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APPENDICES

Appendix A Elemental analysis data of acid-doped polyaniline

Elemental analyzer determined the weight percent of C, H, and N in the undoped, HCl-doped and MA-doped polyaniline by various acid-emeraldine base mole ratios. Raw data and calculated data (%O, %Cl and %oxidant) are shown in Table A.1.

Table A.1 Raw data and calculated data of acid doped polyaniline

Sample	Raw data			%TGA water	Calculated data			
	%C	%H	%N		%O water	%O dopant	%Cl dopant	%oxidant $[SO_4]^-$
EB	73.79	5.305	14.177	4.00	3.556	-	-	3.172
0.2HCl	71.676	4.965	13.806	5.00	4.44	-	1.94	3.17
0.5HCl	67.403	4.615	13.806	5.00	4.44	-	6.56	3.17
1.0HCl	62.033	4.394	11.840	10.25	8.89	-	9.67	3.17
2.0HCl	59.054	4.471	11.138	10.25	8.89	-	13.28	3.17
4.0HCl	58.863	4.460	11.081	10.25	8.89	-	13.54	3.17
5.0HCl	58.509	4.445	11.100	10.25	8.89	-	13.89	3.17
10.0HCl	58.461	4.433	11.175	10.25	8.89	-	13.87	3.17
20.0HCl	58.668	4.209	11.078	10.25	8.89	-	13.98	3.17
0.2MA	71.357	4.652	13.318	4.75	4.22	3.28	-	3.17
0.5MA	67.699	5.199	12.001	4.75	4.22	7.71	-	3.17
1.0MA	63.358	5.070	10.450	4.75	4.22	13.73	-	3.17
2.0MA	60.392	4.573	8.768	4.75	4.222	18.87	-	3.17
4.0MA	60.498	4.545	8.583	4.75	4.222	18.98	-	3.17
5.0MA	60.484	4.499	8.491	4.75	4.22	19.13	-	3.17
10.0MA	60.994	3.903	8.669	4.75	4.22	19.04	-	3.17
20.0MA	60.570	3.149	8.763	4.75	4.22	20.12	-	3.17

The apparent doping levels were calculated by using Equation A.1 and they are shown in Tables A.3 and A.5.

$$\%\text{Apparent Doping level} = [H^+]_{acid}/[N] \times 100 \tag{A.1}$$

To find the $[H^+]$ of acid dopant, firstly, the %O of water molecules in emeraldine base was determined by calculating %weight loss of water from TGA data.

$$\%O, H_2O = \%\text{Weight loss of water} \times \frac{\text{Molecular weight of oxygen}}{\text{Molecular weight of water}} \tag{A.2}$$

Secondly, the %oxidant was determined from undoped polyaniline following Equation A.3. This value is a constant used in calculating %Cl from Equation A.4.

$$\%\text{Oxidant} = 100 - \%C - \%H - \%N - (\%O_{EB}, H_2O) \tag{A.3}$$

Then, the %Cl in the HCl-doped polyaniline samples was calculated as follows.

$$\%Cl = 100 - \%C - \%H - \%N - \%\text{Oxidant, (from A1)} - \%O, H_2O, \text{(from TGA)} \tag{A.4}$$

The percentage of each element was converted to mole ratio in order to calculate doping level by using Equation A.5. The results are shown in Table A.2

$$\text{Mole ratio} = \frac{\%\text{Element} \times \text{PANI-repeating unit}}{100 \times \text{Molecular weight.}} \tag{A.5}$$

where, PANI-repeating unit = 362 g /mole.

i.e. $$[C] = \frac{\%C \times 362 \text{ g/mole}}{100 \times 12 \text{ g/mole}}$$

Table A.2 Mole ratio of each element of PANI-HCl powder

Sample	[C]	[H]	[N]	$[Cl^-]=[H^+]$	[Oxidant]
EB	22.26	19.20	3.67	-	-
0.2HCl	21.62	17.97	3.57	0.20	0.1
0.5HCl	20.33	16.71	3.57	0.67	0.1
1.0HCl	18.71	15.91	3.06	0.99	0.1
2.0HCl	17.81	16.19	2.88	1.35	0.1
4.0HCl	17.76	16.15	2.87	1.38	0.1
5.0HCl	17.65	16.09	2.87	1.42	0.1
10.0HCl	17.64	16.05	2.89	1.41	0.1
20.0HCl	17.70	15.24	2.86	1.43	0.1

Because the aniline has 1 nitrogen atom per molecule, the mole ratio of each element normalized to nitrogen was calculated by dividing mole ratios of each with mole ratio of nitrogen. The chemical structures of PANI-HCl and % apparent doping level are shown in Table A.3.

Table A.3 Chemical structure of PANI-HCl powder and apparent doping level

Sample name	Composition	% Apparent doping level, $\%[H^+]/[N]$
EB625	$C_{6.1}H_{4.4}N_{1.0}(H_2O)_{0.22}$	0
0.2HCl	$C_{6.1}H_{4.4}N_{1.0}(H_2O)_{0.28}(HCl)_{0.0553}$	5.53
0.5HCl	$C_{5.7}H_{3.9}N_{1.0}(H_2O)_{0.28}(HCl)_{0.1874}$	18.74
1.0HCl	$C_{6.1}H_{3.6}N_{1.0}(H_2O)_{0.66}(HCl)_{0.3221}$	32.21
2.0HCl	$C_{6.2}H_{3.8}N_{1.0}(H_2O)_{0.70}(HCl)_{0.4701}$	47.01
4.0HCl	$C_{6.2}H_{3.7}N_{1.0}(H_2O)_{0.70}(HCl)_{0.4817}$	48.17
5.0HCl	$C_{6.1}H_{3.7}N_{1.0}(H_2O)_{0.70}(HCl)_{0.4933}$	49.33
10.0HCl	$C_{6.2}H_{3.7}N_{1.0}(H_2O)_{0.70}(HCl)_{0.4895}$	48.95
20.0HCl	$C_{6.1}H_{3.4}N_{1.0}(H_2O)_{0.70}(HCl)_{0.4978}$	49.78

The apparent doping level of MA-doped polyaniline (PANI-MA) was determined by calculating % O, $C_4H_3O_4^-$ following Equation A.6.

$$(\%\ O,\ C_4H_3O_4^-) = 100 - \%C - \%H - \%N - \%Oxidant\ (from\ A1) - \%O,\ H_2O\ (from\ TGA) \qquad (A.6)$$

The percentage of each element of PANI-MA was converted to mole ratio by using Equation A.5. This result is shown in Table A.4. The chemical structures of PANI-MA powder and resulting doping levels were calculated from Equation A.1 as shown in Table A.5.

Table A.4 Mole ratio of each element of MA-doped polyaniline powder

Sample	[C]	[H]	[N]	$[O_4^-]$	$[H^+]=[O_4^-]/4$	[Oxidant]
EB	22.26	19.20	3.67	-	-	-
0.2MA	21.53	16.84	3.44	0.22	0.0538	0.1
0.5MA	20.42	18.82	3.10	0.56	0.1405	0.1
1.0MA	19.11	18.35	2.70	1.15	0.2873	0.1
2.0MA	18.22	16.55	2.27	1.88	0.4708	0.1
4.0MA	18.25	16.45	2.22	1.93	0.4837	0.1
5.0MA	18.25	16.29	2.20	1.97	0.4929	0.1
10.0MA	18.40	14.13	2.24	1.92	0.4804	0.1
20.0MA	18.27	11.40	2.27	2.01	0.5023	0.1

Table A.5 Chemical structure of PANI-MA powder and apparent doping level

Sample name	Composition	%Apparent doping level, %[H]/[N]
EB625	$C_{6.1}H_{4.4}N_{1.0}(H_2O)_{0.22}$	0
0.2MA	$C_{6.0}H_{4.1}N_{1.0}(H_2O)_{0.28}(C_4H_4O_4)_{0.054}$	5.38
0.5MA	$C_{6.0}H_{5.1}N_{1.0}(H_2O)_{0.31}(C_4H_4O_4)_{0.140}$	14.05
1.0MA	$C_{5.9}H_{5.7}N_{1.0}(H_2O)_{0.35}(C_4H_4O_4)_{0.287}$	28.74
2.0MA	$C_{6.2}H_{6.0}N_{1.0}(H_2O)_{0.42}(C_4H_4O_4)_{0.471}$	47.08
4.0MA	$C_{6.3}H_{6.1}N_{1.0}(H_2O)_{0.43}(C_4H_4O_4)_{0.484}$	48.37
5.0MA	$C_{6.3}H_{6.1}N_{1.0}(H_2O)_{0.44}(C_4H_4O_4)_{0.493}$	49.29
10.0MA	$C_{6.3}H_{5.0}N_{1.0}(H_2O)_{0.43}(C_4H_4O_4)_{0.481}$	48.04
20.0MA	$C_{6.1}H_{3.8}N_{1.0}(H_2O)_{0.42}(C_4H_4O_4)_{0.502}$	50.23

Appendix B FT-IR measurement of acid-doped polyaniline

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

$$A_i = a_i b_i c_i \tag{B.1}$$

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)

To obtain the doping level, the amounts of the benzenoid (C=C) to quinoid part (-N=) in a sample were determined by converting the absorbency of each peak to concentration by the following equation;

$$A_{(C=C)} = a_{(C=C)} b_{(C=C)} c_{(C=C)} \tag{B.2}$$

$$A_{(-N=)} = a_{(-N=)} b_{(-N=)} c_{(-N=)} \tag{B.3}$$

Therefore the doping level or concentration ratio is

$$\frac{c_{(C=C)}}{c_{(-N=)}} = \frac{A_{(C=C)}}{A_{(-N=)}} \cdot \frac{a_{(-N=)} b_{(-N=)}}{a_{(C=C)} b_{(C=C)}} \tag{B.4}$$

But the ratio of $\frac{c_{(C=C)}}{c_{(-N=)}}$ is unknown. We know the for pure emeraldine base or emeraldine salt, the ratios are equal 5.5 and 12 respectively. Therefore we used Equation B.4 under the condition of fully doped emeraldine salt where the left hand side should be 12 and the right hand side should be $\frac{A_{(C=C)}}{A_{(-N=)}}.r$, where $r = \frac{a_{(-N=)} b_{(-N=)}}{a_{(C=C)} b_{(C=C)}}$

From experimental, $\frac{A_{(C=C)}}{A_{(-N=)}}$ values of the last three acid emeraldine ratio were averaged and found to be 1.522, therefore r = 0.126828. Now Equation B.4 can be rewritten:

$$\frac{c_{(C=C)}}{c_{(-N=)}} = \frac{A_{(C=C)} \cdot 0.126828}{A_{(-N=)}} \qquad \text{(B.5)}$$

The area of each peak in a FT-IR spectra could be calculated by using the Gaussian's Equation as shown in Equation B.6.

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

Then the percentage of doping level could be calculated by using Equation B.7 and calculated data shown in Table B.1.

$$\%\ \text{Doping level} = \frac{[X - 5.5] \times 100}{[12 - 5.5]} \qquad \text{(B.7)}$$

where, X = Equation B.5

$$= \frac{c_{(C=C)}}{c_{(-N=)}} = \frac{A_{(C=C)} \cdot 0.126828}{A_{(-N=)}}$$

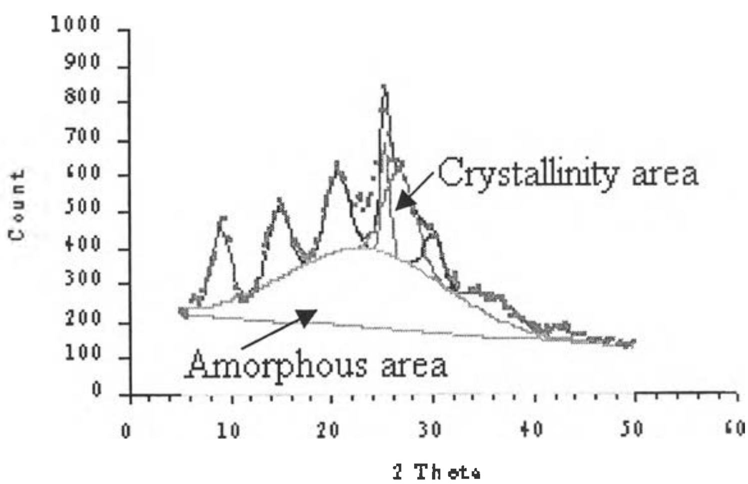
Table B.1 Raw data of absorbence area and doping level of PANI-HCl

Acid ratio	Absorbance area (%)			X	%
	$A_{(-N=)}$	$A_{(C=C)}$	$A_{(C=C)/(-N=)}$	$(c_{(C=C)}/c_{(-N=)})$	doping level
EB	21.4	24.4	0.877	6.915	21.773
0.2	19.7	22.2	0.887	6.997	23.027
0.5	21.8	20.6	1.058	8.344	43.754
	21.4	21.3	1.005	7.922	37.257
1.0	23.9	19.8	1.203	9.485	61.302
	21.6	20.5	1.054	8.308	43.197
2.0	26.0	18.9	1.376	10.847	82.257
	25.4	18.8	1.351	10.653	79.273
4.0	26.7	18.8	1.420	11.198	87.661
5.0	29.0	18.3	1.585	12.495	107.614
	26.6	18.5	1.438	11.337	89.799
10.0	28.7	19.6	1.464	11.545	93.007
	27.5	18.5	1.486	11.721	95.700
20.0	28.8	17.6	1.636	12.902	113.881

Appendix C Crystallinity of acid-doped polyaniline

XRD technique was used to investigate the order and the degree of crystallinity of polyanilines. The diffraction patterns of the emeraldine base were typically of an amorphous polymer. On the other hand, all protonic acid doped polyanilines were semi-crystalline polymers. They were identified as follow: the crystalline one corresponds to a relative sharp peak, and the amorphous one is visible as a broad pattern (Lunzy and Banka, 2000). The percentage of crystallinity was determined from Equation C.1 and shown in Figure C.1. Table C.1 and C.2 show the values of crystallinity of HCl-doped and MA-doped polyanilines as determined by integrating area under assumed Guassian curves, respectively. The effect of crystallinity on specific conductivity is shown in Table C.3 and Figure C.2.

