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APPENDICES

Appendix A Investigation of Characteristic Peaks of FT-IR Spectrum of Undoped and Doped Poly(3-thiopheneacetic acid)

FT-IR spectrometer (Thermo Nicolet, Nexus 670) was used to investigate spectra of poly(3-thiophenemethyl acetate) (P3TMA), undoped and doped poly(3-thiophene acetic acid) (Pth). The spectrometer was operated in the absorption mode with 32 scans and a resolution of ±4 cm^{-1}, covering a wavenumber range of 4000-400 cm^{-1}. Optical grade KBr was used as the background material and the polymers were mixed with dried KBr at a ratio 1:20.

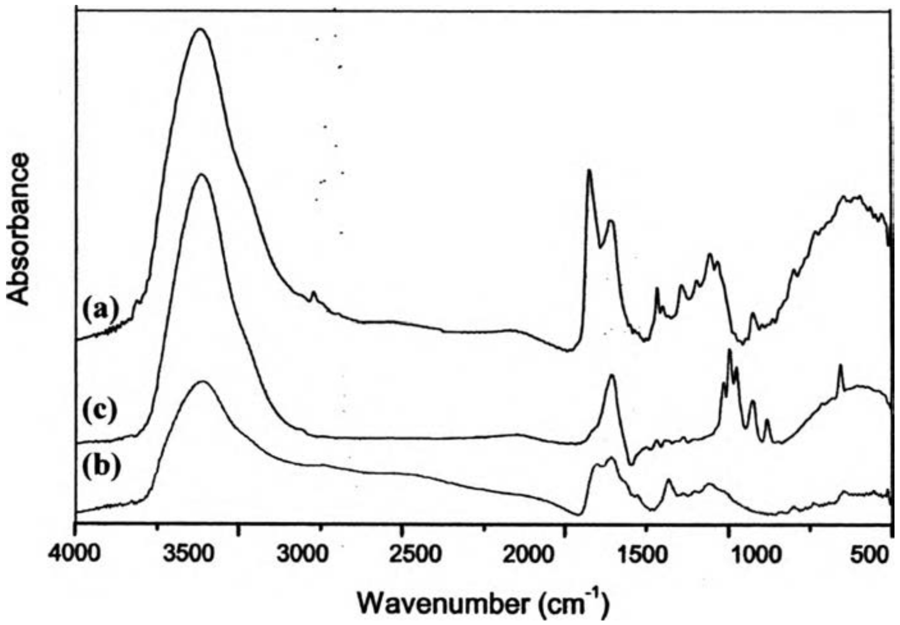


Figure A1 The FT-IR spectra of : a) poly(3-thiophenemethyl acetate); b) undoped poly(3-thiophene acetic acid); and c) poly(3-thiopheneacetic acid) doped with $HClO_4$ at mole ratio of acid to monomer unit of 10:1.

In Figure A1, distinct peaks of P3TMA and Pth appear between 3400-2400 cm^{-1}. A broad peak is the characteristic of hydroxy fuctional group of Pth which ensures us a successful synthesization of this polymer by the oxidation polymerization. After doping with perchloric acid, some characteristic peaks of acid appear on FT-IR spectra. There are appearances of a lower absorbance at 3400-2400 cm^{-1} and a sharp peak at 1200 cm^{-1}.

The assignments of the peaks in the spectrum are shown in Table A1. The characteristic peak of Pth appears at 3200-3000 cm^{-1} and can be assigned to the stretching vibration of the C-H bond on the thiophene ring; peaks between 3000-2800 cm^{-1} represent the aliphatic C-H bonds; a peak at 1700 cm^{-1} represents the C=O stretching vibration; a peak at 1400 cm^{-1} represents the thiophene ring stretching vibration; and peaks between 1300-1200 cm^{-1} represent the C-O stretching vibration. The important feature peak is the extremely broad O-H absorption occurring in the region from 3400 to 2400 cm^{-1}, which is attributed to the strong hydrogen bonding of the dimer. In the same region, the C-H stretching vibrations occurs (Kim *et al.*, 1999).

Table A1 The FT-IR absorption spectrum of undoped and doped PTAA with $HClO_4$

Wavenumber (cm^{-1})	**Assignments**	**References**
3400-2400	O-H stretching vibration	Kim *et al.* (1999)
3200-3000	C-H stretching of thiophene ring	Kim *et al.* (1999)
3000-2800	C-H stretching of aliphatic	Kim *et al.* (1999)
1700	C=O stretching vibration	Kim *et al.* (1999)
1400	Thiophene ring stretching vibration	Kim *et al.* (1999)
1300-1200	C-O stretching vibration	Kim *et al.* (1999)
835	C-H stretching, out of plane of thiophene ring	Kim *et al.* (1999)

Appendix B Investigation of the Thermal Property of Undoped and Doped Pth

Undoped and doped poly(3-thiopheneacetic acid) (Pth) at 10:1 mole ratio of dopant to monomer unit were characterized by a thermal gravimetric analyzer (Perkin Elmer). Measurements were carried out with the temperature scan from 30 to 800 °C and a heating rate of 10 °C/min. The samples were weighed in the range of 5-20 mg and loaded into a platinum pan, and then it was heated under N_2 flow. Two transitions were observed in the undoped poly (3-thiopheneacetic acid). The first transition can be referred to the losses of water and residue solvent. The other transitions can be referred to the side chain degradation and the backbone degradation, respectively (Chotpattananont *et al.*, 2004; Hu *et al.*, 2000). After the doping, the thermal stability decreased as compared to undoped Pth. For doped poly(3-thiopheneacetic acid) (Pth), there are two transitions. The first transition can be referred to the losses of water and residue solvent. The second transition can be referred to the side chain degradation (Kaneungnit *et al.,* 2007).

Table B1 Degradation steps of undoped and doped Pth

Sample	T_d onset (°C)		% Weight loss	
	1	2	1	2
Pth_u	219.0	474.7	25.52	14.94
Pth_10:1	120.7	-	58.91	-

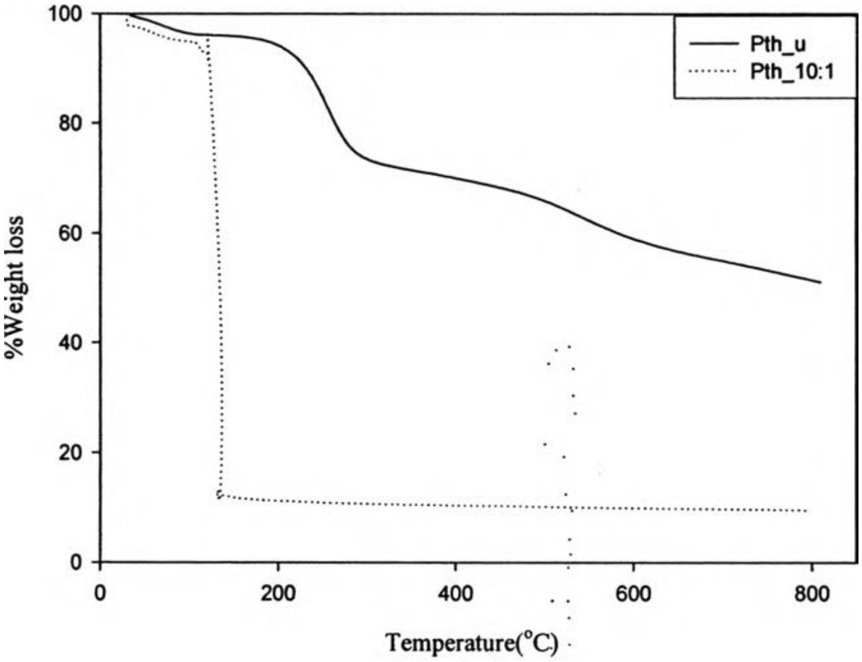


Figure B1 TGA thermograms of undoped and doped Pth with $HClO_4$.

Appendix C Determination of Particle size and Size distribution of Undoped and Doped poly(3-thiopheneacetic acid)

Particle size analyser (Malvern, Mastersizer X Version 2.15) was used to measure the particle size of undoped and doped poly(3-thiophene acetic acid). Poly(3-thiopheneacetic acid) was grounded and sieved with mesh size 38 μm before measurement were taken.

Table C1 Summary data of particle size of undoped and doped poly(3-thiopheneacetic acid)

Samples	Particle diameter (μm)				
	1	2	3	Avg.	STD
Pth_U	39.29	39.01	39.54	39.28	0.2651
Pth_10:1	39.66	39.07	39.85	39.53	0.4067

Table C2 Summary data of particle size of Zeolite Y

Samples	Particle diameter (μm)				
	1	2	3	Avg.	STD
Y	28.74	30.84	30.64	30.07	1.1590

Table C3 The raw data of particle size of undoped poly(3-thiopheneacetic acid)

Particle size diameter (µm)		Undope polythiophene					
Size Low	Size high	In %	Under %	In %	Under %	In %	Under %
0.05	0.12	0.00	0.00	0.00	0.00	0.00	0.00
0.12	0.15	0.00	0.00	0.00	0.00	0.00	0.00
0.15	0.19	0.00	0.00	0.00	0.00	0.00	0.00
0.19	0.23	0.00	0.00	0.00	0.00	0.00	0.00
0.23	0.28	0.00	0.00	0.00	0.00	0.00	0.00
0.28	0.35	0.00	0.00	0.00	0.00	0.00	0.00
0.35	0.43	0.00	0.00	0.00	0.00	0.00	0.00
0.43	0.53	0.00	0.00	0.00	0.00	0.00	0.00
0.53	0.65	0.00	0.00	0.00	0.00	0.00	0.00
0.65	0.81	0.00	0.00	0.00	0.00	0.00	0.00
0.81	1.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	1.23	0.62	0.62	0.65	0.65	0.62	0.62
1.23	1.51	0.61	1.23	0.63	1.29	0.61	1.23
1.51	1.86	0.53	1.76	0.55	1.84	0.61	1.84
1.86	2.30	0.54	2.30	0.56	2.40	0.61	2.45
2.30	2.83	0.49	2.79	0.51	2.92	0.61	3.06
2.83	3.49	0.56	3.35	0.58	3.50	0.54	3.60
3.49	4.30	0.71	4.07	0.73	4.22	0.70	4.30
4.30	5.29	1.07	5.13	1.07	5.30	1.05	5.35
5.29	6.52	1.61	6.75	1.63	6.92	1.59	6.94
6.52	8.04	2.26	9.00	2.28	9.20	2.24	9.18
8.04	9.91	2.73	11.73	2.77	11.97	2.71	11.89
9.91	12.21	2.63	14.35	2.70	14.67	2.60	14.49
12.21	15.04	1.96	16.32	2.05	16.72	1.93	16.42
15.04	18.54	1.60	17.92	1.69	18.41	1.54	17.96
18.54	22.84	2.66	20.60	2.73	21.15	2.57	20.53
22.84	28.15	5.50	26.10	5.54	26.69	5.40	25.93
28.15	34.69	10.15	36.25	10.16	36.85	10.02	35.95
34.69	42.75	16.50	52.75	16.46	53.31	16.44	52.49
42.75	52.68	21.35	74.07	21.21	74.49	21.45	73.94
52.68	64.92	18.06	92.08	17.83	92.27	18.36	92.30
64.92	80.00	7.86	100.00	7.67	100.00	8.08	100.00

Table C4 The raw data of particle size of doped poly(3-thiopheneacetic acid)

Particle size diameter (μm)		**Dope polythiophene with $HClO_4$ at 200:1 mole ratio**					
Size Low	Size high	In %	Under %	In %	Under %	In %	Under %
0.05	0.12	0.00	0.00	0.05	0.05	0.05	0.06
0.12	0.15	0.00	0.00	0.48	0.53	0.50	0.56
0.15	0.19	0.00	0.00	0.85	1.36	0.89	1.43
0.19	0.23	0.00	0.00	0.00	1.38	0.00	1.45
0.23	0.28	0.00	0.00	0.00	1.38	0.00	1.45
0.28	0.35	0.00	0.00	0.00	1.41	0.00	1.48
0.35	0.43	0.00	0.00	1.07	2.45	1.11	2.56
0.43	0.53	0.00	0.00	0.79	3.24	0.82	3.38
0.53	0.65	0.00	0.00	0.49	3.73	0.50	3.88
0.65	0.81	0.00	0.00	0.29	4.02	0.30	4.18
0.81	1.00	0.00	0.00	0.28	4.31	0.29	4.48
1.00	1.23	0.00	0.00	0.51	4.82	0.55	5.03
1.23	1.51	0.37	0.37	0.99	5.81	1.06	6.09
1.51	1.86	0.33	0.70	1.61	7.43	1.73	7.82
1.86	2.30	0.41	1.10	2.58	10.01	2.75	10.58
2.30	2.83	0.41	1.51	3.84	13.85	4.04	14.61
2.83	3.49	0.49	2.00	5.18	19.02	5.37	19.99
3.49	4.30	0.66	2.67	6.27	25.29	6.40	26.38
4.30	5.29	1.03	3.70	7.12	32.41	7.13	33.52
5.29	6.52	1.60	5.30	7.53	39.94	7.43	40.94
6.52	8.04	2.32	7.62	7.18	47.11	6.98	47.92
8.04	9.91	2.95	10.57	5.86	52.97	5.63	53.54
9.91	12.21	3.11	13.68	3.82	56.79	3.62	57.17
12.21	15.04	2.65	16.33	1.74	58.54	1.63	58.79
15.04	18.54	2.21	18.55	0.46	59.00	0.43	59.23
18.54	22.84	2.92	21.48	0.73	59.74	0.77	60.00
22.84	28.15	5.35	26.83	2.81	62.55	2.86	62.86
28.15	34.69	9.60	36.44	6.34	68.90	6.37	69.23
34.69	42.75	15.64	52.08	10.30	79.19	10.27	79.49
42.75	52.68	20.68	72.73	11.73	90.90	11.63	91.12
52.68	64.92	18.41	91.09	7.63	98.48	7.50	98.58
64.92	80.00	8.85	100.00	1.47	100.00	1.38	100.00

Table C5 The raw data of particle size of Zeolite Y

Particle size diameter (µm)		**Zeolite Y**					
Size Low	Size high	In %	Under %	In %	Under %	In %	Under %
0.20	0.48	0.49	0.49	0.32	0.32	0.35	0.35
0.48	0.59	1.39	1.88	1.10	1.42	1.20	1.55
0.59	0.71	1.76	3.64	1.49	2.91	1.61	3.16
0.71	0.86	1.64	5.28	1.60	4.51	1.70	4.85
0.86	1.04	1.33	6.60	1.65	6.16	1.69	6.54
1.04	1.26	1.14	7.74	1.68	7.85	1.69	8.23
1.26	1.52	1.20	8.94	1.71	9.56	1.73	9.96
1.52	1.84	1.57	10.52	1.96	11.53	2.01	11.97
1.84	2.23	2.49	13.01	2.91	14.43	2.97	14.94
2.23	2.70	3.80	16.81	4.29	18.72	4.33	19.27
2.70	3.27	4.65	21.46	4.85	23.57	4.87	24.15
3.27	3.95	5.89	27.35	5.89	29.46	5.87	30.01
3.95	4.79	6.87	34.22	6.52	35.99	6.47	36.49
4.79	5.79	7.49	41.71	6.85	42.83	6.78	43.27
5.79	7.01	7.33	49.04	6.49	49.32	6.42	49.69
7.01	8.48	6.39	55.42	5.54	54.86	5.50	55.18
8.48	10.27	5.08	60.50	4.39	59.25	4.37	59.55
10.27	12.43	3.96	64.46	3.54	62.79	3.54	63.09
12.43	15.05	3.28	67.75	3.14	65.93	3.14	66.23
15.05	18.21	2.89	70.64	2.97	68.90	2.98	69.21
18.21	22.04	2.47	73.11	2.65	71.55	2.65	71.85
22.04	26.68	1.78	74.89	1.92	73.46	1.91	73.77
26.68	32.29	0.84	75.71	0.86	74.31	0.85	74.60
32.29	39.08	0.00	75.73	0.00	74.32	0.00	74.62
39.08	47.30	0.00	75.73	0.00	74.32	0.00	74.62
47.30	57.25	0.36	76.10	0.03	74.38	0.00	74.65
57.25	69.30	2.18	78.27	1.85	76.21	1.77	76.40
69.30	83.87	4.74	83.03	4.53	80.74	4.41	80.82
83.87	101.52	7.06	90.08	7.23	87.96	7.10	87.91
101.52	122.87	6.96	97.02	7.85	95.80	7.79	95.69
122.87	148.72	2.96	99.96	4.19	99.96	4.30	99.96
148.72	180.00	0.00	100.00	0.00	100.00	0.00	100.00

Appendix D Identification of Crytallinity of Undoped and Doped Pth and Structure of Zeolite by X-ray Diffraction

Crystallinity and structures of poly(3-thiopheneacetic acid) and zeolite were identified by a X-ray Diffractometer (XRD) (D/MAX 2200). Powders of polymer and zeolite were packed onto a glasss plate and data were collected after X-ray passed though the sample. Properties of polythiophene can be identified by the peaks of graph. The area of broad peak can be identified as the amorphous part. The structure of zeolite can be considered from the position of each peak.

