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APPENDICES

APPENDIX A Determination of ohmic linear regime.

Linear regime or ohmic regime is the regime that applied voltage depends directly on apply current according to ohmic law in equation (A-1)

In this work, linear regime was determined by ploting applied voltage (V_a) versus current(I). The range that gives the straight line is acceptable for using in conductivity measurement. Figure A-1 and A-2 are the plots of V_a and I that using silicon wafer as the standard material and polyaniline, respectively. This experiment was carried out under 1 atm , 26 °C and 40% humidity.

$$V = IR \qquad \text{(A-1)}$$

where : V = applied voltage (mV)

I = current (mA)

R = resistance (Ω)

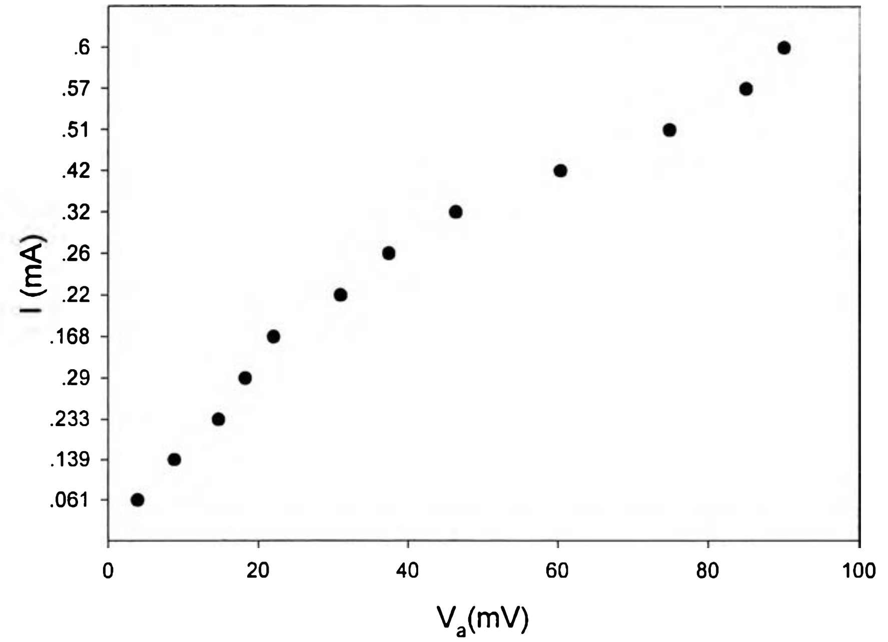


Figure A-1 Linear Regime of V_a and I used Silicon wafer as standard material.

According to Figure A-1, straight line is indicated the range of applied voltage and current corresponding to the ohmic law. The accepted range of those for using in conductivity measurement are 0 to 20 mV and 0 to 0.25 mA, respectively.

Table A-1 Raw data of determination of linear regime (Silicon Wafer).

Applied voltage (mV)	Current (mA)	Volt drop (mV)
3.95	0.06	16.5
8.84	0.14	18.3
14.70	0.23	15.2
18.30	0.29	14.6
22.10	0.17	15.1
31.10	0.22	14.7
37.50	0.26	15.6
46.40	0.32	15.9
60.40	0.42	16.1
74.90	0.51	18.2
85.00	0.57	16.3
90.00	0.60	17.2

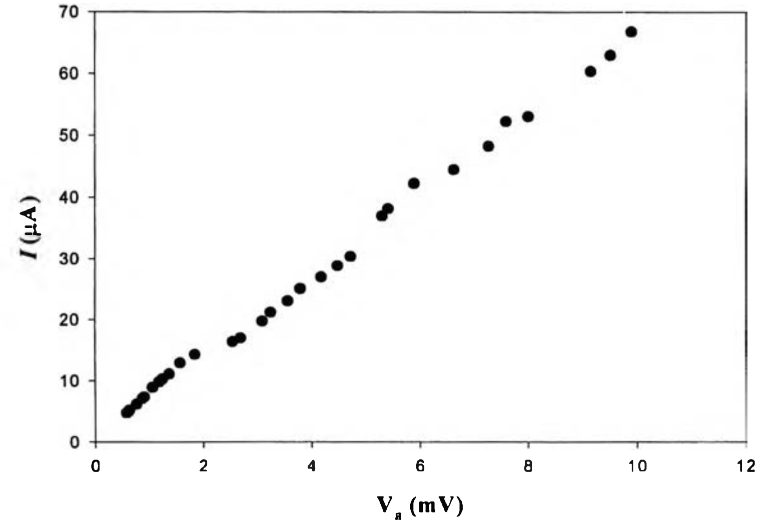


Figure A-2 Linear Regime of V_a and I used polyaniline.

In the case of polyaniline, a straight line can be seen in the range of 0 to 2 mV of applied voltage and 0 to 15 μA of current , respectively. The resulting value is lower than in the case of silicon wafer due to a lower resistance value.

Table A-2 Raw data of determination of linear regime (polyaniline)

Applied voltage (mV)	Current(μA)	Volt drop (mV)
0.592	4.780	224.2
0.620	5.000	223.6
0.640	5.250	225.4
0.771	6.190	226.2
0.879	7.090	226.4
0.915	7.350	227.1
1.070	8.900	226.3
1.188	9.800	225.8
1.249	10.30	228.1
1.371	11.09	226.4
1.581	12.90	226.8
1.851	14.30	225.9
2.550	16.40	224.8
2.700	17.00	221.9
3.100	19.80	222.6
3.250	21.20	226.7
3.570	23.10	228.6
3.800	25.10	227.3
4.190	27.00	225.5
4.490	28.85	225.6
4.730	30.40	224.9
5.310	37.00	223.8
5.420	38.20	226.7

Applied voltage (mV)	Current(μA)	Volt drop (mV)
5.900	42.30	225.5
6.440	44.50	226.1
7.280	48.30	227.4
7.600	52.00	225.2
8.010	53.10	224.9

APPENDIX B Determination of Geometric Correction Factor (K).

Geometric correction factor (K) is a correction factor that takes into account of geometric effects. It depends on the configuration and probe tip spacing. K factor can be determined by using the following equation (B-1). The resistivity of standard materials were calibrated from a using four point probe at King Mongkut's Institute Technology of Lad Krabang.