%Crystallinity = (Area of crystallinity peak/ Total area) x 100 (C.1)



Scheme C.1 Integral area of the diffraction patterns of acid-doped polyaniline

Table C.1 Degree of crystallinity of HCl-doped polyaniline

N_A/N_{EB}	% Area of Crystallinity position								% Area of amorphous			% Crystallinity
	2θ~9	**2θ~15**	**2θ~17**	**2θ~21**	**2θ~25**	**2θ~27**	**2θ~30**	**2θ~36**	**2θ~19**	**2θ~23**	**2θ~33**	
0.2	3.70	11.09	-	10.49	5.57	-	-	-	27.19	41.96	-	30.85
0.5	4.84	8.02	-	9.74	5.77	3.17	2.86	-	12.26	53.34	-	34.40
1.0	6.22	6.69	-	8.07	4.12	12.10	3.62	4.12	-	55.07	-	44.93
2.0 (1)	5.65	7.74	-	8.83	9.60	12.90	4.90	5.18	-	19.59	25.59	54.81
2.0 (2)	8.06	8.06	8.06	10.66	12.59	9.75	-	-	-	18.13	24.68	57.18
4.0 (1)	5.37	7.52	-	11.63	9.54	13.93	4.24	4.79	-	20.30	22.68	57.02
4.0 (2)	7.02	5.69	8.49	9.28	10.97	9.28	2.53	-	-	15.79	30.95	53.25
5.0 (1)	6.71	7.88	-	9.14	6.71	16.36	5.64	3.50	-	18.65	25.39	55.96
10.0 (1)	7.39	9.54	-	8.07	7.39	11.54	5.74	3.43	-	18.69	28.21	53.09
10.0 (2)	5.29	7.90	8.64	12.80	10.21	7.90	2.35	-	-	14.70	30.20	55.10
20.0 (1)	6.97	8.43	-	11.15	7.25	14.14	6.62	2.94	-	14.64	27.86	57.49
20.0 (2)	4.48	5.33	11.34	14.08	9.48	5.79	1.33	-	-	23.14	25.03	51.83

Table C.2 Degree of crystallinity of MA-doped polyaniline

N_A/N_{EB}	% Area of crystallinity position at 2Theta								% Area of amorphous			% Cryst
	2θ~8, 10	**2θ~14**	**2θ~15, 16**	**2θ~17, 18**	**2θ~21**	**2θ~25**	**2θ~27**	**2θ~30**	**2θ~18.9**	**2θ~23**	**2θ~33**	
0.2	3.77	-	10.62	5.06	6.51	4.91	-	-	27.34	41.78	-	30.88
0.5	3.43	-	8.36	4.56	8.46	6.09	4.11	2.25	24.67	38.07	-	37.26
1.0	5.08	-	12.01	-	12.83	10.44	2.39	4.89	5.24	47.12	-	47.64
2.0 (1)	5.83	3.05	12.08	0.93	8.67	6.79	4.93	3.88	-	53.84	-	46.16
2.0 (2)	5.00	-	13.02	-	6.58	5.55	6.20	7.43	8.12	50.73	-	43.77
4.0 (1)	5.72	3.80	8.04	4.71	8.04	6.60	6.16	3.14	-	53.78	-	46.22
4.0 (2)	5.80	-	14.85	-	9.51	5.71	4.49	-	-	52.21	-	40.36
5.0	5.36	3.97	13.05	4.54	9.34	7.72	4.34	3.43	-	48.25	-	51.75
10.0 (1)	3.50	3.03	13.30	2.83	11.97	8.41	7.61	3.86	-	31.49	14.00	54.51
10.0 (2)	2.86	-	14.65	-	17.33	9.96	4.31	8.56	-	27.69	14.65	57.66
20.0 (1)	3.50	1.40	11.88	-	13.28	7.61	6.26	7.07	-	29.35	19.65	51.00
20.0 (2)	4.80	-	20.91	-	11.12	9.88	5.67	9.06	-	27.45	11.12	61.44

Table C.3 Relation between specific conductivity and crystallinity of PANI-HCl

N_A/N_{EB}	Conductivity,σ (S/cm)		%Doping level	σ (S/cm)/%doping		%Crystallinity	
	σ_1	σ_2		Sample1	Sample2	Sample1	Sample2
0.2	1.34E-05	1.34E-05	5.50	2.43E-06	4.33E-07	30.85	-
0.5	3.00E-04	4.00E-04	18.70	1.60E-05	1.16E-05	34.40	-
1.0	4.04E-02	4.18E-02	32.20	1.25E-03	9.31E-04	46.05	-
2.0	2.05E+00	2.24E+00	47.00	4.37E-02	4.08E-02	56.00	57.18
4.0	2.60E+00	3.32E+00	48.20	5.40E-02	5.82E-02	55.15	53.25
5.0	3.18E+00	2.99E+00	49.30	6.45E-02	5.34E-02	56.00	-
10.0	3.01E+00	2.75E+00	48.90	6.15E-02	5.17E-02	54.10	55.10
20.0	3.21E+00	3.42E+00	49.80	6.44E-02	5.94E-02	54.65	51.83

Table C.4 Relation between specific conductivity and crystallinity of PANI-MA

N_A/N_{EB}	Conductivity,σ (S/cm)		%Doping level	σ (S/cm)/%doping		%Crystallinity	
	σ_1	σ_2	MA	Sample1	Sample2	Sample1	Sample2
0.2	7.59E-06	7.73E-06	5.40	1.41E-06	2.50E-07	30.88	-
0.5	5.91E-05	5.62E-05	14.00	4.21E-06	1.61E-06	35.00	-
1.0	3.86E-02	3.96E-02	28.70	1.34E-03	8.64E-04	43.50	-
2.0	4.61E-01	3.33E-01	47.10	9.79E-03	7.37E-03	44.20	43.77
4.0	1.40E+00	1.39E+00	48.40	2.89E-02	3.00E-02	47.00	40.36
5.0	4.34E+00	4.48E+00	49.30	8.81E-02	8.66E-02	51.70	-
10.0	4.32E+00	4.45E+00	48.04	8.99E-02	8.17E-02	56.10	57.66
20.0	4.63E+00	4.40E+00	50.20	9.22E-02	8.64E-02	56.20	61.44

Appendix D Moisture content of acid-doped polyaniline and zeolite A by thermogravimetric analysis

The moisture contents of polyaniline and zeolite were studied by a DuPont model TGA 2950 thermalgravimetric analyzer. Each sample was weighed at 10-15 mg and then put in an aluminum pan. The instrument was set to operate at temperatures from 30 to 700°C at a heating rate of 10°C/min. The raw data of PANI-HCl and PANI-MA dried in vacuum oven for 48 h and zeolite A dried at 120°C ~6 h are shown in Table D.1, D.2 and D.3, respectively. The %weight loss and onset temperature of acid-doped polyaniline and zeolite A sample are shown in Table D.3 and D.6, respectively.

Table D.1 TGA data of HCl-doped polyaniline

Temp (°C)	%Weight loss							
	PANI-0.2HCl		PANI-0.5HCl		PANI-1.0HCl		PANI-2.0HCl	
	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2
35	99.2	99.21	99.19	99.21	99.12	99.17	99	99.03
45	98:37	98.38	98.36	98.38	98.07	98.12	97.63	97.66
55	97.66	97.67	97.65	97.67	97.11	97.16	96.3	96.33
65	97.00	97.01	96.99	97.01	96.2	96.25	95.02	95.05
75	96.33	96.34	96.32	96.34	95.29	95.34	93.79	93.82
85	95.61	95.62	95.6	95.62	94.38	94.43	92.74	92.77
95	94.86	94.87	94.85	94.87	93.49	93.54	91.83	91.86
105	94.16	94.17	94.15	94.17	92.61	92.66	91.09	91.12
115	93.69	93.7	93.68	93.7	91.87	91.92	90.46	90.49
125	93.39	93.4	93.38	93.4	91.35	91.4	89.96	89.99
135	93.22	93.23	93.21	93.23	91.03	91.08	89.5	89.53
145	93.11	93.12	93.1	93.12	90.82	90.87	89.03	89.06
155	93.04	93.05	93.03	93.05	90.64	90.69	88.53	88.56
165	92.98	92.99	92.97	92.99	90.44	90.49	87.96	87.99
175	92.91	92.92	92.9	92.92	90.19	90.24	87.31	87.34
185	92.83	92.84	92.82	92.84	89.86	89.91	86.56	86.59
195	92.73	92.74	92.72	92.74	89.4	89.45	85.72	85.75
205	92.61	92.62	92.6	92.62	88.8	88.85	84.77	84.8
215	92.42	92.43	92.41	92.43	88.08	88.13	83.71	83.74
225	92.14	92.15	92.13	92.15	87.24	87.29	82.55	82.58
235	91.67	91.68	91.66	91.68	86.37	86.42	81.33	81.36
245	91.04	91.05	91.03	91.05	85.51	85.56	80.08	80.11
255	90.29	90.3	90.28	90.3	84.74	84.79	78.85	78.88
265	89.53	89.54	89.52	89.54	84.04	84.09	77.6	77.63
275	88.96	88.97	88.95	88.97	83.51	83.56	76.65	76.68
285	88.65	88.66	88.64	88.66	83.19	83.24	76.28	76.31

Cont.

Temp (°C)	%Weight loss							
	PANI-4.0HCl		PANI-5.0HCl		PANI-10.0HCl		PANI-20.0HCl	
	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2
35	99	99.15	99.67	99.72	99.26	99.36	99.42	99.43
45	97.82	97.97	98.92	98.97	98.15	98.25	98.46	98.47
55	96.63	96.78	97.95	98	96.95	97.05	97.29	97.3
65	95.44	95.59	96.91	96.96	95.81	95.91	95.92	95.93
75	94.26	94.41	95.87	95.92	94.69	94.79	94.46	94.47
85	93.15	93.3	94.8	94.85	93.61	93.71	93.1	93.11
95	92.2	92.35	93.66	93.71	92.49	92.59	91.94	91.95
105	91.35	91.5	92.52	92.57	91.34	91.44	90.85	90.86
115	90.64	90.79	91.31	91.36	90.2	90.3	90.01	90.02
125	90.05	90.2	90.32	90.37	89.16	89.26	89.29	89.3
135	89.53	89.68	89.44	89.49	88.26	88.36	88.68	88.69
145	89.05	89.2	88.7	88.75	87.53	87.63	88.15	88.16
155	88.58	88.73	88.08	88.13	86.89	86.99	87.64	87.65
165	88.07	88.22	87.49	87.54	86.3	86.4	87.12	87.13
175	87.51	87.66	86.92	86.97	85.71	85.81	86.58	86.59
185	86.87	87.02	86.33	86.38	84.92	85.02	85.97	85.98
195	86.14	86.29	85.67	85.72	84.43	84.53	85.29	85.3
205	85.31	85.46	84.93	84.98	83.68	83.78	84.5	84.51
215	84.34	84.49	84.07	84.12	82.85	82.95	83.57	83.58
225	83.27	83.42	83.12	83.17	81.92	82.02	82.48	82.49
235	82.16	82.31	82.1	82.15	80.93	81.03	81.28	81.29
245	81.01	81.16	81.06	81.11	79.99	80.09	79.99	80
255	79.91	80.06	79.99	80.04	79.03	79.13	78.74	78.75
265	78.81	78.96	78.87	78.92	78.02	78.12	77.4	77.41
275	77.83	77.98	78.05	78.1	77.2	77.3	76.16	76.17
285	77.28	77.43	77.67	77.72	76.87	76.97	75.57	75.58
295	77.04	77.19	77.46	77.51	76.68	76.78	75.34	75.35

Table D.2 TGA data of MA-doped polyaniline

Temp (°C)	%Weight loss							
	PANI-0.2MA		PANI-0.5MA		PANI-1.0MA		PANI-2.0MA	
	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2
35	99.46	99.35	99.35	99.46	99.2	99.26	99.39	99.53
45	98.79	98.68	98.68	98.79	98.11	98.17	98.51	98.65
55	98.2	98.09	98.09	98.2	97.14	97.2	97.57	97.71
65	97.62	97.51	97.51	97.62	96.4	96.46	96.77	96.91
75	97.09	96.98	96.98	97.09	95.85	95.91	96.16	96.3
85	96.69	96.58	96.58	96.69	95.44	95.5	95.71	95.85
95	96.35	96.24	96.24	96.35	95.15	95.21	95.41	95.55
105	96.09	95.98	95.98	96.09	94.95	95.01	95.18	95.32
115	95.92	95.81	95.81	95.92	94.78	94.84	94.94	95.08
125	95.8	95.69	95.69	95.8	94.52	94.58	94.47	94.61
135	95.72	95.61	95.61	95.72	94.06	94.12	93.45	93.59
145	95.61	95.5	95.5	95.61	93.19	93.25	91.73	91.87
155	95.45	95.34	95.34	95.45	91.8	91.86	89.41	89.55
165	95.15	95.04	95.04	95.15	89.92	89.98	86.79	86.93
175	94.61	94.5	94.5	94.61	87.7	87.76	84.06	84.2
185	93.78	93.67	93.67	93.78	85.23	85.29	81.26	81.4
195	92.7	92.59	92.59	92.7	82.63	82.69	78.42	78.56
205	91.58	91.47	91.47	91.58	80.09	80.15	75.76	75.9
215	90.67	90.56	90.56	90.67	77.96	78.02	73.51	73.65
225	90.07	89.96	89.96	90.07	76.42	76.48	71.78	71.92
235	89.73	89.62	89.62	89.73	75.48	75.54	70.71	70.85
245	89.5	89.39	89.39	89.5	74.99	75.05	70.17	70.31
255	89.35	89.24	89.24	89.35	74.72	74.78	69.9	70.04
265	89.25	89.14	89.14	89.25	74.54	74.6	69.7	69.84
275	89.17	89.06	89.06	89.17	74.37	74.43	69.52	69.66
285	89.11	89	89	89.11	74.21	74.27	69.36	69.5
295	89.06	88.95	88.95	89.06	74.20	74.27	69.2	69.34
305	89.01	88.9	88.9	89.01	74.20	74.27	69.2	69.3

Cont.