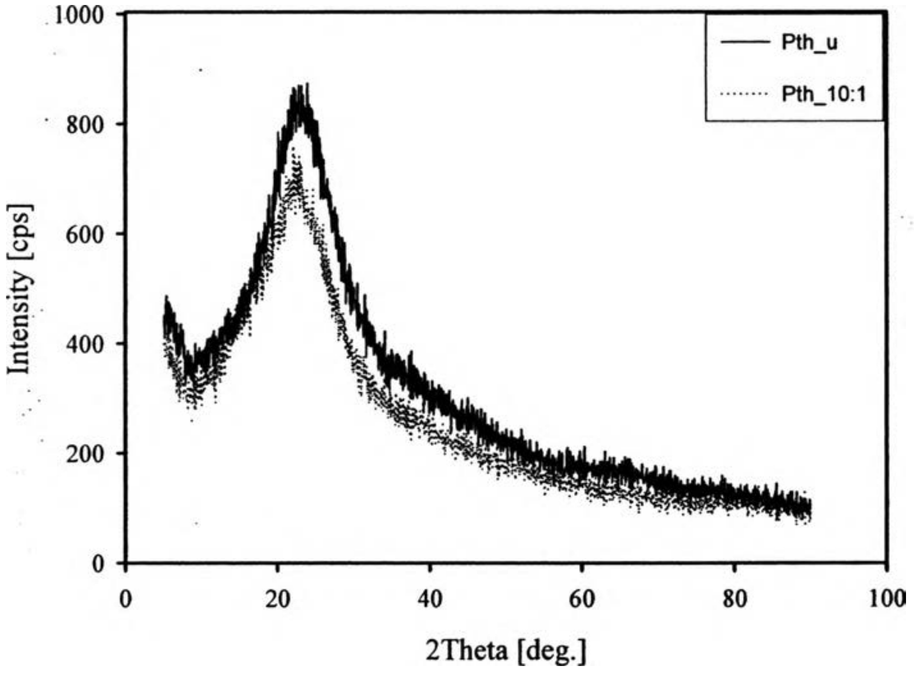


Figure D1 XRD pattern of: a) undoped and; b) doped poly(3-thiphene acetic acid) with $HClO_4$.

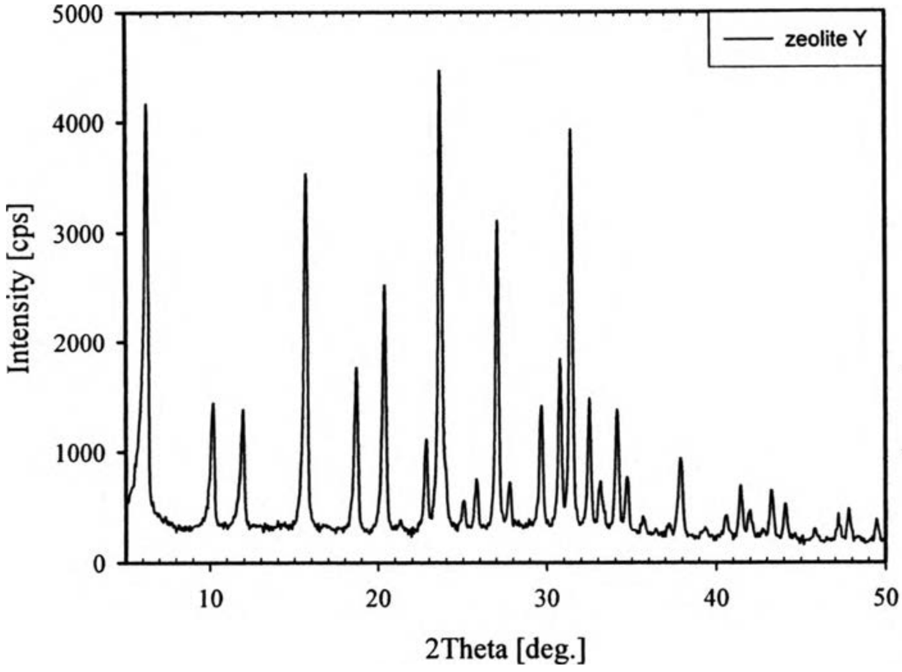


Figure D2 XRD pattern of Zeolite y.

Table D1 Raw data of XRD analysis of undoped and doped poly(3-thiopheneacetic acid)

	2Theta	d-value	Intensity	I/I0
Pth_u	23.30	3.8145	371	100
	25.20	3.5311	319	88
	26.65	3.3422	221	60
Pth_10:1	21.35	4.1583	241	88
	22.15	4.0099	274	100
	23.10	3.8471	263	96
	23.95	3.7125	231	86

Table D2 Raw data of XRD analysis of Zeolite Y

Raw data				**References** (Nurma *et al.* (2007))
2Theta	**d-value (A)**	**Intensity**	**I/I_0**	**2Theta**
6.20	14.2437	2955	80	6.20
10.15	8.7077	952	26	10.10
11.90	7.4308	871	24	11.80
15.65	5.6577	2887	78	15.60
18.70	4.7412	1327	36	18.60
20.35	4.3604	2018	54	20.20
22.80	3.8971	737	20	22.70
23.65	3.7589	3773	100	23.50
27.05	3.2936	2540	68	26.90
29.65	3.0105	1019	28	29.50
31.40	2.8466	3279	88	31.20
32.45	2.7568	1065	30	32.20
34.10	2.6271	1046	28	33.90
37.85	2.3750	695	20	37.60

Appendix E Density Measurement

The specific density (ρ_p) of the conductive polymer and zeolite can be measured by using a pycnometer. At first, we measured the weight of the blank pycnometer then added the water to the pycnometer and measured the total weight again. The specific density of water at testing temperature can be calculated by equation (E.1).

$$\rho_w = \frac{(a-b)}{V} \qquad \text{(E.1)}$$

where ρ_w is the specific density of water (g.cm^{-3}), a is the weight of pycnometer with water (g), b is the weight of blank pycnometer (g), and V is the volume of the pycnometer.

Next step, we measured the weight of the blank pycnometer again and then we added polymer or zeolite powders and measured the total weight. Then we added water into the pycnometer and then measured the total weight of pycnometer. The specific density of polymer and zeolite at a testing temperature can be calculated from equations (E2) – (E.3).

$$V_{H_2O} = \frac{(e-d)}{\rho_w} \qquad \text{(E.2)}$$

where V_{H_2O} is the volume of water added into the pycnometer (cm^3), e is the weight of the pycnometer with water and polymer or zeolite (g), d is the weight of polymer or zeolite powder and the pycnometer (g), and ρ_w is the specific density of water (g.cm^{-3}) that calaulated from equation E.1.

$$\rho_m = \frac{(d-b)}{V - V_{H_2O}} \qquad \text{(E.3)}$$

where ρ_m is the specific density of material (g.cm^{-3}), d is the weight of polymer or zeolite powder and the pycnometer (g), b is the weight of blank pycnometer (g), V is the volume of the pycnometer, and V_{H_2O} is the volume of water added into the pycnometer (cm^3).

Table E1 Summary data of the specific density of materials

Materials	**Cation types**	**Si/Al ratios**	**ρ_m (g/cm^3)**		**AVG**
H_2O	-	-	0.9964	0.9964	0.9964
Pth	-	-	1.6039	1.5908	1.5974
Zeolite Y	Na^+	5.1	1.8380	1.7481	1.7931
	NH_4^+	5.1	1.9019	1.7705	1.8362
	H^+	5.1	2.4852	2.1832	2.3342
	H^+	30	1.9070	2.0720	1.9895
	H^+	60	1.5819	1.6510	1.6164
	H^+	80	1.5989	1.6144	1.6066

Appendix F Determination of the Correction Factor (K)

The electrical conductivity of the conductive polymer was measured by using two-point probe meter. The surface of sample was in contact with two probes connected to a source meter (Keithley, Model 6517A). A constant voltage was applied and the resultant was measured.

The geometrical correction factor was taken into account of geometric effects, depending on the configuration and probe tip spacing.

$$K = \frac{w}{l} \qquad \text{(F.1)}$$

K is the geometrical correction factor, w is the width of probe tip spacing (cm), l is the length between probes (cm).

In this measurement, the constant *K* value was determined by using standard materials where specific resistivity values were known; we used silicon wafer chips (SiO_2). In our case, the sheet resistivity was measured by using our custom made two-point probe and then the geometric correction factor was calculated by equation (F.2) as follows:

$$K = \frac{\rho}{R \times t} = \frac{I \times \rho}{V \times t} \qquad \text{(F.2)}$$

K is the geometric correction factor, ρ is the resistivity of standard silicon wafer, which was calibrated by using a four point probe at King Mongkut's Institute Technology of Lad Krabang (Ω.cm), t is the film thickness (cm), R is the film resistance (Ω), I is the measured current (A), and V is the voltage drop (V).

Standard Si wafers were cleaned to remove organic impurities prior to be used according to the standard RCA method (Kern, 1993).

Materials

Acetones (Scharlau, 99.5%), Methanol (CARLO ERBA, 99.9%), Ammonium hydroxide (Merk, 99.9%), Hydrogen peroxide (CARLO ERBA, 30% in water), and dilute (2%) Hydrofuric acid

Experiment

The cleaning procedures contain 3 steps: the solvent clean, the RCA01 and the HF dip. The first step is the solvent clean step, employed to remove oils and organic residues that appeared on Si wafer surface. The Si wafer was placed into the acetone at 55 °C for 10 min, removed and placed in methanol for 2-5 min, subsequently rinsed with deionized water and blown dried with nitrogen gas. The second step is the RCA clean, to remove organic residues from silicon wafers. This process oxidized the silicon wafer and left a thin oxide on the surface of the wafer. RCA solution was prepared with 5 parts of water (H_2O), 1 part of 27% ammonium hydroxide (NH_4OH), and 1 part of 30% hydrogen peroxide (H_2O_2). 65 ml of NH_4OH (27%) was added into 325 ml of deionized water in a beaker and then heated to 70 ± 5°C. The mixture would bubble vigorously after 1-2 min, indicated that it was ready to use. Silicon wafer was soaked in the solution for 15 min, consequently overflowed with deionized water in order to rinse and remove the solution. The third step is the HF dip, which was carried out to remove native silicon dioxide from wafer. 480 ml of deionised water was added to the polypropylene bottle and then added to 20 ml HF. Wafer was soaked in this solution for 2 min, removed and checked for hydrophobicity by performing the wetting test. Deionized water was poured onto the surface wafer; the clean silicon surface would show that the beads of water would roll off. Clean Si wafer was further blown dried with nitrogen and stored in a clean and dry environment.

Table F1 Determination the correction factor of two point probe

Probe	K (correction factor)			
	1	2	3	Average
1	1.07E-04	1.07E-04	1.07E-04	1.07E-04

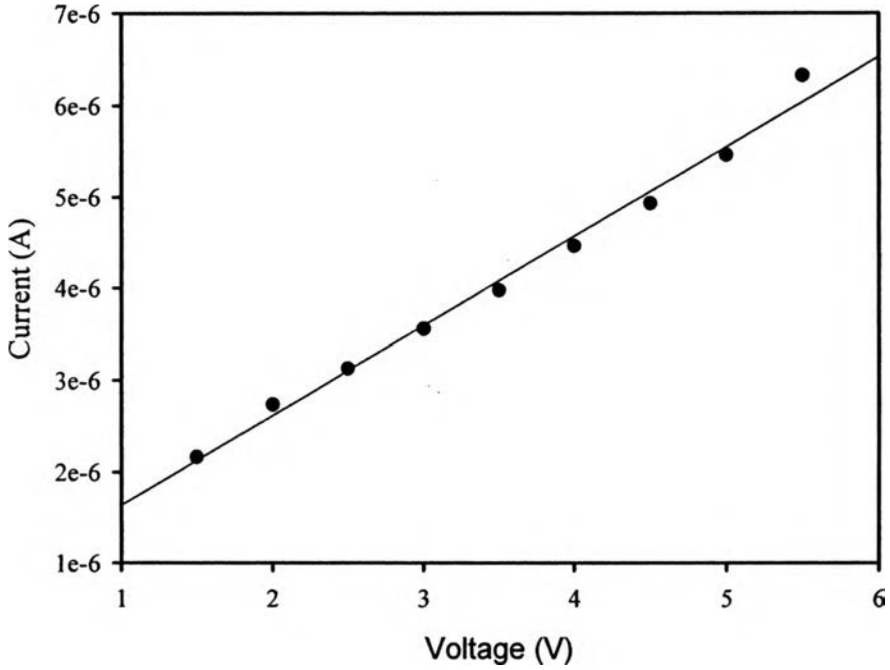


Figure F1 The calibration data of Si-wafer: K tay which $\frac{specific\ resistivity\ (\rho)}{thickness\ (t)} =$ 107.373 Ω, 24-25°C, 55-59 %R.H.

Table F2 Determination the correction factor of probe 1 with standard Si wafer ($\frac{specific\ resistivity\ (\rho)}{thickness\ (t)}$ = 107.373 Ω, 24-25°C, 55-59% R.H)

Volt Applied (V)			Current (A)			
1	2	3	1	2	3	Average
1.5	1.5	1.5	2.16E-06	2.18E-06	2.16E-06	2.16E-06
2.0	2.0	2.0	2.76E-06	2.73E-06	2.72E-06	2.74E-06
2.5	2.5	2.5	3.14E-06	3.13E-06	3.11E-06	3.13E-06
3.0	3.0	3.0	3.60E-06	3.57E-06	3.50E-06	3.56E-06
3.5	3.5	3.5	4.04E-06	3.97E-06	3.92E-06	3.98E-06
4.0	4.0	4.0	4.56E-06	4.47E-06	4.37E-06	4.46E-06
4.5	4.5	4.5	4.95E-06	4.94E-06	4.90E-06	4.93E-06
5.0	5.0	5.0	5.53E-06	5.48E-06	5.37E-06	5.46E-06
5.5	5.5	5.5	6.42E-06	6.28E-06	6.28E-06	6.33E-06

Appendix G Conductivity Measurement

The specific conductivity was measured with a two point probe connected to a source meter (Keithley, Model 6517A), and in contact with sample surface and a constant voltage was applied. So a responsive current was measured under the atmospheric pressure, 54-60% relative humidity and 24-25 °C. When a responsive current varies linearly with voltage in this region, it is called the linear ohmic regime which can be identified by plotting the applied voltage versus the current. The applied voltage and the current change in the linear ohmic regime were converted to the electrical conductivity of the polymer by using equation (G1) as follows:

$$\sigma = \frac{1}{\rho} = \frac{1}{R_s \times t} = \frac{I}{K \times V \times t} \qquad \text{(G1)}$$

where σ is the specific conductivity (S/cm), ρ is the specific resistivity (Ω.cm), R_s is the sheet resistivity (Ω), I is the measured current (A), K is the geometric correction factor, V is the applied voltage (voltage drop) (V), and t is the pellet thickness (cm).

In this measurement, the geometric correction factor (K) of probe 1 is 1.07×10^{-4} and the thickness of sample pellets was measured by using a thickness gauge.

In addition the conductivity of matrixes can be measured by using the resistivity testing fixture (Keithley, Model 8009) connected to a source meter (Keithley, Model 6517A) for a constant voltage source and reading resultant current under the atmospheric pressure, 54-60% relative humidity and 24-25°C. The conductivity of matrixes can calculated by using equation (G2 – G3) as follows:

$$K_v = \frac{\pi \times \left(D + [\beta \times g]\right)^2}{4} \qquad \text{(G2)}$$

where K_v is effective area of the guarded electrode for the particular electrode arrangement employed (cm^2), D is diameter of the guarded electrode (cm),

β is effective area coefficient (cm^2) (β is always zero), g is distance between the guarded electrode and the ring electrode (cm).

$$\sigma = \frac{1}{\rho} = \frac{t \times I}{22.9 \times V} \qquad \text{(G3)}$$

where σ is the specific conductivity (S/cm), ρ is the specific resistivity (Ω.cm), I is the measured current (A), V is the applied voltage (voltage drop) (V), and t is the sheet thickness (cm).

Table G1 Determination the specific conductivity (S/cm) of undoped and doped poly(3-thiopheneacetic acid) with different mole ratio of $HClO_4$ to monomer unit

Code	**Specific conductivity (S/cm)**		**AVG**	**STD**
Pth_u	1.26E-04	1.06E-04	1.16E-04	1.41E-05
Pth_1:1	6.22E-04	6.79E-04	6.51E-04	4.00E-05
Pth_3:1	1.39E-02	4.34E-02	2.86E-02	2.08E-02
Pth_5:1	2.42E-02	2.98E-02	2.70E-02	3.94E-02
Pth_7:1	5.36E-02	3.37E-02	4.36E-02	1.40E-02
Pth_10:1	8.47E+00	12.15E+00	10.31E+00	2.61E+00
Pth_50:1	10.23E+00	5.62E+00	7.93E+00	3.26E+00
Pth_100:1	7.23E+00	4.53E+00	5.88E+00	1.91E+00
Pth_200:1	8.23E+00	2.49E+00	5.36E+00	4.06E+00
Pth_300:1	1.04E+00	1.25E+00	1.15E+00	0.15E+00

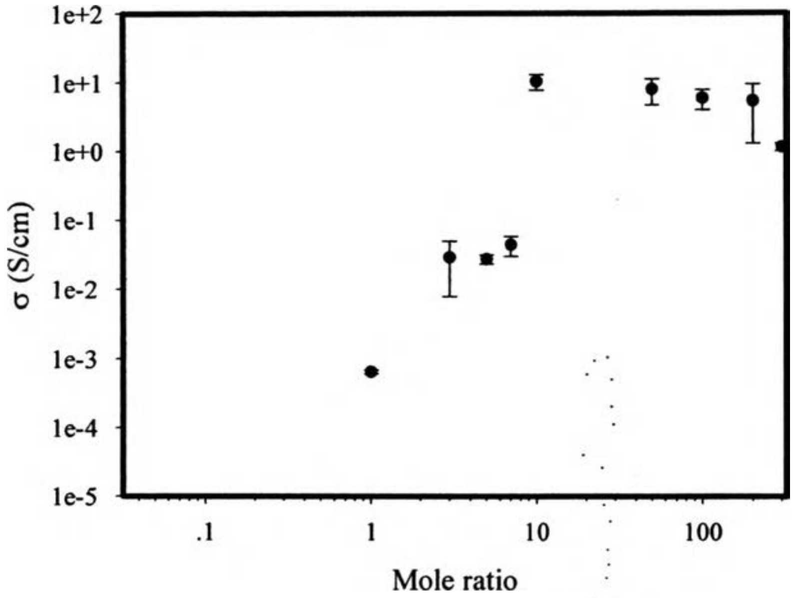


Fig G1 the specific conductivity (S/cm) of undoped and doped poly(3-thiopheneacetic acid) with different mole ratio of $HClO_4$ to monomer unit

Table G2 Determination the specific conductivity (S/cm) of Zeolite

Code	Cation type	Si/Al ratios	Specific conductivity (S/cm)		AVG	STD
Y	Na^+	5.1	5.14E-04	1.83E-04	3.48E-04	2.34E-04
	NH_4^+	5.1	1.81E-04	7.80E-05	1.30E-04	7.31E-05
	H^+	5.1	6.70E-04	4.00E-04	3.55E-04	4.45E-04
	H^+	30	2.72E-04	6.15E-04	4.43E-04	2.42E-04
	H^+	60	8.52E-02	1.59E-03	4.34E-02	5.91E-02
	H^+	80	2.38E-02	5.89E-04	1.22E-02	1.64E-02

Table G3 The raw data of the determination of linear regime of undoped poly(3-thiopheneacetic acid) at 24-25°C, 54-60% R.H.

