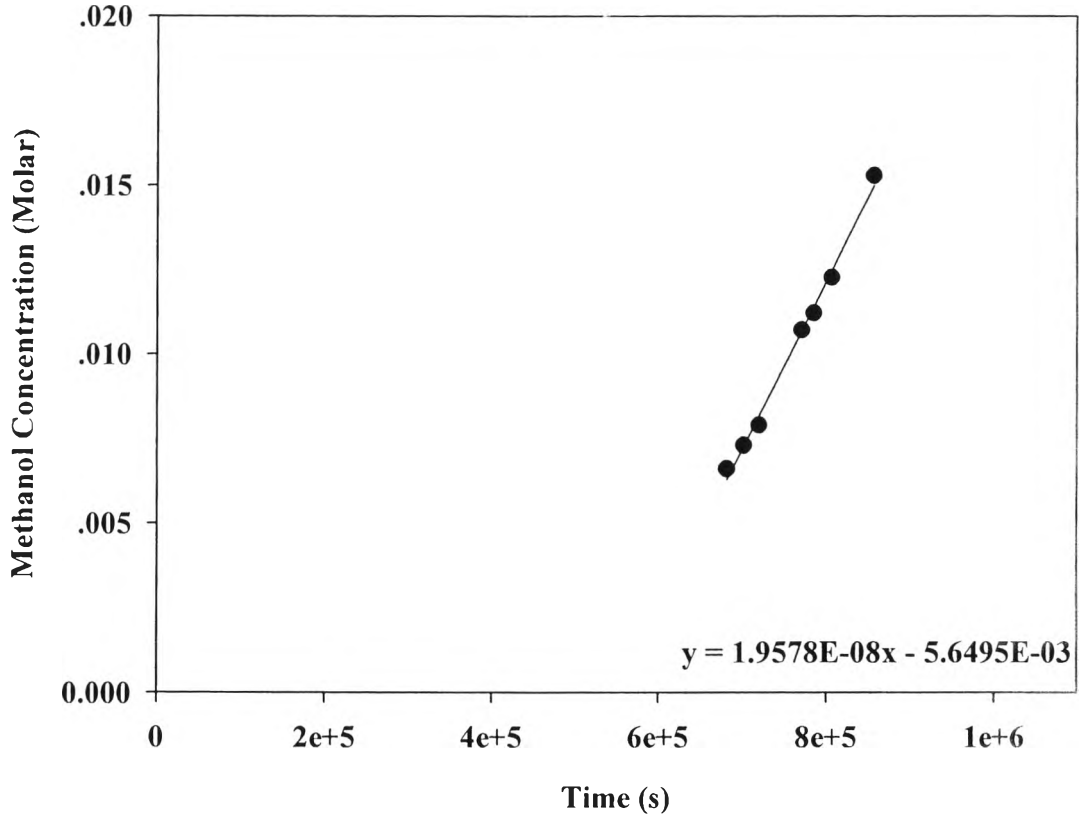


Figure G3 Methanol concentration (Molar) in compartment B vs. time (s) of SDH 0.

Table G4 Raw data of methanol permeability calculation of SDH 1 SDDM: DDM: HDA (1: 4: 5)

No.1 Thickness 0.203 mm		
Time (second)	**MeOH concentration (M)**	
	Comp. A	**Comp. B**
54000	2.5010	0.0016
140400	2.4993	0.0028
162000	2.4935	0.0032
183600	2.4735	0.0034
226800	2.4430	0.0042
248400	2.3439	0.0045
270000	2.2335	0.0049
313200	2.2149	0.0055
334800	2.2039	0.0059
356400	2.1949	0.0063
399600	2.1796	0.0069

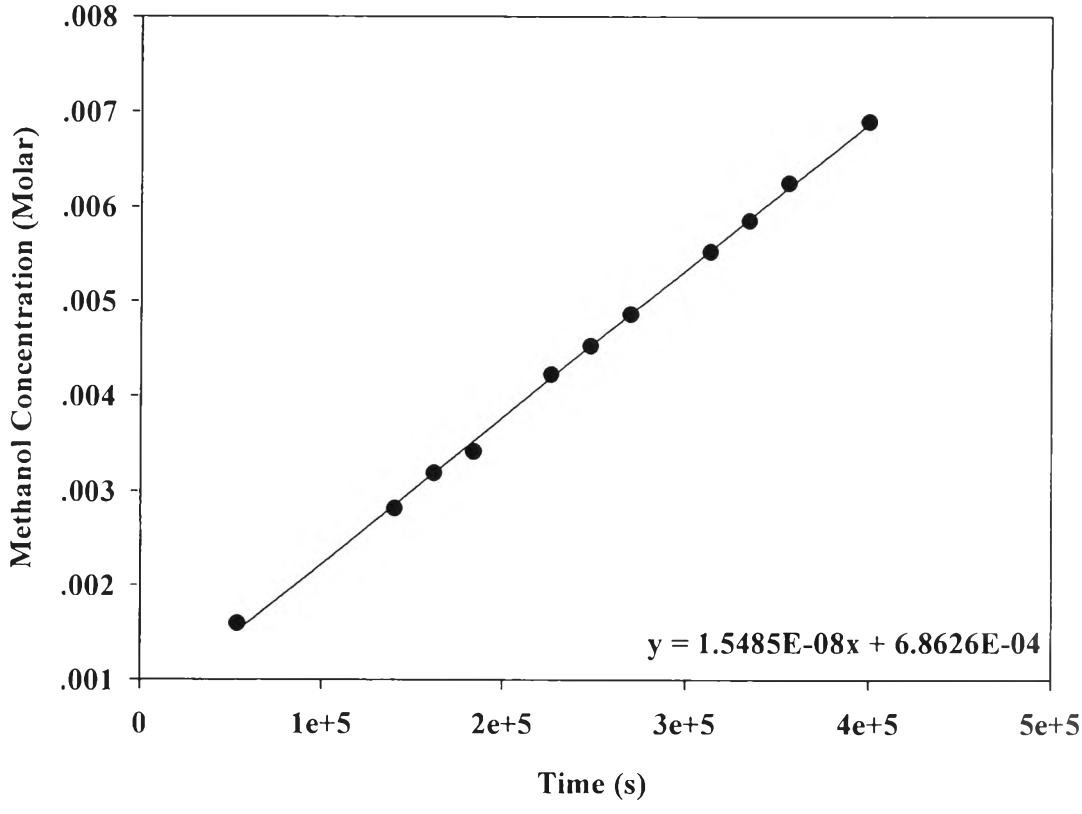


Figure G4 Methanol concentration (Molar) in compartment B vs. time (s) of SDH 1.

Table G4 Raw data of methanol permeability calculation of SDH 2 SDDM:DDM:HDA (2: 3: 5)

No.1 Thickness 0.438 mm		
Time (second)	**MeOH concentration (M)**	
	Comp. A	**Comp. B**
54000	2.5127	0.0010
140400	2.5166	0.0027
162000	2.4965	0.0032
183600	2.3766	0.0036
226800	2.3635	0.0044
248400	2.2339	0.0049
270000	2.2267	0.0054
313200	2.2330	0.0061
334800	2.2402	0.0066
356400	2.2090	0.0071
399600	2.1783	0.0078

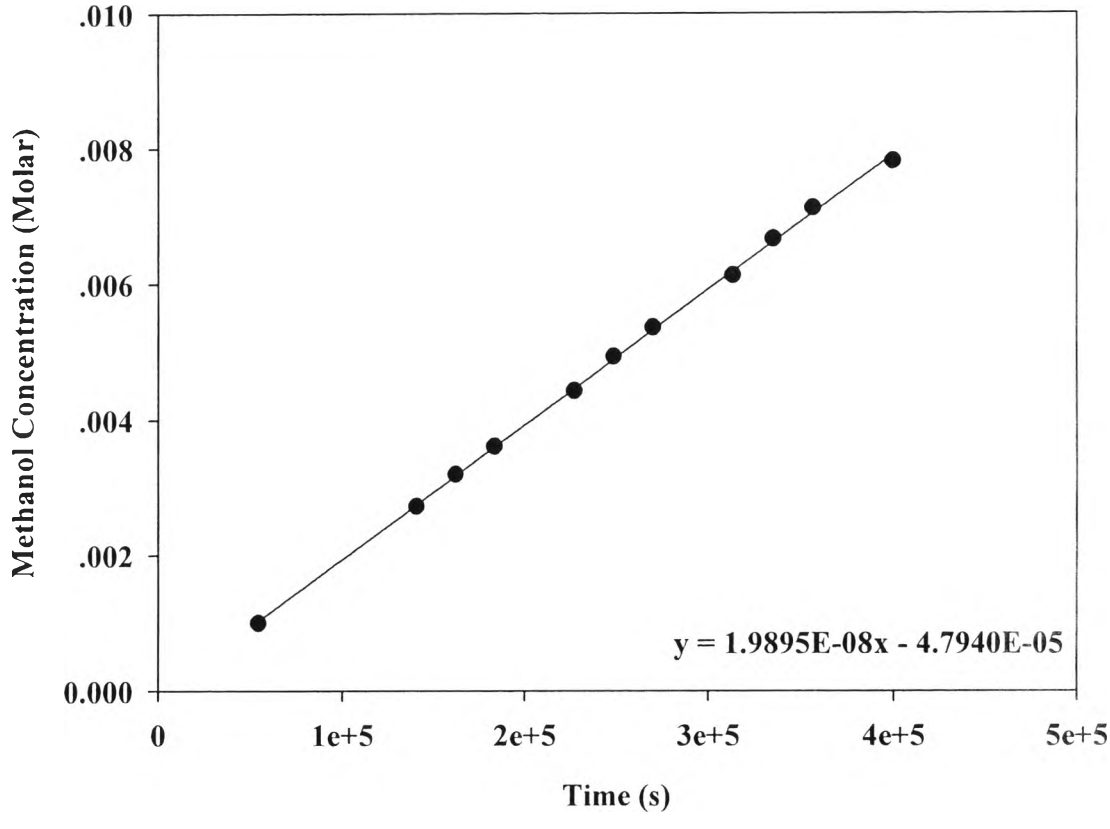


Figure G5 Methanol concentration (Molar) in compartment B vs. time (s) of SDH 2.