Temp (°C)	%Weight loss							
	PANI-4.0MA		PANI-5.0MA		PANI-10.0MA		PANI-20.0MA	
	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2	Sample1	Sample2
35	99.06	99.08	99.43	99.63	98.94	98.97	99	99.01
45	97.72	97.74	98.33	98.53	97.67	97.7	97.65	97.66
55	96.59	96.61	97.16	97.36	96.42	96.45	96.35	96.36
65	95.8	95.82	96.29	96.49	95.44	95.47	95.36	95.37
75	95.26	95.28	95.73	95.93	94.82	94.85	94.74	94.75
85	94.89	94.91	95.39	95.59	94.49	94.52	94.41	94.42
95	94.63	94.65	95.13	95.33	94.24	94.27	94.14	94.15
105	94.4	94.42	94.71	94.91	93.89	93.92	93.73	93.74
115	94.01	94.03	93.91	94.11	93.17	93.2	92.82	92.83
125	93.23	93.25	92.28	92.48	91.6	91.63	90.94	90.95
135	91.73	91.75	89.51	89.71	88.9	88.93	87.92	87.93
145	89.46	89.48	85.88	86.08	85.33	85.36	84.07	84.08
155	86.7	86.72	82.06	82.26	81.5	81.53	80.11	80.12
165	83.84	83.86	78.58	78.78	77.96	77.99	76.58	76.59
175	81.02	81.04	75.49	75.69	74.84	74.87	73.5	73.51
185	78.17	78.19	72.58	72.78	71.92	71.95	70.63	70.64
195	75.31	75.33	69.64	69.84	69.04	69.07	67.79	67.8
205	72.59	72.61	66.75	66.95	66.25	66.28	65.04	65.05
215	70.33	70.35	64.18	64.38	63.79	63.82	62.62	62.63
225	68.76	68.78	62.36	62.56	61.86	61.89	60.79	60.8
235	67.9	67.92	61.35	61.55	60.75	60.78	59.73	59.74
245	67.53	67.55	60.88	61.08	60.08	60.11	59.3	59.31
255	67.32	67.34	60.68	60.88	59.94	59.97	59.1	59.11
265	67.16	67.18	60.54	60.74	59.81	59.84	58.96	58.97
275	67.01	67.03	60.43	60.63	59.69	59.72	58.84	58.85
285	66.87	66.89	60.31	60.51	59.57	59.6	58.72	58.73

Table D.3 Weight loss and onset temperature of PANI-HCl powder

N_A/N_{EB}	First-step				Second-step			
	Sample 1		Sample 2		Sample 1		Sample 2	
	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)
0.2	6.0	80	6.5	85	10	220	9.4	224
0.5	6.5	75	7.0	82	10.5	221	10.3	198
1.0	9.2	85	10.6	87	11.8	219	7.7	211
2.0	10.4	65	11.0	79	13.0	213	18.5	222
4.0	10.9	69	11.3	72	12.3	215	11.0	215
5.0	12.9	81	13.3	80	10.7	221	9.4	209
10.0	13.8	83	11.0	81	11.8	217	12.3	215
20.0	12.3	60	10.2	68	8.8	215	7.7	220

Table D.4 Weight loss and onset temperature of PANI-MA powder

N_A/N_{EB}	First-step				Second-step			
	Sample 1		Sample 2		Sample 1		Sample 2	
	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)
0.2	4.2	60	3.6	66	19.6	201	20	198
0.5	4.2	56	4.2	50	20.0	199	19	199
1.0	4.9	58	5.2	51	19.6	193	19.5	194
2.0	4.6	50	4.1	49	23.0	193	43.1	190
4.0	5.3	53	4.0	49	35.3	197	32	203
5.0	4.6	50	4.3	49	37.0	200	36	198
10.0	5.4	42	3.98	50	35.5	196	41	190
20.0	4.8	52	3.47	50	34.9	190	35.5	190

Table D.5 TGA data of zeolite A after drying at 120°C ~6 h

Temp (°C)	%Weight loss of Zeolite 3A		Temp (°C)	%Weight loss of Zeolite 3A		Temp (°C)	%Weight loss of Zeolite 4A	
	Sample1	Sample2		Sample1	Sample 2		Sample1	Sample2
30	99.94	99.82	340	81.62	81.5	30	99.8	99.87
40	99.43	99.31	350	81.58	81.46	40	99.67	99.35
50	98.77	98.65	360	81.55	81.43	50	99.11	98.77
60	98.06	97.94	370	81.52	81.4	60	98.5	98.15
70	97.34	97.22	380	81.49	81.37	70	97.83	97.46
80	96.59	96.47	390	81.47	81.35	80	97.12	96.71
90	95.8	95.68	400	81.45	81.33	90	96.31	95.87
100	94.93	94.81	410	81.43	81.31	100	95.38	94.91
110	93.92	93.8	420	81.41	81.29	110	94.24	93.83
120	92.71	92.59	430	81.4	81.28	120	92.83	92.46
130	91.29	91.17	440	81.38	81.26	130	91.22	90.86
140	89.67	89.55	450	81.37	81.25	140	89.57	89.23
150	87.99	87.87	460	81.36	81.24	150	88.12	87.82
160	86.47	86.35	470	81.35	81.23	160	87.06	86.8
170	85.25	85.13	480	81.34	81.22	170	86.38	86.15
180	84.38	84.26	490	81.33	81.21	180	85.93	85.73
190	83.76	83.64	500	81.33	81.21	190	85.59	85.41
200	83.31	83.19	510	81.32	81.2	200	85.31	85.15
210	82.96	82.84	520	81.32	81.2	210	85.06	84.92
220	82.69	82.57	530	81.32	81.2	220	84.83	84.71
230	82.48	82.36	540	81.31	81.19	230	84.64	84.53
240	82.31	82.19	550	81.31	81.19	240	84.45	84.36
250	82.17	82.05	560	81.31	81.19	250	84.27	84.2
260	82.06	81.94	570	81.31	81.19	260	84.09	84.05
270	81.96	81.84	580	81.31	81.19	270	83.91	83.91
280	81.88	81.76	590	81.31	81.19	280	83.73	93.76
290	81.81	81.69	600	81.32	81.2	290	83.55	83.62
300	81.75	81.63	610	81.32	81.2	300	83.36	83.47
310	81.7	81.58	620	81.32	81.2	310	83.17	83.32
320	81.76	81.64	630	81.33	81.21	320	82.97	83.18
330	81.66	81.54	640	81.33	81.21	330	82.78	83.02

Cont.

Temp (°C)	%Weight loss of Zeolite 4A		Temp (°C)	%Weight loss of Zeolite 5A		Temp (°C)	%Weight loss of Zeolite 5A	
	Sample1	Sample2		Sample1	Sample 2		Sample1	Sample2
340	82.58	82.87	30	99.8	99.87	340	81.62	81.5
350	82.38	82.71	40	99.67	99.35	350	81.58	81.46
360	82.2	82.55	50	99.11	98.77	360	81.55	81.43
370	82.03	82.4	60	98.5	98.15	370	81.52	81.4
380	81.87	82.26	70	97.83	97.46	380	81.49	81.37
390	81.37	82.14	80	97.12	96.71	390	81.47	81.35
400	81.62	82.02	90	96.31	95.87	400	81.45	81.33
410	81.52	81.92	100	95.38	94.91	410	81.43	81.31
420	81.43	81.84	110	94.24	93.83	420	81.41	81.29
430	81.36	81.77	120	92.83	92.46	430	81.4	81.28
440	81.29	81.71	130	91.22	90.86	440	81.38	81.26
450	81.24	81.66	140	89.57	89.23	450	81.37	81.25
460	81.19	81.62	150	88.12	87.82	460	81.36	81.24
470	81.15	81.58	160	87.06	86.8	470	81.35	81.23
480	81.12	81.55	170	86.38	86.15	480	81.34	81.22
490	81.08	81.52	180	85.93	85.73	490	81.33	81.21
500	81.05	81.5	190	85.59	85.41	500	81.33	81.21
510	81.02	81.48	200	85.31	85.15	510	81.32	81.2
520	80.99	81.46	210	85.06	84.92	520	81.32	81.2
530	80.97	81.44	220	84.83	84.71	530	81.32	81.2
540	80.95	81.41	230	84.64	84.53	540	81.31	81.19
550	80.93	81.4	240	84.45	84.36	550	81.31	81.19
560	80.92	81.39	250	84.27	84.2	560	81.31	81.19
570	80.91	81.38	260	84.09	84.05	570	81.31	81.19
580	80.9	81.37	270	83.91	83.91	580	81.31	81.19
590	80.89	81.36	280	83.73	93.76	590	81.31	81.19
600	80.88	81.35	290	83.55	83.62	600	81.32	81.2
610	80.87	81.34	300	83.36	83.47	610	81.32	81.2
620	80.86	81.33	310	83.17	83.32	620	81.32	81.2
630	80.85	81.33	320	82.97	83.18	630	81.33	81.21
640	80.84	81.32	330	82.78	83.02	640	81.33	81.21

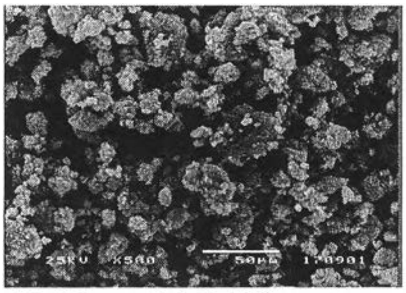
Table D.6 Weight loss and onset temperature of zeolite A powder

Step loss	Zeolite 3A			
	Sample 1		Sample 2	
	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)
First-step	2.55	62	2.4	60.5
Second-step	15.9	143	15	141
Third-step	-	-	-	-

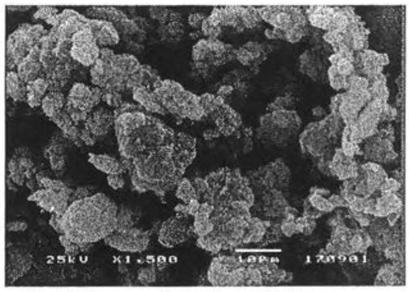
Step loss	Zeolite 4A			
	Sample 1		Sample 2	
	%Wt. loss	Onset (°C)	%Wt. loss	Onset (°C)
First-step	1.5	56	2	58
Second-step	15.8	131	15.5	132
Third-step	1.7	345	3.5	343

Step loss	Zeolite 5A			
	Sample 1		Sample 2	
	%Wt. Loss	Onset (°C)	%Wt. loss	Onset (°C)
First-step	2.88	46.7	3.09	42.0
Second-step	8.59	121.7	8.51	122.8
Third-step	8.1	183.2	7.78	184.3

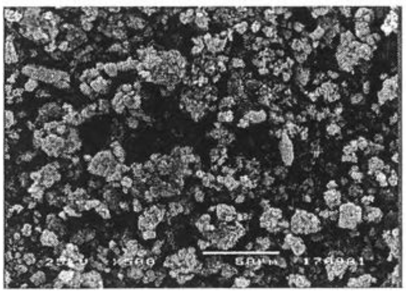
Appendix E Morphology of polyaniline and zeolite samples



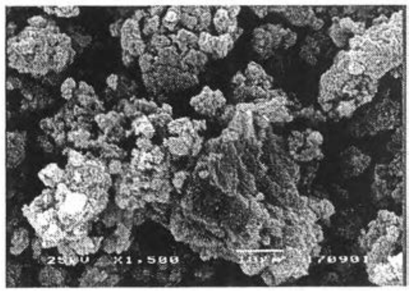
N_A/N_{EB} = 1.0 (x500)



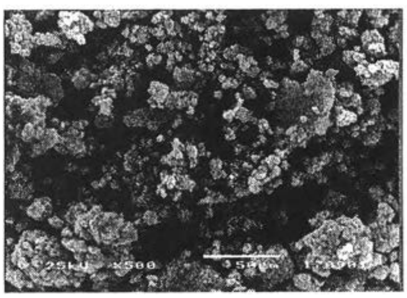
N_A/N_{EB} = 1.0 (x1500)



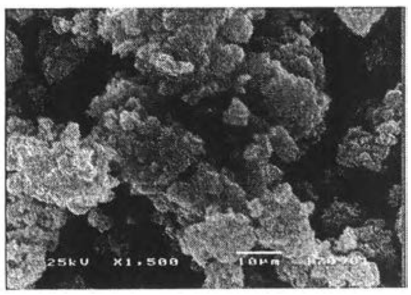
N_A/N_{EB} = 10.0 (x500)



N_A/N_{EB} = 10.0 (x1500)



N_A/N_{EB} = 20.0 (x500)



N_A/N_{EB} = 20.0 (x1500)

Figure E1 Morphology of polyaniline powders after doping with HCl at different acid-emeraldine base mole ratios, N_A/N_{EB}.