Sample	Thickness (cm)	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
		1	2	1	2	1	2
Pth_u	1) 0.0222	0.7	0.3	3.62E-09	3.56E-09	2.18E-03	6.29E-03
	2) 0.0177	0.8	0.4	3.62E-09	3.57E-09	1.91E-03	4.71E-03
		0.9	0.5	3.66E-09	3.58E-09	1.71E-03	3.78E-03
		1.0	0.6	3.66E-09	3.61E-09	1.54E-03	3.18E-03
		1.5	0.7	3.83E-09	3.61E-09	1.08E-03	2.73E-03
		2.0	0.8	3.97E-09	3.61E-09	8.35E-04	2.39E-03
		2.5	0.9	4.07E-09	3.66E-09	6.85E-04	2.15E-03
		3.0	1.0	4.29E-09	3.70E-09	6.02E-04	1.96E-03
		3.5	1.5	4.34E-09	3.80E-09	5.22E-04	1.34E-03
		4.0	2.0	4.60E-09	3.89E-09	4.84E-04	1.03E-03
		4.5	2.5	4.72E-09	3.97E-09	4.42E-04	8.41E-04
		5.0	3.0	4.87E-09	4.07E-09	4.10E-04	7.18E-04
		5.5	3.5	5.02E-09	4.16E-09	3.85E-04	6.28E-04
		6.0	4.0	5.22E-09	4.22E-09	3.67E-04	5.58E-04
		6.5	4.5	5.23E-09	4.32E-09	3.38E-04	5.08E-04
		7.0	5.0	5.34E-09	4.41E-09	3.21E-04	4.66E-04
		7.5	5.5	5.55E-09	4.48E-09	3.11E-04	4.31E-04
		8.0	6.0	5.69E-09	4.56E-09	2.99E-04	4.02E-04

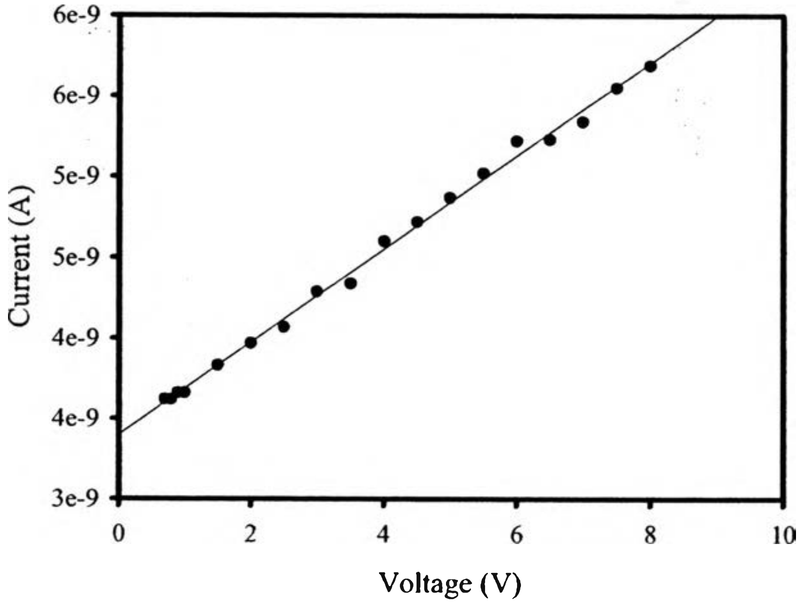


Fig G2 The linear regime of undoped poly(3-thiopheneacetic acid) at 24-25°C, 54-60% R.H.

Table G4 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 1:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness (cm)	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
		1	2	1	2	1	2
Pth_1:1	1) 0.0300	0.60	3.00	3.89E-09	6.05E-09	2.02E-03	6.27E-04
	2) 0.0275	0.70	3.50	4.68E-09	6.33E-09	2.08E-03	5.63E-04
		0.80	4.00	3.49E-09	6.45E-09	1.36E-03	5.01E-04
		0.90	4.50	3.85E-09	8.40E-09	1.33E-03	5.81E-04
		1.00	5.00	5.43E-09	8.17E-09	1.69E-03	5.09E-04
		1.20	5.50	5.48E-09	9.58E-09	1.42E-03	5.42E-04
		1.40	6.00	5.72E-09	1.04E-08	1.27E-03	5.37E-04
		1.60	6.50	5.81E-09	1.08E-08	1.13E-03	5.15E-04
		1.80	7.00	5.90E-09	1.17E-08	1.02E-03	5.21E-04
		2.00		6.76E-09		1.05E-03	
		2.20		8.25E-09		1.17E-03	
		2.40		8.21E-09		1.06E-03	
		2.60		8.50E-09		1.02E-03	
		2.80		7.73E-09		8.59E-04	
		3.00		9.37E-09		9.72E-04	
		3.50		1.13E-08		1.00E-03	
		4.00		1.19E-08		9.29E-04	
		4.50		1.24E-08		8.55E-04	
		5.00		1.43E-08		8.93E-04	
		5.50		1.39E-08		7.87E-04	
		6.00		1.60E-08		8.28E-04	
		6.50		1.70E-08		8.15E-04	

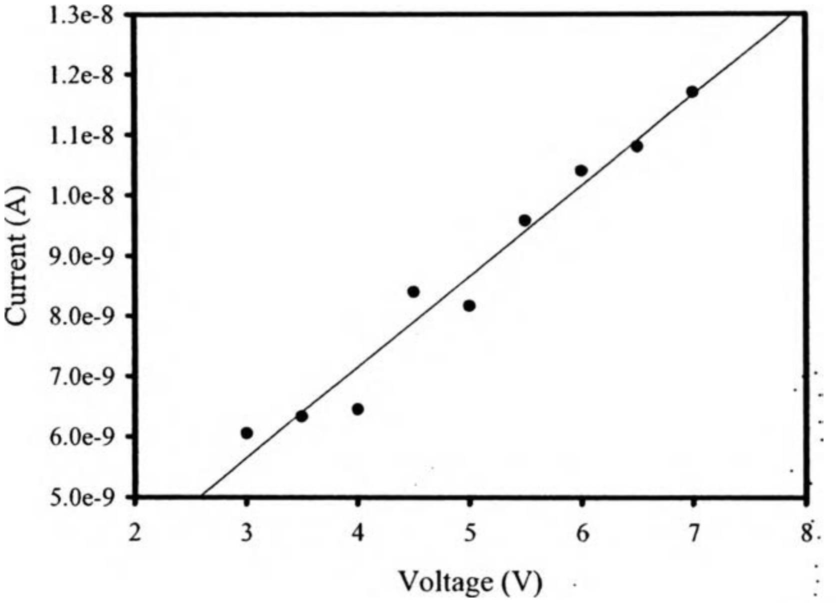


Fig G3 The linear regime of doped poly(3-thiopheneacetic acid) 1:1 at 24-25°C, 54-60% R.H.

Table G5 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 3:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Pth_3:1	1) 0.0605	3.00	3.00	3.94E-07	1.11E-06	2.03E-02	5.36 E-02
	2) 0.0646	3.50	3.50	4.44E-07	1.33E-06	1.96E-02	5.50 E-02
		4.00	4.00	5.03E-07	1.50E-06	1.94E-02	5.43 E-02
		4.50	4.50	5.60E-07	1.66E-06	1.92E-02	5.32 E-02
		5.00	5.00	6.14E-07	1.81E-06	1.90E-02	5.25 E-02
		5.50	5.50	6.66E-07	1.97E-06	1.87E-02	5.18 E-02
		6.00	6.00	7.37E-07	2.12E-06	1.90E-02	5.10 E-02
		6.50	6.50	7.62E-07	2.29E-06	1.81E-02	5.10 E-02
		7.00	7.00	8.03E-07	2.36E-06	1.77E-02	4.88 E-02
		7.50	7.50	8.44E-07	2.41E-06	1.74E-02	4.65 E-02
		8.00	8.00	8.95E-07	2.51E-06	1.73E-02	4.54 E-02
		8.50	8.50	9.05E-07	2.62E-06	1.64E-02	4.46 E-02
		9.00	9.00	9.35E-07	2.73E-06	1.60E-02	4.39 E-02
		9.50	9.50	9.60E-07	2.96E-06	1.56E-02	4.51 E-02

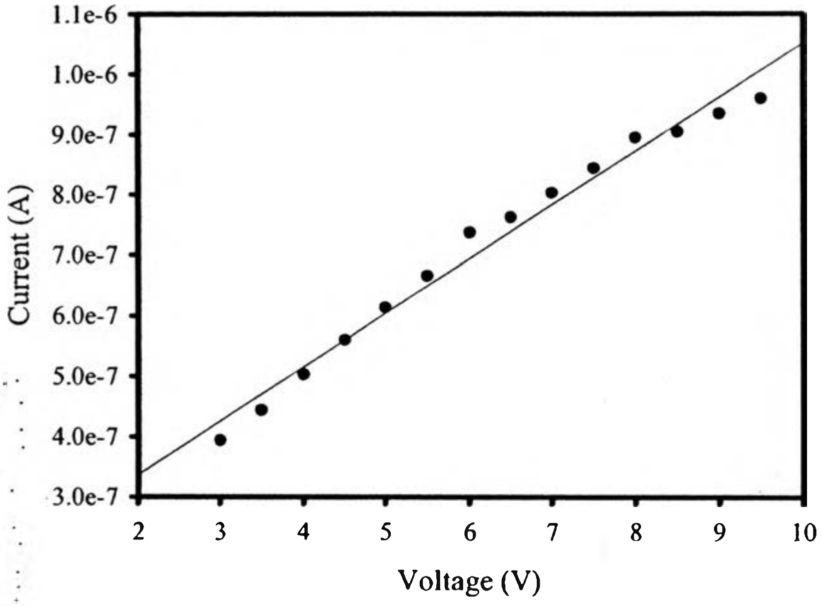


Fig G4 The linear regime of doped poly(3-thiopheneacetic acid) 3:1 at 24-25°C, 54-60% R.H..

Table G6 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 5:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Pth_5:1	1) 0.0771	2.50	1.50	8.07E-07	2.85E-07	3.91E-02	2.83 E-02
	2) 0.0627	3.00	2.00	9.24E-07	3.60E-07	3.73E-02	2.68 E-02
		3.50	2.50	1.04E-06	4.42E-07	3.61E-02	2.64 E-02
		4.00	3.00	1.18E-06	5.00E-07	3.58E-02	2.48 E-02
		4.50	3.50	1.27E-06	5.79E-07	3.43E-02	2.47 E-02
		5.00	4.00	1.40E-06	6.67E-07	3.39E-02	2.49 E-02
		5.50	4.50	1.53E-06	7.68E-07	3.37E-02	2.54 E-02
		6.00	5.00	1.58E-06	8.38E-07	3.20E-02	2.50 E-02
		6.50	5.50	1.67E-06	9.21E-07	3.11E-02	2.50 E-02
		7.00	6.00	1.75E-06	9.98E-07	3.04E-02	2.48 E-02
		7.50	6.50	1.84E-06	1.06E-06	2.97E-02	2.43 E-02
		8.00	7.00	1.90E-06	1.13E-06	2.89E-02	2.40 E-02
		8.50	7.50	2.05E-06	1.19E-06	2.93E-02	2.36 E-02
			8.00		1.24E-06		2.32 E-02

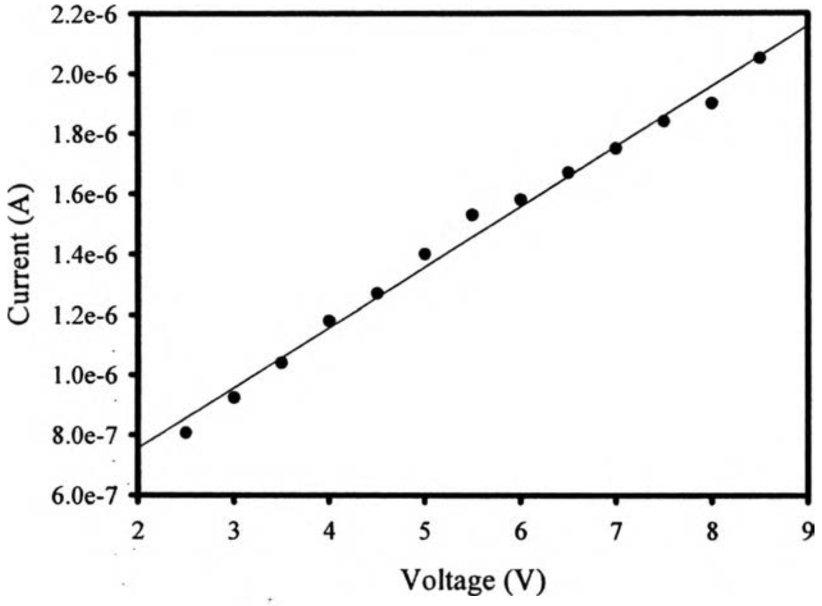


Fig G5 The linear regime of doped poly(3-thiopheneacetic acid) 5:1 at 24-25°C, 54-60% R.H.

Table G7 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 7:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Ptb_7:1	1) 0.0349	1.50	1.00	2.34E-07	2.28E-07	4.17E-02	3.84 E-02
	2) 0.0555	2.00	1.50	3.12E-07	3.64E-07	4.18E-02	4.08 E-02
		2.50	2.00	3.99E-07	5.02E-07	4.28E-02	4.23 E-02
		3.00	2.50	4.73E-07	6.04E-07	4.22E-02	4.07 E-02
		3.50	3.00	5.65E-07	7.43E-07	4.33E-02	4.17 E-02
		4.00	3.50	6.53E-07	8.62E-07	4.37E-02	4.15 E-02
		4.50	4.00	7.17E-07	9.49E-07	4.27E-02	4.00 E-02
		5.00	4.50	8.12E-07	1.08E-06	4.35E-02	4.06 E-02
		5.50	5.00	9.05E-07	1.21E-06	4.40E-02	4.08 E-02
		6.00	5.50	9.92E-07	1.35E-06	4.43E-02	4.15 E-02
		6.50	6.00	1.08E-06	1.48E-06	4.47E-02	4.16 E-02
		7.00	6.50	1.18E-06	1.59E-06	4.50E-02	4.12 E-02
		7.50	7.00	1.27E-06	1.69E-06	4.53E-02	4.08 E-02
		8.00		1.36E-06		4.55E-02	
		8.50		1.45E-06		4.56E-02	
		9.00		1.52E-06		4.51E-02	
		9.50		1.57E-06		4.44E-02	

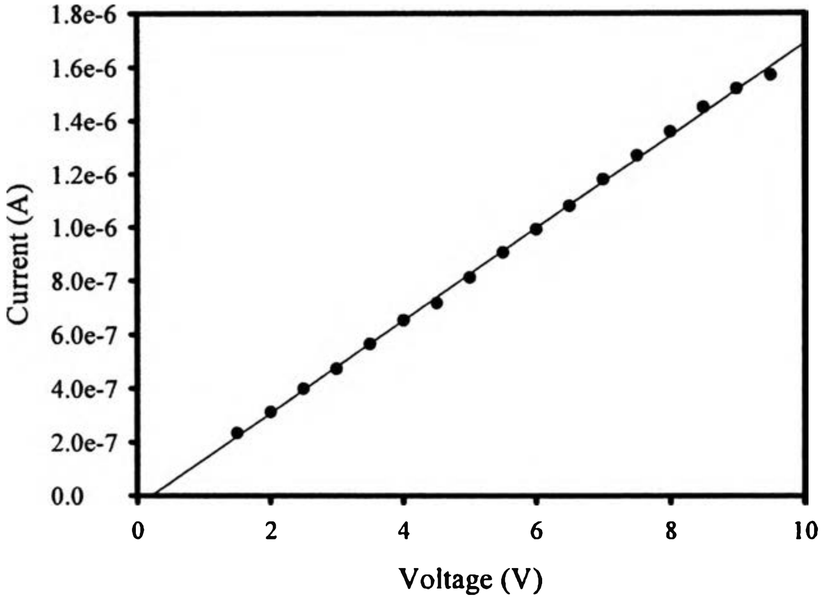


Fig G6 The linear regime of doped poly(3-thiopheneacetic acid) 7:1 at 24-25°C, 54-60% R.H.