Table G5 Raw data of methanol permeability calculation of SDH 3 SDDM:DDM:HDA (3: 2: 5)

No.1 Thickness 0.231 mm		
Time (second)	**MeOH concentration (M)**	
	Comp. A	**Comp. B**
356400	2.5006	0.0044
399600	2.4945	0.0051
421200	2.4571	0.0052
442800	2.4476	0.0055
486000	2.4467	0.0063
507600	2.4051	0.0068
529200	2.4156	0.0071
572400	2.4035	0.0077
594000	2.3883	0.0079
615600	2.3764	0.0083
658800	2.3676	0.0087

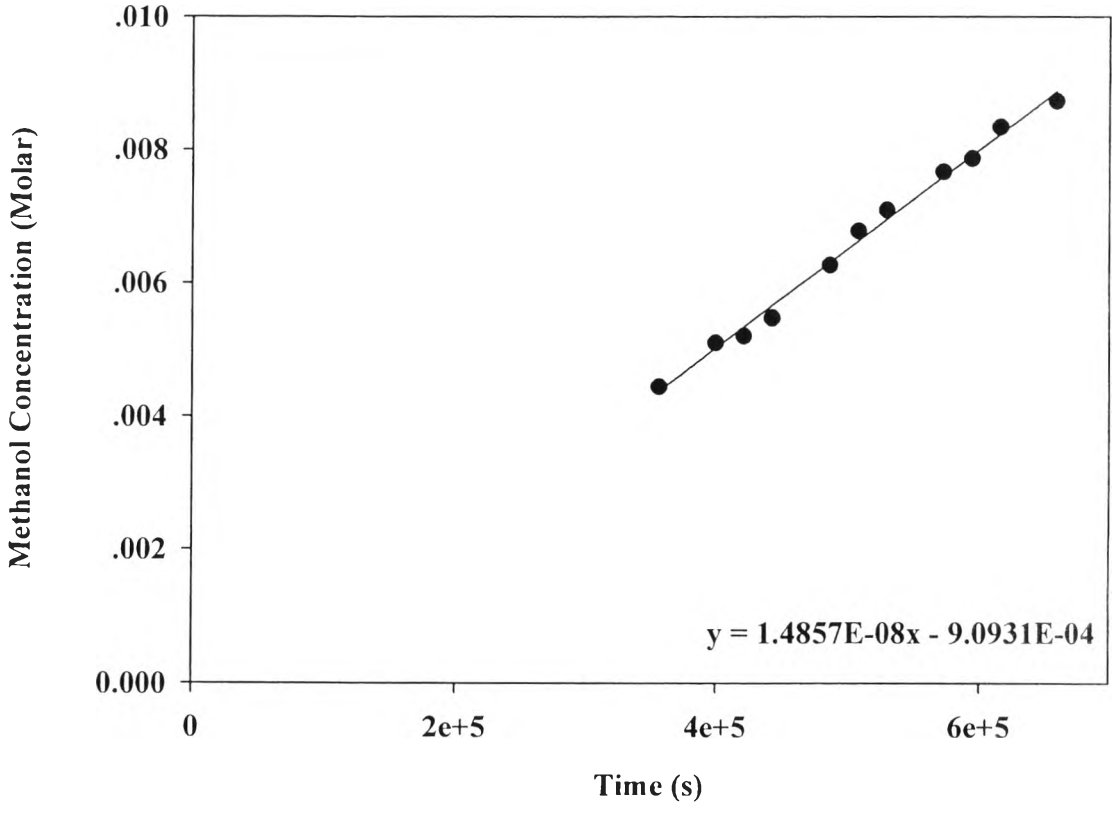


Figure G6 Methanol concentration (molar) in compartment B vs. time (s) of SDH 3.

Table G6 Raw data of methanol permeability calculation of SDH 4 SDDM: DDM: HDA (4:1:5)

No.1 Thickness 0.179 mm		
Time	**MeOH concentration (M)**	
(second)	**Comp. A**	**Comp. B**
302400	2.5874	0.0086
316800	2.5053	0.0100
324000	2.5086	0.0098
331812	2.5079	0.0107
346032	2.4973	0.0108
389088	2.4266	0.0139
411012	2.4262	0.0160
475200	2.4259	0.0207
496800	2.4184	0.0234
518400	2.3975	0.0256

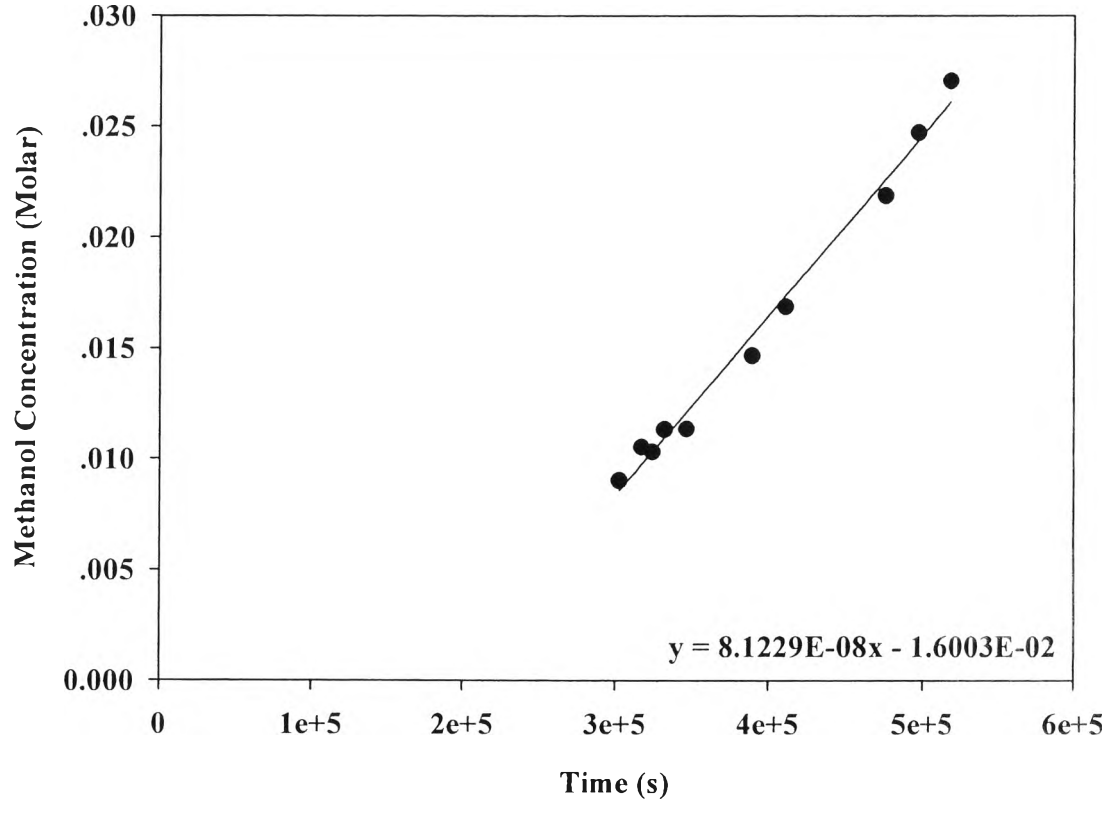


Figure G7 Methanol concentration (M) in compartment B vs. time (s) of SDH 4.

Table G7 Raw data of methanol permeability calculation of SDH 5 SDDM: DDM: HDA (5:0:5)

No.1 Thickness 0.209 mm		
Time	**MeOH concentration (M)**	
(second)	**Comp. A**	**Comp. B**
190800	2.8147	0.0094
234000	2.7926	0.0191
277200	2.7646	0.0250
320400	2.7496	0.0482
342000	2.7487	0.0526
363600	2.7385	0.0574
428400	2.7284	0.0758
493200	2.7195	0.094
536400	2.7073	0.1027
622800	2.6965	0.1166
666000	2.6853	0.1301

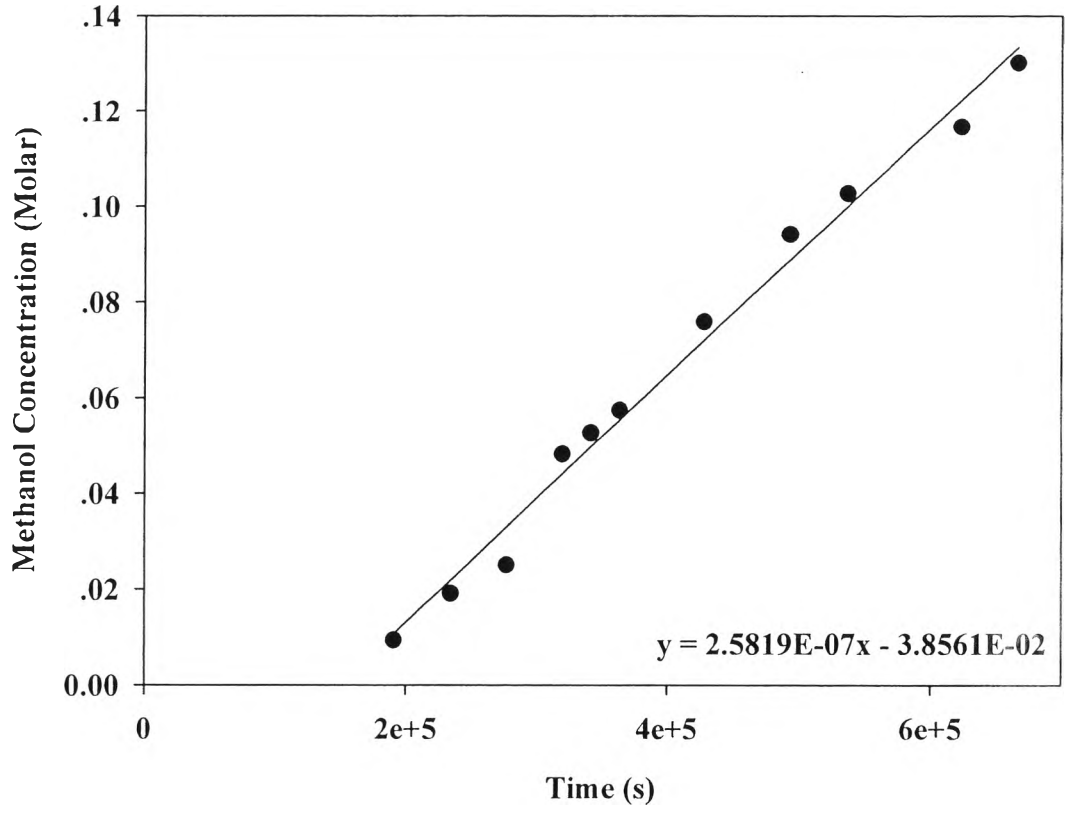


Figure G8 Methanol concentration (M) in compartment B vs. time (s) of SDH 5.

Table G8 Raw data of methanol permeability calculation of Nafion®

No.1 Thickness 0.209 mm		
Time (second)	**MeOH concentration (M)**	
	Comp. A	**Comp. B**
0	2.5028	0
7200	2.4293	0.0282
10800	2.3868	0.0430
18000	2.3007	0.0707
21600	2.3619	0.0887
25200	2.2070	0.1023
70200	2.1946	0.2992
86400	2.1774	0.3403