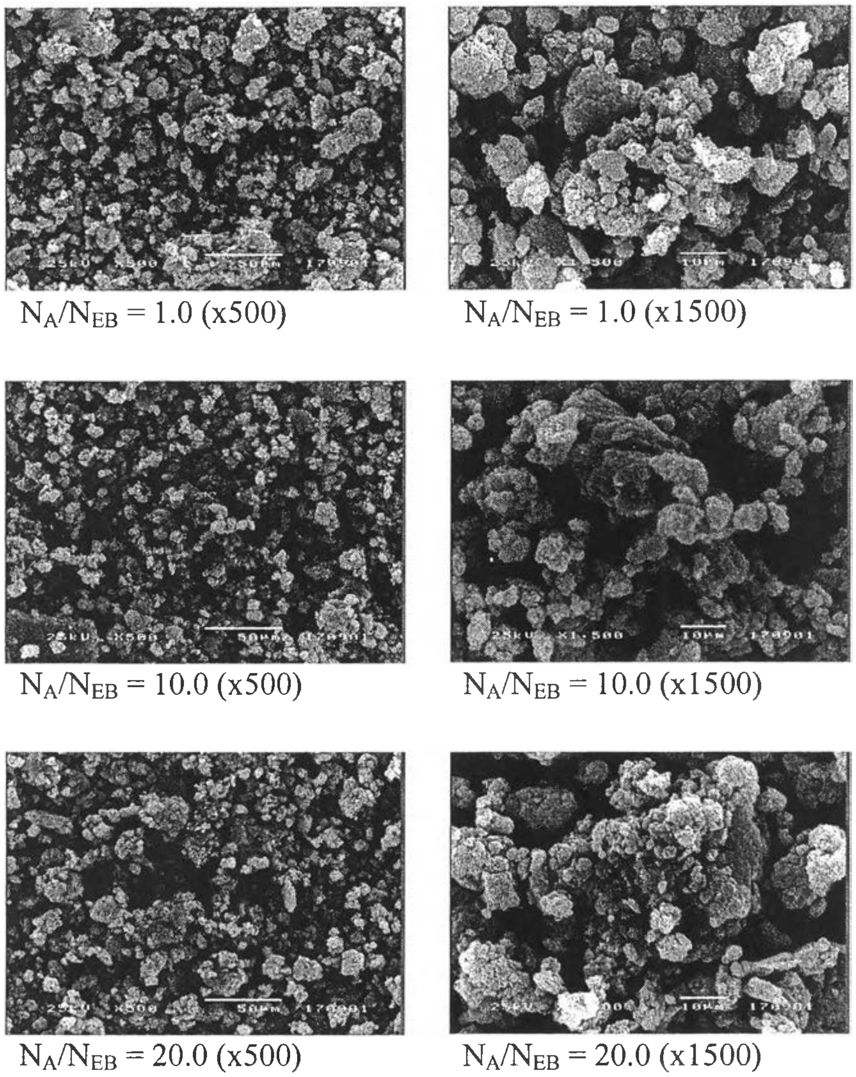
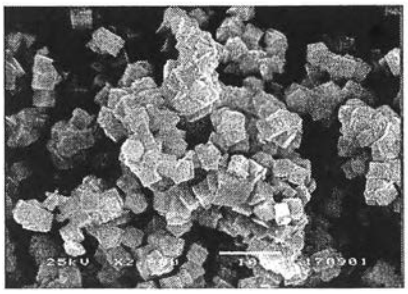
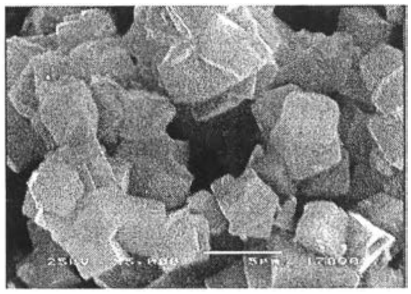


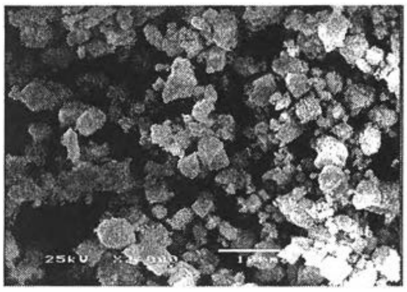
Figure E2 Morphology of polyaniline powders after doping with MA at different acid-emeraldine base mole ratios, N_A/N_{EB}.



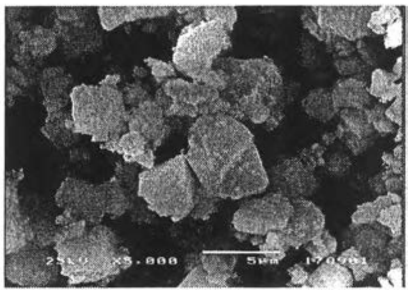
Zeolite NaKA, (3A), x2000



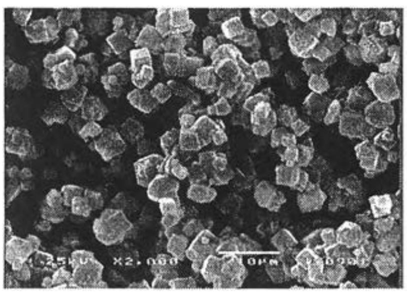
Zeolite NaKA, (3A), x5000



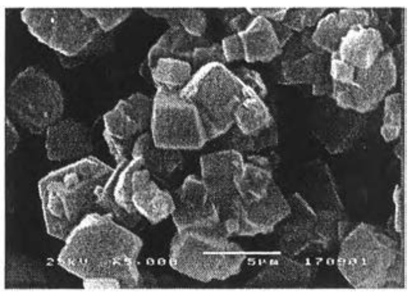
Zeolite NaA, (4A), x2000



Zeolite NaA, (4A), x5000



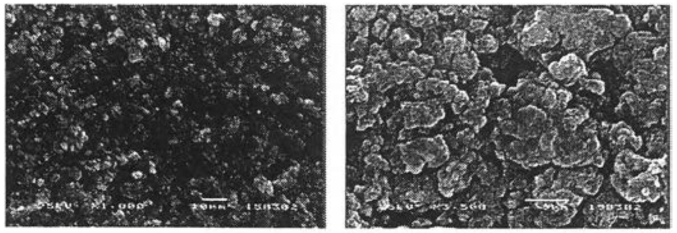
Zeolite NaCaA, (5A), x2000



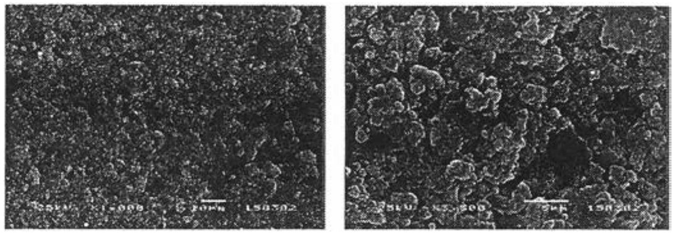
Zeolite NaCaA, (5A), x5000

Figure E3 Morphology of zeolite powders at different molecular structure.

Figure E4 Morphological structure of PANI-HCl pellet at (a) $N_A/N_{EB} = 1.0$ and (b) $N_A/N_{EB} = 10.0$

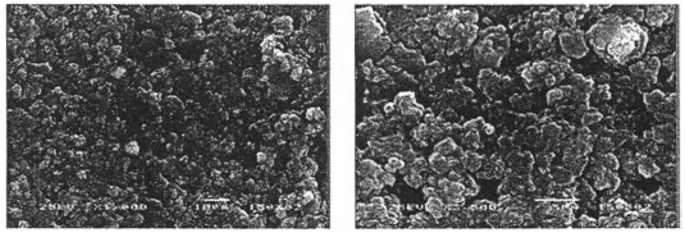


(x1000) (a) (x3500)

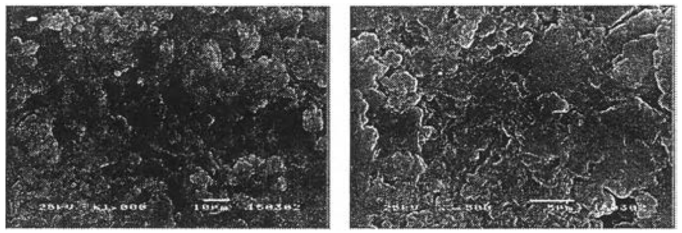


(x1000) (b) (x3500)

Figure E5 Morphological structure of PANI-MA pellet at (a) $N_A/N_{EB} = 1.0$ and (b) $N_A/N_{EB} = 10.0$

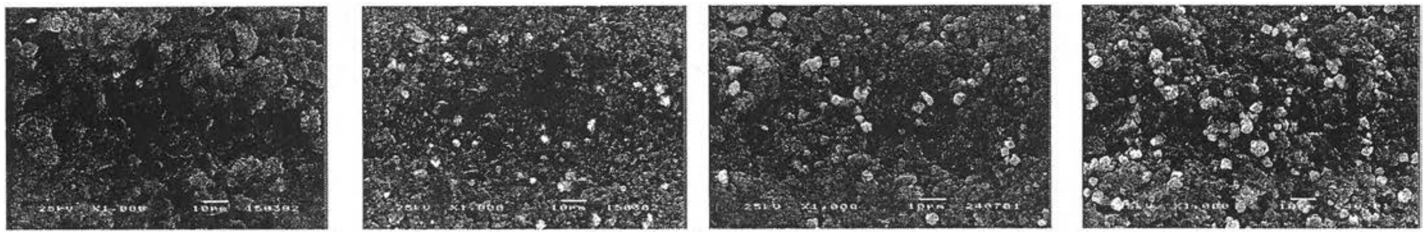


(x1000) (a) (x3500)

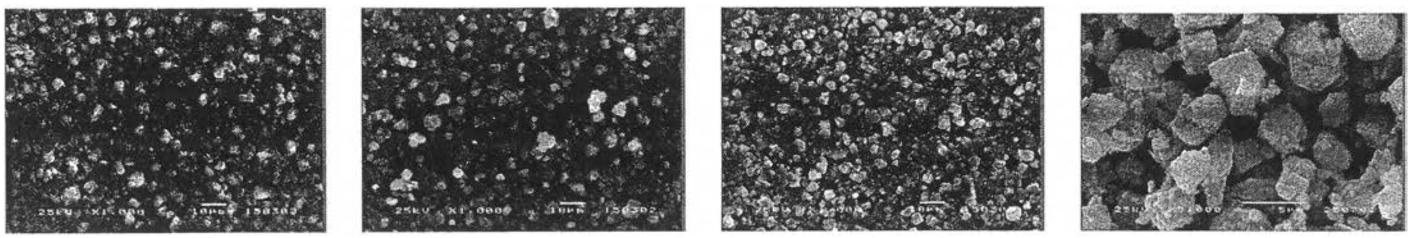


(x1000) (b) (x3500)

Figure E6 Morphological structure of PANI-10MA, Zeolite 4A and Zeolite4A/ PANI-10MA at various zeolite contents (x1000)



PANI-10MA | PANI-10MA/5Zeolite 4A | PANI-10MA/10Zeolite 4A | PANI-10MA/20Zeolite 4A



PANI-10MA/30Zeolite 4A | PANI-10MA/40Zeolite 4A | PANI-10MA/50Zeolite 4A | Zeolite 4A

Appendix F Particle size of polyaniline and zeolite A powder

The particle size of polyaniline and zeolite sample A was determined by using a Masterizer X Version. 2.15 particle size analyzer, (Malvern Instruments Ltd.). The lenses used in this experiment were 45 for zeolite A measurement and 300 mm for polyaniline powder. The beam length was 2.40 mm. The sample was placed in a sample cell across a laser beam. This instrument measured the average particle size and standard size distribution. Raw data of agglomerate particle size of polyaniline powder that ground with a ball mill for 3 h and sieved with mesh (53μm) are listed in Table F.1. Particle size distribution is shown in Figure F.1. For three types of zeolite A powder, raw data of agglomerate particle size are listed in Table F.2 and F.3. Particle size distributions of zeolite 3A, 4A and 5A are shown in Figure F.2.