Table G8 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 10:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	**Thickness**	**Applied voltage (V)**		**Measured Current (A)**		**Conductivity (S/cm)**	
	(cm)	**1**	**2**	**1**	**2**	**1**	**2**
Pth_10:1	1) 0.0883	1.00	0.60	8.34E-05	1.05E-05	7.79E+00	1.63E+00
	2) 0.1000	1.50	0.70	1.63E-04	1.47E-05	10.17E+00	1.96E+00
		2.00	0.80	2.37E-04	1.92E-05	11.07E+00	2.24E+00
		2.50	0.90	3.09E-04	2.38E-05	11.57E+00	2.47E+00
		3.00	1.00	3.78E-04	2.79E-05	11.79E+00	2.61E+00
		3.50	1.50	4.35E-04	5.46E-05	11.63E+00	3.40E+00
		4.00	2.00	4.79E-04	7.99E-05	11.18E+00	3.74E+00
		4.50	2.50	5.31E-04	1.05E-04	11.03E+00	3.92E+00
		5.00	3.00	6.09E-04	1.26E-04	11.38E+00	3.92E+00
		5.50	3.50	6.57E-04	1.43E-04	11.17E+00	3.82E+00
		6.00		7.10E-04		11.06E+00	
		6.50		7.83E-04		11.27E+00	
		7.00		8.45E-04		11.28E+00	
		7.50		9.33E-04		11.62E+00	

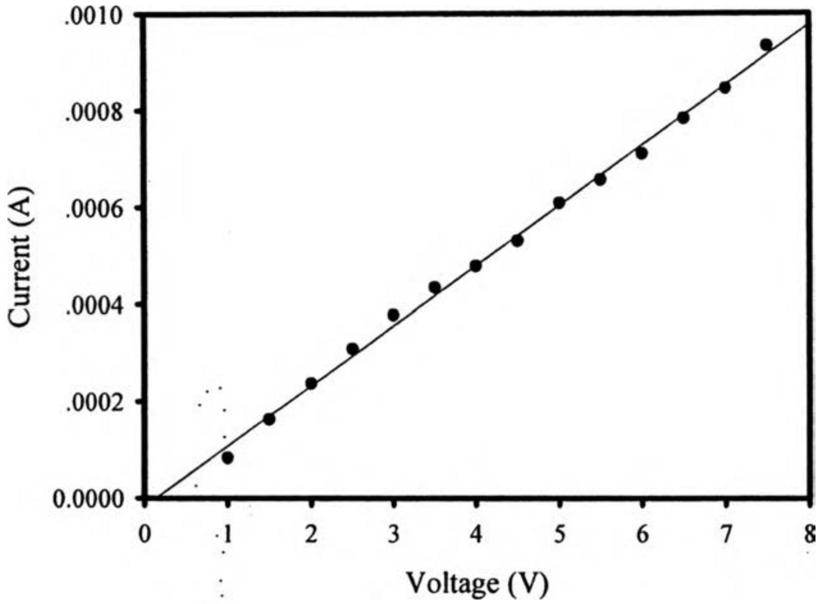


Fig G7 The linear regime of doped poly(3-thiopheneacetic acid) 10:1 at 24-25°C, 54-60% R.H.

Table G9 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 50:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Pth_50:1	1) 0.0731	0.30	0.40	1.70E-06	2.77E-06	7.24E-01	7.78E-01
	2) 0.0832	0.40	0.50	4.24E-06	5.32E-06	1.36E+00	1.20E+00
		0.50	0.60	1.03E-05	9.20E-06	2.63E+00	1.72E+00
		0.60	0.70	1.64E-05	1.40E-05	3.49E+00	2.25E+00
		0.70	0.80	2.32E-05	1.87E-05	4.24E+00	2.63E+00
		0.80	0.90	3.08E-05	2.25E-05	4.92E+00	2.81E+00
		0.90	1.00	3.83E-05	2.50E-05	5.44E+00	2.81E+00
		1.00	1.50	4.03E-05	5.50E-05	5.16E+00	4.12E+00
		1.50	2.00	8.62E-05	8.34E-05	7.35E+00	4.68E+00
		2.00	2.50	1.35E-04	1.10E-04	8.61E+00	4.95E+00
		2.50	3.00	1.83E-04	1.28E-04	9.34E+00	4.81E+00
		3.00	3.50	2.14E-04	1.41E-04	9.13E+00	4.52E+00
		3.50		2.46E-04		8.98E+00	

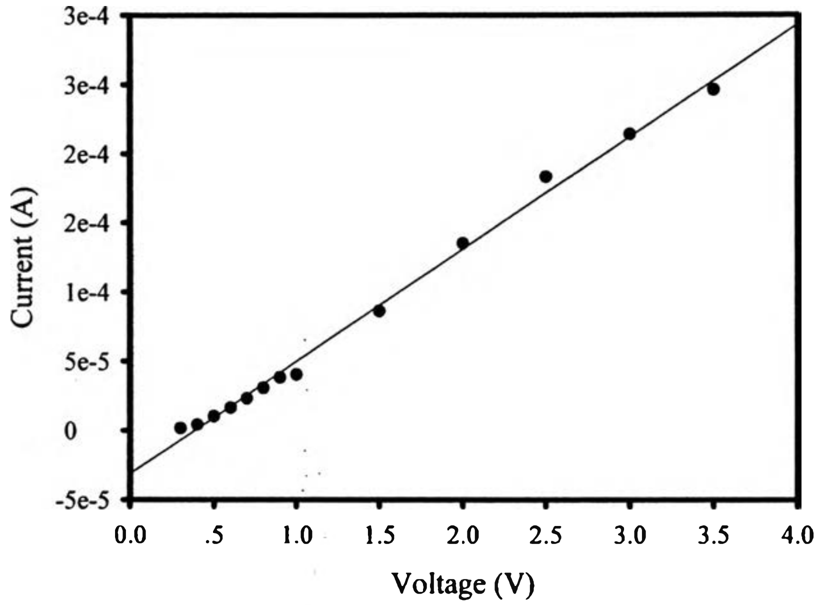


Fig G8 The linear regime of doped poly(3-thiopheneacetic acid) 50:1 at 24-25°C, 54-60% R.H.

Table G10 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 100:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Pth_100:1	1) 0.0388	0.20	0.20	2.57E-06	2.43E-06	3.10E+00	2.76E+00
	2) 0.0412	0.30	0.30	3.73E-06	3.40E-06	3.00E+00	2.57E+00
		0.40	0.40	5.25E-06	4.47E-06	3.16E+00	2.53E+00
		0.50	0.50	7.14E-06	5.80E-06	3.44E+00	2.63E+00
		0.60	0.60	9.45E-06	7.42E-06	3.80E+00	2.80E+00
		0.70	0.70	1.21E-05	9.28E-06	4.16E+00	3.01E+00
		0.80	0.80	1.49E-05	1.13E-05	4.48E+00	3.20E+00
		0.90	0.90	1.78E-05	1.34E-05	4.76E+00	3.36E+00
		1.00	1.00	2.03E-05	1.51E-05	4.90E+00	3.42E+00
		1.50	1.50	3.62E-05	2.61E-05	5.82E+00	3.94E+00
		2.00	2.00	5.20E-05	3.76E-05	6.27E+00	4.26E+00
		2.50	2.50	6.76E-05	4.85E-05	6.52E+00	4.40E+00
		3.00	3.00	8.23E-05	5.89E-05	6.61E+00	4.45E+00
		3.50	3.50	9.74E-05	6.86E-05	6.71E+00	4.44E+00
		4.00	4.00	1.14E-04	7.76E-05	6.87E+00	4.40E+00
		4.50		1.21E-04		6.46E+00	

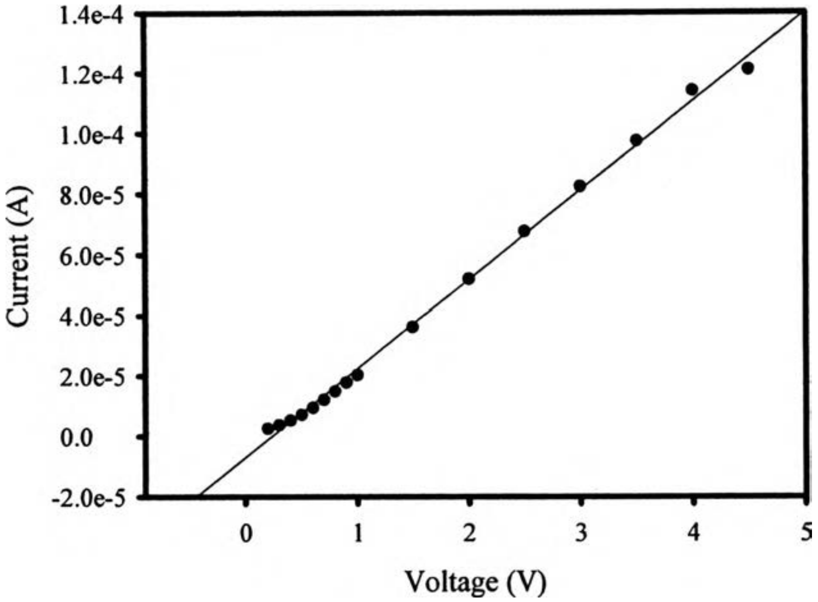


Fig G9 The linear regime of doped poly(3-thiopheneacetic acid) 100:1 at 24-25°C, 54-60% R.H.

Table G11 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 200:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Ptb_200:1	1) 0.0795	0.40	0.70	1.05E-06	9.76E-06	3.08E-01	2.05E+00
	2) 0.0752	0.50	0.80	2.73E-06	1.20E-05	6.41E-01	2.21E+00
		0.60	0.90	6.60E-06	1.41E-05	1.29E+00	2.29E+00
		0.70	1.00	1.23E-05	1.58E-05	2.07E+00	2.32E+00
		0.80	1.50	1.84E-05	2.91E-05	2.70E+00	2.85E+00
		0.90	2.00	2.48E-05	4.18E-05	3.24E+00	3.06E+00
		1.00	2.50	2.94E-05	5.53E-05	3.46E+00	3.24E+00
		1.50	3.00	7.04E-05	6.81E-05	5.51E+00	3.33E+00
		2.00	3.50	1.14E-04	8.02E-05	6.67E+00	3.36E+00
		2.50	4.00	1.45E-04	9.07E-05	6.83E+00	3.33E+00
		3.00		1.76E-04		6.88E+00	
		3.50		1.99E-04		6.67E+00	
		4.00		2.26E-04		6.65E+00	

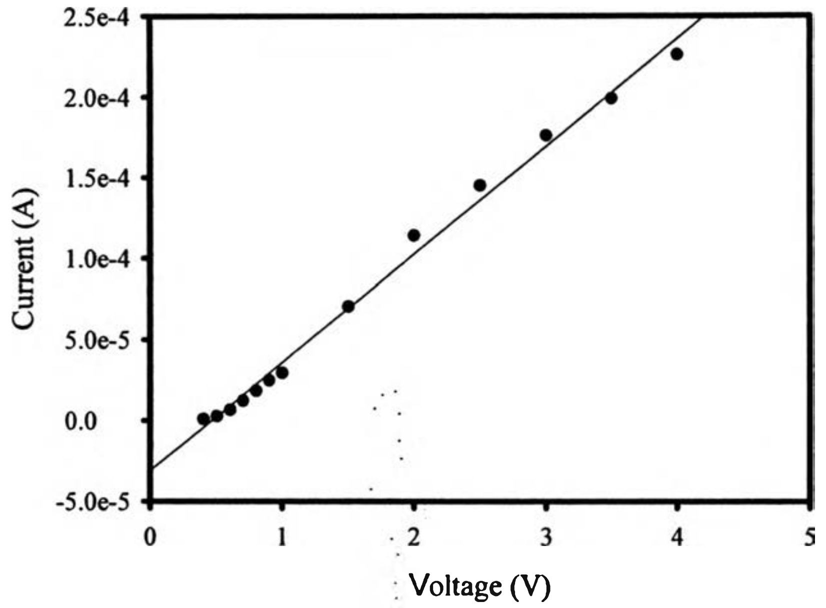


Fig G10 The linear regime of doped poly(3-thiopheneacetic acid) 200:1 at 24-25°C, 54-60% R.H.

Table G12 The raw data of the determination of linear regime of doped poly(3-thiopheneacetic acid) 300:1 at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Thickness	Applied voltage (V)		Measured Current (A)		Conductivity (S/cm)	
	(cm)	1	2	1	2	1	2
Pth_300:1	1) 0.0900	0.50	0.20	4.04E-06	1.46E-07	8.40E-01	8.99E-02
	2) 0.0760	0.60	0.30	5.46E-06	3.20E-07	9.45E-01	1.31 E-01
		0.70	0.40	6.88E-06	5.36E-07	1.02E+00	1.65 E-01
		0.80	0.50	8.17E-06	7.96E-07	1.06E+00	1.96 E-01
		0.90	0.60	8.58E-06	1.08E-06	9.90E-01	2.22 E-01
		1.00	0.70	9.44E-06	1.35E-06	9.81E-01	2.37 E-01
		1.20	0.80	1.18E-05	1.57E-06	1.02E+00	2.42 E-01
		1.40	0.90	1.43E-05	1.74E-06	1.06E+00	2.38 E-01
		1.60	1.00	1.65E-05	1.93E-06	1.07E+00	2.38 E-01
		1.80	1.20	1.83E-05	2.43E-06	1.06E+00	2.49 E-01
		2.00		2.00E-05		1.04E+00	

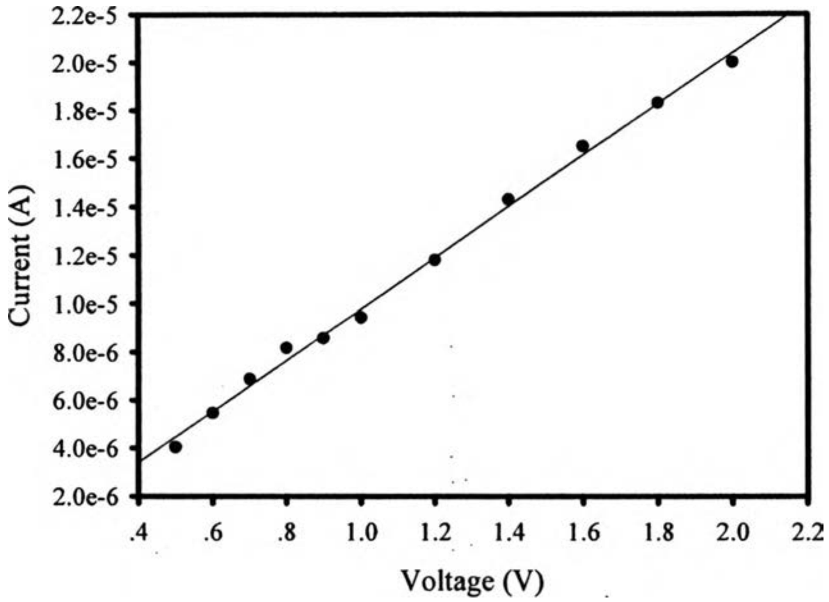


Fig G11 The linear regime of doped poly(3-thiopheneacetic acid) 300:1 at 24-25°C, 54-60% R.H.

Table G13 The raw data of the determination of linear regime of Zeolite Y (Na^+, Si/Al = 5.1) at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Cation type	Si/Al ratios	Thickness	Applied voltage (v)		Measure Current (A)		Conductivity (S/cm)	
			(cm)	1	2	1	2	1	2
Y	*Na⁺*	5.1	1) 0.0364	4.50	4.00	6.66E-09	6.40E-09	3.80E-04	4.11E-04
			2) 0.0510	5.00	4.50	7.06E-09	5.50E-09	3.63E-04	3.14E-04
				5.50	5.00	8.71E-09	6.71E-09	4.06E-04	3.45E-04
				6.00	5.50	9.43E-09	8.08E-09	4.04E-04	3.77E-04
				6.50	6.00	1.02E-08	8.51E-09	4.03E-04	3.64E-04
				7.00	6.50	9.77E-09	6.83E-09	3.58E-04	2.70E-04
				7.50	7.00	9.35E-09	9.25E-09	3.20E-04	3.39E-04
				8.00	7.50	1.18E-08	1.05E-08	3.78E-04	3.59E-04
				8.50	8.00	1.24E-08	1.04E-08	3.75E-04	3.35E-04
				9.00	8.50	1.27E-08	1.30E-08	3.62E-04	3.91E-04
				9.50	9.00	1.23E-08	1.89E-08	3.32E-04	5.41E-04
				10.00	9.50	1.46E-08	1.19E-08	3.75E-04	3.21E-04
				15.00	10.00	2.38E-08	1.30E-08	4.07E-04	3.34E-04
					15.00		2.11E-08		3.61E-04
					20.00		2.68E-08		3.44E-04
					25.00		3.39E-08		3.48E-04
					30.00		4.48E-08		3.83E-04

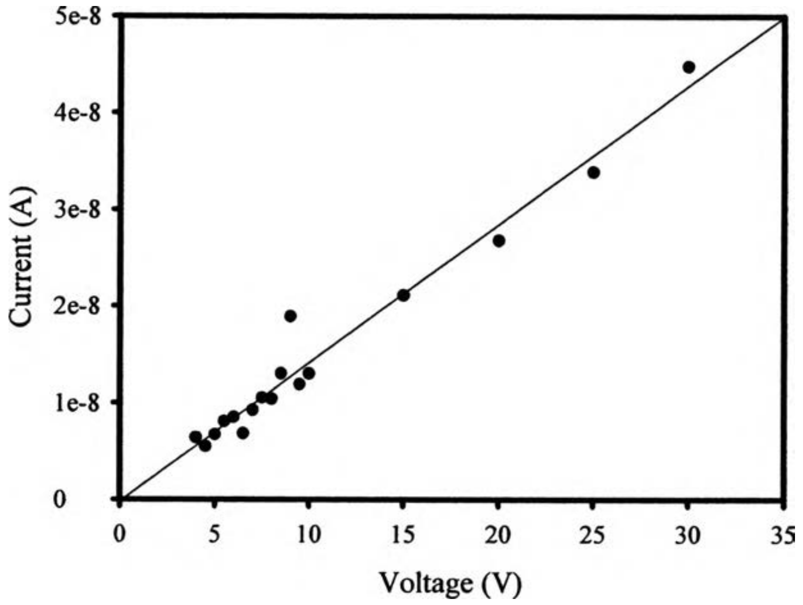


Fig G12 The linear regime of Zeolite Y Y (Na^+, Si/Al = 5.1) at 26 °C ± 1 °C, (54 to 60) % R.H.