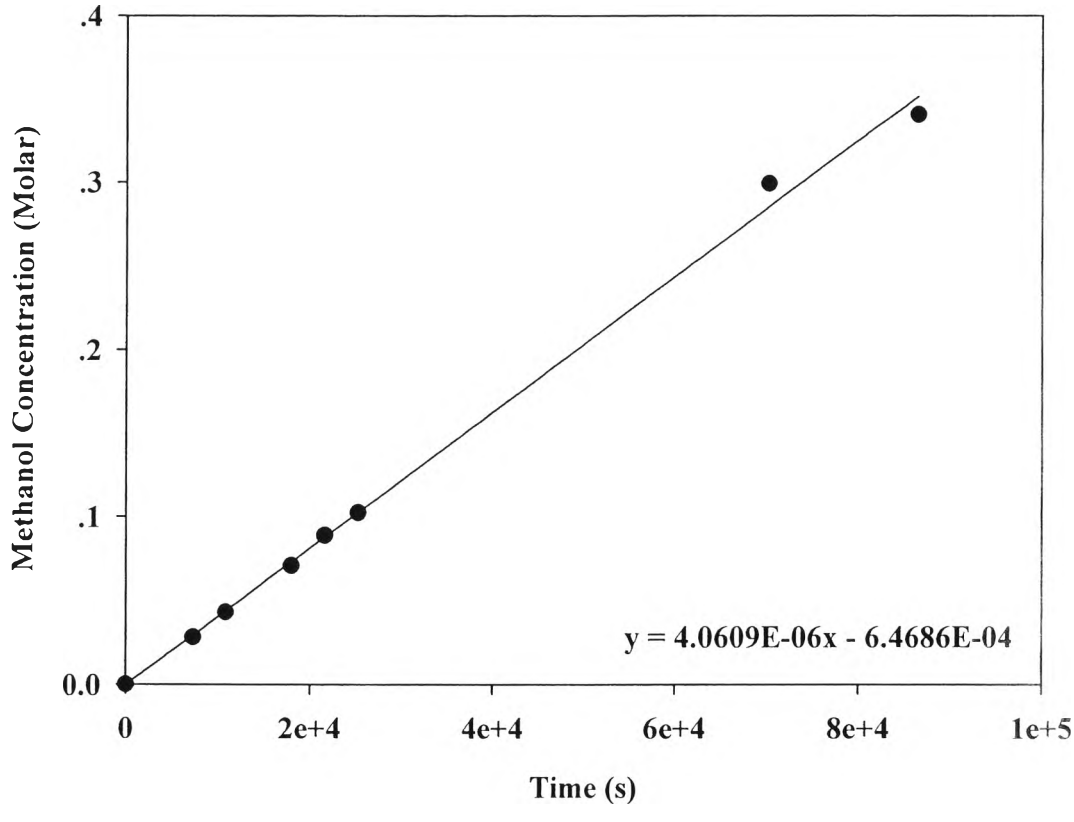
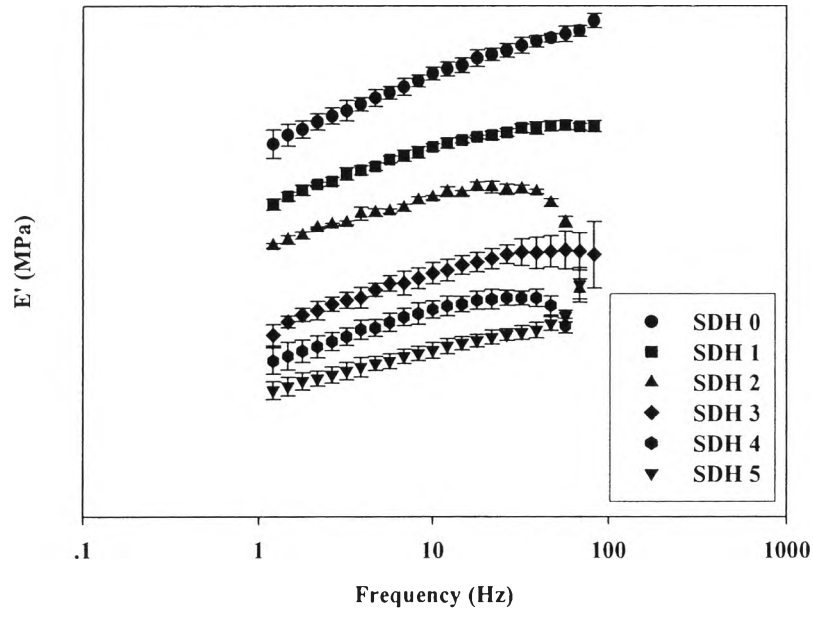


Figure G9 Methanol concentration (M) in compartment B vs. time (s) of Nafion®

Appendix H Dynamic Mechanical Analysis

The mechanical properties of the copolyimide membranes were measured by DMA (EPLEXOR® 100N GABO qualimeter) from 1 Hz to 100 Hz at 30 °C and 60 °C. The membrane at least three samples were measured. The membranes were cut into pieces with 10 mm width for the measurement (Sultan *et al.*, 2011).

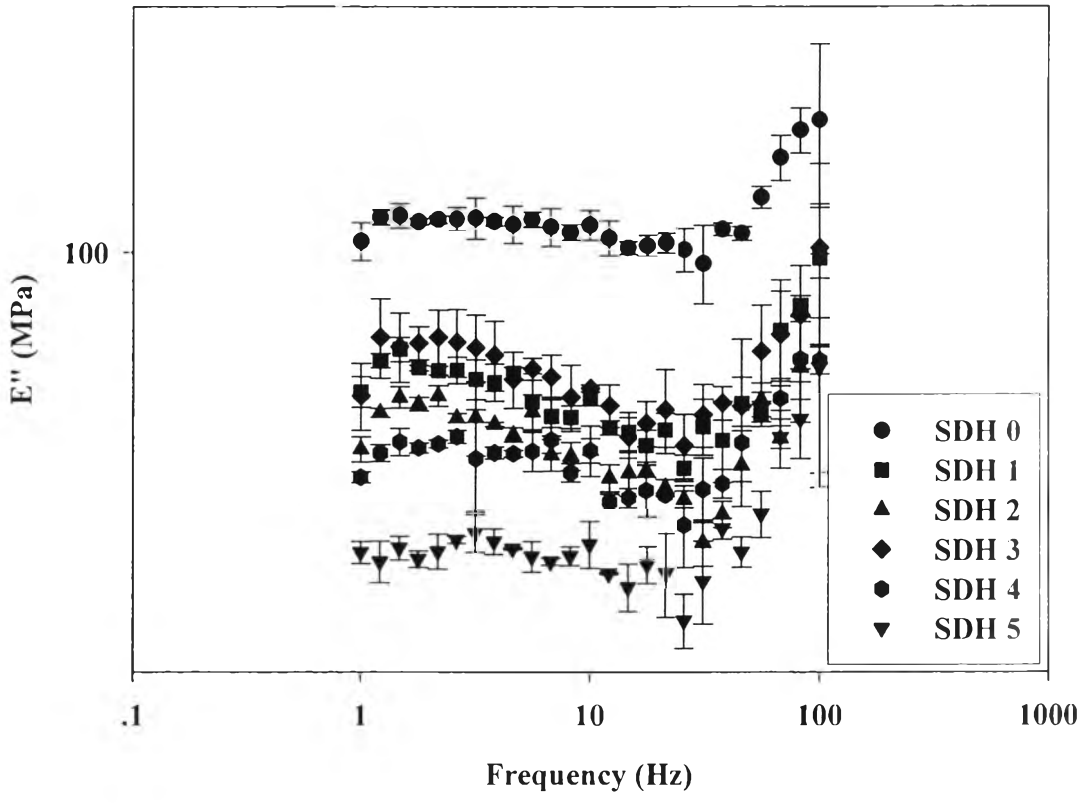


SDH 0 = SDDM: DDM: HDA (0:5:5) SDH 1 = SDDM: DDM: HDA (1:4:5)

SDH 2 = SDDM: DDM: HDA (2:3:5) SDH 3 = SDDM: DDM: HDA (3:2:5)

SDH 4 = SDDM: DDM: HDA (4:1:5) SDH 5 = SDDM: DDM: HDA (5:0:5)

Figure H1 Comparison of storage modulus (E') of sulfonated copolyimide under various frequency at 30 °C.



SDH 0 = SDDM: DDM: HDA (0:5:5) SDH 1 = SDDM: DDM: HDA (1:4:5)

SDH 2 = SDDM: DDM: HDA (2:3:5) SDH 3 = SDDM: DDM: HDA (3:2:5)

SDH 4 = SDDM: DDM: HDA (4:1:5) SDH 5 = SDDM: DDM: HDA (5:0:5)

Figure H2 Comparison of loss modulus (E'') of sulfonated copolyimide under various Frequency at 30 °C.

Table H1 E' of sulfonated copolyimide SDH 0 at 30 °C and 60 °C

Frequency	E' (MPa) at 30 °C			E' (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	3077.02	3117.11	3132.23	2608.87	2724.67	2758.58
1.21	3165.71	3201.46	3225.88	2638.33	2747.52	2785.02
1.47	3194.28	3214.61	3240.44	2653.32	2764.45	2800.69
1.78	3211.02	3225.92	3247.10	2673.71	2784.42	2813.02
2.15	3228.74	3241.13	3262.61	2693.66	2794.71	2833.46
2.61	3241.34	3253.40	3275.88	2711.62	2809.43	2844.12
3.16	3246.65	3267.17	3290.35	2727.63	2818.98	2864.25
3.83	3267.95	3280.31	3296.74	2744.01	2832.11	2871.76
4.64	3277.70	3294.66	3313.90	2757.10	2848.80	2886.38
5.62	3291.47	3307.73	3319.26	2774.39	2865.77	2901.64
6.81	3300.71	3319.30	3337.42	2777.68	2879.10	2910.87
8.25	3319.84	3331.01	3345.55	2797.91	2890.88	2923.15
10.00	3334.08	3349.02	3361.21	2817.91	2907.21	2940.38
12.12	3344.52	3355.03	3375.26	2825.85	2914.87	2948.35
14.68	3354.20	3359.81	3384.67	2845.63	2932.10	2963.81
17.78	3365.12	3378.70	3401.70	2854.65	2941.08	2967.87
21.54	3376.21	3390.91	3403.63	2869.39	2957.47	2986.79
26.10	3385.17	3396.48	3415.61	2881.65	2970.79	3004.39
31.62	3392.64	3408.95	3428.57	2888.55	2974.33	3010.45
38.31	3408.64	3415.66	3434.29	2904.88	2988.09	3015.00
46.42	3422.68	3419.96	3438.38	2911.82	2992.06	3026.49
56.23	3419.41	3434.28	3454.67	2931.21	2991.08	3026.03
68.13	3439.13	3432.79	3457.17	2934.67	3031.38	3042.74
82.54	3454.48	3459.63	3484.78	2940.02	3022.56	3043.90
100.00	3442.50	3485.74	3465.10	2964.34	3018.08	3070.60

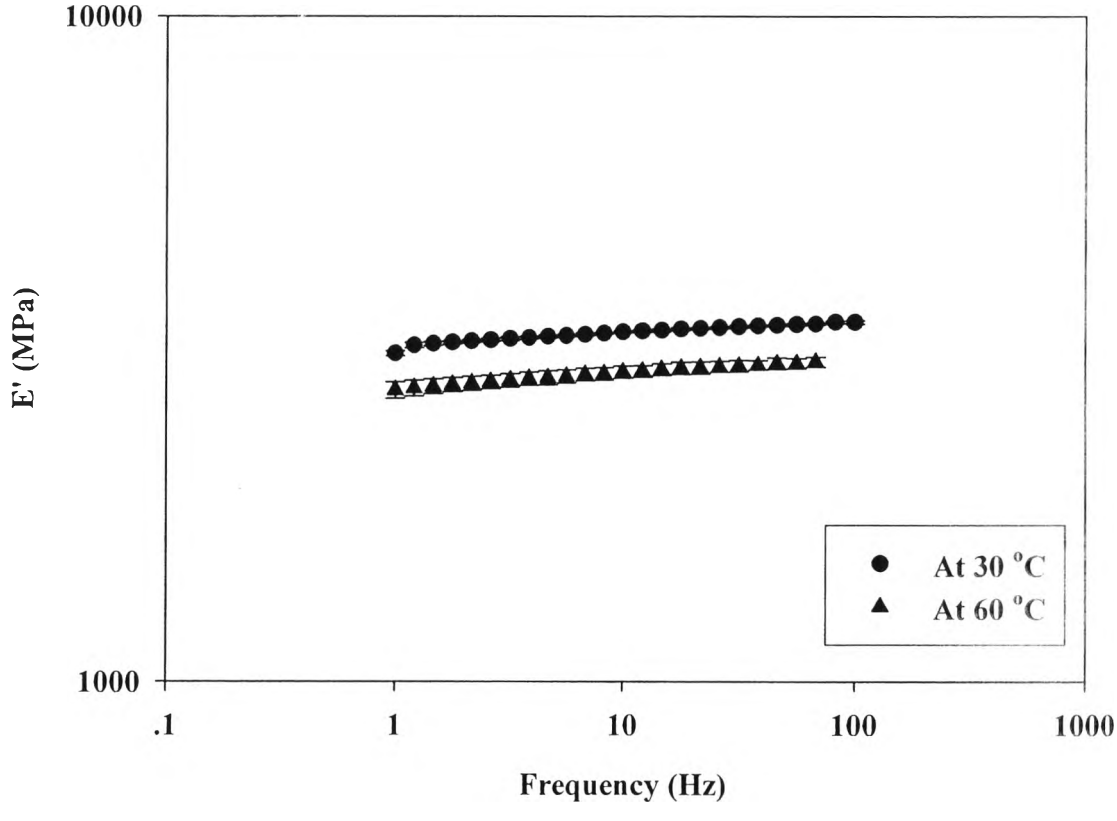


Figure H3 Mechanical strength (E') of sulfonated copolyimide SDH 0 under various frequency at 30 °C and 60 °C.