Table F.1 Agglomerate particle size of polyaniline powder ground with a ball mill for 3 h and sieved with mesh (53μm)

Agglomerate Particle size (μm)			PANI		
			Sample 1	Sample 2	Sample 3
Size Low (μm)		Size High (μm)	In %	In %	In %
0.50	0.91	1.32	0.05	0.05	0
1.32	1.46	1.60	0.1	0.1	0.23
1.60	1.78	1.95	0.13	0.13	0.53
1.95	2.17	2.38	0.13	0.13	0.94
2.38	2.64	2.90	0.14	0.16	1.51
2.90	3.22	3.53	0.24	0.27	2.29
3.53	3.92	4.30	0.53	0.58	3.28
4.30	4.77	5.24	1.09	1.16	4.46
5.24	5.82	6.39	2.01	2.08	5.71
6.39	7.09	7.78	3.3	3.36	6.78
7.78	8.63	9.48	4.97	4.99	7.44
9.48	10.52	11.55	6.86	6.82	7.55
11.55	12.82	14.08	8.7	8.59	7.2
14.08	15.62	17.15	10.18	10.03	6.9
17.15	19.03	20.90	11.14	10.98	6.78
20.90	23.18	25.46	11.48	11.34	6.8
25.46	28.24	31.01	11.08	11.01	6.72
31.01	34.40	37.79	9.83	9.88	6.21
37.79	41.91	46.03	7.84	7.98	5.07
46.03	51.06	56.09	5.42	5.57	3.46
56.09	62.21	68.33	3.05	3.16	1.81
68.33	75.80	83.26	1.21	1.32	0.58
83.26	92.35	101.44	0.14	0.32	0
101.44	112.52	123.59	0	0	0
123.59	137.08	150.57	0	0	0
150.57	167.01	183.44	0.01	0	0
183.44	203.48	223.51	0.13	0	0
223.51	247.91	272.31	0.13	0	0
272.31	302.04	331.77	0.08	0	0
331.77	367.99	404.21	0.03	0	0
404.21	448.34	492.47	0	0	0
492.47	546.24	600.00	0	0	0
Mean Diameters:			25.42	24.82	21.28

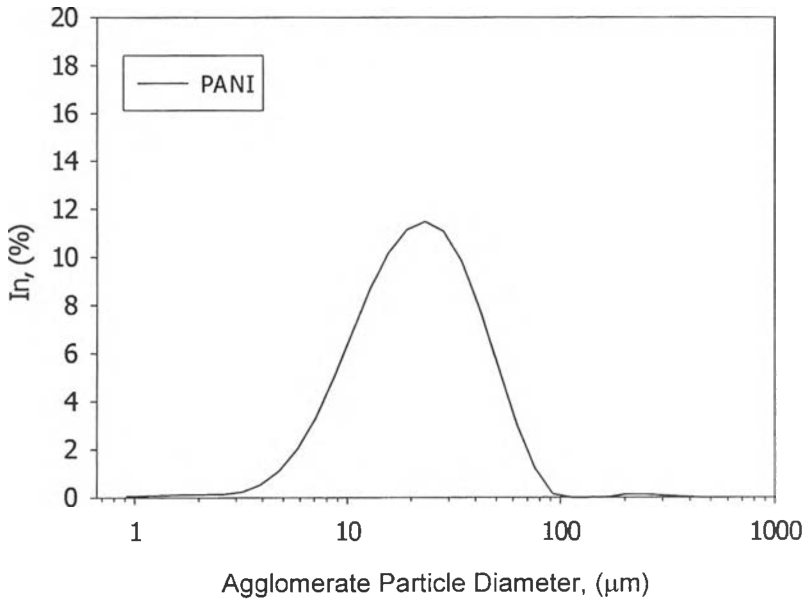


Figure F.1 Particle size distribution of polyaniline powder ground with a ball mill for 3 h and sieved with mesh (53μm).

Table F.2 Agglomerate particle size of zeolite 3A powder

Agglomerate Particle size (μm)			Zeolite 3A		
			Sample 1	Sample 2	Sample 3
Size Low (μm)		Size High (μm)	In %	In %	In %
0.05	0.09	0.12	0	0	0
0.12	0.14	0.15	0	0	0.02
0.15	0.17	0.19	0.03	0.03	0.06
0.19	0.21	0.23	0.08	0.08	0.11
0.23	0.26	0.28	0.17	0.17	0.19
0.28	0.32	0.35	0.3	0.29	0.31
0.35	0.39	0.43	0.47	0.47	0.46
0.43	0.48	0.53	0.68	0.68	0.66
0.53	0.59	0.65	0.92	0.93	0.87
0.65	0.73	0.81	1.16	1.17	1.1
0.81	0.91	1.00	1.36	1.36	1.31
1.00	1.12	1.23	1.46	1.43	1.44
1.23	1.37	1.51	1.35	1.3	1.39
1.51	1.69	1.86	1.02	0.95	1.1
1.86	2.08	2.30	0.67	0.58	0.77
2.30	2.57	2.83	0.47	0.35	0.59
2.83	3.16	3.49	0.6	0.44	0.73
3.49	3.90	4.30	1.14	0.96	1.27
4.30	4.80	5.29	2.14	1.99	2.26
5.29	5.91	6.52	3.65	3.61	3.77
6.52	7.28	8.04	5.76	5.87	5.88
8.04	8.98	9.91	8.45	8.65	8.51
9.91	11.06	12.21	11.26	11.38	11.14
12.21	13.63	15.04	13.26	13.2	12.96
15.04	16.79	18.54	13.43	13.31	13.12
18.54	20.69	22.84	11.59	11.56	11.41
22.84	25.50	28.15	8.6	8.7	8.55
28.15	31.42	34.69	5.49	5.64	5.48
34.69	38.72	42.75	2.98	3.15	3
42.75	47.72	52.68	1.29	1.42	1.3
52.68	58.80	64.92	0.22	0.33	0.24
64.92	72.46	80.00	0	0	0
Mean Diameters:			15.11	15.35	15.02

Table F.3 Agglomerate particle size of zeolite 4A powder

Agglomerate Particle size (µm)			Zeolite 4A		
			Sample 1	Sample 2	Sample 3
Size Low (µm)		Size High (µm)	In %	In %	In %
0.05	0.09	0.12	0	0	0
0.12	0.14	0.15	0	0	0
0.15	0.17	0.19	0	0	0
0.19	0.21	0.23	0	0	0.01
0.23	0.26	0.28	0	0	0.04
0.28	0.32	0.35	0.07	0.12	0.14
0.35	0.39	0.43	0.34	0.36	0.34
0.43	0.48	0.53	0.79	0.75	0.7
0.53	0.59	0.65	1.44	1.35	1.25
0.65	0.73	0.81	2.28	2.14	2.01
0.81	0.91	1.00	3.38	3.21	3.07
1.00	1.12	1.23	4.94	4.78	4.66
1.23	1.37	1.51	6.6	6.53	6.5
1.51	1.69	1.86	7.13	7.18	7.18
1.86	2.08	2.30	7.48	7.58	7.61
2.30	2.57	2.83	8.16	8.27	8.3
2.83	3.16	3.49	9.99	10.09	10.13
3.49	3.90	4.30	12.07	12.16	12.25
4.30	4.80	5.29	13.05	13.12	13.25
5.29	5.91	6.52	11.13	11.18	11.31
6.52	7.28	8.04	7.11	7.15	7.22
8.04	8.98	9.91	3.25	3.26	3.27
9.91	11.06	12.21	0.79	0.77	0.76
12.21	13.63	15.04	0	0	0
15.04	16.79	18.54	0	0	0
18.54	20.69	22.84	0	0	0
22.84	25.50	28.15	0	0	0
28.15	31.42	34.69	0	0	0
34.69	38.72	42.75	0	0	0
42.75	47.72	52.68	0	0	0
52.68	58.80	64.92	0	0	0
64.92	72.46	80.00	0	0	0
Mean Diameters:			3.64	3.65	3.67

Table F.4 Agglomerate particle size of zeolite 5A powder

Agglomerate Particle size (µm)			Zeolite 5A		
			Sample 1	Sample 2	Sample 3
Size Low (µm)		Size High (µm)	In %	In %	In %
0.05	0.09	0.12	0	0	0
0.12	0.14	0.15	0	0	0
0.15	0.17	0.19	0	0	0
0.19	0.21	0.23	0	0	0
0.23	0.26	0.28	0	0	0
0.28	0.32	0.35	0.04	0.06	0.06
0.35	0.39	0.43	0.34	0.33	0.35
0.43	0.48	0.53	0.77	0.76	0.78
0.53	0.59	0.65	1.35	1.32	1.36
0.65	0.73	0.81	2.04	2.01	2.07
0.81	0.91	1.00	2.79	2.77	2.84
1.00	1.12	1.23	3.49	3.48	3.56
1.23	1.37	1.51	3.71	3.73	3.8
1.51	1.69	1.86	3.11	3.18	3.23
1.86	2.08	2.30	2.49	2.58	2.62
2.30	2.57	2.83	2.64	2.72	2.77
2.83	3.16	3.49	4	4.04	4.13
3.49	3.90	4.30	6.43	6.43	6.57
4.30	4.80	5.29	9.3	9.23	9.4
5.29	5.91	6.52	11.42	11.31	11.45
6.52	7.28	8.04	11.88	11.81	11.84
8.04	8.98	9.91	10.73	10.69	10.59
9.91	11.06	12.21	8.55	8.53	8.32
12.21	13.63	15.04	6.1	6.07	5.83
15.04	16.79	18.54	3.93	3.87	3.69
18.54	20.69	22.84	2.27	2.23	2.12
22.84	25.50	28.15	1.21	1.21	1.16
28.15	31.42	34.69	0.62	0.67	0.63
34.69	38.72	42.75	0.35	0.43	0.36
42.75	47.72	52.68	0.23	0.29	0.23
52.68	58.80	64.92	0.15	0.18	0.15
64.92	72.46	80.00	0.5	0.06	0.08
Mean Diameters:			7.37	7.44	7.27

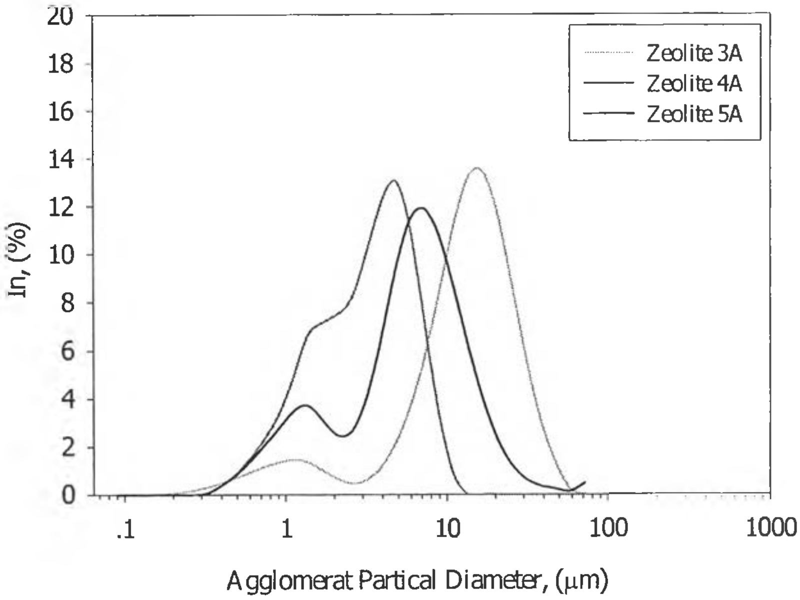


Figure F.2 Particle size distribution of zeolite A powder.

Appendix G Determination of Ohmic law regime

Ohmic regime or linear regime is the regime in which applied voltage is limearly dependent on current according to the Ohmic's law in Equation G.1.

Due to the specific conductivity given by the Equation 3.1, the acceptable current which was used in the experiments should be in the ohmic's regime. Figures G.1 and G.2 are the plots of V_a and I using silicon wafer as a standard material and using polyaniline, respectively. These experiments were done under a pressure 1 atm, 64% relative humidity, and 26±1°C.

$$V_a = IR \tag{G.1}$$

where V_a = applied voltage (mV)

I = current (mA)

R = resistance (Ω)

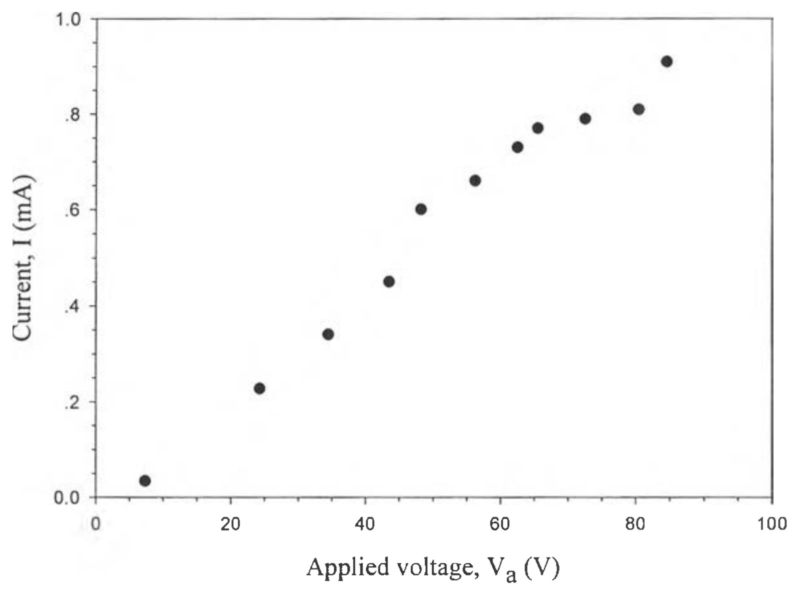


Figure G.1 Ohmic law region of the current and the applied voltage by using the silicon wafer Si 10-28A as a standard sheet.