Table G14 The raw data of the determination of linear regime of Zeolite Y(NH_4^+, Si/Al = 5.1) at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Cation type	Si/Al ratios	Thickness	Applied voltage (v)		Measure Current (A)		Conductivity (S/cm)	
			(cm)	1	2	1	2	1	2
Y	NH_4^+	5.1	1) 0.0309	9.00	20.00	5.42E-09	8.34E-09	1.82E-04	1.26E-04
			2) 0.0479	9.50	25.00	5.48E-09	1.00E-08	1.75E-04	1.21E-04
				10.00	30.00	4.47E-09	1.02E-08	1.35E-04	1.02E-04
				15.00	35.00	9.69E-09	1.12E-08	1.95E-04	9.69E-05
				20.00	40.00	1.22E-08	1.14E-08	1.84E-04	8.64E-05
				25.00	50.00	1.23E-08	1.54E-08	1.49E-04	9.34E-05
				30.00	60.00	1.81E-08	2.22E-08	1.82E-04	1.12E-04
				35.00	70.00	2.17E-08	2.48E-08	1.88E-04	1.07E-04
				40.00	80.00	2.54E-08	3.01E-08	1.92E-04	1.14E-04
				50.00	90.00	3.10E-08	3.78E-08	1.88E-04	1.27E-04

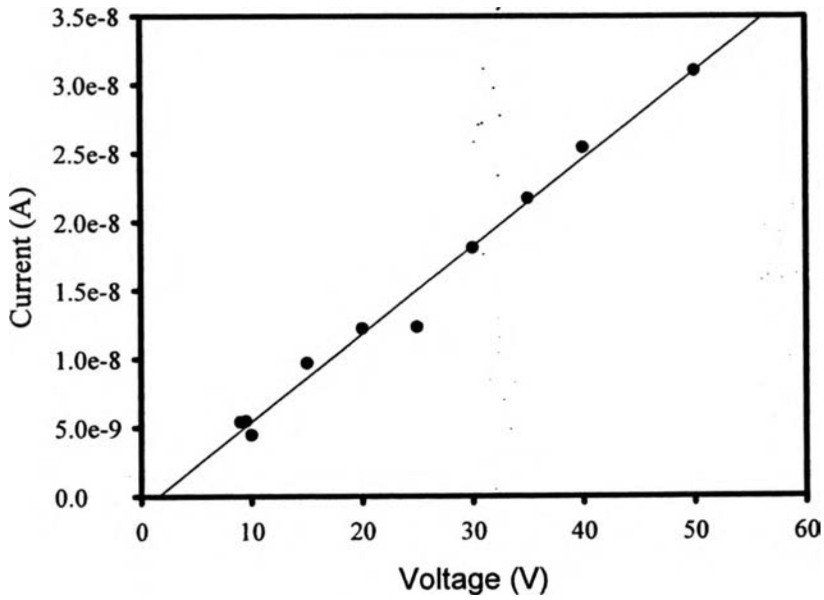


Fig G13 The linear regime of Zeolite Y (NH_4^+, Si/Al = 5.1) at 26 °C ± 1 °C, (54 to 60) % R.H.

Table G15 The raw data of the determination of linear regime of Zeolite Y (H^+, Si/Al = 5.1) at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Cation type	Si/Al ratios	Thickness	Applied voltage (v)		Measure Current (A)		Conductivity (S/cm)	
			(cm)	1	2	1	2	1	2
Y	H^+	5.1	1) 0.0558	2.00	4.50	1.14E-08	3.79E-09	9.52E-04	1.41E-04
			2) 0.0699	2.50	5.00	1.16E-08	3.83E-09	7.79E-04	1.28E-04
				3.00	5.50	1.24E-08	4.30E-09	6.94E-04	1.31E-04
				3.50	6.00	1.44E-08	4.35E-09	6.88E-04	1.21E-04
				4.00	6.50	1.66E-08	3.87E-09	6.97E-04	9.98E-05
				4.50	7.00	1.76E-08	4.27E-09	6.55E-04	1.02E-04
				5.00	7.50	1.98E-08	4.29E-09	6.62E-04	9.59E-05
				5.50	8.00	2.66E-08	4.60E-09	8.10E-04	9.63E-05
					8.50		4.50E-09		8.87E-05
					9.00		3.18E-09		5.91E-05
					9.50		5.22E-09		9.20E-05
					10.00		5.06E-09		8.48E-05
					15.00		5.40E-09		6.03E-05
					20.00		7.65E-09		6.40E-05
					25.00		8.67E-09		5.81E-05
					30.00		1.11E-08		6.19E-05
					35.00		1.22E-08		5.86E-05
					40.00		1.37E-08		5.75E-05

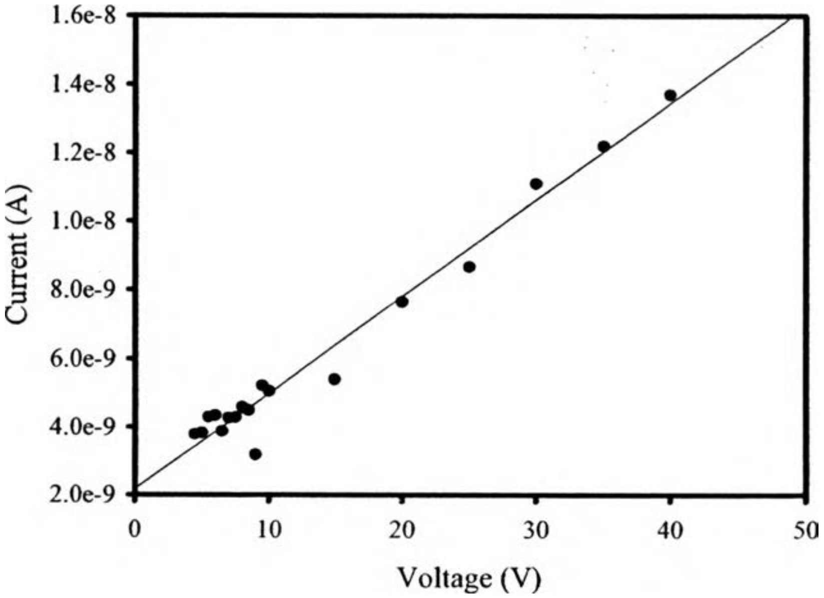


Fig G14 The linear regime of Zeolite Y (H^+, Si/Al = 5.1) at 26 °C ± 1 °C, (54 to 60) % R.H.

Table G16 The raw data of the determination of linear regime of Zeolite Y (H^+, Si/Al = 30) at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Cation type	Si/Al ratios	Thickness	Applied voltage (v)		Measure Current (A)		Conductivity (S/cm)	
			(cm)	1	2	1	2	1	2
Y	H^+	30	1) 0.0344	0.40	0.70	3.71E-09	2.17E-09	2.52E-03	8.45E-04
			2) 0.0304	0.50	0.80	3.06E-09	2.04E-09	1.66E-03	6.94E-04
				0.60	0.90	3.70E-09	2.75E-09	1.68E-03	8.31E-04
				0.70	1.00	3.79E-09	2.85E-09	1.47E-03	7.76E-04
				0.80	1.50	4.23E-09	3.61E-09	1.44E-03	6.54E-04
				0.90	2.00	2.54E-09	5.66E-09	7.67E-04	7.70E-04
				1.00	2.50	4.34E-09	5.67E-09	1.18E-03	6.17E-04
				1.50	3.00	3.64E-09	8.11E-09	6.60E-04	7.35E-04
				2.00	3.50	4.34E-09	8.46E-09	5.90E-04	6.57E-04
				2.50	4.00	6.24E-09	1.05E-08	6.79E-04	7.17E-04
				3.00	4.50	4.18E-09	1.12E-08	3.79E-04	6.76E-04
				3.50	0.70	7.20E-09	2.17E-09	5.59E-04	8.45E-04
				4.00		6.83E-09		4.64E-04	
				4.50		7.53E-09		4.55E-04	
				5.00		8.34E-09		4.53E-04	
				5.50		7.71E-09		3.81E-04	

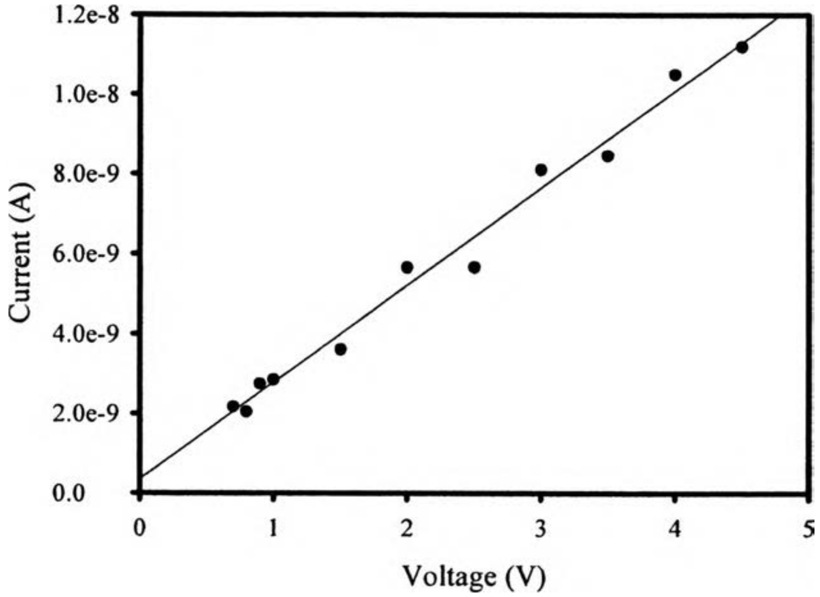


Fig G15 The linear regime of Zeolite Y (H^+, Si/Al = 30) at 26 °C ± 1 °C, (54 to 60) % R.H.

Table G17 The raw data of the determination of linear regime of Zeolite Y (H^+, Si/Al = 60) at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Cation type	Si/Al ratios	Thickness	Applied voltage (v)		Measure Current (A)		Conductivity (S/cm)	
			(cm)	1	2	1	2	1	2
Y	H^+	60	1) 0.0329	1.00	0.80	1.46E-08	9.76E-09	4.14E-03	3.47E-03
			2) 0.0353	1.50	0.90	2.92E-07	1.03E-08	5.54E-02	3.25E-03
				2.00	1.00	3.96E-07	9.53E-09	5.62E-02	2.71E-03
				2.50	1.50	5.21E-07	1.65E-08	5.92E-02	3.12E-03
				3.00	2.00	6.40E-07	1.64E-08	6.06E-02	2.33E-03
				3.50	2.50	7.93E-07	1.47E-08	6.43E-02	1.66E-03
				4.00	3.00	9.04E-07	1.84E-08	6.42E-02	1.75E-03
				4.50	3.50	1.14E-06	2.24E-08	7.21E-02	1.82E-03
					4.00		2.58E-08		1.83E-03
					4.50		3.57E-08		7.17E-04

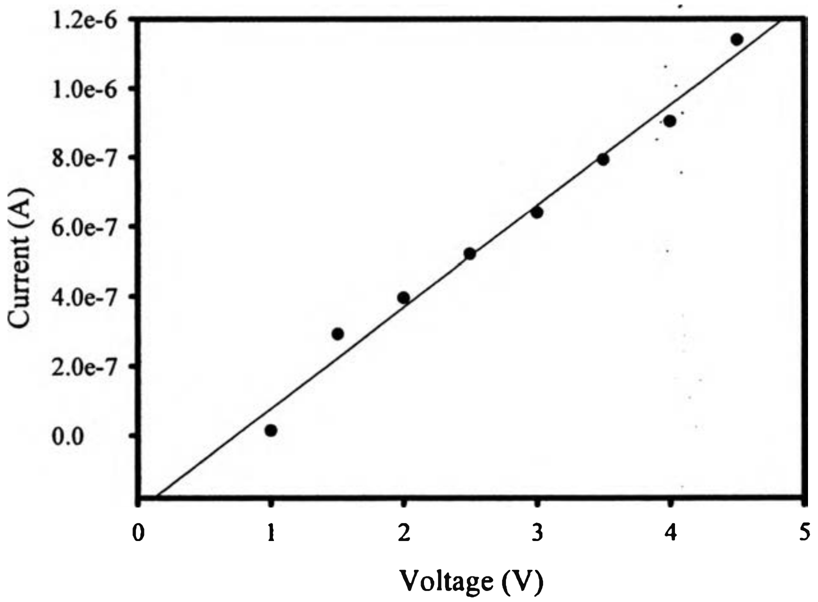


Fig G16 The linear regime of Zeolite Y (H^+, Si/Al = 60) at 26 °C ± 1 °C, (54 to 60) % R.H.

Table G18 The raw data of the determination of linear regime of Zeolite Y (H^+, Si/Al = 80) at 26 °C ± 1 °C, (54 to 60) % R.H.

Sample	Cation type	Si/Al ratios	Thickness	Applied voltage (v)		Measure Current (A)		Conductivity (S/cm)	
			(cm)	1	2	1	2	1	2
Y	H^+	80	1) 0.0314	6.00	4.00	2.57E-07	5.53E-09	1.28E-02	4.12E-04
			2) 0.0476	6.50	4.50	2.90E-07	7.94E-09	1.33E-02	5.26E-04
				7.00	5.00	3.26E-07	9.25E-09	1.39E-02	5.51E-04
				7.50	5.50	3.66E-07	1.04E-08	1.45E-02	5.62E-04
				8.00	6.00	4.02E-07	1.13E-08	1.50E-02	5.60E-04
				8.50	6.50	4.47E-07	1.26E-08	1.57E-02	5.78E-04
				9.00	7.00	4.89E-07	1.24E-08	1.62E-02	5.27E-04
				9.50	7.50	5.42E-07	1.62E-08	1.70E-02	6.44E-04
				10.00	8.00	5.99E-07	1.74E-08	1.78E-02	6.50E-04
					8.50		1.79E-08		6.26E-04

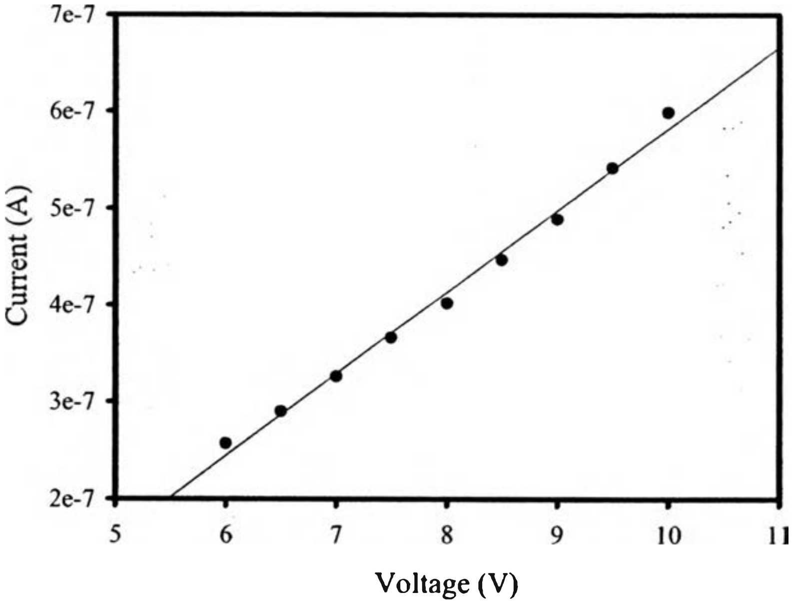


Fig G17 The linear regime of Zeolite Y (H^+, Si/Al = 80) at 26 °C ± 1 °C, (54 to 60) % R.H.