In this experiment, silicon wafer will be used as a standard material. Resistivities of materials were measured by using the four-point probe. The geometric correction factor was calculated and tabulated in the Table B-1 below:

$$K = \frac{\rho_{ref}}{R \times t} = \frac{w}{l} \qquad \text{(B-1)}$$

where K = geometric correction Factor

ρ_{ref} = known resistivity from the polymer handbook (Ω.cm)

R = resistivity (Ω)

t = sheet thickness (cm)

w = width (cm)

l = length (cm)

Table B-1 Data of K correction factor determination

Material	t(cm)	ρ_{ref}(Ω.cm)	Probe no.	K
SiO_2/TaA	0.0715	9.3×10^3	1	0.09151
			2	0.10550
Si 10-28A	0.0522	3.5×10^1	1	0.11471
			2	0.09457

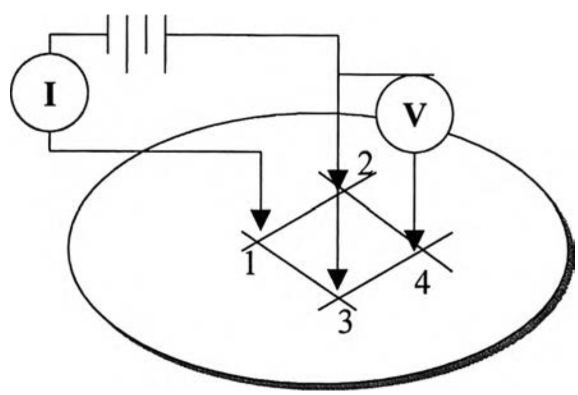


Figure B-1 Schematic draw of four-point probe.

Table B-2 Raw data of K of probe 1 using silicon wafers as the standard materials (26°C , 40% relative humidity and Applied voltage = 0.30V).

Si 10-28A			SiO_2/TaA		
I (mA)	V (mV)	K	*I* (mA)	V (mV)	K
0.000355	2.5	0.09521	0.0198	0.031	0.08420
0.000415	2.4	0.11590	0.0442	0.070	0.08272
0.000572	2.9	0.13225	0.0522	0.083	0.08172
0.000600	3.2	0.12570	0.0735	0.116	0.08206
0.000944	4.5	0.14065	0.0970	0.151	0.08383
0.001887	9.8	0.12900	0.1160	0.166	0.09023
0.001721	9.7	0.11896	0.1260	0.176	0.09338
0.002351	13.5	0.11670	0.1350	0.192	0.09135
0.002378	14.1	0.11308	0.1430	0.200	0.09323
0.002584	16.3	0.10629	0.1480	0.201	0.09609
0.002744	17.8	0.10336	0.1540	0.207	0.09700
0.002915	19.9	0.09822	0.1600	0.209	0.09926
0.003014	21.1	0.09577	0.1650	0.213	0.10130
0.003043	21.9	0.09317	0.1660	0.206	0.10471
	Average	0.11471		Average	0.09151

Table B-3 Raw data of K of probe 2 using silicon wafers as the standard material (26°C , 40% relative humidity and Applied voltage = 0.30 V).

Si 10-28A			SiO_2/TaA		
I (mA)	V (mV)	K	*I* (mA)	V (mV)	K
0.000665	5.20	0.08574	0.045	0.473	0.1237
0.000650	5.10	0.08546	0.050	0.0530	0.1227
0.000650	4.90	0.08894	0.065	0.0601	0.1406
0.000700	5.10	0.09203	0.075	0.0753	0.1295
0.000700	5.20	0.09026	0.075	0.0810	0.1204
0.000630	5.00	0.08448	0.085	0.0993	0.1113
0.000600	4.90	0.08210	0.100	0.1235	0.1053
0.000700	4.70	0.09415	0.105	0.1471	0.0928
0.000800	5.40	0.09986	0.115	0.1537	0.0973
0.000800	5.60	0.09578	0.125	0.1694	0.0960
0.000800	5.10	0.10518	0.130	0.1975	0.0856
0.000580	4.20	0.09259	0.135	0.2120	0.0828
0.000670	4.50	0.09983	0.140	0.2180	0.0835
0.000780	4.10	0.12756	0.145	0.2210	0.0853
	Average	0.09457		Average	0.1055

APPENDIX C Determination of % bipolaron and polaron by UV-Visible spectrometer.

According to the Beer's law (Chambell and White,1989),

$$A_i = a_i b_i c_i \quad \text{(C-1)}$$

where A_i = area of each peak

a_i = absorptivity (cm^2/g)

b_i = path length (cm)

c_i = concentration of emeraldine base in solution (g/cm^3)

The calibration curves in which the areas are plotted as a function of the concentration of emeraldine base in the solution can give some important peaks. These are ~ 325 nm representing the benzenoid part, ~ 440 nm showing the bipolaron part, ~ 625 nm representing the quinoid part, and ~ 700-900 nm giving the polaron part. The slopes of the calibration curves, thus, provide the product of absorptivity of particular species, a_i and b_i. To obtain the amount of the polaron and bipolaron in an unknown sample, the concentration can be calculated by the following equation;

$$C_i = A_i/a_i b_i \quad \text{(C-2)}$$

Hence, the % bipolaron and % polaron could be calculated by equations if the areas of the benzenoid, quinoid, bipolaron and polaron part are known

$$A_{BZ} + A_{BP} + A_Q + A_P = A_{total} \quad \text{(C-3)}$$

$$\%\ \text{bipolaron} = (A_{BP}/A_{total})*100 \quad \text{(C-4)}$$

$$\%\ \text{polaron} = (A_P/A_{total})*100 \quad \text{(C-5)}$$

The area of each peaks in a UV-Visible spectra could be calculated by using the Gaussian's Equation as shown in equation C-6.

$$\text{Gaussian equation} = (1/(SD*((2*(22/7))^{0.5})))*\exp(0.5(((x\text{-}avg)/SD)^2))*area \quad (C\text{-}6)$$

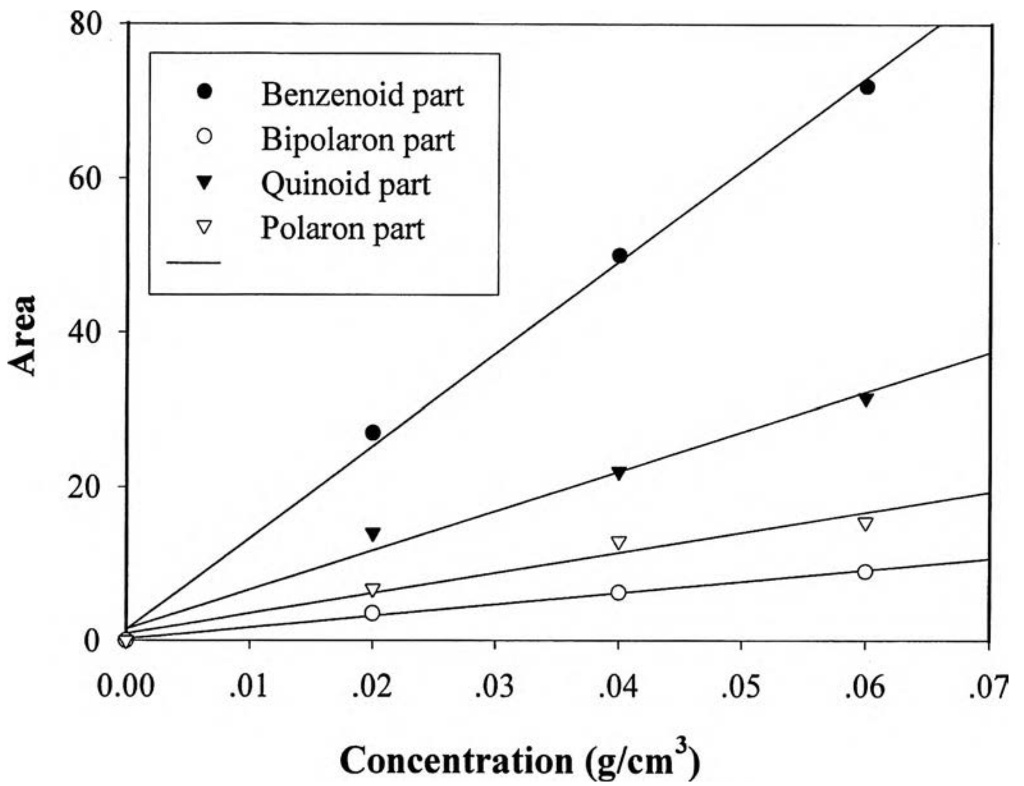


Figure C-1 The calibration curve of PANI-H_2SO_4/CSA.