Table G.1 Raw data of determination of linear regime of Silicon Wafer:
Si 10-28A

Applied voltage (V)	Current (mA)
7.38	0.03
24.30	0.23
34.50	0.34
43.50	0.45
48.20	0.60
56.20	0.66
62.50	0.73
65.50	0.77
72.50	0.79
80.40	0.81
84.50	0.91
89.30	1.08

From the Figure G.1, the voltage using for determination of geometric correction factor (K) of the probes should be in the range of 0-45 V.

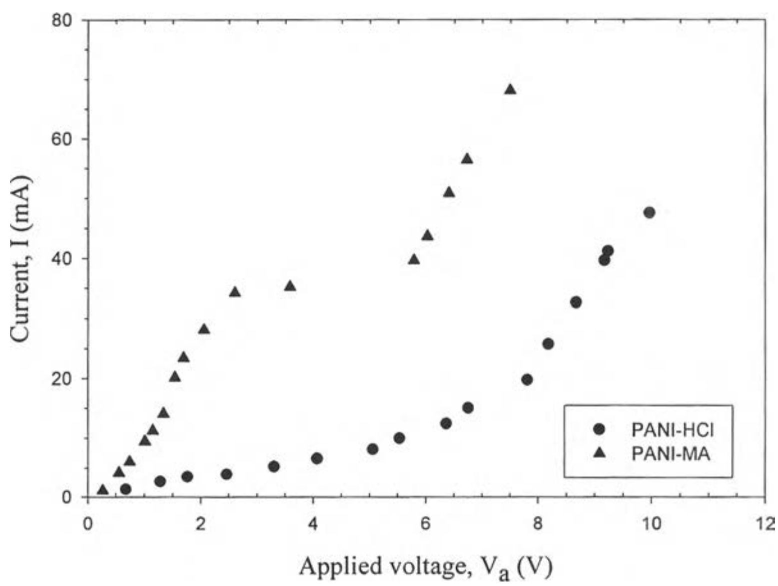


Figure G.2 Ohmic law region of the current and the applied voltage by using PANI-MA and PANI-HCl at doping ratio of $N_A/N_{EB} = 10$.

From the Figure G.2, the voltage that could be used in the experiments should be in the range of 0-2.5 V.

Table G.2 Raw data of determination of linear regime of polyaniline

PANI-MA

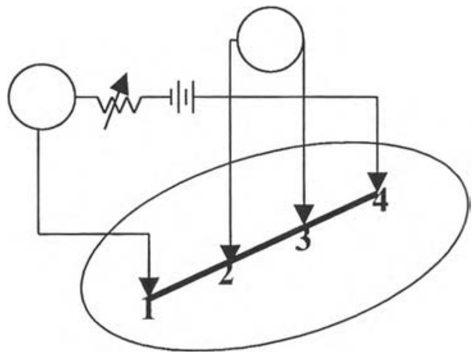
Applied voltage, V (mV)	Current, I (mA)
0.26	1.05
0.55	4.16
0.74	6.03
1.01	9.44
1.15	11.23
1.34	14.08
1.54	20.10
1.69	23.40
2.05	28.10
2.60	34.20
3.58	35.20
5.78	39.60
6.02	43.60
6.40	50.80
6.72	56.40
7.49	68.10

PANI-HCl

Applied voltage, V (mV)	Current, I (mA)
0.67	1.30
1.28	2.62
1.76	3.44
2.46	3.89
3.30	5.21
4.07	6.55
5.06	8.08
5.53	9.96
6.36	12.38
6.75	15.00
7.81	19.72
8.18	25.70
8.67	32.60
9.17	39.60
9.23	41.10
9.96	47.50

Appendix H Determination of geometric correction factor (K)

A four-point probe meter commonly measured the electrical conductivity of polyaniline thin film. Probe head assemblies are available in two different arrangements of the probe pins: the linear array and the square array. For the linear array, a constant current (I) was applied to the two outer electrodes and the sample voltage (V) was measured between the two inner electrodes as shown in Scheme H.1.



Scheme H.1 Linear array four-point probe meter

As in the case of microelectronic structures, four point probe sheet resistance measurements are susceptible to geometric error, we needed to determine the geometric correction factor K which can be determine by using Equation H.1.

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

where	K	=	geometric correction factor
	w	=	probe width (cm)
	l	=	probe length (cm).

In this measurement, the constant K value was determined by using a standard sheet with a known resistivity value; we used silicon wafer chips (SiO). K was calculated by using Equation H.2.

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

where K = geometric correction factor

ρ = resistivity of stand materials which were calibrated from using a four point probe at King Mongkut's Institute Technology of Lad Krabang (Ω.cm)

t = film thickness (cm)

R = film resistance (Ω)

I = current (A)

V = Voltage drop (V).

The sheet resistivity (ρ) and thickness of silicon wafer chips are shown in Table H.1.

Table H.1 Sheet resistivity and thickness of standard sheet (SiO)

Material	Sheet Resistivity, ρ, (Ω.cm)	Thickness (cm)	K value
Si 0.8-3.5 A	1.54E+00	5.36E-02	4.22E-01
K-TAY	1.43E-02	7.24E-02	3.04E+00
Si 10-28A	4.59E+01	5.35E-02	3.55E+00
		Average	3.62E+00

Table H.2 Determination of K factor of the constructed four point probe meter

Condition:

Temperature	26-28°C
Relative humidity	46-47%
Press	1 atm

Standard	I (mA)	V (mV)	K	Standard	I (mA)	V (mV)	K
Si 0.8-3.5 A	6.27	40.90	4.40E+00	K-TAY	24.4	1.6	3.00E+00
	13.26	83.20	4.58E+00		31.5	2.1	2.96E+00
	25.70	162.60	4.54E+00		32.4	2.1	3.04E+00
	30.70	202.00	4.36E+00		36.5	2.3	3.13E+00
	35.60	235.00	4.35E+00				
	Average		4.22E-01		Average		3.04E+00
	SD		1.05E-01		SD		7.22E-02

Standard	I (mA)	V (mV)	K	Standard	I (mA)	V (mV)	K
Si 10-28A	0.17	44.30	3.29E+00	Si 10-28A	0.364	97.7	3.20E+00
	0.239	56.10	3.66E+00		0.369	99	3.20E+00
	0.311	70.10	3.81E+00		0.38	101	3.23E+00
	0.39	87.50	3.80E+00		0.368	101.1	3.12E+00
	0.50	97.90	4.34E+00		0.44	116.5	3.24E+00
	Average		3.88E+00		Average		3.20E+00
	SD		3.76E-01		SD		4.56E-02
					K value		3.55E+00

Appendix I Conductivity measurements

Specific conductivity values of polyaniline pellets and polyaniline/zeolite pellets were measured by using the four-point probe under the atmospheric pressure, at 65-69 % relative humidity and at 27-28°C. The K value of the probe was 3.62 from Appendix H. A thickness gauge was used to measure the thickness of pellets. The data of conductivity measurement are shown in Table I.1, Table I.2 and Table I.3, respectively as follow Equation I.1

$$\sigma = \frac{I}{K \times V \times t} \qquad (I.1)$$

where σ = specific conductivity (S/cm.)

I = current (A)

K = geometric correction factor

V = voltage drop (V)

t = pellet thickness (cm).

Table I.1 Raw data of conductivity measurement of PANI-HCl in air

HCl-doped PANI		Supplied Voltage (V)		Current (mA)		Voltage drop (mV)		σ (S/cm)	
N_A/N_{EB}	Thickness (cm)	1	2	1	2	1	2	1	2
0.2	(1) 0.01559	13.5	13.4	2.00E-04	3.00E-04	304	569	1.17E-05	9.48E-06
	(2) 0.01536	24.4	20.1	4.00E-04	4.00E-04	622	781	1.14E-05	9.21E-06
		40.0	27.3	7.00E-04	6.00E-04	1026	1130	1.21E-05	9.55E-06
		45.4	36.0	8.00E-04	8.00E-04	1178	1431	1.20E-05	1.01E-05
		51.7	45.2	9.00E-04	1.00E-03	1409	1859	1.13E-05	9.67E-06
		35.1	28.4	6.00E-04	6.20E-04	9080	1150	1.17E-05	9.59E-06
0.5	(1) 0.01287	6.6	8.9	1.23E-02	1.33E-02	876	777	3.01E-04	3.72E-04
	(2) 0.01270	8.5	10.4	1.60E-02	1.57E-02	1142	915	3.01E-04	3.73E-04
		14.4	12.3	2.84E-02	1.91E-02	1975	1112	3.09E-04	3.74E-04
		17.0	14.8	3.37E-02	2.34E-02	2345	1359	3.08E-04	3.75E-04
		19.8	17.1	4.06E-02	2.74E-02	2815	1585	3.10E-04	3.76E-04
		11.2	14.7	2.07E-02	2.33E-02	1290	1410	3.43E-04	3.56E-04
1.0	(1) 0.01521	9.4	5.9	2.87	2.59	770	1046	6.77E-02	5.83E-02
	(2) 0.01173	11.6	7.4	3.53	3.32	942	1334	6.81E-02	5.86E-02
		13.3	9.6	3.58	4.31	960	1726	6.77E-02	5.88E-02
		16.9	13.1	4.49	5.68	1188	2195	6.86E-02	6.09E-02
		21.1	14.9	5.88	6.12	1564	2365	6.83E-02	6.09E-02
		10.8	53.5	2.76	1.63	1240	912	4.04E-02	4.19E-02

HCl-doped PANI		Supplied Voltagc (V)		Current (mA)		Voltage drop (mV)		σ (S/cm)	
N_A/N_{EB}	Thickness (cm)	1	2	1	2	1	2	1	2
2.0	(1) 0.01277	2.91	1.841	9.85	7.82	69.00	60	3.09E+00	2.94E+00
	(2) 0.01224	3.31	2.31	11.55	10.1	86.00	75	2.91E+00	3.04E+00
		3.56	2.8	13.94	13.39	102.00	98	2.96E+00	3.08E+00
		3.55	2.77	17.20	16.2	127.00	117	2.93E+00	3.12E+00
		3.77	3.13	20.10	22.7	147.00	163	2.96E+00	3.14E+00
		3.55	3.28	7.77	9.58	8.18E+01	96.7	2.05E+00	2.23E+00
4.0	(1) 0.0127	1.95	0.43	7.75	5.82	48	33	3.51E+00	3.70E+00
	(2) 0.01316	2.41	0.54	8.25	6.17	50	35	3.59E+00	3.70E+00
		3.10	1.00	9.5	6.87	57	38	3.63E+00	3.79E+00
		3.51	1.50	12.04	8.71	72	47	3.64E+00	3.89E+00
		3.86	2.50	14.45	10.22	85	54	3.70E+00	3.97E+00
		3.10	0.93	10.0	10.5	83.7	38	2.60E+00	3.32E+00
5.0	(1) 0.01335	1.48	1.28	6.27	7.60	36	48	3.60E+00	3.17E+00
	(2) 0.01381	2.61	1.59	8.70	8.88	47	54	3.83E+00	3.29E+00
		3.26	1.93	11.42	10.14	61	62	3.87E+00	3.27E+00
		3.47	2.66	12.02	13.15	64	79	3.89E+00	3.33E+00
		3.76	3.56	13.34	18.80	70	110	3.94E+00	3.42E+00
		3.26	1.93	11.42	10.14	61	62	3.19E+00	2.54E+00

HCl-doped PANI		Supplied Voltage (V)		Current (mA)		Voltage drop (mV)		σ (S/cm)	
N_A/N_{EB}	Thickness (cm)	1	2	1	2	1	2	1	2
10.0	(1) 0.01362	0.68	0.62	10.47	11.64	53	61	4.01E+00	3.80E+00
	(2) 0.01388	0.79	0.76	11.22	13.70	57	72	3.99E+00	3.79E+00
		1.08	0.93	12.60	16.41	63	84	4.06E+00	3.89E+00
		1.53	1.13	14.50	18.20	73	93	4.03E+00	3.89E+00
		1.44	1.10	16.20	20.30	79	105	4.16E+00	3.85E+00
		1.08	1.13	12.6	16.41	63	84	3.01E+00	2.75E+00
20.0	(1) 0.01288	0.62	0.53	12.50	11.9	63	55	4.26E+00	4.68E+00
	(2) 0.01278	0.73	0.62	14.45	13.7	72	64	4.30E+00	4.63E+00
		0.96	0.80	18.59	17.2	91	78	4.38E+00	4.76E+00
		0.91	0.93	20.50	19.4	100	87	4.40E+00	4.82E+00
		1.10	0.85	24.60	21.3	120	96	4.40E+00	4.80E+00
		0.96	0.80	18.59	17.2	91	78	3.22E+00	3.42E+00