Table H2 E" of sulfonated copolyimide SDH 0 at 30 °C and 60 °C

Frequency	E" (MPa) at 30 °C			E" (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	99.96	105.56	100.12	100.85	103.79	101.63
1.21	104.46	106.93	106.45	103.39	105.80	105.98
1.47	104.21	106.11	108.46	107.39	107.14	103.28
1.78	105.47	105.58	104.53	107.31	105.48	104.93
2.15	104.83	105.91	106.03	104.69	103.18	104.89
2.61	107.09	103.29	106.55	112.09	106.21	104.98
3.16	101.75	108.52	107.22	108.12	119.86	98.92
3.83	104.80	104.85	106.08	110.73	108.86	106.69
4.64	108.47	103.16	102.60	109.14	107.89	105.17
5.62	104.08	106.00	106.64	109.57	101.87	99.12
6.81	107.68	104.06	101.17	110.06	100.58	101.95
8.25	101.83	104.12	104.24	110.68	103.59	104.89
10.00	102.29	107.39	104.19	105.90	109.18	107.43
12.12	103.53	99.10	104.65	101.84	103.86	103.48
14.68	101.43	99.53	101.37	108.85	104.05	104.78
17.78	101.36	99.30	102.81	105.91	105.38	96.88
21.54	103.37	100.08	101.46	108.59	108.91	102.30
26.10	100.37	104.13	96.97	102.61	98.73	101.26
31.62	103.59	91.23	99.98	101.08	104.87	109.15
38.31	103.60	105.15	103.13	110.67	107.78	105.64
46.42	103.39	104.39	102.02	108.09	117.98	107.08
56.23	107.29	110.64	110.74	123.43	108.50	120.24
68.13	121.84	114.76	114.12	129.64	121.91	116.64
82.54	122.05	126.85	117.86	130.81	115.91	132.29
100.00	105.53	137.07	130.25	155.13	147.04	155.23

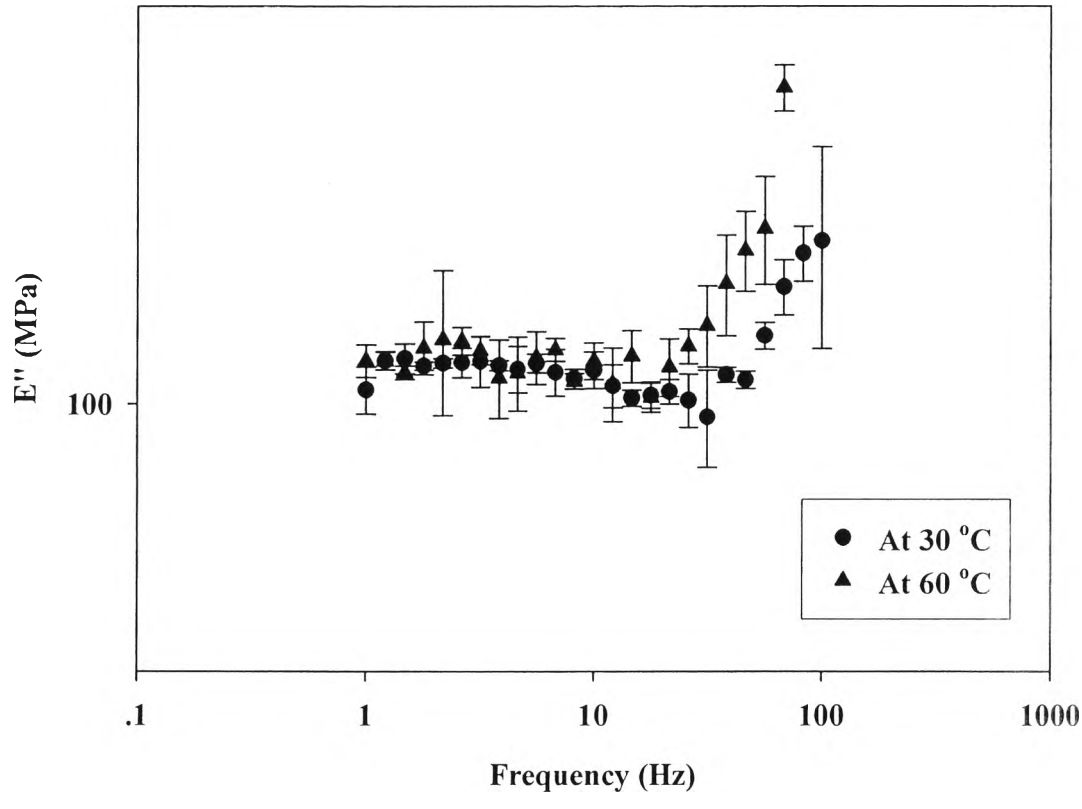


Figure H4 Mechanical strength (E") of sulfonated copolyimide SDH 0 under various frequency at 30 °C and 60 °C.

Table H3 E' of sulfonated copolyimide SDH 1 at 30 °C and 60 °C

Frequency	E' (MPa) at 30 °C			E' (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	2912.59	2966.06	2991.00	2217.72	2246.84	2297.55
1.21	2937.83	2987.09	3008.34	2341.34	2344.92	2374.33
1.47	2943.46	3003.83	3018.56	2274.36	2365.52	2396.02
1.78	2912.59	2966.06	2991.00	2344.62	2388.00	2405.47
2.15	2937.83	2987.09	3008.34	2354.76	2399.10	2422.42
2.61	2943.46	3003.83	3018.56	2365.67	2406.03	2434.84
3.16	2912.59	2966.06	2991.00	2383.63	2426.25	2449.21
3.83	2937.83	2987.09	3008.34	2388.51	2431.65	2467.93
4.64	2943.46	3003.83	3018.56	2442.74	2450.93	2476.17
5.62	2912.59	2966.06	2991.00	2430.62	2459.01	2486.36
6.81	2937.83	2987.09	3008.34	2468.84	2463.67	2500.09
8.25	2943.46	3003.83	3018.56	2460.34	2471.30	2555.80
10.00	2912.59	2966.06	2991.00	2463.41	2529.96	2540.18
12.12	2937.83	2987.09	3008.34	2475.03	2500.32	2539.38
14.68	2943.46	3003.83	3018.56	2480.84	2516.16	2543.01
17.78	2912.59	2966.06	2991.00	2492.18	2521.59	2559.49
21.54	2937.83	2987.09	3008.34	2506.63	2539.50	2564.05
26.10	2943.46	3003.83	3018.56	2514.67	2538.05	2574.13
31.62	2912.59	2966.06	2991.00	2515.77	2547.17	2583.92
38.31	2937.83	2987.09	3008.34	2529.27	2566.19	2591.85
46.42	2943.46	3003.83	3018.56	2540.78	2579.44	2596.52
56.23	2912.59	2966.06	2991.00	2554.38	2576.56	2601.40
68.13	2937.83	2987.09	3008.34	2593.34	2623.07	2648.18
82.54	2943.46	3003.83	3018.56	2555.56	2614.41	2596.42
100.00	2912.59	2966.06	2991.00	2526.27	2567.08	2546.04

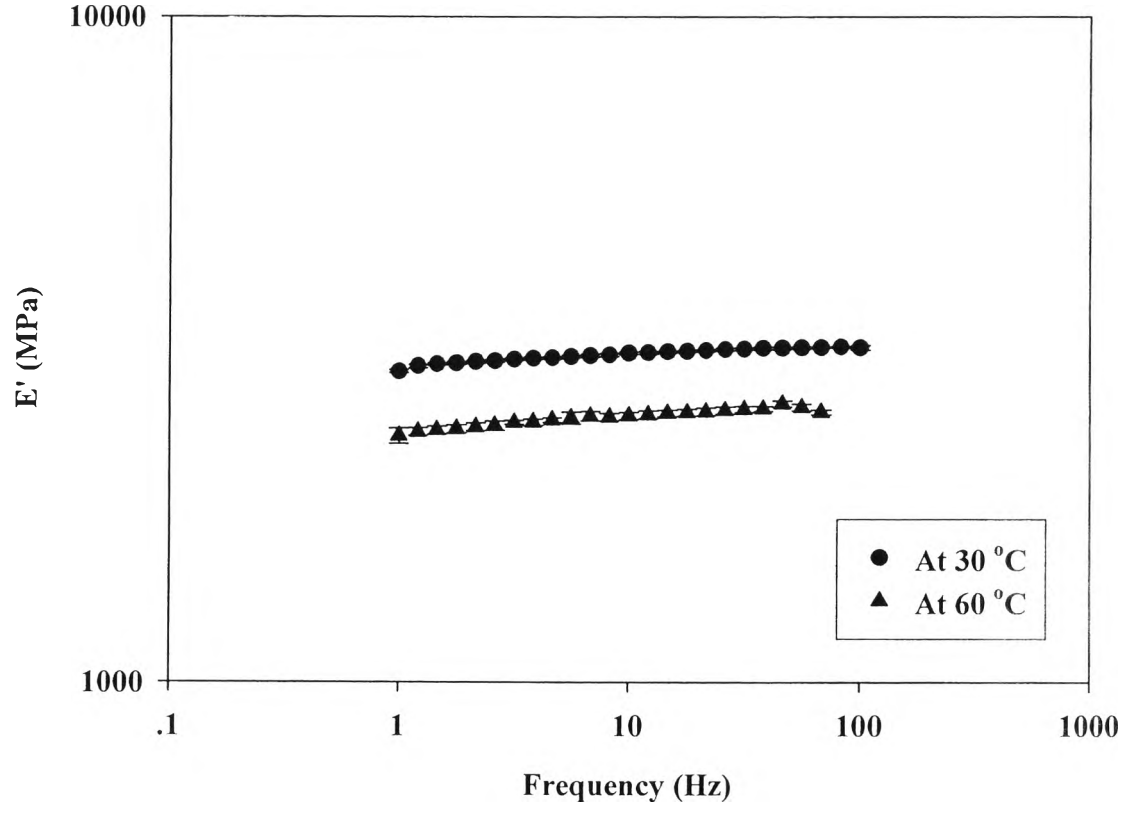


Figure H5 Mechanical strength (E') of sulfonated copolyimide SDH 1 under various frequency at 30 °C and 60 °C.