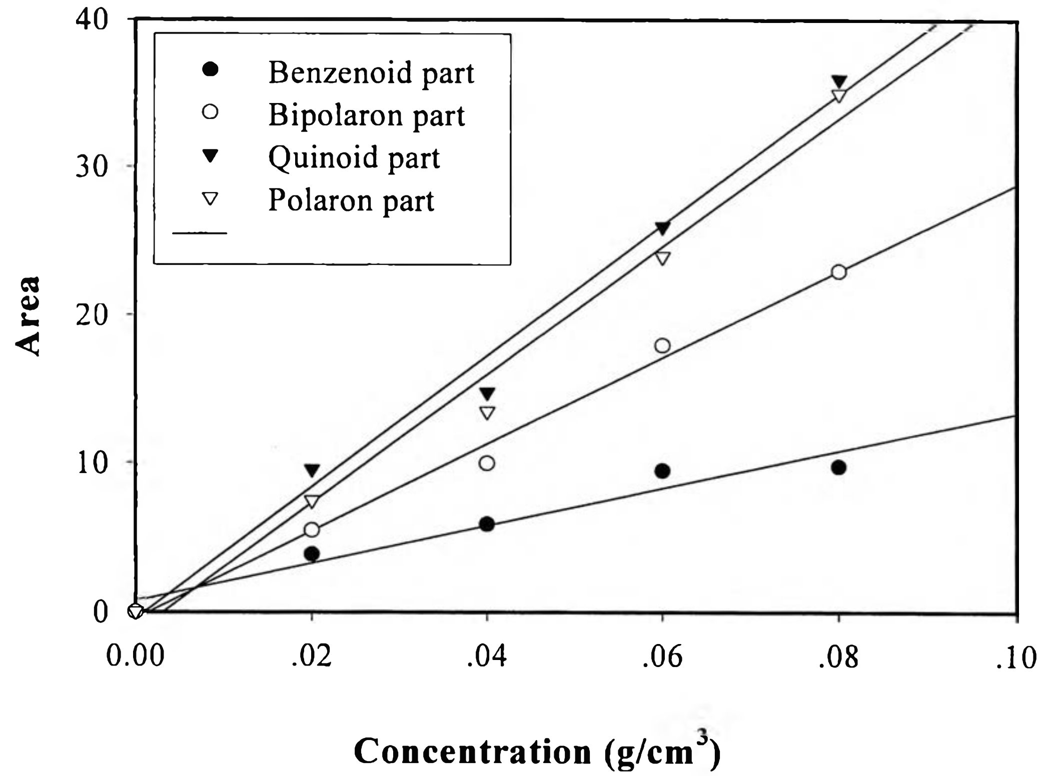


Figure C-2 The calibration curve of PANI-H_2SO_4/HNO_3.

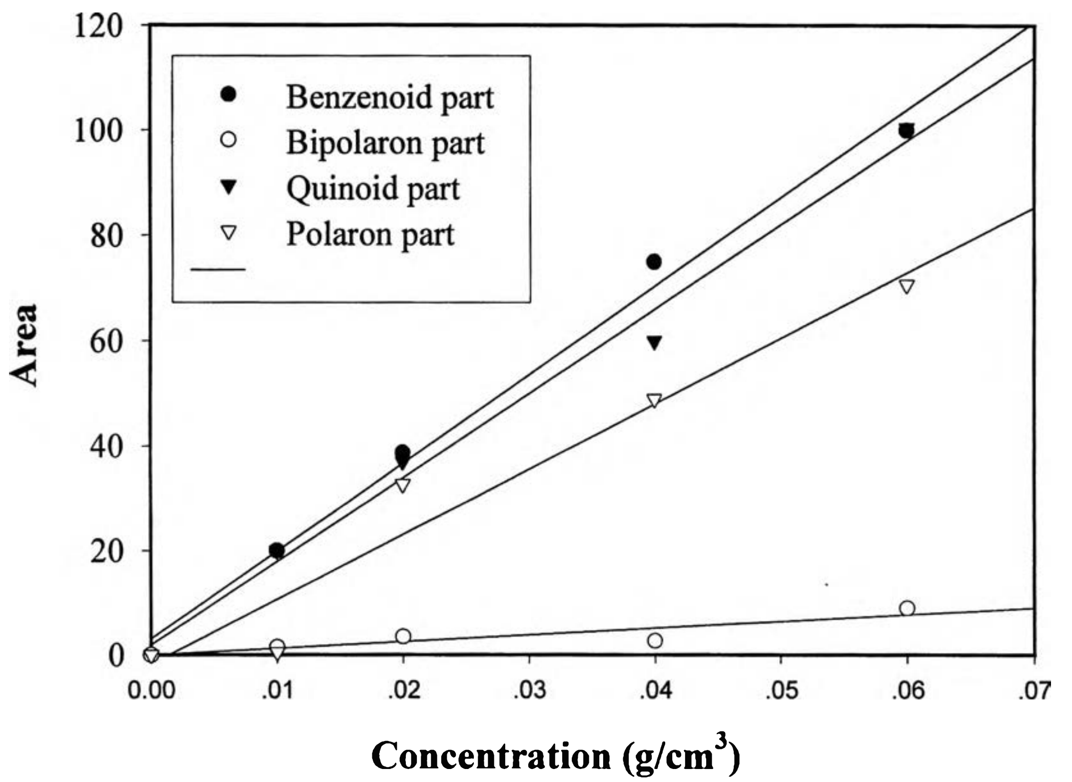


Figure C-3 The calibration curve of PANI-H_2SO_4/HCOOH.

From Equation C-1, the slopes of the calibration curves, thus , provide the product of particular species, a_I and b_i. Table C-1 shows the molar absorption coefficient of particular species of doped polyaniline.

Table C-1 The product of absorptivity (a_i) of particular species and $b_i$of doped polyaniline.