Table I.2 Raw data of conductivity measurement of PANI-MA in air

HCl-doped PANI		Supplied Voltage (V)		Current (mA)		Voltage drop (mV)		(S/cm)	
N_A/N_{EB}	Thickness (cm)	1	2	1	2	1	2	1	2
0.2	(1) 1.41E-02	77.9	95.9	4.00E-04	4.00E-04	1078	1068	7.25E-06	7.47E-06
	(2) 1.39E-02	112.2	136.0	6.00E-04	6.00E-04	1569	1558	7.47E-06	7.68E-06
		145.6	181.5	8.00E-04	8.00E-04	2035	2095	7.68E-06	7.62E-06
		160.9	174.0	9.00E-04	9.00E-04	2245	2325	7.83E-06	7.72E-06
		185.0	194.0	1.00E-03	1.00E-03	2615	2585	7.47E-06	7.72E-06
		145	181.5	8.00E-04	8.00E-04	2035	2095	7.59E-06	7.73E-06
0.5	(1) 1.51E-02	58.3	23.3	2.06E-02	7.00E-03	5875	2085	6.42E-05	6.19E-05
	(2) 1.50E-02	62.2	29.8	2.21E-02	9.00E-03	6315	2735	6.41E-05	6.06E-05
		65.8	36.0	2.34E-02	1.08E-02	6705	3355	6.39E-05	5.93E-05
		69.1	39.3	2.45E-02	1.20E-02	7035	3755	6.38E-05	5.89E-05
		71.1	44.3	2.55E-02	1.37E-02	7325	4315	6.38E-05	5.85E-05
		65.8	36.0	2.34E-02	1.08E-02	6705	3355	6.39E-05	5.91E-05
1.0	(1) 1.19E-02	4.89	4.29	0.69	0.67	421	361	3.79E-02	3.85E-02
	(2) 1.34E-02	6.29	6.79	0.99	1.31	613	689	3.73E-02	3.92E-02
		7.01	10.73	1.21	2.31	737	1214	3.81E-02	3.93E-02
		9.24	11.61	1.64	2.60	998	1365	3.81E-02	3.94E-02
		16.07	15.57	3.34	3.67	1962	1918	3.94E-02	3.96E-02
		7.01	10.73	1.21	2.31	737	1214	3.86E-02	3.96E-02

HCl-doped PANI		Supplied Voltage (V)		Current (mA)		Voltage drop (mV)		σ (S/cm)	
N_A/N_{EB}	Thickness (cm)	1	2	1	2	1	2	1	2
2.0	(1) 1.21E-02	10.06	5.66	10.72	4.36	291	205	8.41E-01	4.65E-01
	(2) 1.26E-02	11.85	7.17	14.03	6.65	375	310	8.54E-01	4.69E-01
		13.09	8.90	16.63	9.30	443	431	8.57E-01	4.72E-01
		15.3	12.61	21.10	15.87	560	735	8.60E-01	4.72E-01
		16.71	14.18	24.20	19.36	636	898	8.69E-01	4.72E-01
		13.09	8.90	16.63	9.30	443	431	8.61E-01	4.68E-01
4.0	(1) 1.18E-02	6.16	14.87	11.4	22.4	191	415	1.40E+00	1.37E+00
	(2) 1.09E-02	12.86	15.45	26.2	23.9	440	442	1.40E+00	1.37E+00
		13.58	16.74	30.5	27.0	516	494	1.39E+00	1.39E+00
		13.85	19.08	34.4	34.1	580	625	1.39E+00	1.39E+00
		15.09	19.51	37.5	36.5	631	666	1.39E+00	1.39E+00
		13.58	16.74	30.5	27.0	516	494	1.40E+00	1.39E+00
5.0	(1) 1.02E-02	2.10	1.99	29.4	28.2	185	188	4.32E+00	4.47E+00
	(2) 9.28E-03	2.30	2.3	34.1	32.4	213	215	4.35E+00	4.49E+00
		2.49	2.48	37.9	34.8	238	231	4.33E+00	4.48E+00
		2.60	-	40.7	-	254	-	4.35E+00	-
		2.77	-	44.6	-	278	-	4.36E+00	-
		2.49	2.48	37.9	34.8	238	231	4.34E+00	4.48E+00

HCl-doped PANI		Supplied Voltage (V)		Current (mA)		Voltage drop (mV)		σ (S/cm)	
N_A/N_{EB}	Thickness (cm)	1	2	1	2	1	2	1	2
10.0	(1) 9.52E-03	1.39	2.9	5.95	21.0	45	133	3.84E+00	4.26E+00
	(2) 1.02E-02	1.56	4.0	8.16	26.0	61	164	3.88E+00	4.28E+00
		1.67	5.9	9.36	34.1	68	215	3.99E+00	4.28E+00
		1.91	6.7	11.62	36.7	84	228	4.01E+00	4.35E+00
		2.23	7.3	13.52	39.7	97	247	4.04E+00	4.34E+00
		1.67	5.9	9.36	34.1	68	215	4.00E+00	4.32E+00
20.0	(1) 1.01E-02	0.36	0.446	3.93	4.51	23.1	26.2	4.64E+00	4.43E+00
	(2) 1.07E-02	0.47	0.716	5.30	7.92	31.0	46.1	4.67E+00	4.43E+00
		0.61	0.997	7.10	11.59	41.6	67.5	4.66E+00	4.42E+00
		1.00	1.396	12.99	20.70	76.5	121.9	4.63E+00	4.37E+00
		1.35	1.566	18.73	24.50	110.3	144	4.63E+00	4.38E+00
		0.61	0.997	7.10	11.59	41.6	67.5	4.63E+00	4.40E+00

Table I.3 Raw data of conductivity measurement of polyaniline/zeolite 4A composite in air

%Zeolite (w/w)	Composition		Thickness (cm)	Supplied Voltage (V)	Current (mA)	Voltage drop (mV)	σ (S/cm)
	PANI-10MA (g)	Zeolite 4A (g)					
0.00	0.0750	0 (1)	9.52E-03	1.98E+00	1.16E+01	8.36E+01	4.00E+00
		0 (2)	1.02E-02	6.24E+00	3.67E+01	2.29E+02	4.32E+00
		0 (3)	1.04E-02	2.49E+00	4.55E+01	2.72E+02	4.45E+00
1.00	0.0693	0.00075(1)	1.08E-02	5.00E+00	1.70E-02	1.02E-02	4.16E+00
		0.00075(2)	1.24E-02	6.50E+00	2.23E-02	9.77E-02	5.23E+00
5.00	0.0663	0.00375(1)	1.18E-02	5.00E+00	1.57E-02	1.12E-02	3.42E+00
		0.00375(2)	1.13E-02	5.10E+00	1.61E-02	9.77E-02	3.97E+00
10.00	0.0625	0.0075 (1)	1.17E-02	5.00E+00	1.58E-02	9.28E-02	4.03E+00
		0.0075 (2)	1.17E-02	5.00E+00	1.70E-02	1.17E-01	3.27E+00
		0.0075 (3)	1.26E-02	6.50E+00	1.72E-02	1.22E-02	3.14E+00
20.00	0.0550	0.015 (1)	1.13E-02	5.00E+00	1.48E-02	2.05E-01	1.71E+00
		0.015 (2)	1.10E-02	5.00E+00	1.28E-02	1.42E-01	2.16E+00

%Zeolite (w/w)	Composition		Thickness (cm)	Supplied Voltage (V)	Current (mA)	Voltage drop (mV)	σ (S/cm)
	PANI-10MA (g)	Zeolite 4A (g)					
30.00	0.7275	0.0225 (1)	1.30E-02	1.36E+01	6.82E-03	1.11E-01	1.27E+00
		0.0225 (2)	1.30E-02	1.74E+01	9.80E-03	1.66E-01	1.23E+00
40.00	0.7200	0.0300 (1)	1.30E-02	1.49E+01	4.92E-03	1.50E-01	6.83E-01
		0.0300 (2)	1.30E-02	2.16E+01	1.68E-03	5.10E-02	6.61E-01
		0.0300 (3)	1.30E-02	4.20E+00	8.50E-03	2.75E-01	6.50E-01
50.00	0.7125	0.0375 (1)	1.30E-02	1.56E+01	3.18E-03	1.40E-01	4.73E-01
		0.0375 (2)	1.30E-02	1.59E+01	3.11E-03	1.59E-01	4.08E-01

Appendix J Sensitivity measurement ($\Delta\sigma$)

Sensitivity measurements of polyaniline and polyaniline-10MA/zeolite pellets were carried by using the four point probe at various CO/N_2 concentrations under the pressure guage of 1 atm, 65-69% relative humidity and 26-28°C. The thickness of pellets was measured by a thickness gauge. Sensitivity ($\Delta\sigma$) was calculated by the following Equation:

$$\Delta\sigma = \sigma_{CO} - \sigma_{Final\ N2} \quad (J.1)$$

where; $\Delta\sigma$ = Sensitivity (S/cm)

σ_{CO} = Specific conductivity in CO (S/cm)

$\sigma_{Final\ N2}$ = Specific conductivity in nitrogen after the lowest CO concentration exposure (S/cm).

The data of sensitivity measurement of acid-doped polyaniline are shown in the Table J.1 - Table J.4. The data of sensitivity measurement of polyaniline/zeolite A composites are shown in the Table J.5 - Table J.9.

Table J.1 Sensitivity measurement data of HCl-doped polyaniline at N_A/N_{EB} = 1.0

SAMPLE NAME	: PANI-1.0HCl, #1	INITIAL σ_{air} (S/cm)	: 3.70E+00
THICKNESS (cm)	: 0.01521	INITIAL σ_{N2} (S/cm)	: 2.98E+00
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	: 2.62E+00
$V_{applied}$ (V)	: 19		

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{co} - \sigma_{N2final}$
1000.00	2.98E+00	3.23E+00	6.06E-01
500.00	2.98E+00	3.06E+00	4.39E-01
250.00	2.88E+00	2.92E+00	2.96E-01
125.00	2.81E+00	2.87E+00	2.48E-01
62.50	2.78E+00	2.83E+00	2.10E-01
31.25	2.73E+00	2.79E+00	1.61E-01
15.63	2.73E+00	2.74E+00	1.13E-01
7.81	2.68E+00	2.72E+00	9.60E-02

SAMPLE NAME	: PANI-1.0HCl, #3	INITIAL $_{air}$ (S/cm)	: 4.33E+00
THICKNESS (cm)	: 0.01483	INITIAL $_{N2}$ (S/cm)	: 3.30E+00
K-PROBE	: 2.941	FINAL (S/cm)	: 2.70E+00
$V_{applied}$ (V)	: 15.6		

CO conc.(ppm)	$_{vac}$	$_{co}$	$_{co} - _{N2final}$
1000.00	3.30E+00	3.59E+00	8.90E-01
500.00	3.30E+00	3.35E+00	6.50E-01
250.00	3.10E+00	3.11E+00	4.14E-01
125.00	2.92E+00	2.95E+00	2.50E-01
62.50	2.86E+00	2.84E+00	1.38E-01
31.25	2.84E+00	2.87E+00	1.70E-01
15.63	2.81E+00	2.83E+00	1.34E-01
7.81	2.75E+00	2.76E+00	5.80E-02

SAMPLE NAME : PANI-1.0HCl, #6
THICKNESS (cm) : 0.01483
K-PROBE : 3.62
$V_{applied}$ (V) : 19.8

INITIAL σ_{air} (S/cm) : 4.36E-02
INITIAL σ_{N2} (S/cm) : 3.19E-02
FINAL σ_{N2} (S/cm) : 2.75E-02

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	3.02E-02	3.12E-02	3.70E-03
500.00	2.89E-02	2.91E-02	1.60E-03
250.00	2.86E-02	3.05E-02	3.00E-03
125.00	2.88E-02	3.02E-02	2.70E-03
62.50	2.87E-02	2.95E-02	2.00E-03
31.25	2.85E-02	2.87E-02	1.20E-03
15.63	2.82E-02	2.85E-02	1.00E-03
7.81	2.77E-02	2.79E-02	4.00E-04

Table J.2 Sensitivity measurement data of HCl-doped polyaniline at $N_A/N_{EB} = 10.0$

SAMPLE NAME : PANI-10.0HCl, #1
THICKNESS (cm) : 0.01316
K-PROBE : 3.62
Vapplied (V) : 5

INITIAL σ_{air} (S/cm) : 1.45E+00
INITIAL σ_{N2} (S/cm) : 8.70E-01
FINAL σ_{N2} (S/cm) : 6.20E-01

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	7.58E-01	8.21E-01	2.01E-01
500.00	7.43E-01	8.09E-01	1.89E-01
250.00	7.25E-01	7.53E-01	1.33E-01
125.00	6.88E-01	7.12E-01	9.20E-02
62.50	6.60E-01	6.73E-01	5.30E-02
31.25	6.43E-01	6.56E-01	3.60E-02
15.63	6.27E-01	6.33E-01	1.30E-02
7.81	6.20E-01	6.24E-01	4.00E-03

SAMPLE NAME : PANI-10.0HCl, #2
THICKNESS (cm) : 0.01388
K-PROBE : 2.941
Vapplied (V) : 6

INITIAL σ_{air} (S/cm) : 3.20E+00
INITIAL σ_{N2} (S/cm) : 1.93E+00
FINAL σ_{N2} (S/cm) : 1.61E+00

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.82E+00	2.11E+00	4.98E-01
500.00	1.77E+00	2.17E+00	5.62E-01
250.00	1.81E+00	2.05E+00	4.34E-01
125.00	1.63E+00	1.87E+00	2.56E-01
62.50	1.64E+00	1.76E+00	1.50E-01
31.25	1.56E+00	1.70E+00	8.70E-02
15.63	1.57E+00	1.67E+00	6.00E-02
7.81	1.56E+00	1.64E+00	3.00E-02

SAMPLE NAME : PANI-10.0HCl, #5
THICKNESS (cm) : 0.01239
K-PROBE : 3.62
Vapplied (V) : 7

INITIAL σ_{air} (S/cm) : 2.65E+00
INITIAL σ_{N2} (S/cm) : 1.52E+00
FINAL σ_{N2} (S/cm) : 1.41E+00