Appendix H Electrical Conductivity Sensitivity Measurement

The electrical conductivity sensitivity measurements of poly(3-thiopheneacetic acid) and poly(3-thiopheneacetic acid)/zeolite pellets were carried out by using the two point probe with ammonia gas under the pressure of 1.1 atm, 57 %RH to 67 %RH, and 26 °C ± 1°C. The electrical conductivity response of sample was calculated from the difference between the equilibrium conductivity of sample upon exposed to NH_3 and the steady state conductivity value of sample in N_2.

$$\Delta\sigma = \sigma_{NH_3} - \sigma_{N_2 initial} \tag{H.1}$$

The electrical conductivity sensitivity was defined as the electrical conductivity response divided by the conductivity itself at the N_2.

$$\text{electrical conductivity sensitivity} = \Delta\sigma/\sigma_{N2\ initial} \tag{H.2}$$

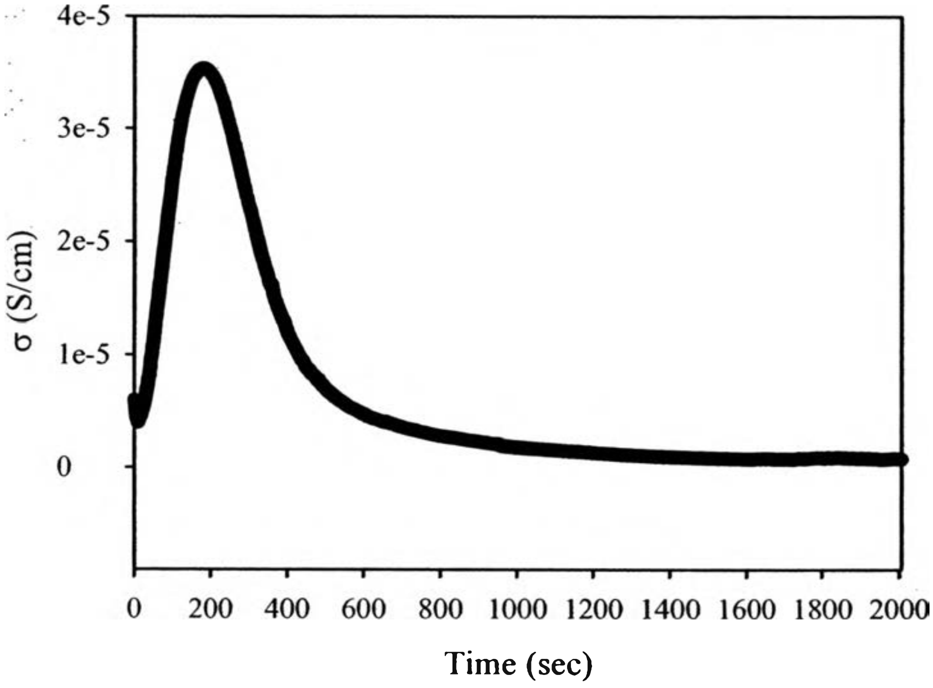


Figure H1 Specific conductivity of Pth_10:1(1) when exposed to NH_3.

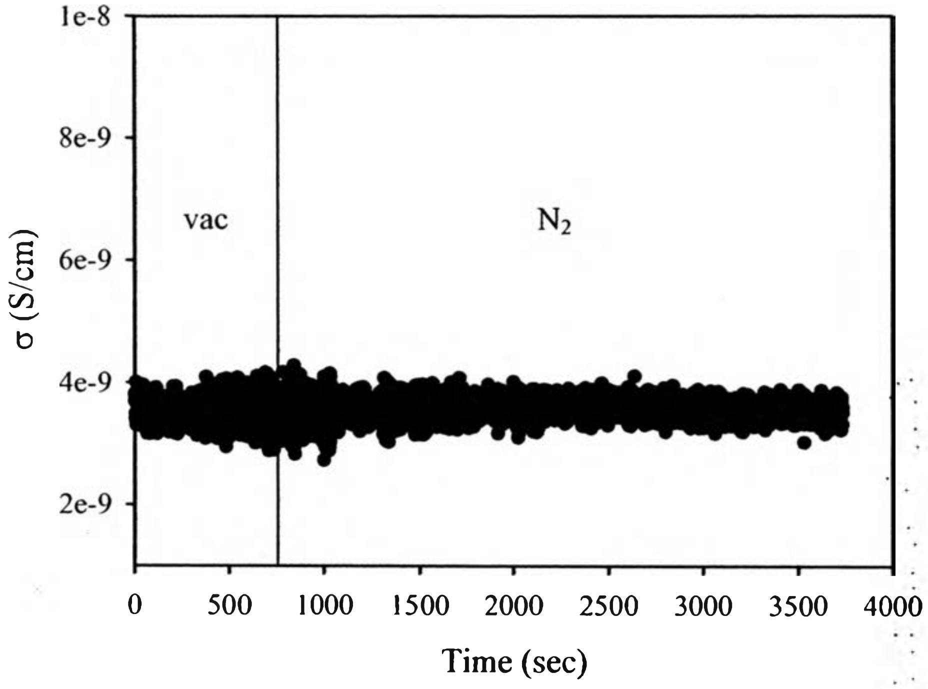


Figure H2 Specific conductivity of Pth_10:1(1) after evacuating NH_3 and exposed to N_2.

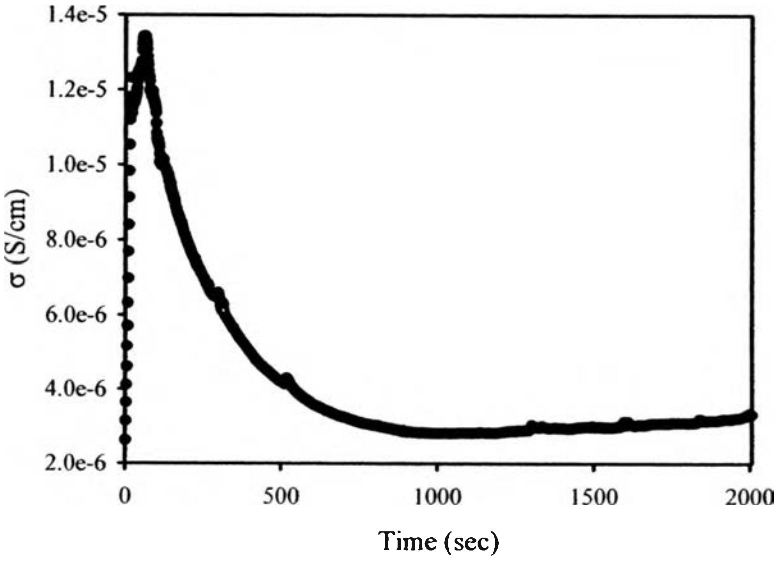


Figure H3 Specific conductivity of Pth_10:1/Y_10%(1) when exposed to NH_3.

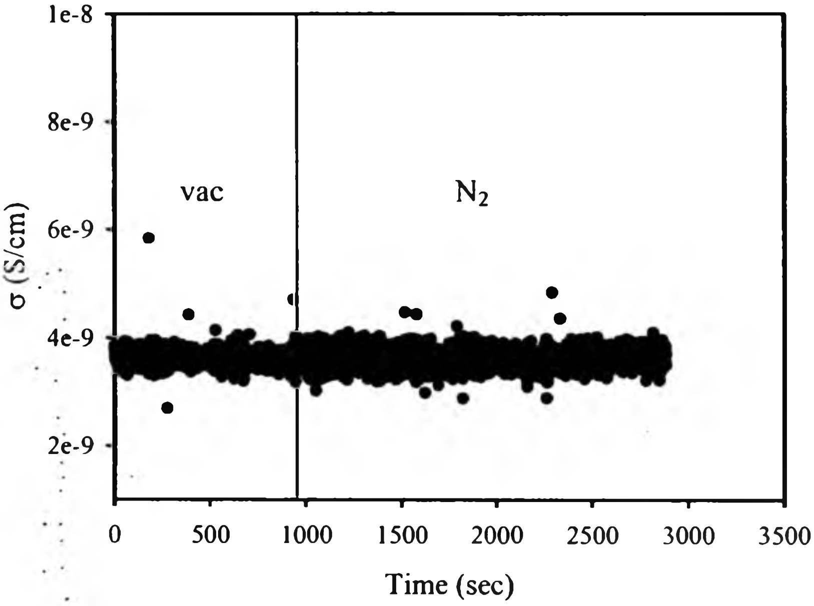


Figure H4 Specific conductivity of Pth_10:1/Y_10%(1) after evacuating NH_3 and exposed to N_2.

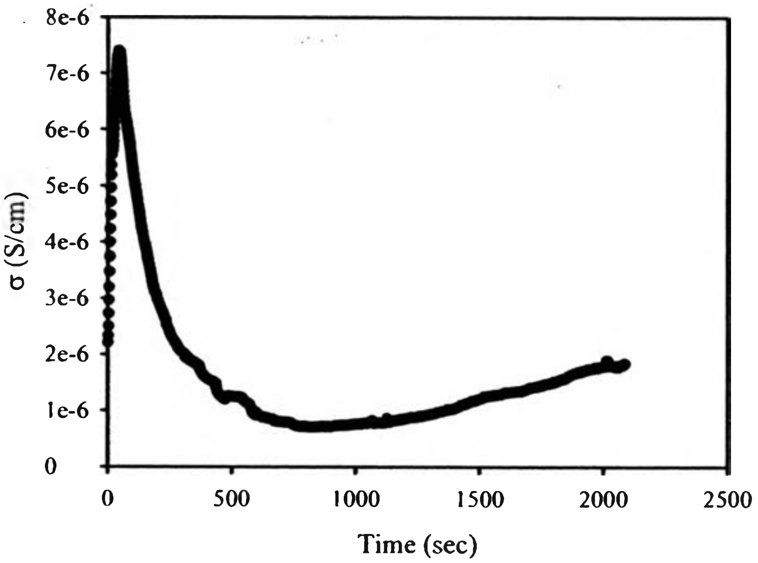


Figure H5 Specific conductivity of Pth_10:1/Y_20%(1) when exposed to NH_3.

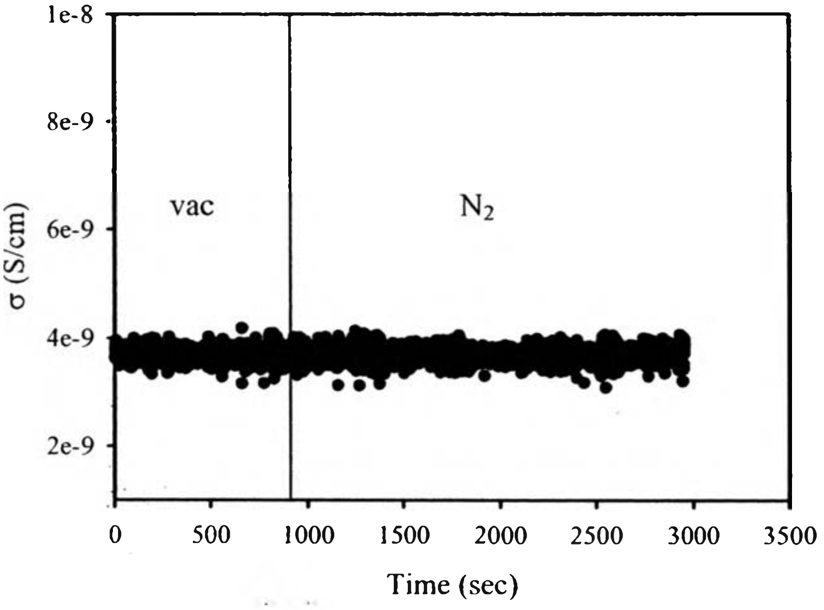


Figure H6 Specific conductivity of Pth_10:1/Y_20%(1) after evacuating NH_3 and exposed to N_2.

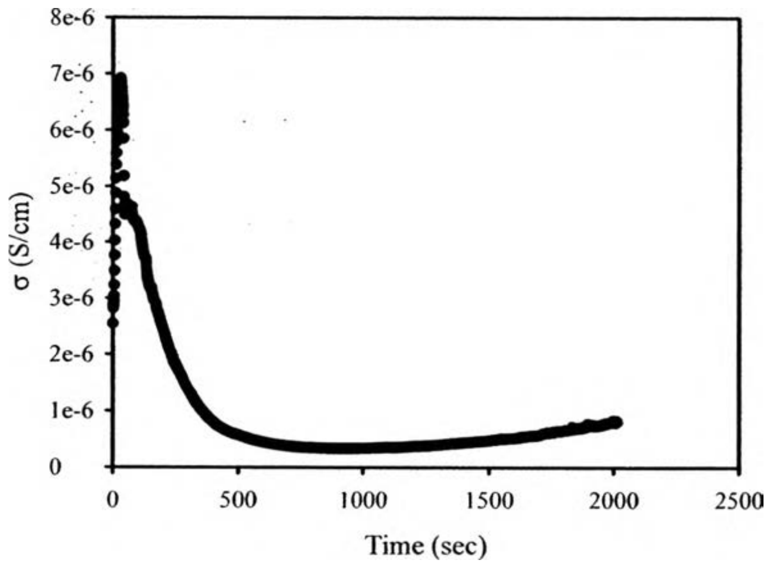


Figure H7 Specific conductivity of Pth_10:1/Y_30%(1) when exposed to NH_3.

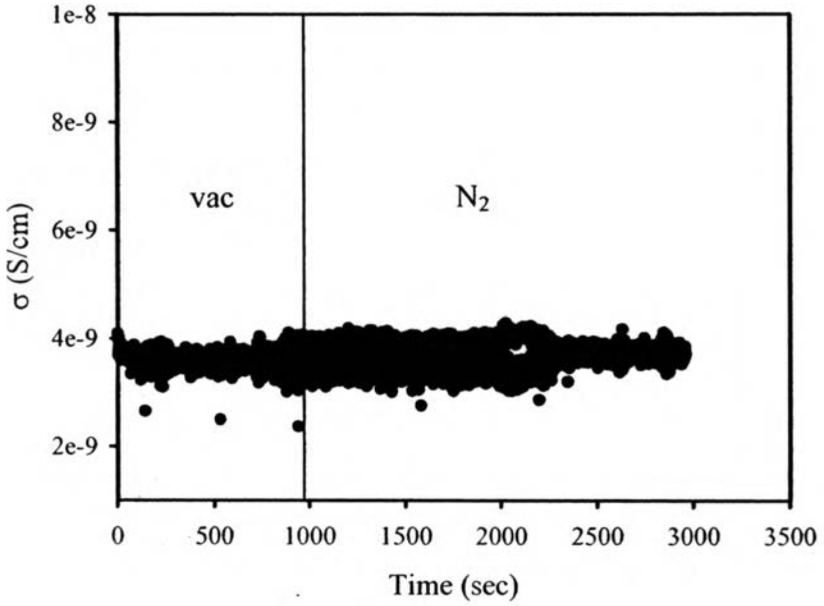


Figure H8 Specific conductivity of Pth_10:1/Y_30%(1) after evacuating NH_3 and exposed to N_2.

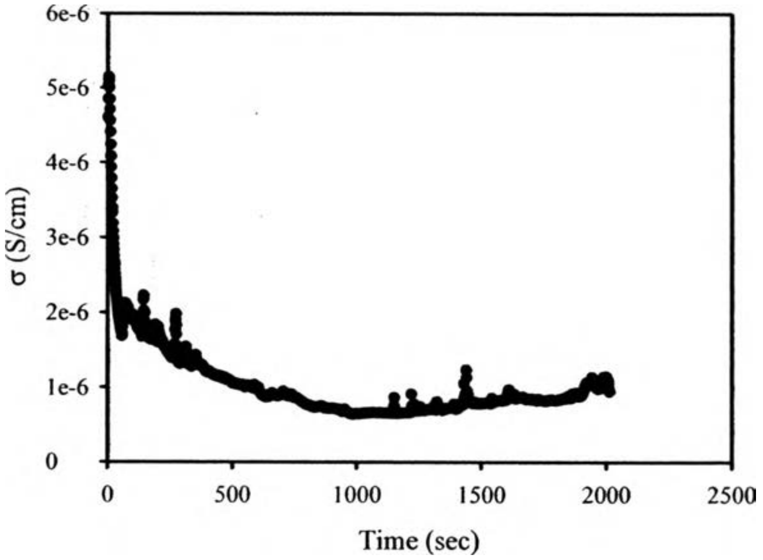


Figure H9 Specific conductivity of Pth_10:1/Y_40%(1) when exposed to NH_3.

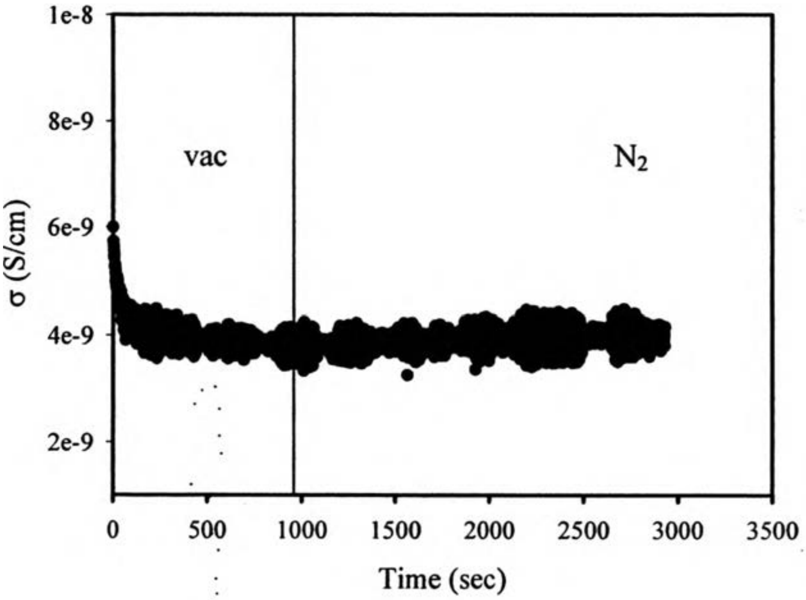


Figure H10 Specific conductivity of Pth_10:1/Y_40%(1) after evacuating NH_3 and exposed to N_2.