Doped PANI	$a_{benzenoid}*b_i$	$a_{bipolaron}*b_i$	$a_{quinoid}*b_i$	$a_{polaron}*b_i$
PANI/CSA	1.20e+3	1.49e+2	5.13e+2	2.64e+2
PANI/HNO_3	1.26e+2	2.93e+2	4.42e+2	4.33e+2
PANI/HCOOH	1.68e+3	1.29e+2	1.60e+3	1.24e+3

Table C-2 Raw data of % bipolaron and % polaron determination.

Acid	Doping ratio	Area				Concentration				%				%BP+%P
		BZ	BP	Q	P	BZ	BP	Q	P	BZ	BP	Q	P	
HCOOH	1	220	6.8	470	15	0.13	0.05	0.29	0.01	30.9	0.96	66.0	2.11	3.07
	2	205	7.15	448	17.5	0.12	0.06	0.3	0.01	30.3	1.06	66.1	2.58	3.64
	4	188	7.47	421	18	0.11	0.06	0.26	0.01	29.6	1.18	66.4	2.84	4.01
	10	175	7.55	398	25	0.10	0.06	0.27	0.02	28.9	1.25	65.7	4.13	5.38
	20	150	7.6	289	32.5	0.10	0.06	0.20	0.03	31.3	1.59	60.3	6.78	8.37
	40	170	7.5	321	35.7	0.10	0.06	0.20	0.03	31.8	1.40	60.1	6.68	8.09
	50	160	7	276	25	0.10	0.05	0.70	0.02	34.2	1.50	59.0	5.34	6.84
	180	45	3.8	230	7.45	0.03	0.03	0.14	0.01	15.7	1.33	80.3	2.6	3.93
	200	39.4	1.8	2.28	0.72	0.02	0	0	0	71.7	4.07	4.15	1.63	5.70
HNO_3	1	235	78	725	451	1.87	0.27	1.64	1.04	15.8	5.24	48.7	30.3	35.5
	2	235	85	711	469	1.87	0.29	1.61	1.08	15.7	5.67	47.4	31.3	36.9
	4	212	100	684	486	1.68	0.30	1.55	1.12	14.3	6.75	46.2	32.8	39.5
	10	215	120	600	500	1.71	0.41	1.36	1.15	15.0	8.36	31.8	34.8	43.2
	20	220	135	500	539	1.75	0.46	1.13	1.24	15.8	9.68	35.9	38.7	48.4
	30	220	145	200	625	1.75	0.49	0.45	1.44	18.5	12.2	16.8	52.5	64.7
	40	234	366	180	648	1.86	1.25	0.41	1.50	16.4	23.5	12.6	45.4	68.9
CSA	1	170	28.7	7	170	0.14	0.19	0.01	0.64	45.2	7.64	1.86	45.3	52.9
	2	173	33	68	359	0.14	0.22	0.13	1.36	27.3	5.21	10.7	56.7	61.9
	4	173	31.1	7.5	220	0.14	0.21	0.01	0.83	40.1	7.21	1.74	51.0	58.2
	10	179	35	32.9	415	0.15	0.24	0.06	1.57	27.0	5.29	4.97	62.7	68.0
	20	183	33	30.5	425	0.15	0.22	0.06	1.61	27.3	4.91	4.54	63.3	68.2
	30	34	9.42	6.8	120	0.03	0.06	0.01	0.45	20.0	5.53	3.99	70.5	76.0
	40	177	38	38.4	398	0.15	0.26	0.07	1.51	25.1	8.50	5.44	62.4	70.89
	80	178	33	72	315	0.15	0.22	0.14	1.19	29.8	5.52	12.0	52.7	58.2
	160	185	32.5	29.6	300	0.15	0.22	0.06	1.14	33.8	5.94	5.41	54.8	60.8
	250	165	35	65	395	0.14	0.24	0.13	1.50	25.0	5.30	9.85	59.9	65.2

Molecular weight of synthesized PANI was equal to 22,000 g/mol (Matt,1991)

Number of charge carriers (#) can be calculated from the following equation:

$$MW = N \times MW \text{ of repeating unit}$$

$$\# \text{ of charge carriers}_{Total} = \# \text{ of charge carriers}_{BP} + \# \text{ of charge carriers}_{P} \quad (C\text{-}7)$$

$$\# \text{ of charge carriers}_{BP} = 2 \times N \times (\%\text{bipolaron}) \quad (C\text{-}8)$$

$$\# \text{ of charge carriers}_{P} = N \times (\%\text{polaron}) \quad (C\text{-}9)$$

where N is degree of polymerization.