Table H4 E" of sulfonated copolyimide SDH 1 at 30 °C and 60 °C

Frequency	E" (MPa) at 30 °C			E" (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	81.08	80.07	77.19	90.10	96.50	94.56
1.21	82.90	83.28	84.78	92.52	95.06	99.03
1.47	86.99	85.11	83.55	89.89	96.95	96.96
1.78	82.31	83.04	82.63	95.11	98.71	100.15
2.15	82.47	82.77	81.60	98.69	98.85	101.86
2.61	82.37	84.08	80.51	101.52	97.27	100.87
3.16	79.13	80.08	84.15	102.22	97.51	99.47
3.83	82.33	77.86	81.91	97.01	98.33	97.36
4.64	82.49	82.33	81.04	104.22	98.50	100.33
5.62	74.71	77.67	82.07	100.06	101.72	101.24
6.81	76.98	73.65	78.36	96.30	96.49	96.02
8.25	76.51	77.48	74.68	96.27	97.68	100.43
10.00	77.53	79.22	78.94	101.72	104.36	101.68
12.12	75.53	73.87	75.25	97.91	98.71	94.65
14.68	74.04	76.93	72.06	94.75	97.60	96.60
17.78	70.95	74.72	72.50	91.98	92.42	96.50
21.54	76.45	72.34	75.07	95.11	96.64	95.06
26.10	68.34	71.00	70.90	98.42	92.87	92.63
31.62	72.57	79.02	73.57	96.88	95.92	93.35
38.31	78.67	72.33	69.06	94.90	96.13	96.56
46.42	74.40	81.33	78.18	99.12	99.28	97.74
56.23	78.02	75.19	76.24	95.11	98.10	107.50
68.13	96.52	85.69	81.66	114.49	100.67	104.12
82.54	90.06	93.11	91.77	104.98	106.55	111.98
100.00	98.84	108.49	89.90	131.58	122.05	117.80

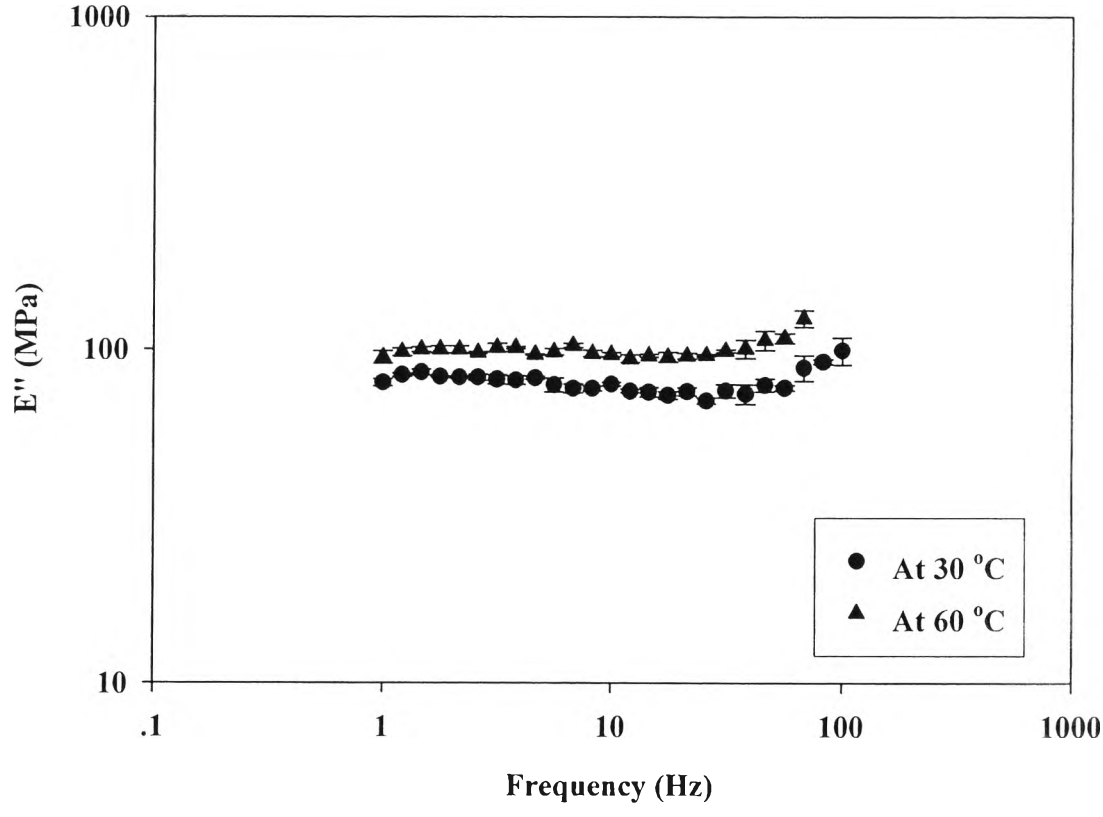


Figure H6 Mechanical strength (E") of sulfonated copolyimide SDH 1 under various frequency at 30 °C and 60 °C.

Table H5 E' of sulfonated copolyimide SDH 2 at 30 °C and 60 °C

Frequency	E' (MPa) at 30 °C			E' (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	2768.38	2797.96	2795.71	2662.86	2752.95	2271.51
1.21	2957.32	2973.16	2969.82	2776.27	2826.02	2464.20
1.47	2969.95	2984.22	2981.02	2800.98	2842.88	2519.54
1.78	2986.34	2994.31	2986.03	2807.66	2854.93	2538.97
2.15	2991.58	3000.95	3008.98	2828.75	2892.76	2585.21
2.61	3012.07	3001.22	3013.70	2834.82	2895.05	2599.01
3.16	3021.93	3024.13	3026.51	2853.72	2909.83	2606.32
3.83	3030.44	3028.56	3033.65	2864.63	2920.30	2626.90
4.64	3029.96	3035.02	3037.66	2876.66	2930.54	2644.52
5.62	3044.56	3068.44	3046.01	2889.19	2935.52	2653.80
6.81	3046.15	3061.19	3058.13	2899.04	2950.71	2668.71
8.25	3054.30	3056.62	3062.44	2911.30	2963.01	2677.56
10.00	3059.89	3062.28	3073.12	2927.33	2976.10	2685.79
12.12	3088.54	3075.02	3077.11	2941.19	2991.16	2688.54
14.68	3090.80	3084.05	3082.86	2948.12	3001.09	2714.04
17.78	3089.33	3094.70	3108.98	2955.31	3006.55	2720.86
21.54	3089.80	3093.44	3100.76	2971.97	3018.05	2731.58
26.10	3112.14	3098.32	3115.48	2978.49	3024.01	2731.35
31.62	3100.75	3120.97	3099.03	2989.15	3039.11	2738.41
38.31	3093.78	3114.21	3097.57	2996.29	3054.48	2739.47
46.42	3103.64	3110.53	3094.44	3001.29	3051.94	2732.52
56.23	3103.03	3095.74	3094.48	3001.04	3063.96	2752.78
68.13	3066.06	3082.56	3076.14	3017.94	3059.87	2756.94
82.54	3024.96	3047.62	3036.37	3023.24	3068.91	2723.63
100.00	2893.32	2893.15	2926.36	3032.95	3054.23	2621.47

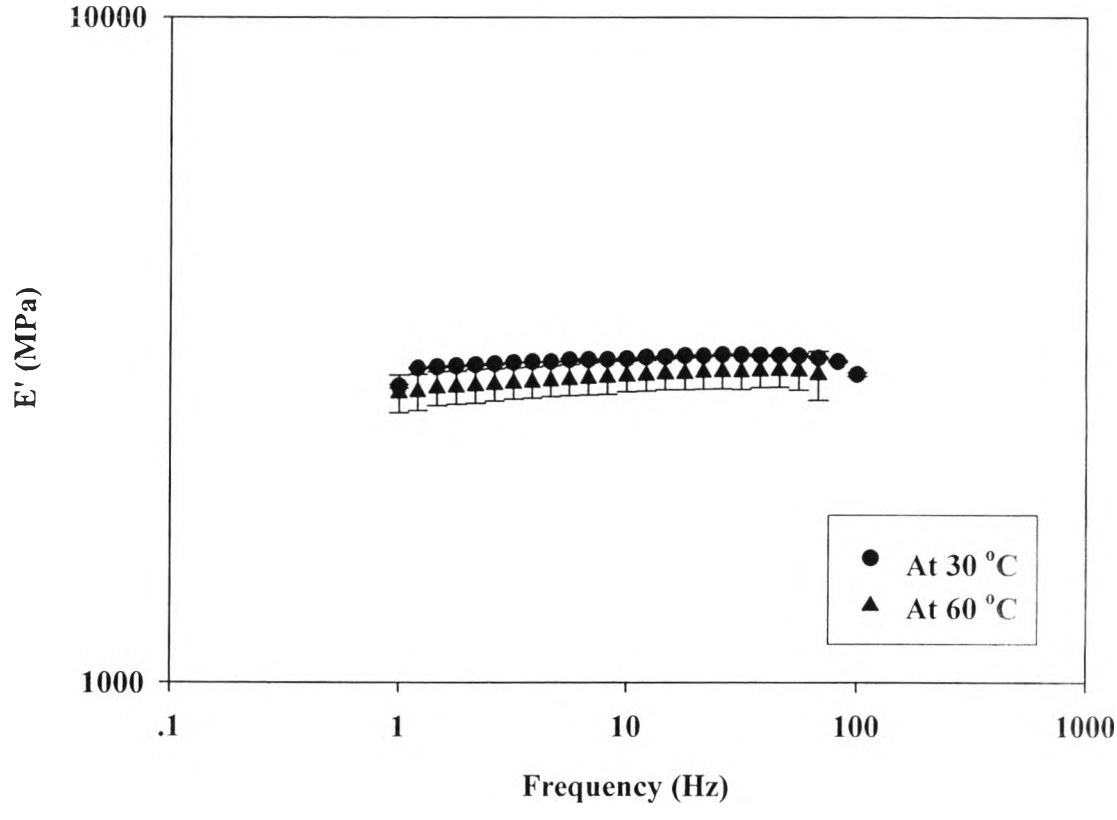


Figure H7 Mechanical strength (E') of sulfonated copolyimide SDH 2 under various frequency at 30 °C and 60 °C.

Table H6 E" of sulfonated copolyimide SDH 2 at 30 °C and 60 °C

Frequency	E" (MPa) at 30 °C			E" (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	71.27	71.63	73.99	86.36	91.72	77.95
1.21	77.26	76.14	76.86	93.80	95.25	83.01
1.47	78.31	77.65	80.27	96.99	95.15	84.89
1.78	78.15	78.56	76.88	89.36	94.38	87.04
2.15	78.70	77.70	80.36	95.85	95.70	88.66
2.61	76.05	75.55	76.68	99.10	94.73	85.91
3.16	78.97	78.71	70.75	97.96	98.06	90.03
3.83	75.03	75.39	75.54	98.07	95.62	88.48
4.64	74.78	74.17	73.08	97.55	97.67	91.71
5.62	78.96	77.09	74.54	100.71	96.48	90.90
6.81	69.65	71.89	73.29	94.69	97.46	87.51
8.25	73.22	71.27	69.93	96.18	96.78	87.45
10.00	68.92	74.83	72.70	95.57	95.52	88.39
12.12	70.72	67.91	68.31	97.90	95.95	84.00
14.68	70.32	66.65	71.66	94.98	93.33	86.38
17.78	68.95	69.97	70.31	93.93	92.02	84.11
21.54	68.58	68.28	66.90	93.96	93.75	86.54
26.10	67.08	65.52	67.15	95.56	94.31	83.12
31.62	59.45	62.57	64.07	91.09	89.37	87.13
38.31	63.92	64.45	66.59	97.73	98.10	87.91
46.42	71.59	74.38	65.32	98.86	98.40	90.66
56.23	78.28	80.74	76.34	101.86	102.70	92.67
68.13	76.95	69.96	73.86	99.93	103.58	94.33
82.54	80.57	76.92	90.77	119.09	111.52	94.85
100.00	74.79	102.25	74.42	95.10	103.71	90.30