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.70E+00	1.98E+00	5.73E-01
500.00	1.69E+00	1.96E+00	5.55E-01
250.00	1.66E+00	1.87E+00	4.60E-01
125.00	1.60E+00	1.70E+00	2.92E-01
62.50	1.54E+00	1.58E+00	1.74E-01
31.25	1.35E+00	1.49E+00	8.20E-02
15.63	1.36E+00	1.47E+00	5.80E-02
7.81	1.38E+00	1.43E+00	1.90E-02

Table J.3 Sensitivity measurement data of MA-doped polyaniline at $N_A/N_{EB} = 1.0$

SAMPLE NAME : PANI-1.0MA, #1

THICKNESS (cm) : 0.0123

K-PROBE : 3.62

Vapplied (V) : 20.3

INITIAL σ_{air} (S/cm) : 1.77E-02

INITIAL σ_{N2} (S/cm) : 5.85E-03

FINAL σ_{N2} (S/cm) : 4.34E-03

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{co} - \sigma_{N2final}$
1000.00	8.28E-03	9.65E-03	5.31E-03
500.00	6.34E-03	7.45E-03	3.11E-03
250.00	5.56E-03	6.37E-03	2.03E-03
125.00	4.71E-03	6.02E-03	1.68E-03
62.50	4.76E-03	5.23E-03	8.90E-04
31.25	4.58E-03	4.90E-03	5.60E-04
15.63	4.36E-03	4.67E-03	3.30E-04
7.81	4.39E-03	4.45E-03	1.10E-04

SAMPLE NAME : PANI-1.0MA, #2

THICKNESS (cm) : 0.0136

K-PROBE : 3.62

Vapplied (V) : 16

INITIAL σ_{air} (S/cm) : 6.42E-02

INITIAL σ_{N2} (S/cm) : 1.82E-02

FINAL σ_{N2} (S/cm) : 1.47E-02

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{co} - \sigma_{N2final}$
1000.00	1.60E-02	1.92E-02	4.55E-03
500.00	1.58E-02	1.86E-02	3.95E-03
250.00	1.59E-02	1.72E-02	2.55E-03
125.00	1.51E-02	1.71E-02	2.45E-03
62.50	1.52E-02	1.59E-02	1.25E-03
31.25	1.49E-02	1.57E-02	1.05E-03
15.63	1.50E-02	1.55E-02	8.50E-04
7.81	1.46E-02	1.53E-02	6.50E-04

SAMPLE NAME : PANI-1.0MA, #3

THICKNESS (cm) : 0.01326

K-PROBE : 3.62

Vapplied (V) : 13.7

INITIAL σ_{air} (S/cm) : 5.01E-02

INITIAL σ_{N2} (S/cm) : 2.07E-02

FINAL σ_{N2} (S/cm) : 1.86E-02

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	2.69E-02	3.47E-02	1.61E-02
500.00	2.88E-02	3.33E-02	1.47E-02
250.00	2.91E-02	3.48E-02	1.62E-02
125.00	2.49E-02	3.05E-02	1.19E-02
62.50	2.34E-02	2.88E-02	1.02E-02
31.25	2.31E-02	2.50E-02	6.45E-03
15.63	2.26E-02	2.36E-02	4.97E-03
7.81	2.05E-02	2.17E-02	3.07E-03

Table J.4 Sensitivity measurement data of MA-doped polyaniline at $N_A/N_{EB} = 10.0$

SAMPLE NAME : PANI-10.0MA, #1

THICKNESS (cm) : 0.00952

K-PROBE : 3.62

Vapplied (V) : 7.2

INITIAL σ_{air} (S/cm) : 3.33E+00

INITIAL σ_{N2} (S/cm) : 2.27E+00

FINAL σ_{N2} (S/cm) : 1.77E+00

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	2.043	2.095	3.25E-01
500.00	2.043	2.067	2.97E-01
250.00	1.917	2.035	2.65E-01
125.00	1.906	1.987	2.17E-01
62.50	1.897	1.975	2.05E-01
31.25	1.875	1.942	1.72E-01
15.63	1.855	1.898	1.28E-01
7.81	1.818	1.854	8.40E-02

SAMPLE NAME : PANI-10.0MA, #2
THICKNESS (cm) : 0.01023
K-PROBE : 3.62
Vapplied (V) : 15

INITIAL σ_{air} (S/cm) : 3.10E+00
INITIAL σ_{N2} (S/cm) : 2.85E+00
FINAL σ_{N2} (S/cm) : 2.16E+00

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	2.48	2.57	4.10E-01
500.00	2.35	2.54	3.80E-01
250.00	2.35	2.46	3.00E-01
125.00	2.35	2.41	2.50E-01
62.50	2.29	2.38	2.20E-01
31.25	2.20	2.30	1.40E-01
15.63	2.16	2.24	8.00E-02
7.81	-	-	-

SAMPLE NAME : PANI-10.0MA, #4
THICKNESS (cm) : 0.00952
K-PROBE : 3.62
Vapplied (V) : 5

INITIAL σ_{air} (S/cm) : 4.20E+00
INITIAL σ_{N2} (S/cm) : 4.00E+00
FINAL σ_{N2} (S/cm) : 2.79E+00

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	3.220	3.470	6.80E-01
500.00	3.150	3.320	5.30E-01
250.00	3.060	3.100	3.10E-01
125.00	2.970	3.080	2.90E-01
62.50	2.750	3.000	2.10E-01
31.25	2.830	2.940	1.50E-01
15.63	2.850	2.870	8.00E-02
7.81	2.790	2.800	1.00E-02

Table J.5 Sensitivity measurement data of PANI-10MA/10Zeolite 4A

SAMPLE NAME	: 10%Zeolite4A-10MA, #3	INITIAL σ_{air} (S/cm)	: 1.64E+00
THICKNESS (cm)	: 0.0125	PREEXPOSE σ_{N2} (S/cm)	: 1.53E+00
K-PROBE	: 2.941	FINAL σ_{N2} (S/cm)	: 1.20E+00
Vapplied (V)	: 7.7	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.278	1.503	3.07E-01
500.00	0.984	1.036	-1.60E-01
250.00	1.193	1.574	3.78E-01
125.00	1.537	1.539	3.43E-01
62.50	1.220	1.381	1.85E-01
31.25	1.264	1.374	1.78E-01
15.63	1.196	1.557	3.61E-01

SAMPLE NAME	: 10%Zeolite4A-10MA#5	INITIAL σ_{air} (S/cm)	: 2.06E+00
THICKNESS (cm)	: 0.01	PREEXPOSE σ_{N2} (S/cm)	: 1.80E+00
K-PROBE	: 3.26	FINAL σ_{N2} (S/cm)	: 1.05E+00
Vapplied (V)	: 1	%INITIAL MOISTURE	: 27

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.686	1.594	5.45E-01
500.00	1.541	1.467	4.18E-01
250.00	1.358	1.359	3.10E-01
125.00	1.290	1.247	1.98E-01
62.50	1.231	1.212	1.63E-01
31.25	1.154	1.206	1.57E-01
15.63	1.102	1.151	1.02E-01
7.86	1.089	1.119	7.00E-02

SAMPLE NAME	: 10%Zeolite4A-10MA, #6	INITIAL σ_{air} (S/cm)	: 2.05E+00
THICKNESS (cm)	: 0.01	PREEXPOSE σ_{N2}(S/cm)	: 2.00E+00
K-PROBE	: 2.941	FINAL σ_{N2} (S/cm)	: 5.92E-01
Vapplied (V)	: 10	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	-	-	-5.92E-01
500.00	-	-	-5.92E-01
250.00	-	-	-5.92E-01
125.00	0.673	0.864	2.72E-01
62.50	0.722	0.858	2.66E-01
31.25	0.720	0.839	2.47E-01
15.63	0.718	0.814	2.22E-01
7.86	0.668	0.755	1.63E-01

Table J.6 Sensitivity measurement data of PANI-10MA/20Zeolite 4A

SAMPLE NAME	: 20%Zeolite4A-10MA, #5	INITIAL σ_{air} (S/cm)	: 1.90E+00
THICKNESS (cm)	: 0.0111	PREEXPOSE σ_{N2}(S/cm)	: 1.60E+00
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	: 1.23E+00
$V_{applied}$ (V)	: 10	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	s_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.413	1.495	2.66E-01
500.00	1.379	1.425	1.96E-01
250.00	1.332	1.376	1.47E-01
125.00	1.293	1.347	1.18E-01
62.50	1.256	1.307	7.80E-02
31.25	1.244	1.290	6.10E-02
15.63	1.227	1.262	3.30E-02

SAMPLE NAME	: 20%Zeolite4A-10MA, #6	INITIAL σ_{air} (S/cm)	: 6.89E-01
THICKNESS (cm)	: 0.1	PREEXPOSE σ_{N2} (S/cm)	: 6.20E-01
K-PROBE	: 2.941	FINAL σ_{N2} (S/cm)	: 6.00E-01
Vapplied (V)	: 10	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	s_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	0.45	0.60	4.79E-01
500.00	0.34	0.50	3.75E-01
250.00	0.31	0.39	2.68E-01
125.00	0.23	0.31	1.88E-01
62.50	0.12	0.14	1.50E-02
31.25	0.11	0.13	4.00E-03

Table J.7 Sensitivity measurement data of PANI-10MA/40Zeolite 4A

SAMPLE NAME	: 40%Zeolite4A-10MA, #1	INITIAL σ_{air} (S/cm)	: 3.37E-01
THICKNESS (cm)	: 0.013	PREEXPOSE σ_{N2} (S/cm)	: 1.55E-01
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	: 1.06E-01
Vapplied (V)	: 8	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{co} - \sigma_{N2final}$
1000.00	0.112	0.138	3.20E-02
500.00	0.101	0.146	4.00E-02
250.00	0.111	0.118	1.20E-02
125.00	0.102	0.127	2.10E-02
62.50	0.107	0.124	1.80E-02
31.25	0.103	0.112	6.00E-03
15.63	0.104	0.116	1.00E-02

SAMPLE NAME	: 40%Zeolite4A-10MA, #5	INITIAL σ_{air} (S/cm)	: 5.05E-01
THICKNESS (cm)	: 0.01196	PREEXPOSE σ_{N2}(S/cm)	: 3.22E-01
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	: 2.05E-01
Vapplied (V)	: 8	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	0.264	0.336	1.31E-01
500.00	0.262	0.317	1.12E-01
250.00	0.243	0.288	8.30E-02
125.00	0.232	0.272	6.70E-02
62.50	0.226	0.256	5.10E-02
31.25	0.226	0.250	4.50E-02
15.63	0.206	0.225	2.00E-02
7.81	0.205	0.238	3.30E-02

Table J.8 Sensitivity measurement data of PANI-10MA/20Zeolite 3A

SAMPLE NAME	: 20%Zeolite3A-10MA, #1	INITIAL σ_{air} (S/cm)	: 1.82E+00
THICKNESS (cm)	: 0.012	PREEXPOSE σ_{N2}(S/cm)	:1.64E+00
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	:1.39E+00
Vapplied (V)	: 8	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.521	1.584	1.94E-01
500.00	1.491	1.557	1.67E-01
250.00	1.469	1.555	1.65E-01
125.00	1.457	1.546	1.56E-01
62.50	1.454	1.513	1.23E-01
31.25	1.427	1.485	9.54E-02
15.63	1.416	1.450	6.00E-02

SAMPLE NAME	: 20%Zeolite3A-10MA, #3	INITIAL σ_{air} (S/cm)	: 2.59E+00
THICKNESS (cm)	: 0.0111	PREEXPOSE σ_{N2}(S/cm)	: 2.20E+00
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	: 2.05E+00
Vapplied (V)	: 10	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	2.2	2.28	2.30E-01
500.00	2.16	2.25	2.00E-01
250.00	2.16	2.23	1.80E-01
125.00	2.13	2.18	1.30E-01
62.50	2.10	2.16	1.10E-01
31.25	2.06	2.15	1.00E-01
15.63	2.03	2.07	2.00E-02

Table J.9 Sensitivity measurement data of PANI-10MA/20Zeolite 5A

SAMPLE NAME	: 20%Zeolite5A-10MA, #1	INITIAL σ_{air} (S/cm)	: 1.32E+00
THICKNESS (cm)	: 0.0112	PREEXPOSE σ_{N2}(S/cm)	: 7.89E-01
K-PROBE	: 3.62	FINAL σ_{N2} (S/cm)	: 5.32E-01
Vapplied (V)	: 8	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	0.779	1.005	4.73E-01
500.00	0.869	0.879	3.47E-01
250.00	0.752	0.816	2.84E-01
125.00	0.628	0.729	1.97E-01
62.50	0.680	0.758	2.26E-01
31.25	0.686	0.732	2.00E-01
15.63	0.579	0.650	1.18E-01

SAMPLE NAME	: 20%Zeolite5A-10MA, #2	INITIAL σ_{air} (S/cm)	: 1.71E+00
THICKNESS (cm)	: 0.01101	PREEXPOSE σ_{N2} (S/cm)	: 1.14E+00
K-PROBE	: 2.941	FINAL σ_{N2} (S/cm)	: 8.70E-01
Vapplied (V)	: 8	%INITIAL MOISTURE	: 4.75

CO conc.(ppm)	σ_{vac}	σ_{co}	$\Delta\sigma = \sigma_{CO} - \sigma_{N2final}$
1000.00	1.254	1.328	4.58E-01
500.00	1.080	1.148	2.78E-01
250.00	1.288	1.086	2.16E-01
125.00	0.930	1.077	2.07E-01
62.50	0.929	0.999	1.29E-01
31.25	0.891	0.973	1.03E-01
15.63	0.929	1.012	1.42E-01

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