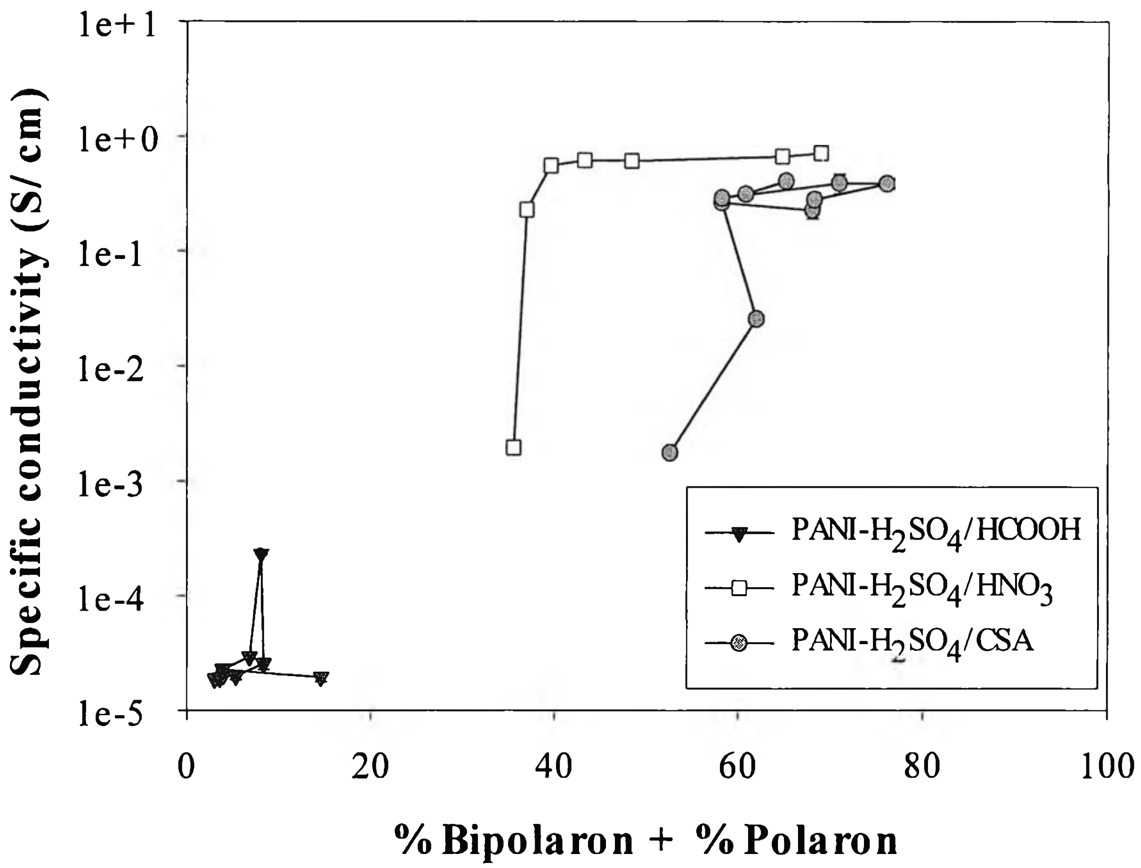
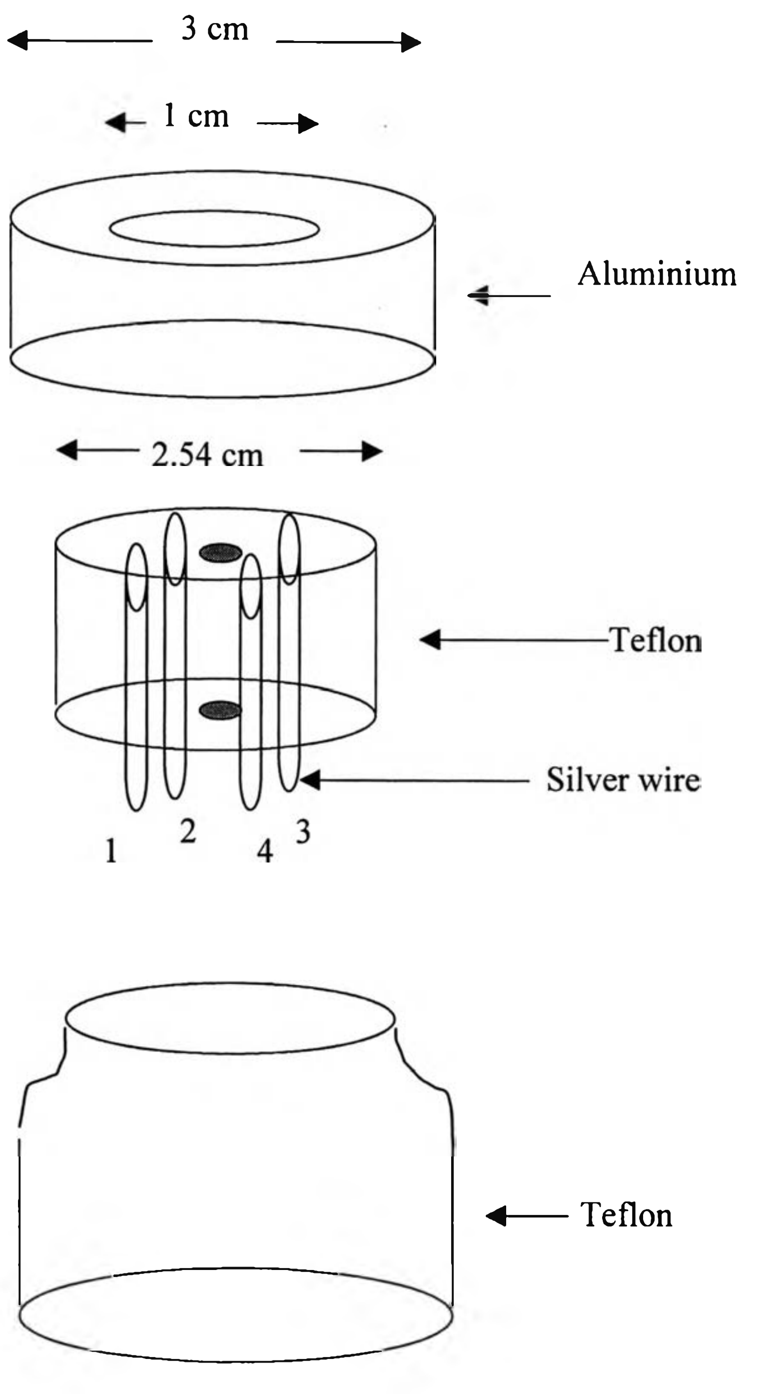


Figure C-4 The effect of %bipolaron + %polaron on the specific conductivity.

Table C-3 Raw data of number of carrier molecules.

Acid	Doping ratio	%BP	%P	n_{BP}	n_P	$n_{Bp} + n_P$	σ (S/cm)
HCOOH	1	0.96	2.11	1.16684928	1.28231874	2.44916802	1.89E-05
	2	1.1	2.58	1.28839608	1.56795372	2.8563498	1.93E-05
	4	1.18	2.84	1.43425224	1.72596456	3.1602168	1.95E-05
	10	1.25	4.13	1.519335	2.50994142	4.02927642	2.51E-05
	20	1.59	6.78	1.93259412	4.12043652	6.05303064	2.98E-05
	40	1.4	6.68	1.7016552	4.05966312	5.76131832	2.32E-04
	50	1.5	5.34	1.823202	3.24529956	5.06850156	2.22E-05
	180	1.33	2.6	1.61657244	1.5801084	3.19668084	2.00E-05
	200	4.07	1.63	4.94695476	0.99060642	5.93756118	2.00E-05
HNO_3	1	5.24	30.3	6.36905232	18.4143402	24.7833925	1.93E-03
	2	5.67	31.3	6.89170356	19.0220742	25.9137778	2.39E-01
	4	6.75	32.8	8.204409	19.9336752	28.1380842	5.85E-01
	10	8.36	34.8	10.1613125	21.1491432	31.3104557	6.16E-01
	20	9.68	38.7	11.7657302	23.5193058	35.285036	6.38E-01
	30	12.2	52.5	14.8287096	31.906035	46.7347446	6.92E-01
	40	23.5	45.4	28.563498	27.5911236	56.1546216	7.17E-01
CSA	1	7.64	45.3	9.28617552	27.5303502	36.8165257	1.79E-03
	2	5.21	56.7	6.33258828	34.4585178	40.7911061	2.56E-02
	4	7.21	51	8.76352428	30.994434	39.7579583	2.65E-01
	10	5.29	62.7	6.42982572	38.1049218	44.5347475	2.89E-01
	20	4.91	63.3	5.96794788	38.4695622	44.4375101	3.27E-01
	30	5.53	70.5	6.72153804	42.845247	49.566785	3.95E-01
	40	8.5	62.4	10.331478	37.9226016	48.2540796	4.20E-01
	80	5.52	52.7	6.70938336	32.0275818	38.7369652	3.95E-01
	160	5.94	54.8	7.21987992	33.3038232	40.5237031	2.58E-01
	250	5.3	59.9	6.4419804	36.4032666	42.845247	2.49E-01

APPENDIX D Probe Configuration.



APPENDIX E Conductivity Measurement of Doped PANI under the condition of 1 atm, 60% relative humidity and 28° C.

Table E-1 Raw data of conductivity measurement in air.