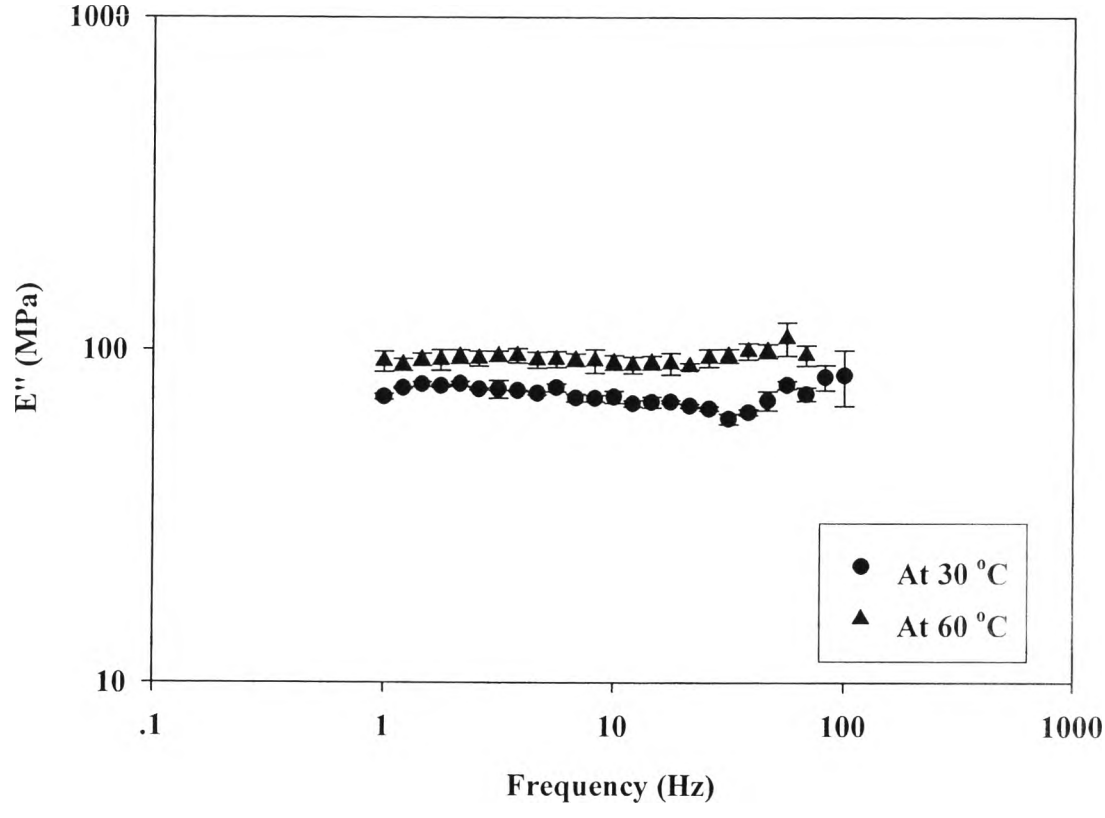


Figure H8 Mechanical strength (E") of sulfonated copolyimide SDH 2 under various frequency at 30 °C and 60 °C.

Table H7 E' of sulfonated copolyimide SDH 3 at 30 °C and 60 °C

Frequency	E' (MPa) at 30 °C			E' (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	2640.04	2639.81	2735.45	2283.26	2352.55	2227.67
1.21	2799.84	2813.30	2939.00	2414.37	2442.42	2329.39
1.47	2842.45	2831.48	2952.98	2432.29	2457.65	2355.44
1.78	2845.08	2851.05	2968.97	2443.92	2476.67	2364.14
2.15	2851.34	2855.18	2983.39	2451.92	2487.56	2376.31
2.61	2868.40	2866.43	2990.70	2469.31	2498.61	2391.99
3.16	2867.97	2881.43	2998.99	2468.61	2501.90	2408.61
3.83	2873.11	2879.35	3010.29	2482.30	2519.98	2416.91
4.64	2899.66	2891.42	3016.64	2488.41	2526.28	2434.44
5.62	2902.73	2909.69	3031.40	2501.89	2538.06	2439.63
6.81	2894.96	2910.63	3040.89	2510.75	2552.72	2451.11
8.25	2907.13	2920.91	3046.69	2521.08	2553.10	2460.89
10.00	2922.43	2923.53	3058.60	2528.26	2572.32	2477.68
12.12	2928.75	2928.49	3065.02	2532.42	2572.54	2478.20
14.68	2940.11	2939.94	3071.79	2542.24	2587.15	2480.72
17.78	2942.93	2947.66	3077.86	2550.16	2589.52	2487.39
21.54	2948.62	2954.74	3085.99	2550.34	2589.86	2492.10
26.10	2959.24	2962.53	3092.56	2558.54	2596.28	2498.65
31.62	2959.39	2961.47	3106.30	2566.32	2600.18	2512.96
38.31	2956.09	2957.19	3110.03	2571.32	2601.59	2509.82
46.42	2958.48	2960.53	3112.96	2570.09	2612.13	2506.61
56.23	2955.67	2962.14	3122.26	2571.44	2622.42	2510.21
68.13	2953.10	2959.69	3119.98	2567.58	2595.42	2496.85
82.54	2926.68	2940.85	3146.55	2534.01	2566.71	2452.81
100.00	2839.36	2845.07	3175.18	2433.13	2464.92	2369.86

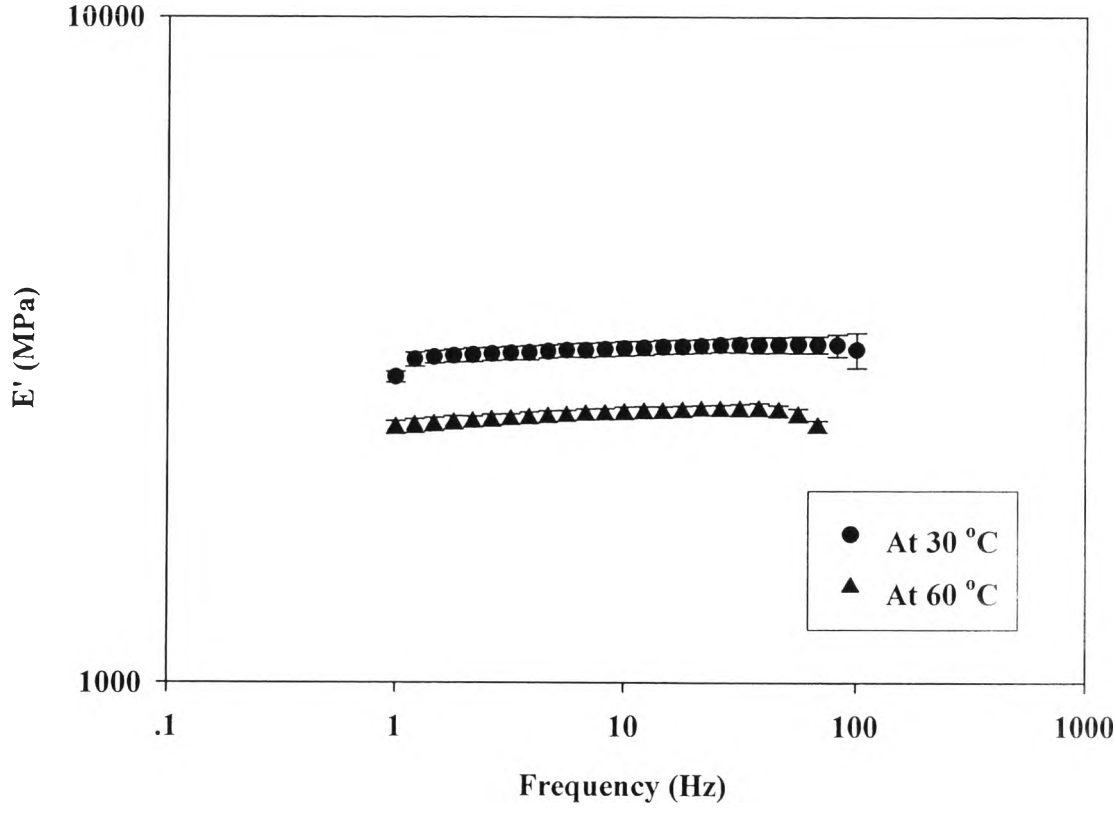


Figure H9 Mechanical strength (E') of sulfonated copolyimide SDH 3 under various frequency at 30 °C and 60 °C.

Table H8 E" of sulfonated copolyimide SDH 3 at 30 °C and 60 °C

Frequency	E" (MPa) at 30 °C			E" (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	77.25	75.65	83.85	72.36	75.14	78.00
1.21	82.83	84.55	93.41	83.80	80.37	81.86
1.47	83.50	82.10	91.17	81.79	82.49	81.37
1.78	85.14	84.41	88.77	78.12	80.58	80.30
2.15	84.14	85.08	91.47	81.11	82.66	81.95
2.61	83.17	83.71	91.73	81.00	79.55	81.61
3.16	80.66	85.44	90.18	83.10	75.27	83.58
3.83	82.56	80.74	89.88	83.34	84.73	82.14
4.64	77.37	81.04	84.89	84.46	79.12	88.21
5.62	82.89	80.87	83.79	83.61	80.48	82.53
6.81	82.91	78.00	83.45	81.80	82.48	83.85
8.25	78.25	74.71	83.27	83.68	82.78	82.80
10.00	80.23	80.15	79.35	83.30	75.17	82.69
12.12	77.77	74.89	80.37	82.22	76.59	77.36
14.68	70.93	75.56	74.73	75.49	79.00	81.26
17.78	74.79	73.00	78.51	76.76	77.48	80.59
21.54	71.41	78.01	82.01	77.44	76.65	84.78
26.10	70.80	70.22	77.17	77.06	76.10	80.76
31.62	74.67	73.78	81.09	79.00	75.20	77.54
38.31	78.05	75.84	80.14	75.33	78.78	79.00
46.42	70.57	74.40	87.91	80.61	78.57	81.34
56.23	92.80	81.00	81.18	84.90	83.23	83.06
68.13	80.42	88.40	93.26	88.88	88.65	85.00
82.54	87.41	84.30	98.92	97.84	89.56	85.80
100.00	117.99	91.40	93.09	116.22	111.71	83.38

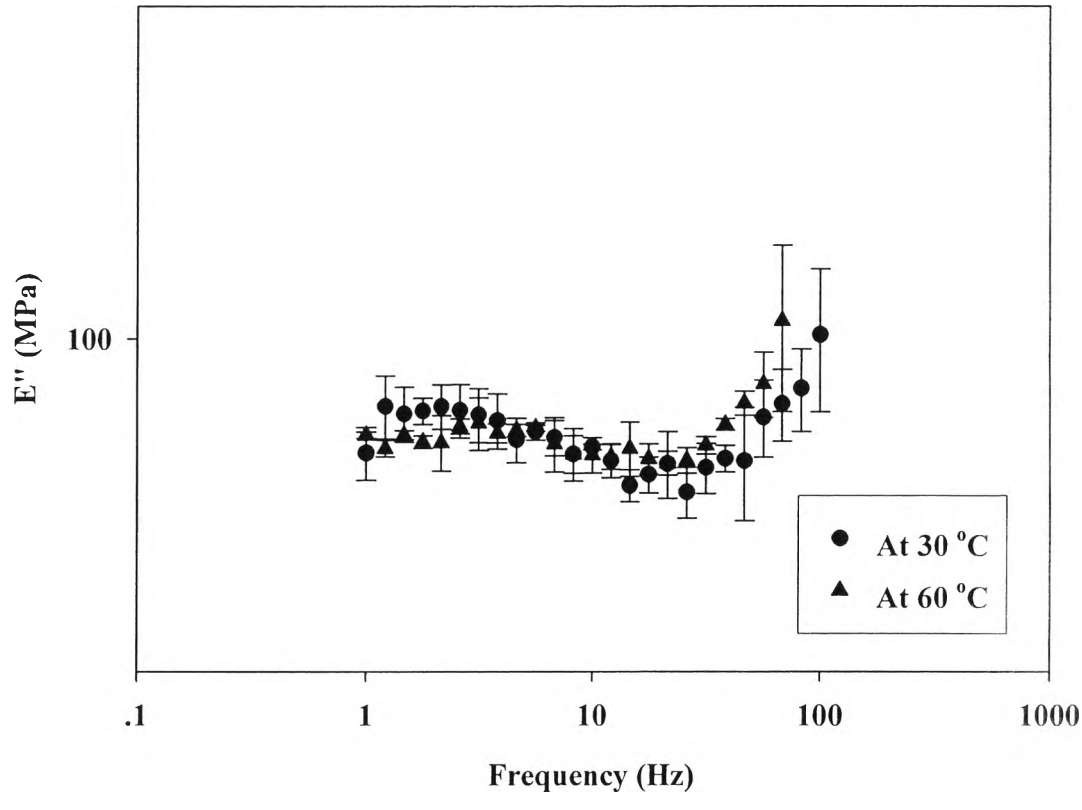


Figure H10 Mechanical strength (E'') of sulfonated copolyimide SDH 3 under various frequency at 30 °C and 60 °C.