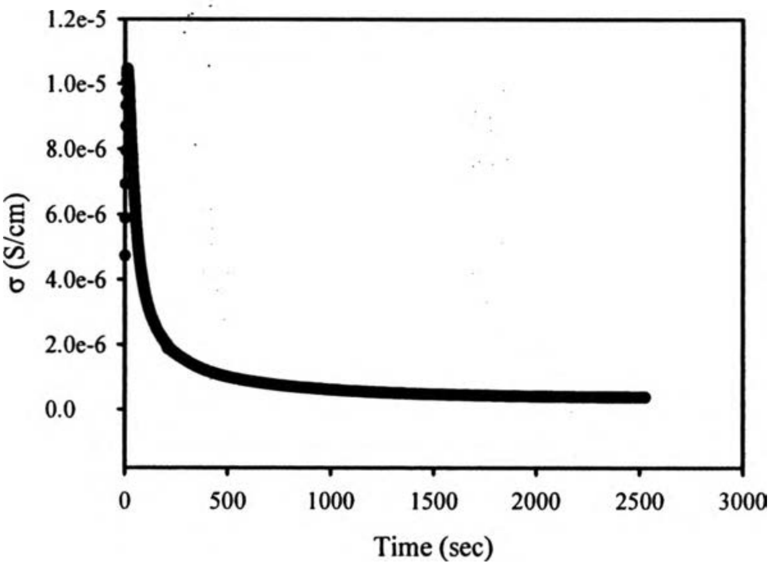


Figure H11 Specific conductivity of Pth_10:1/Y_50%(1) when exposed to NH_3.

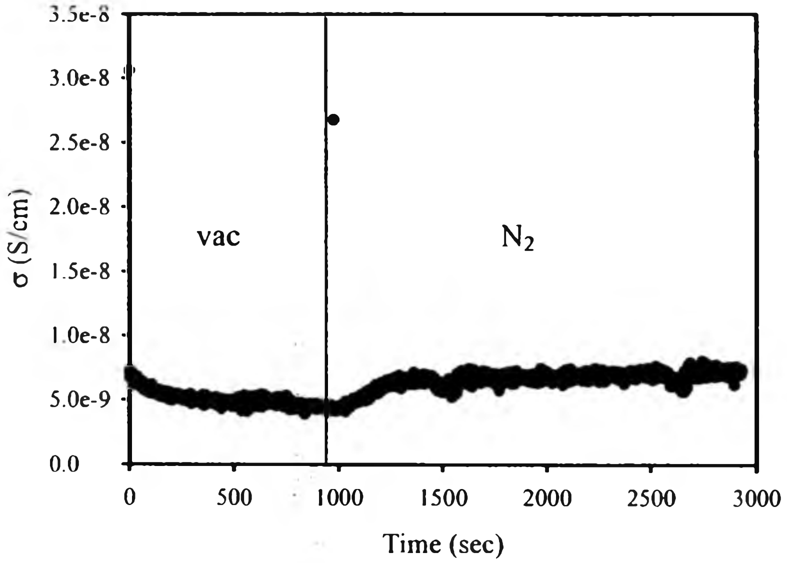


Figure H12 Specific conductivity of Pth_10:1/Y_50%(1) after evacuating NH_3 and exposed to N_2.

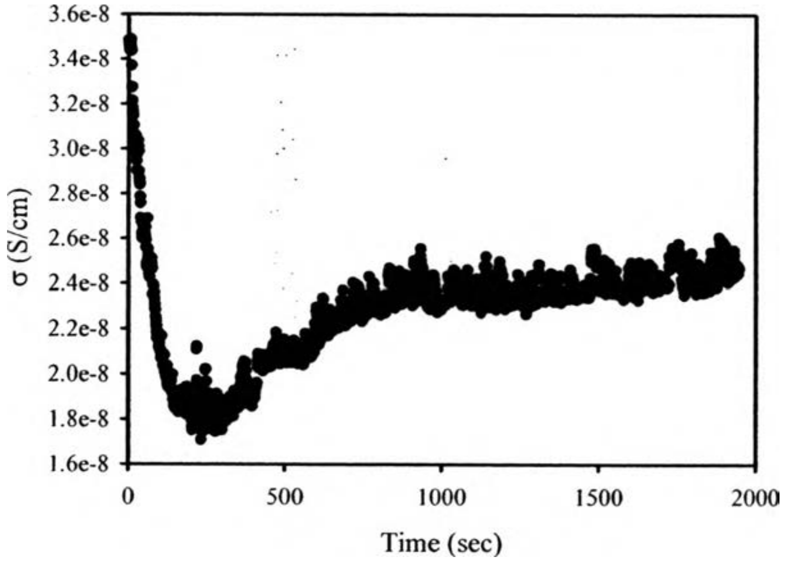


Figure H13 Specific conductivity of Pth_10:1/HY_10%_5.1(1) when exposed to NH_3.

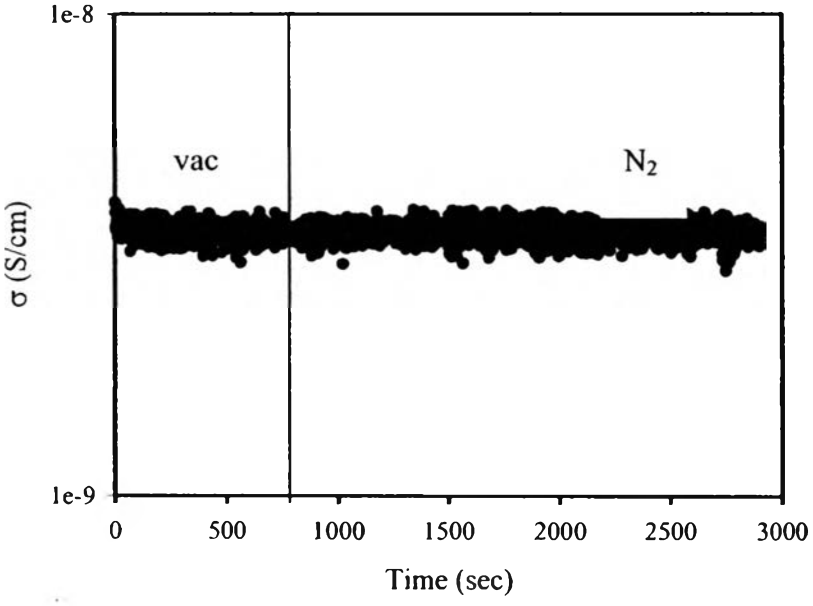


Figure H14 Specific conductivity of Pth_10:1/HY_10%_5.1(1) after evacuating NH_3 and exposed to N_2.

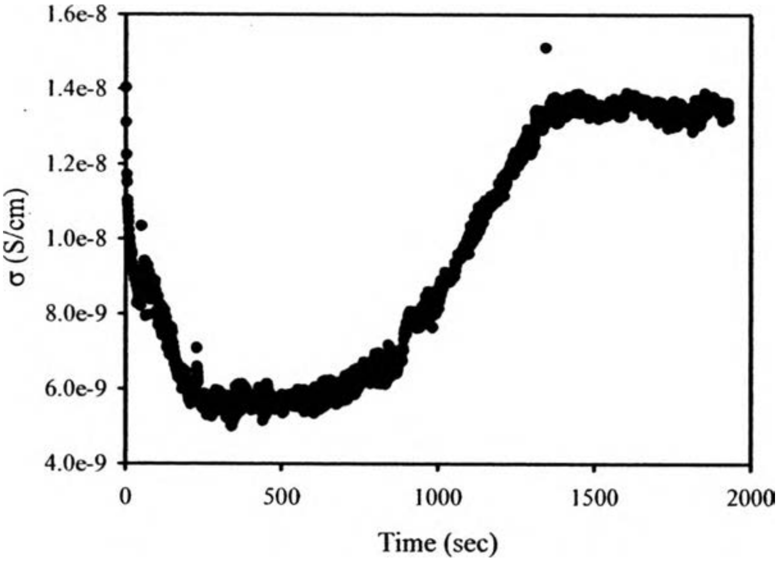


Figure H15 Specific conductivity of Pth_10:1/HY_10%_30(1) when exposed to NH_3.

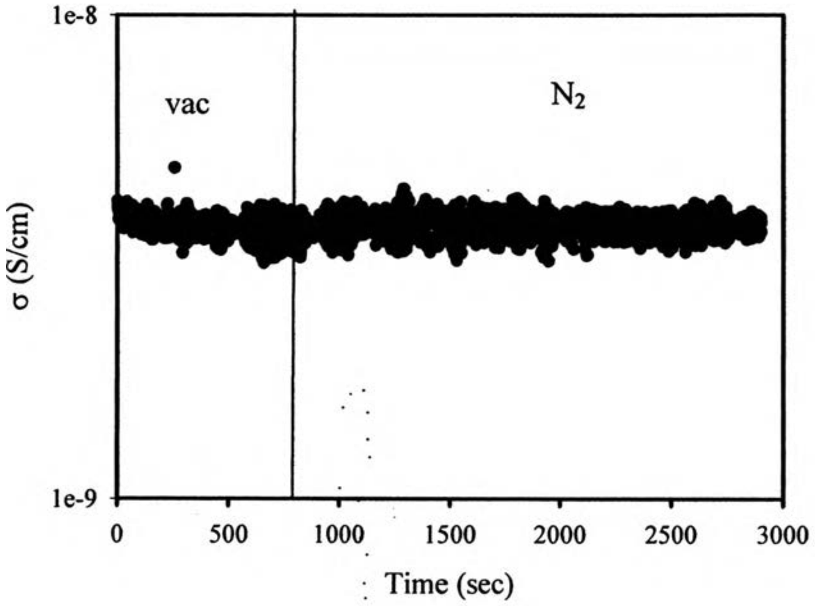


Figure H16 Specific conductivity of Pth_10:1/HY_10%_30(1) after evacuating NH_3 and exposed to N_2.

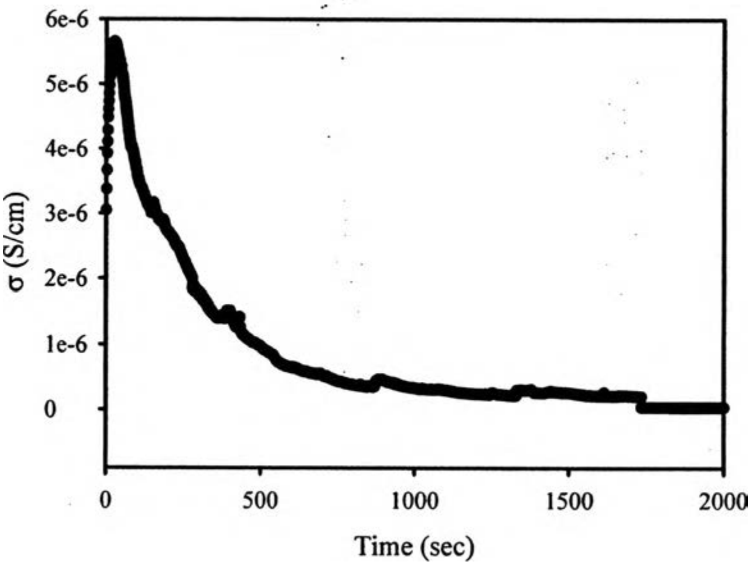


Figure H17 Specific conductivity of Pth_10:1/HY_10%_60(1) when exposed to NH_3.

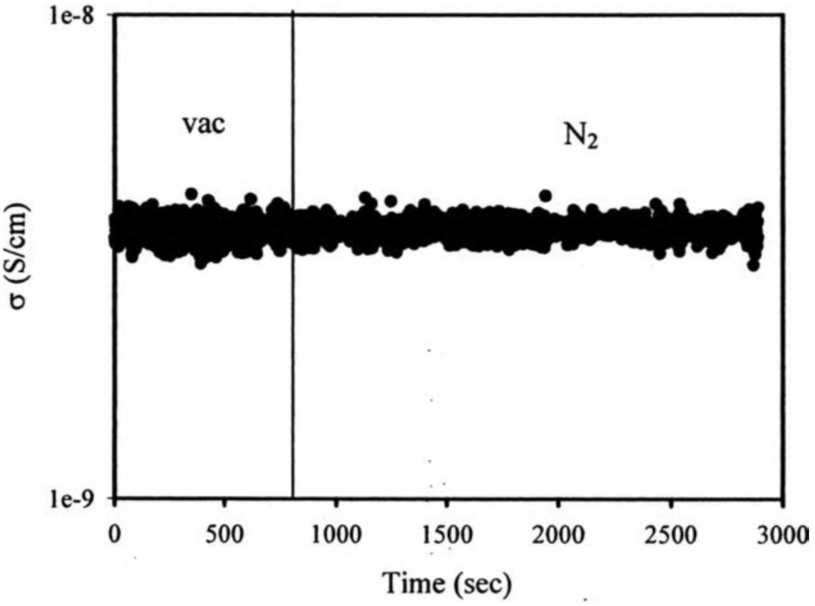


Figure H18 Specific conductivity of Pth_10:1/HY_10%_60(1) after evacuating NH_3 and exposed to N_2.

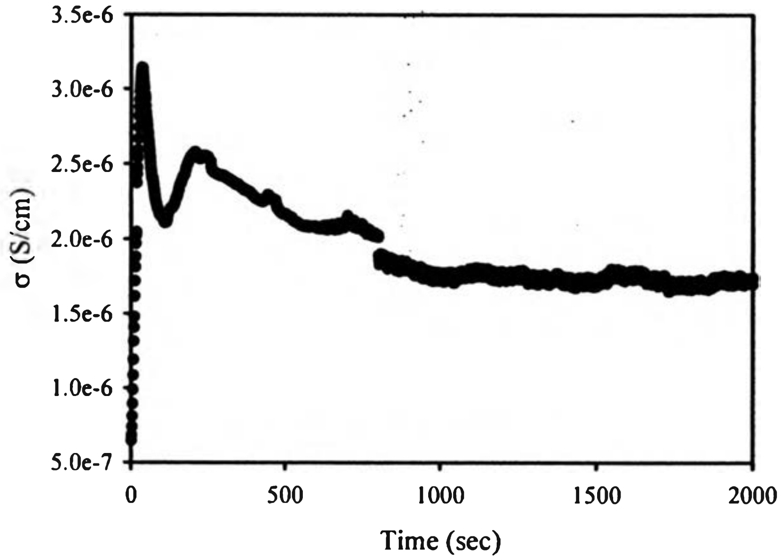


Figure H19 Specific conductivity of Pth_10:1/HY_10%_80(1) when exposed to NH_3.

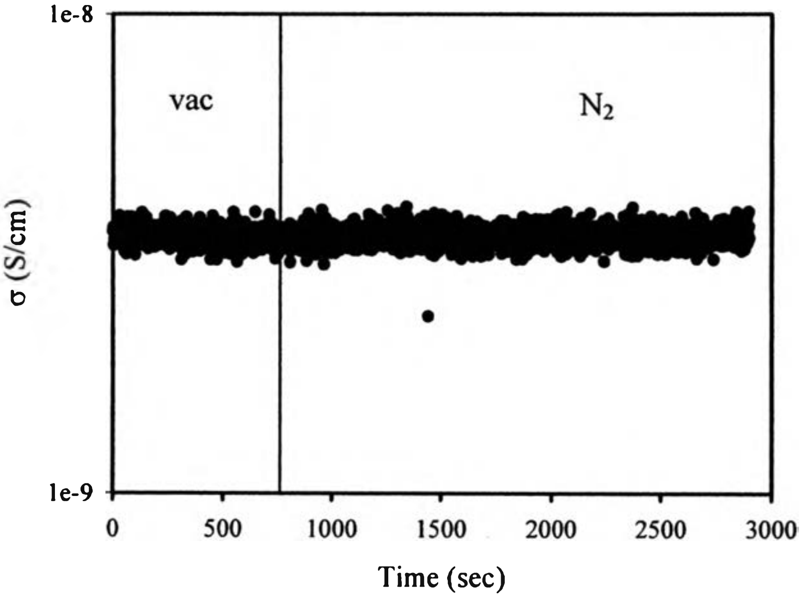
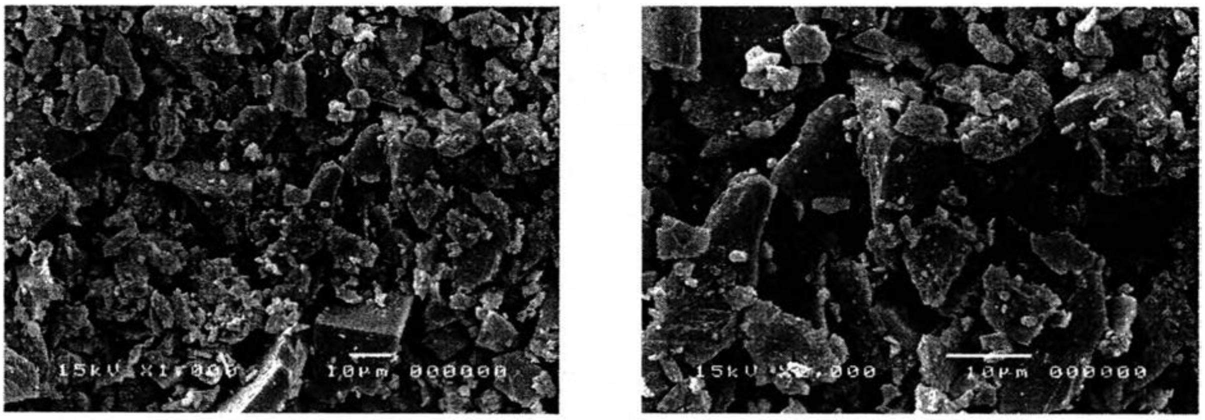


Figure H20 Specific conductivity of Pth_10:1/HY_10%_80(1) after evacuating NH_3 and exposed to N_2.