Doping		Thickness	Applied	Current		Voltage drop		σ	
ratio	Acid	(cm)	voltage	(mA)		(mV)		(S/cm)	
			(V)	Avg.	SD	Avg.	SD	Avg.	SD
0	Undoped (1)	0.01065	0.55	1.86E-03	1.17E-04	97382.5	1324.8	1.74E-05	1.09E-06
	Undoped (2)	0.01018	0.55	1.97E-03	1.34E-04	97082.5	953.1	1.93E-05	1.48E-06
	Undoped (3)	0.01127	0.55	2.12E-03	1.48E-04	96832.5	1115.6	1.88E-05	1.30E-06
1	HCOOH (1)	0.01121	0.55	2.14E-03	1.43E-04	96932.5	1077.1	1.91E-05	1.30E-06
	HCOOH (2)	0.00991	0.35	1.83E-03	1.89E-04	97682.5	1989.3	1.83E-05	2.02E-06
	HCOOH (3)	0.01114	0.35	2.16E-03	2.22E-04	97382.5	1819.5	1.93E-05	1.97E-06
2	HCOOH (1)	0.01093	0.35	2.15E-03	1.51E-04	97732.5	1209.3	1.95E-05	1.42E-06
	HCOOH (2)	0.01112	0.35	2.10E-03	2.31E-04	97682.5	1767.5	1.87E-05	1.99E-06
	HCOOH (3)	0.01012	0.35	1.99E-03	2.18E-04	97382.5	1693	1.96E-05	2.10E-06
4	HCOOH (1)	0.01129	0.55	2.35E-03	1.08E-04	97882.5	1353.8	2.06E-05	1.08E-06
	HCOOH (2)	0.01029	0.55	2.06E-03	1.58E-04	98382.5	1090.2	1.97E-05	1.47E-06
	HCOOH (3)	0.01225	0.55	2.29E-03	1.37E-04	99192.50	1953	1.83E-05	1.02E-06
10	HCOOH (1)	0.00981	0.55	2.29E-03	8.76E-05	99842.5	2270.2	2.27E-05	5.39E-07
	HCOOH (2)	0.01065	0.55	2.61E-03	1.30E-04	97682.5	2228	2.43E-05	1.13E-06
	HCOOH (3)	0.01225	0.55	3.49E-03	9.94E-05	97592.5	2175.9	2.83E-05	7.14E-07
20	HCOOH (1)	0.01029	0.55	3.22E-03	1.62E-04	97272.5	1786.4	3.12E-05	1.57E-06
	HCOOH (2)	0.00925	0.55	2.64E-03	1.77E-04	98382.5	1090.2	2.81E-05	1.21E-06
	HCOOH (3)	0.01129	0.55	3.42E-03	1.32E-04	97472.5	2291.1	3.02E-05	1.25E-06
40	HCOOH (1)	0.01181	0.35	2.86E-02	3.98E-04	95732.5	3036.1	2.45E-04	3.34E-06
	HCOOH (2)	0.01216	0.35	2.73E-02	3.02E-04	95172.5	1320.8	2.29E-04	2.56E-06
	HCOOH (3)	0.01177	0.25	2.59E-02	8.76E-05	96532.5	1697.7	2.21E-04	8.02E-06
50	HCOOH (1)	0.01452	0.38	3.45E-03	2.01E-04	96332.5	1081.2	2.39E-05	1.49E-06
	HCOOH (2)	0.01543	0.38	3.28E-03	2.90E-04	96732.5	1068.8	2.13E-05	1.90E-06
	HCOOH (3)	0.01216	0.38	2.61E-03	1.10E-04	97212.5	1818.7	2.14E-05	1.03E-06
180	HCOOH (1)	0.01454	0.38	2.67E-03	2.31E-04	97272.5	1203.7	1.83E-05	1.62E-06
	HCOOH (2)	0.01520	0.27	3.26E-03	2.22E-04	96132.5	1276.3	2.16E-05	1.43E-06
	HCOOH (3)	0.01225	0.27	2.47E-03	2.36E-04	97172.5	1104.6	2.01E-05	1.92E-06
200	HCOOH (1)	0.01205	0.27	2.13E-03	2.41E-04	97252.5	1037.4	1.76E-05	2.01E-06
	HCOOH (2)	0.01264	0.27	2.68E-03	2.10E-04	97222.5	921.1	2.11E-05	1.56E-06
	HCOOH (3)	0.01197	0.30	2.56E-03	2.59E-04	97372.5	894.5	2.13E-05	2.13E-06

Doping		Thickness	Applied	Current		Voltage drop		σ	
ratio	Acid	(cm)	voltage	(mA)		(mV)		(S/cm)	
			(V)	Avg.	SD	Avg.	SD	Avg.	SD
1	CSA (1)	0.01108	0.30	1.65E-01	1.84E-02	80612.5	1966.6	1.79E-03	1.67E-04
	CSA (2)	0.01205	0.33	1.75E-01	1.08E-02	80462.5	2257.4	1.75E-03	1.39E-04
	CSA (3)	0.01095	0.33	1.63E-01	1.16E-02	79902.5	2937.1	1.81E-03	1.08E-04
2	CSA (1)	0.01135	0.23	4.98E-01	1.93E-02	15932.5	343.3	2.67E-02	1.17E-02
	CSA (2)	0.01149	0.23	4.78E-01	2.52E-02	16342.5	529.6	2.47E-02	1.71E-01
	CSA (3)	0.01098	0.31	4.66E-01	2.88E-01	16072.5	412.8	2.56E-02	1.68E-02
4	CSA (1)	0.01356	0.31	7.44	1.90E-01	16162.5	457.5	3.30E-01	1.56E-02
	CSA (2)	0.01068	0.28	5.06	2.37E-01	19282.5	1650.5	2.40E-01	2.83E-02
	CSA (3)	0.01387	0.28	5.84	4.38E-01	18562.5	1230.4	2.21E-01	1.96E-02
10	CSA (1)	0.01659	0.34	9.13	3.37E-01	19822.5	1478.6	2.71E-01	2.61E-02
	CSA (2)	0.01353	0.34	8.99	3.28E-01	22002.5	763.0	2.93E-01	8.75E-02
	CSA (3)	0.01038	0.37	8.11	3.31E-01	24772.5	2867.5	3.10E-01	3.30E-02
20	CSA (1)	0.00996	0.37	8.34	3.63E-01	24012.5	2705.8	3.42E-01	3.76E-02
	CSA (2)	0.00978	0.42	7.09	2.56E-01	24852.5	3263.0	2.87E-01	3.78E-02
	CSA (3)	0.00861	0.42	7.47	5.23E-01	24712.50	3411.2	3.47E-01	5.76E-01
30	CSA (1)	0.01097	0.42	12.41	2.69E-01	25092.5	3006.5	4.44E-01	6.19E-02
	CSA (2)	0.00970	0.31	6.87	2.56E-01	18665.5	2126.3	3.72E-01	4.40E-02
	CSA (3)	0.00970	0.31	7.00	2.62E-01	18592.5	2082.4	3.81E-01	4.35E-02
40	CSA (1)	0.01044	0.31	9.52	4.98E-01	18892.5	806.2	4.69E-01	3.32E-02
	CSA (2)	0.01227	0.31	10.95	4.77E-01	18082.5	742.1	4.79E-01	1.90E-02
	CSA (3)	0.01249	0.36	7.90	2.82E-01	19622.5	1151.6	3.14E-01	2.00E-02
80	CSA (1)	0.01253	0.36	9.65	8.48E-01	18262.5	895.9	4.10E-01	4.38E-02
	CSA (2)	0.01252	0.37	9.95	3.40E-01	18212.5	919.5	4.24E-01	1.98E-02
	CSA (3)	0.01290	0.37	8.89	2.81E-01	19082.5	1039.0	3.51E-01	3.69E-02
160	CSA (1)	0.01344	0.55	1.31	8.19E-03	4602.5	115.5	2.05E-01	5.03E-02
	CSA (2)	0.01514	0.55	2.41	4.24E-02	4772.5	92.6	3.23E-01	5.49E-02
	CSA (3)	0.01044	0.55	1.30	1.20E-02	4602.5	115.5	2.63E-01	6.05E-02
250	CSA (1)	0.01264	0.27	6.70	7.86E-01	19672.5	1249.9	2.62E-01	3.63E-02
	CSA (2)	0.01093	0.27	4.66	7.04E-01	21602.5	1465.2	1.91E-01	2.34E-02
	CSA (3)	0.01304	0.30	7.55	3.72E-01	18512.5	1461.7	3.05E-01	2.35E-02
1	HNO_3 (1)	0.01007	0.4	1.94E-02	1.70E-02	91102.5	1523.9	2.05E-03	2.00E-04
	HNO_3 (2)	0.00910	0.4	1.60E-01	8.17E-03	92172.5	1699.7	1.85E-03	8.66E-05
	HNO_3 (3)	0.01011	0.35	1.80E-01	1.56E-02	91822.5	3424.0	1.88E-03	1.92E-04