Table H9 E' of sulfonated copolyimide SDH 4 at 30 °C and 60 °C

Frequency	E' (MPa) at 30 °C			E' (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	2588.77	2644.19	2639.70	2588.06	2588.06	2721.80
1.21	2712.47	2751.69	2767.58	2624.19	2624.19	2763.27
1.47	2730.36	2767.76	2780.76	2644.44	2644.44	2781.80
1.78	2744.32	2774.30	2791.43	2660.39	2660.39	2794.56
2.15	2750.95	2785.72	2799.81	2684.17	2684.17	2808.46
2.61	2765.97	2790.70	2806.88	2686.49	2686.49	2820.53
3.16	2776.12	2794.84	2816.95	2701.97	2701.97	2832.14
3.83	2787.64	2807.55	2821.08	2715.92	2715.92	2847.69
4.64	2797.83	2815.32	2830.15	2730.41	2730.41	2855.05
5.62	2810.13	2827.18	2845.64	2742.27	2742.27	2865.14
6.81	2813.21	2835.25	2843.62	2755.22	2755.22	2879.07
8.25	2823.39	2841.55	2857.92	2766.62	2766.62	2885.23
10.00	2835.31	2849.85	2867.84	2779.53	2779.53	2901.94
12.12	2838.04	2856.33	2877.81	2789.74	2789.74	2912.79
14.68	2847.86	2867.80	2880.13	2802.15	2802.15	2924.78
17.78	2852.89	2872.28	2890.57	2812.18	2812.18	2935.66
21.54	2859.92	2877.44	2888.90	2822.20	2822.20	2941.71
26.10	2866.55	2880.17	2900.68	2840.70	2840.70	2942.64
31.62	2865.88	2884.53	2903.44	2842.70	2842.70	2959.18
38.31	2872.67	2887.64	2901.53	2849.23	2849.23	2969.37
46.42	2874.16	2885.54	2900.76	2855.69	2855.69	2968.47
56.23	2869.42	2888.74	2902.49	2866.04	2866.04	2980.46
68.13	2855.90	2870.00	2891.82	2867.70	2867.70	2977.67
82.54	2822.17	2831.97	2849.23	2869.48	2869.48	2971.21
100.00	2765.86	2780.24	2773.82	2869.98	2869.98	2922.81

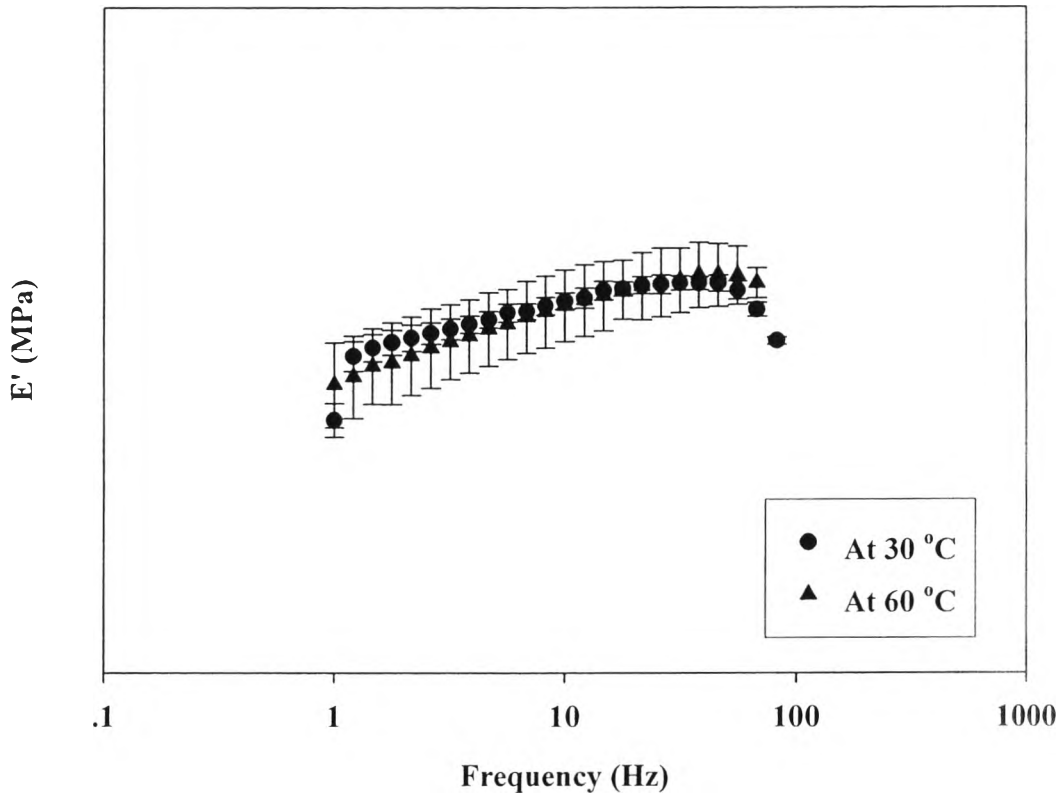


Figure H11 Mechanical strength (E') of sulfonated copolyimide SDH 4 under various frequency at 30 °C and 60 °C.

Table H10 E" of sulfonated copolyimide SDH 4 at 30 °C and 60 °C

Frequency	E" (MPa) at 30 °C			E" (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	69.60	69.20	68.39	73.22	73.22	74.30
1.21	70.80	71.91	72.80	73.45	73.45	77.03
1.47	71.28	73.94	74.28	74.53	74.53	75.95
1.78	72.00	73.12	72.17	75.27	75.27	78.99
2.15	72.42	72.97	73.34	77.89	77.89	76.53
2.61	73.50	73.16	74.69	77.90	77.90	77.21
3.16	64.61	76.35	72.55	75.93	75.93	79.37
3.83	71.05	72.34	72.15	78.65	78.65	78.64
4.64	72.15	71.65	71.42	76.00	76.00	78.24
5.62	74.38	71.92	69.78	77.51	77.51	80.80
6.81	72.81	72.22	75.13	79.46	79.46	79.89
8.25	68.53	69.61	70.60	77.53	77.53	77.28
10.00	70.66	73.57	72.16	80.42	80.42	80.75
12.12	65.38	67.02	66.55	77.84	77.84	74.60
14.68	66.72	65.75	67.82	74.69	74.69	74.21
17.78	65.43	70.88	66.34	75.22	75.22	73.45
21.54	67.20	66.84	67.15	73.64	73.64	74.54
26.10	66.20	58.91	66.36	73.59	73.59	78.66
31.62	69.95	63.58	69.54	76.99	76.99	74.80
38.31	66.62	69.80	68.57	74.50	74.50	75.93
46.42	68.17	76.96	74.07	77.60	77.60	78.27
56.23	77.00	79.61	75.91	77.48	77.48	75.64
68.13	80.95	79.17	75.72	88.74	88.74	88.52
82.54	89.69	79.15	82.73	91.40	91.40	83.78
100.00	82.72	85.84	82.51	84.97	84.97	115.19

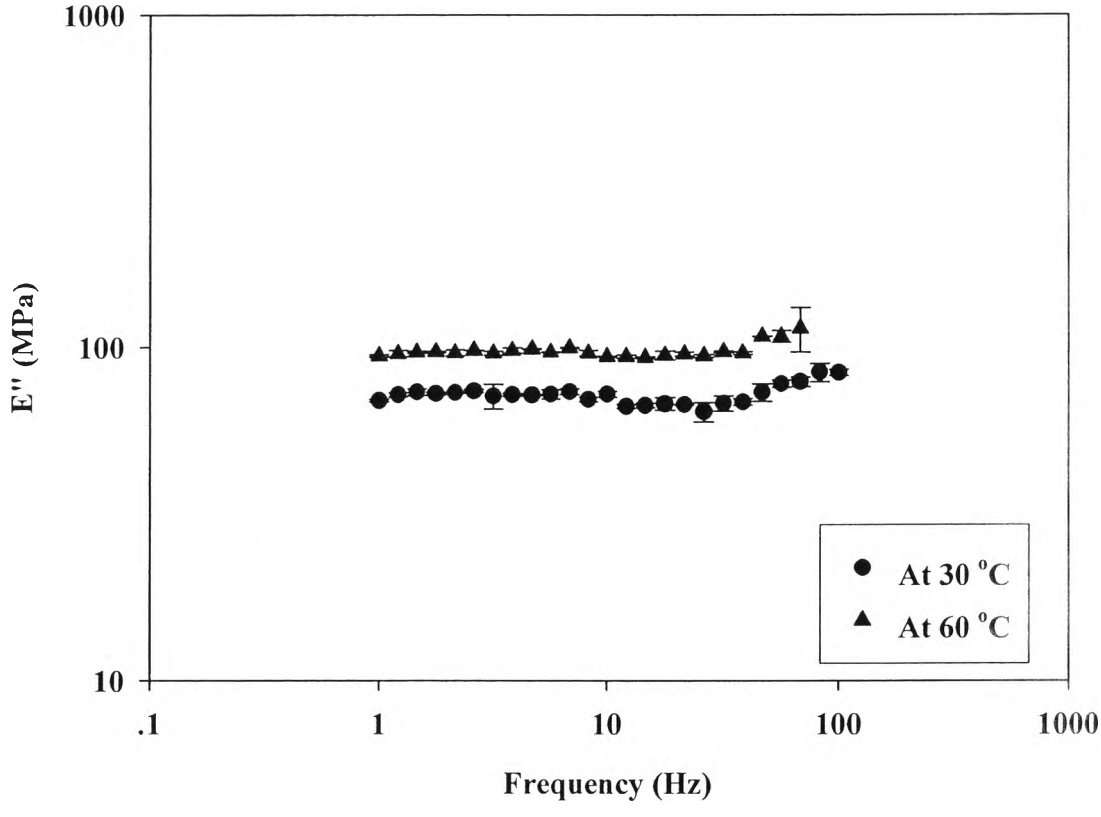


Figure H12 Mechanical strength (E") of sulfonated copolyimide SDH 4 under various frequency at 30 °C and 60 °C.