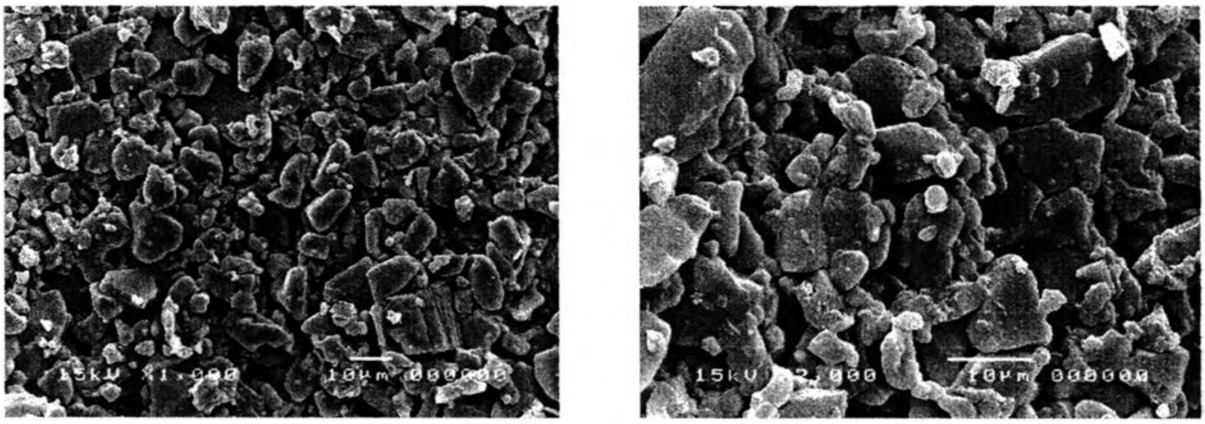
Appendix I Identification Morphology of Materials

Undoped and doped poly(3-thiopheneacetic acid), zeolite, and composites were observed for their morphology by scanning electron microscopy (SEM)(JEOL, JSM-5410LV). Sample was coated with gold for improving conductivity. Undoped and doped poly(3-thiopheneacetic acid) powders appear irregular shapes and distribution of particle size, as shown in Figure I1 and I2. For the morphology of zeolite appears regular shape due to its properties, as shown in Figure I3.



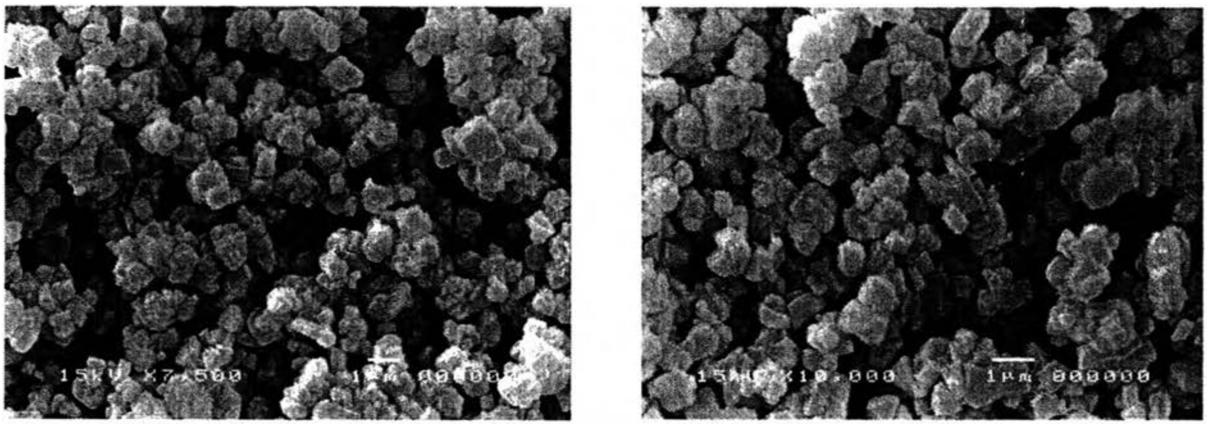
(a) (b)

Figure I1 SEM photographs of undoped poly(3-thiopheneacetic acid) at magnification (a)1000 and (b)2000.



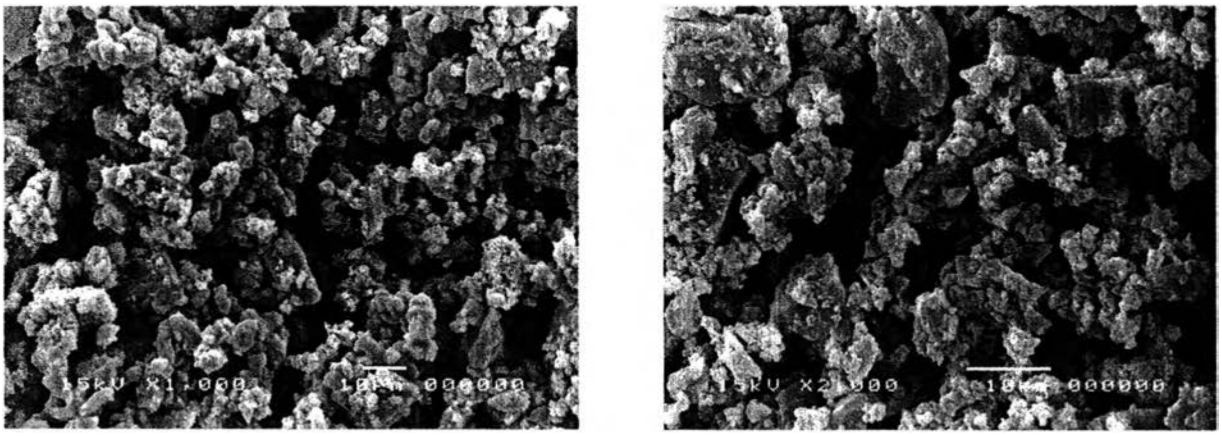
(a) (b)

Figure 12 SEM photographs of doped poly(3-thiopheneacetic acid) 10:1 at magnification (a)1000 and (b)2000.



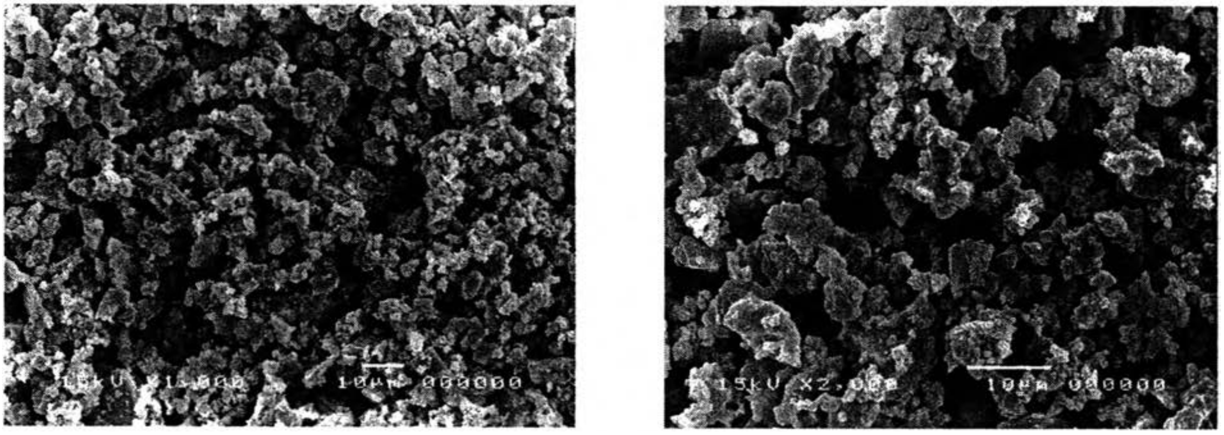
(a) (b)

Figure 13 SEM photographs: Zeolite Y at magnification (a) 7500 and (b) 10000.



(a) (b)

Figure 14 SEM photographs: Pth_10:1/Y_10% at magnification (a) 1000 and (b)2000.



(a) (b)

Figure 15 SEM photographs: Pth_10:1/Y_20% at magnification (a) 1000 and (b)2000.

Appendix J Surface area and Pore size of Zeolite

Surface area and pore size of zeolite Y were measured by using a surface area analyzer (Physisorption) (Quantachrome, Autosorb-1MP). Zeolite powder was weighed and out gassed at 300 °C over night before the adsorption and the desorption with He and N_2 gases. During the operation, zeolite powder was cooling by liquid N_2.

Table J1 Surface area and pore size of zeolite Y

Cation type	Si/Al ratios	Surface area (m^2/g)			Pore volume (cm^3/g)			Pore size (Å)		
		1	2	AVG	1	2	AVG	1	2	AVG
Na^+	5.1	611.0	640.0	625.5 ± 20.5	3.73E-01	3.80E-01	0.3764	3.68	3.675	3.6775
NH_4^+	5.1	594.3	583.2	588.8 ± 7.8	3.67E-01	3.60E-01	0.3635	3.675	3.675	3.675
H^+	5.1	601.2	633.3	617.3 ± 22.7	3.93E-01	4.12E-01	0.40285	3.675	3.675	3.675
H^+	30	634.9	742.6	688.8 ± 76.1	5.59E-01	5.79E-01	0.5689	3.675	3.675	3.675
H^+	60	713.9	748.1	731.0 ± 24.2	6.28E-01	5.88E-01	0.6076	3.675	3.675	3.675
H^+	80	768.4	763.8	766.1 ± 3.2	4.98E-01	6.12E-01	0.5548	3.675	3.675	3.675

Appendix K The Interaction between Doped Pth, Zeolite Y and NH_3 by FTIR

The interaction of the active sites of Pth_10:1 and zeolite NaY with NH_3 were investigated by FTIR spectroscopy at 26 ± 1 °C and under pressure 1.1 atm. FTIR spectra were taken by KBr pellet technique. The sample pellet was placed on sample holder and put it into the gas cell. The spectrums of samples were recorded, before NH_3 exposure, when exposed to NH_3, and after the NH_3 exposure, in order to study the interaction between these samples and NH_3, as shown in Figure K1, K2.

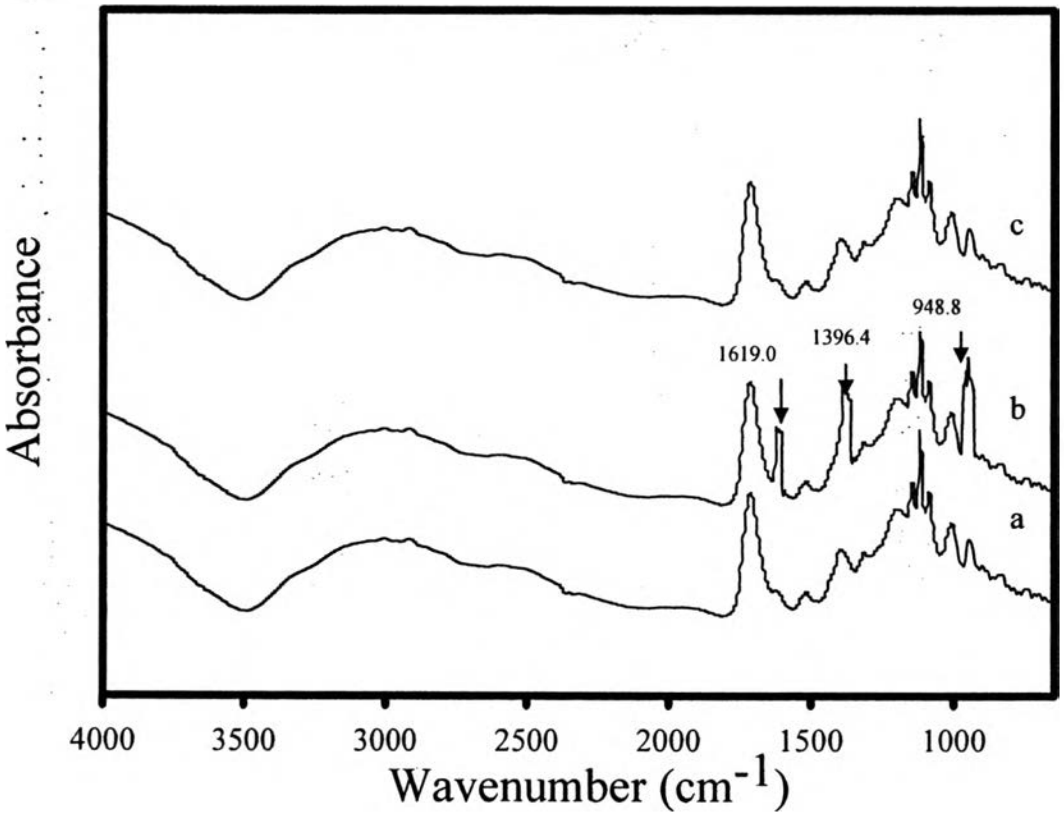


Figure K1 The FT-IR spectra of Pth_10:1 : (a) before; (b) exposed; and (c) after exposed to NH_3.

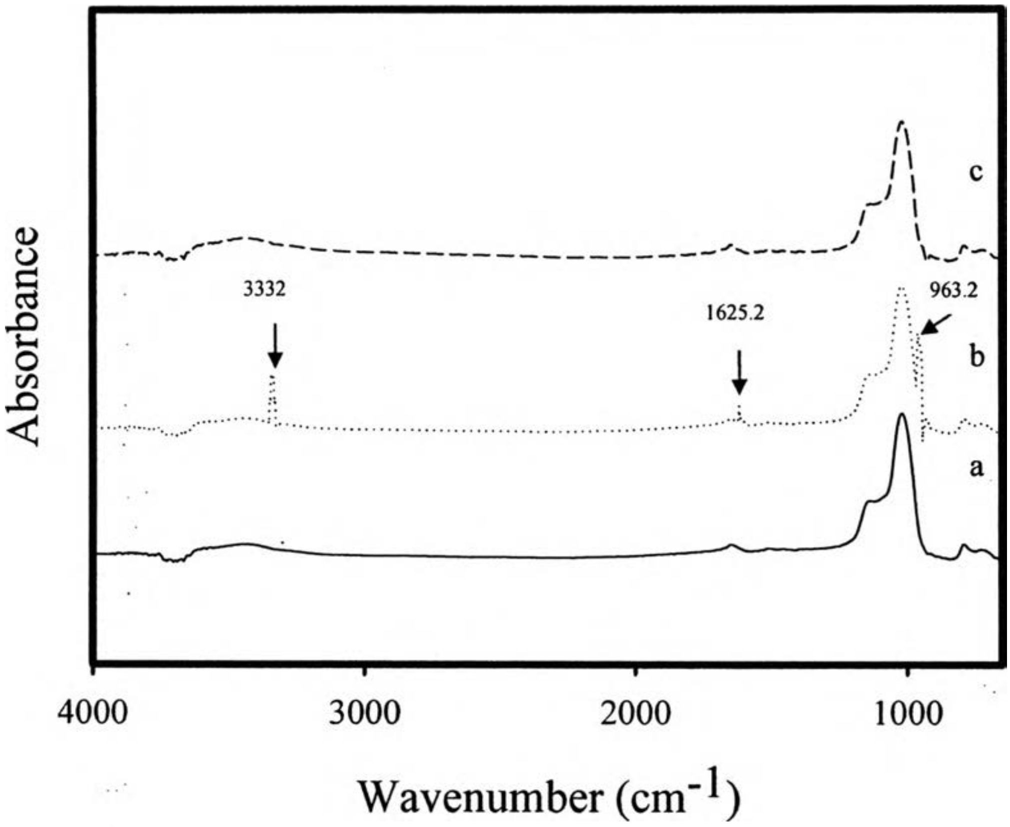


Figure K2 The FT-IR spectra of zeolite NaY : (a) before; (b) exposed; and (c) after exposed to NH_3.

When the NH_3 exposed, FTIR spectra were taken every 5 minutes for a duration of 45 min, each FTIR spectrum has the same patterns but different the intensity evolving in time. Peaks at 948.8 and 1619.0 cm^{-1} can be assigned to the vibrations of NH_3 molecules, and a peak at 1396.5 cm^{-1} belonging to the vibration of NH_4^+ molecules (Yin *et al.*, 1997). After replacing NH_3 with N_2, the bands at 948.8, 1396.5, and 1619.0 cm^{-1} disappear from the FTIR spectra. Therefore the interaction of NH_3 and doped Pth is reversible, as shown in Figure K1.

From the FTIR spectra of NaY before, during, and after the NH_3 exposure. The bands at 963.2 cm^{-1} appear when the NH_3 exposed, but it disappears when NH_3 was replaced by N_2. This peaks shifts from 968.09 cm^{-1} that represent the Lewis sites of NH_3 molecules (Yin *et al.*, 1997). The IR spectrum shows a new peak at 3332cm^{-1}

which can be assigned to NH_4^+ interacting with oxygen on zeolite Y (Zecchina *et al.*, 1996). Figure K2 show that there is no significant difference in the band patterns before and after the exposure to NH_3 so the interaction between NH_3 and NaY is reversible based on the FTIR spectrum.

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Presentation:

1. Konkayan, S.; and Sirivat, A. (2010, April 22) Development of Poly(3-thiopheneacetic acid)/Zeolite Y as a Gas Sensor Material for Ammonia. Paper presented at The 1st National Research Symposium on Petroleum, Petrochemicals, and Advanced Materials and The 16th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.