Doping		Thickness	Applied	Current		Voltage	drop	σ	
ratio	Acid	(cm)	voltage	(mA)		(mV)		(S/cm)	
			(V)	Avg.	SD	Avg.	SD	Avg.	SD
2	HNO_3 (1)	0.01174	0.30	1.93	1.83E-01	6212.5	218.3	2.57E-01	2.43E-02
	HNO_3 (2)	0.01210	0.28	1.68	1.62E-01	6306.5	332.3	2.14E-01	2.45E-02
	HNO_3 (3)	0.01241	0.40	1.88	1.69E-01	6152.6	201.4	2.45E-01	2.06E-02
4	HNO_3 (1)	0.01205	0.55	2.85	6.41E-01	4363.5	71.4	5.25E-01	3.36E-03
	HNO_3 (2)	0.0172	0.55	2.95	7.33E-02	4137.5	109.6	5.90E-01	8.17E-03
	HNO_3 (3)	0.01171	0.55	2.96	8.35E-02	3842.5	108.7	6.39E-01	8.71E-03
10	HNO_3 (1)	0.01095	0.45	2.93	7.70E-02	4117.5	93.1	6.31E-01	1.07E-02
	HNO_3 (2)	0.01104	0.40	2.87	1.28E-01	4127.5	129.6	6.11E-01	4.49E-02
	HNO_3 (3)	0.01227	0.40	3.08	1.39E-01	3977.5	143.9	6.12E-01	2.64E-02
20	HNO_3 (1)	0.01324	0.35	3.31	1.19E-01	3772.5	205.8	6.43E-01	4.06E-02
	HNO_3 (2)	0.01227	0.35	2.97	1.84E-01	4042.5	135.0	5.80E-01	4.31E-02
	HNO_3 (3)	0.01709	0.35	4.86	3.31E-01	3922.5	161.9	7.03E-01	5.27E-02
30	HNO_3 (1)	0.01639	0.35	4.71	4.07E-01	4022.5	139.8	6.92E-01	5.32E-02
	HNO_3 (2)	0.01616	0.35	3.95	1.18E-01	3952.5	117.9	7.34E-01	5.44E-02
	HNO_3 (3)	0.1583	0.35	4.15	4.93E-01	3902.5	149.1	6.53E-01	8.65E-02
40	HNO_3 (1)	0.01256	0.35	3.92	2.04E-01	3922.5	204.4	7.14E-01	4.18E-02
	HNO_3 (2)	0.01274	0.25	3.51	1.60E-01	3882.5	204.4	6.90E-01	5.40E-02
	HNO_3 (3)	0.01213	0.30	3.57	1.77E-01	3952.5	171.6	7.23E-01	3.70E-02

Table E-2 Raw data of conductivity measurement of PANI-H_2SO_4/CSA when exposed to 100%ethanol.

	Doping	Thickness	Applied	Current		Voltage drop		σ (S/cm)	
ratio	Acid	(cm)	voltage	(mA)		(mV)			
			(V)	Avg.	SD	Avg.	SD	Avg.	SD
1	CSA (1)	0.01108	0.30	2.33E-01	1.40E-02	70424.3	1407.3	2.90E-03	1.87E-04
	CSA (2)	0.01205	0.33	2.31E-01	7.40E-03	6662.5	1885.9	2.79E-03	5.73E-05
2	CSA (1)	0.01135	0.23	1.21E+00	6.43E-02	18202.5	920.1	5.66E-02	8.58E-04
	CSA (2)	0.01149	0.23	1.14E+00	8.53E-02	18102.5	784.6	5.30E-02	2.16E-03
4	CSA (1)	0.01356	0.31	8.31E+00	2.39E-01	17762.5	356.5	3.35E-01	1.20E-02
	CSA (2)	0.01068	0.28	7.97E+00	3.30E-01	21302.5	828.7	3.40E-01	1.09E-02
10	CSA (1)	0.01659	0.34	1.05E+01	2.72E-01	16667.5	464.3	3.70E-01	5.63E-03
	CSA (2)	0.01353	0.34	9.69E+00	2.60E-01	18487.5	452.2	3.76E-01	3.10E-03
20	CSA (1)	0.00996	0.37	1.02E+01	2.50E-01	23822.5	1521.5	4.20E-01	2.65E-02
	CSA (2)	0.00978	0.42	1.03E+01	3.03E-01	23362.5	982.2	4.37E-01	1.46E-02
30	CSA (1)	0.01097	0.42	1.29E+01	5.32E-01	23612.5	1143.5	4.81E-01	6.68E-03
	CSA (2)	0.0097	0.31	1.06E+01	3.13E-01	22522.5	661.3	4.69E-01	5.45E-03
40	CSA (1)	0.01044	0.31	1.31E+01	1.94E-01	16342.5	469.5	6.23E-01	1.39E-02
	CSA (2)	0.01227	0.31	1.31E+01	1.55E-01	16642.5	327.3	6.24E-01	1.11E-02
80	CSA (1)	0.01253	0.36	1.22E+01	2.72E-01	18022.5	887.9	5.23E-01	2.35E-02
	CSA (2)	0.01252	0.37	1.24E+01	2.64E-01	18712.5	652.3	5.12E-01	1.98E-02
160	CSA (1)	0.01344	0.55	1.29E+00	3.00E-02	3602.5	115.5	2.59E-01	1.12E-02
	CSA (2)	0.01514	0.55	1.49E+00	9.18E-02	3587.5	184.2	2.67E-01	2.55E-02

Table E-3 Raw data of sensitivity of PANI-H_2SO_4/CSA at N_A/N_{EB} equal to 1:40 when exposed to ethanol.