Table H11 E' of sulfonated copolyimide SDH 5 at 30 °C and 60 °C

Frequency	E' (MPa) at 30 °C			E'(MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	2630.58	2666.74	2674.99	2487.59	2547.77	2589.65
1.21	2677.79	2706.44	2712.39	2542.94	2601.78	2648.33
1.47	2688.42	2715.14	2721.41	2557.59	2610.78	2654.72
1.78	2698.38	2724.47	2727.31	2574.02	2621.42	2666.46
2.15	2704.92	2730.67	2735.32	2584.59	2638.98	2677.65
2.61	2716.09	2737.50	2746.13	2602.72	2649.18	2685.70
3.16	2723.13	2742.52	2748.44	2616.46	2651.95	2694.64
3.83	2727.89	2748.70	2756.57	2627.88	2666.61	2702.28
4.64	2734.14	2755.19	2765.19	2637.60	2674.64	2711.88
5.62	2739.29	2763.65	2773.17	2648.43	2683.45	2720.03
6.81	2751.03	2770.14	2774.54	2657.48	2691.61	2731.84
8.25	2754.30	2772.24	2781.08	2667.72	2702.74	2743.70
10.00	2764.11	2780.25	2789.63	2679.53	2714.33	2753.63
12.12	2769.96	2784.03	2795.95	2687.13	2721.35	2754.59
14.68	2772.98	2793.43	2801.14	2694.01	2726.91	2762.16
17.78	2781.73	2799.20	2809.59	2694.85	2730.66	2766.55
21.54	2789.35	2803.85	2813.90	2703.69	2739.16	2776.18
26.10	2794.89	2808.72	2817.78	2718.29	2746.43	2781.86
31.62	2798.78	2818.55	2822.75	2716.19	2753.38	2789.95
38.31	2805.95	2820.32	2827.92	2724.25	2768.10	2799.21
46.42	2806.91	2830.73	2828.03	2732.04	2762.37	2805.03
56.23	2810.69	2829.82	2839.28	2727.90	2772.27	2809.44
68.13	2824.33	2842.33	2849.34	2741.26	2782.69	2812.51
82.54	2840.61	2855.42	2861.86	2757.40	2775.30	2810.46
100.00	2885.33	2901.60	2949.35	2771.09	2782.47	2819.63

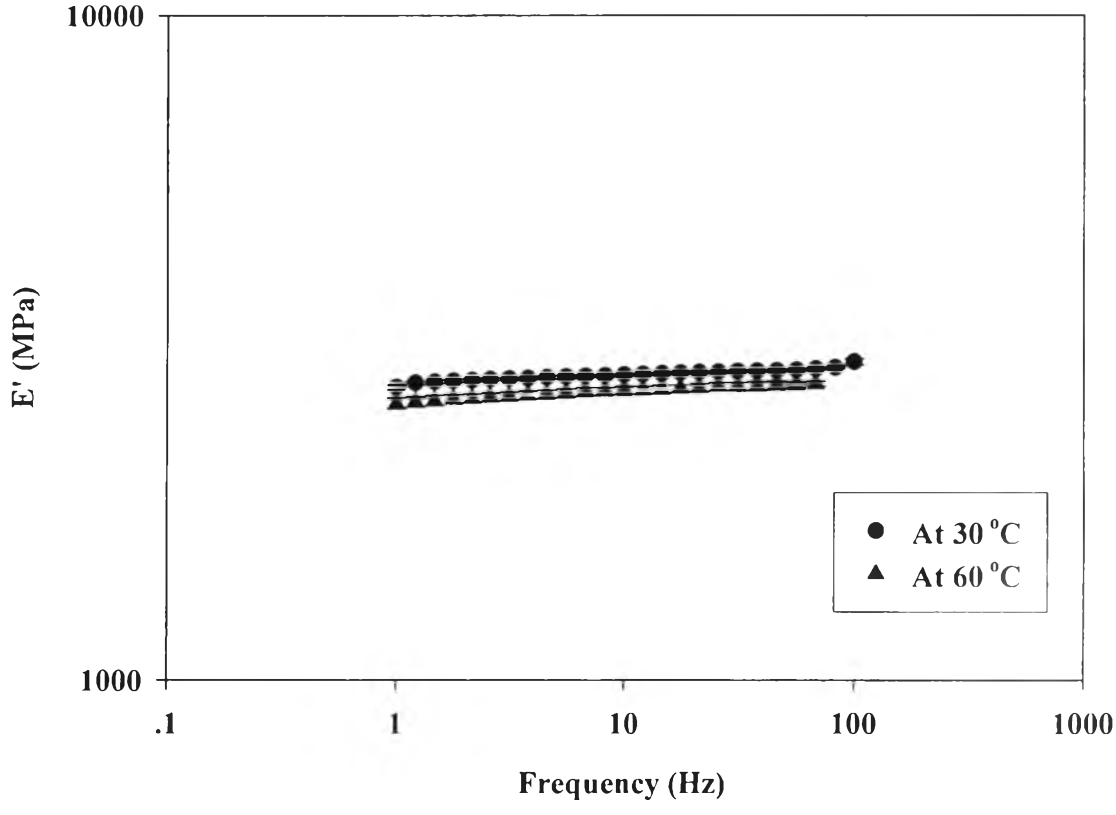


Figure H13 Mechanical strength (E') of sulfonated copolyimide SDH 5 under various frequency at 30 °C and 60 °C.

Table H12 E" of sulfonated copolyimide SDH 5 at 30 °C and 60 °C

Frequency	E" (MPa) at 30 °C			E" (MPa) at 60 °C		
(Hz)	No.1	No.2	No.3	No.1	No.2	No.3
1.00	60.11	60.58	62.22	74.98	72.29	70.90
1.21	61.73	57.77	60.66	70.86	74.70	75.20
1.47	60.09	61.74	62.40	72.51	73.44	75.27
1.78	61.24	59.69	59.95	77.16	77.16	74.85
2.15	60.27	63.09	59.84	77.59	76.28	75.22
2.61	61.82	62.44	62.38	73.78	78.39	75.20
3.16	63.90	60.69	64.21	78.49	76.62	75.27
3.83	63.50	61.65	60.98	73.61	76.08	75.55
4.64	61.20	61.37	61.41	73.97	75.47	75.31
5.62	62.26	59.96	59.40	72.92	77.17	78.21
6.81	59.87	59.81	60.47	74.27	75.43	73.97
8.25	61.09	59.51	61.15	75.28	74.56	74.06
10.00	64.20	59.47	61.65	74.81	74.74	73.88
12.12	58.77	58.86	58.98	77.04	77.33	74.80
14.68	56.90	60.08	55.70	72.99	72.38	76.75
17.78	57.65	60.69	60.91	72.39	71.85	74.45
21.54	59.88	54.46	62.34	73.15	74.81	73.03
26.10	51.90	54.97	56.77	73.51	74.84	73.88
31.62	62.82	56.07	55.80	70.41	74.59	74.70
38.31	62.36	63.54	64.53	72.20	79.19	77.26
46.42	61.92	62.04	59.35	77.46	78.79	77.04
56.23	62.35	67.13	65.59	75.35	84.30	82.29
68.13	72.35	75.10	73.76	84.76	88.05	90.64
82.54	70.61	79.91	77.36	96.24	92.77	88.76
100.00	95.82	82.87	69.44	88.22	71.15	81.30

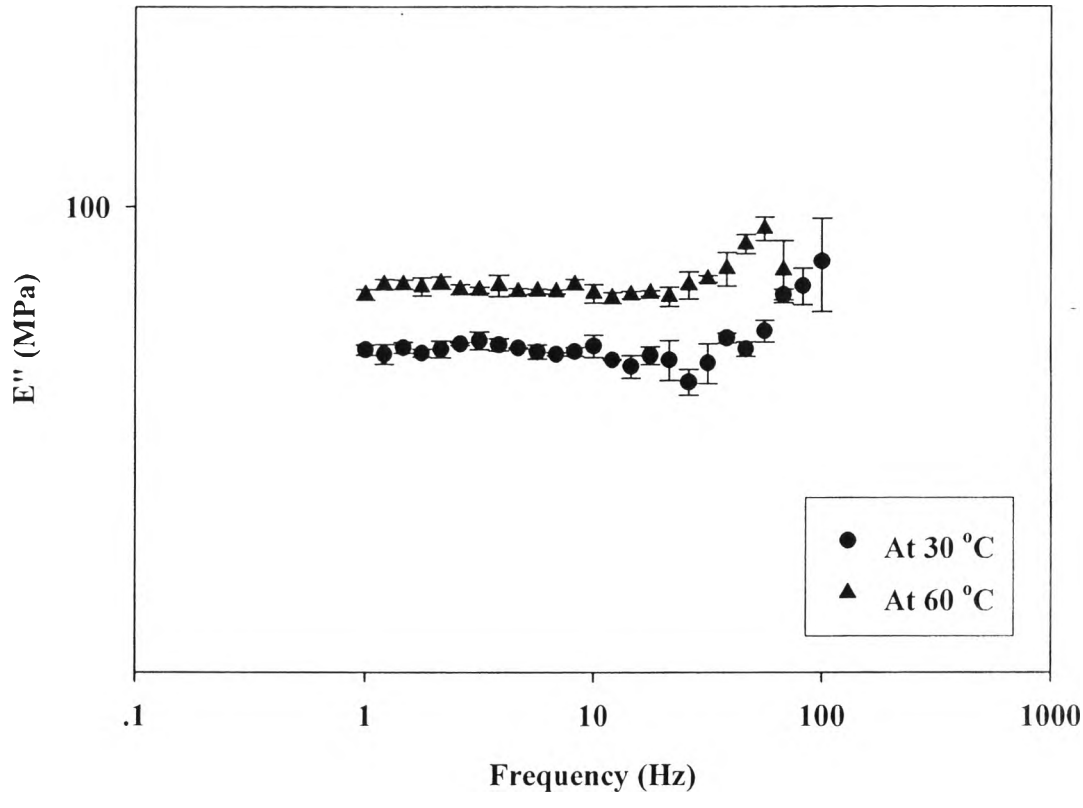


Figure H14 Mechanical strength (E'') of sulfonated copolyimide SDH 5 under various frequency at 30 °C and 60 °C.

CURRICULUM VITAE

Name: Ms. Phornpussadee Umsarika

Date of Birth: December 24, 1987

Nationality: Thai

University Education:

2006-2009 Bachelor Degree of Science (Chemistry), Faculty of Science, Chulalongkorn University, Bangkok, Thailand

Proceedings:

1. Umsarika, P., and Sirivat, A. (2012, March) Novel Proton Exchange Membrane for Direct Methanol Fuel Cell. Proceedings of the 243rd ACS National Meeting & Exposition, San diego Convention Center, San diego, California, USA.
2. Umsarika, P., and Sirivat, A. (2012, April) Novel Proton Exchange Sulfonated Polyimide Membrane for Direct Methanol Fuel Cell. Proceedings of the 3rd Research Symposium on Petrochemical and Materials Technology and the 18th PPC Symposium on Petroleum, Petrochemicals, and Polymer, Ballroom, Queen Sirikit National Convention Center, Bangkok, Thailand.

Presentation:

1. Umsarika, P., and Sirivat, A. (2012, March) Novel Proton Exchange Membrane for Direct Methanol Fuel Cell. Paper presented at the 243rd ACS National Meeting & Exposition, San diego Convention Center, San diego, California, USA.
2. Umsarika, P., and Sirivat, A. (2012, April) Novel Proton Exchange Sulfonated Polyimide Membrane for Direct Methanol Fuel Cell. Paper presented at the 3rd Research Symposium on Petrochemical and Materials Technology and the 18th PPC Symposium on Petroleum, Petrochemicals, and Polymer, Ballroom, Queen Sirikit National Convention Center, Bangkok, Thailand.