Ethanol	Thickness	Applied	Current	(mA)	Volt drop	before (mV)	Volt drop	after (mV)	σ (S/cm)	before	σ (S/cm)	after	Δσ (S/cm)
(%)	(cm)	Voltage (V)	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	
0	0.00997	0.35	1.0142	0.0214	4559.0	26.9	2924.0	65.3	0.2164	0.00153	0.3374	0.0023	0.1210
	0.01104	0.35	1.1057	0.0196	4888.2	46.1	3042.9	42.3	0.1987	0.00215	0.3192	0.0048	0.1205
1	0.00993	0.55	1.1629	0.0265	6082.5	44.7	3879.2	40.4	0.1800	0.0012	0.2943	0.0025	0.1142
	0.01223	0.55	0.7056	0.0192	3327.8	29.3	1960.6	16.1	0.1681	0.0012	0.2845	0.0029	0.1164
2.3	0.01014	0.55	1.1002	0.0281	5582.5	83.7	4167.5	35.4	0.1835	0.0014	0.2628	0.0048	0.0826
	0.01429	0.55	1.2157	0.0201	5021.8	71.3	3276.7	25.7	0.1643	0.0012	0.2518	0.0053	0.0875
4.6	0.01344	0.55	1.4106	0.0201	4702.5	27.9	4202.5	253.9	0.2108	0.0067	0.2436	0.0165	0.0662
	0.01426	0.55	1.4283	0.0119	5355.5	37.2	3844.4	21.3	0.1810	0.0005	0.2527	0.0143	0.0713
9.2	0.01249	0.55	1.4112	0.0183	4515.0	138.4	3865.0	197.4	0.2380	0.0091	0.2878	0.0146	0.0629
	0.01149	0.52	1.5675	0.0720	6111.2	100.1	4797.3	107.3	0.2165	0.0074	0.2758	0.0153	0.0593

Ethanol	Thickness	Applie d	Current	(mA)	Volt drop	before (mV)	Volt drop	after (mV)	σ (S/cm)	before	σ (S/cm)	after	$\Delta\sigma$ (S/cm)
(%)	(cm)	Voltag e (V)	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	
15	0.01302	0.55	1.2819	0.0116	5982.5	44.7	5424.1	89.4	0.1570	0.0012	0.1758	0.0017	0.0188
	0.01416	0.46	1.3231	0.0284	5223.3	40.6	4724.9	74.2	0.1735	0.0016	0.1918	0.0011	0.0183
20	0.01314	0.46	1.3707	0.0156	5835.8	81.6	5513.7	85.4	0.1724	0.0035	0.1835	0.0025	0.0110
	0.01171	0.46	1.2144	0.0149	5549.1	46.8	5218.1	39.1	0.1812	0.0015	0.1928	0.0017	0.0115
30	0.01038	0.29	1.1238	0.0169	5534.7	56.1	5255.9	42.5	0.1897	0.0017	0.1998	0.0013	0.00976
	0.01159	0.29	1.1179	0.0117	4595.5	72.3	4384.2	39.7	0.2036	0.0021	0.2134	0.0027	0.00981

TableE-4 Raw data of sensitivity of PANI-H_2SO_4/CSA at N_A/N_{EB} equal to 1:160 when exposed to ethanol.

Ethanol	Thickness	Applied	Current	(mA)	Volt drop	before (mV)	Volt drop	after (mV)	σ (S/cm)	before	σ (S/cm)	after	Δσ (S/cm)
(%)	(cm)	Voltage (V)	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	
0	0.01271	0.35	1.0173	0.0121	4136.3	36.2	2514.8	30.1	0.1877	0.0027	0.3087	0.0014	0.1210
	0.01151	0.35	1.0694	0.0097	4520.3	59.2	2791.1	67.3	0.1993	0.0063	0.3228	0.0011	0.1235
1	0.01162	0.64	0.9409	0.0908	4054.4	17.8	2484.5	46.3	0.1937	0.0071	0.3161	0.0018	0.1224
	0.01042	0.64	1.0176	0.0867	4419.6	26.9	2820.5	21.1	0.2143	0.0050	0.3358	0.0021	0.1215
2.3	0.01182	0.39	1.1703	0.0238	4207.7	39.3	3154.4	47.2	0.2282	0.0035	0.3044	0.0026	0.0762
	0.01239	0.48	1.1777	0.0375	3782.2	45.1	3039.1	49.7	0.2437	0.0032	0.3033	0.0028	0.0596
4.6	0.01149	0.48	1.2439	0.0069	4522.6	102.3	3800.6	99.7	0.2322	0.0032	0.2763	0.0019	0.0441
	0.01064	0.25	0.7015	0.0116	3068.6	66.4	2491.0	69.9	0.2084	0.0050	0.2517	0.0164	0.0433

Ethanol	Thickness	Applied	Current	(mA)	Volt drop	before (mV)	Volt drop	after (mV)	σ (S/cm)	before	σ (S/cm)	after	Δσ (S/cm)
(%)	(cm)	Voltage (V)	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	Avg.	SD.	
9.2	0.01084	0.48	1.2123	0.0443	5102.5	60.8	4552.5	70.7	0.2120	0.0014	0.2547	0.0051	0.0427
	0.01134	0.48	1.1182	0.0307	4335.3	79.8	3651.6	63.1	0.2206	0.0057	0.2619	0.0052	0.0413
15	0.00780	0.53	0.9246	0.0222	7505.3	52.3	6813.2	49.7	0.1531	0.0042	0.1687	0.0036	0.0156
	0.00830	0.53	0.9942	0.0051	5406.6	67.7	5002.3	41.4	0.2149	0.0115	0.2319	0.0048	0.0170
20	0.01064	0.53	1.0696	0.0407	5415.0	72.1	5200.6	63.1	0.1800	0.0007	0.1875	0.0032	0.00742
	0.00964	0.47	1.0754	0.0398	4819.2	43.2	4617.3	56.2	0.2245	0.0062	0.2343	0.0071	0.00982
30	0.01017	0.30	1.0534	0.0097	4987.1	41.3	4764.1	49.1	0.2014	0.0011	0.2109	0.0025	0.00943
	0.01062	0.30	1.0050	0.0128	4651.3	39.2	4473.3	49.9	0.1973	0.0022	0.2052	0.0031	0.00785

CURRICULUM VITAE

Name : Jutharat Amornlertratanatada

Date of Birth: April 4, 1978

Nationality : Thai

University Education:

1995-1998 : Bachelor Degree of Science in Material Science, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.