REFERENCES

Banka, E., Beadle, P.M., and Nicolau, Y.F. (1997). Spectrophotometric investigation of CSA-protonated polyaniline solution and films. Synthetic Metals, 84, 585-586.

Barisci, J.N., Conn, C., and Wallace, G.G. (1996). Conducing polymer sensors. Reviews, 4(9), 307-311.

Cassignol, C., Olivier, P., and Ricard, A. (1998). Influence of the dopant on the polypyrrole moisture content: effect on conductivity and thermal stability. Journal of Applied Polymer Science, 70, 1567-1577.

Chan, H.S., Ng, S.C., and Ho, P.H. (1994) Polyaniline doped with phosphoric acid: their preparation and characterization. Macromolecules, 27, 2159-2164.

Chen, S.A., and Fang, W.G. (1991). Electrically conductive polyanjiline – poly(vinyl alcohol) composite films: physical properties and morphological structures. Macromolecules, 24, 1242-1248.

Chen, S.A., and Lee, T.S. (1987). Fibrillar morphology of the electrochemically polymerized polyaniline in tetrafluoroboric acid aqueous solution. Journal of Polymer Science: Part C: Polymer Letters, 25, 455-460.

Chiou, W.H., and Kuo, C.T. (1997). Field-effect transistor with polyaniline thin film as semiconductor. Synthetic Metals, 88, 23-30.

Dalas, E., Vitoratos, E., and Sakkopoulos, S. (1998). Conductivity degradation due to thermal aging in conducting polyaniline and polypyrrole. Synthetic Metals, 92, 63-67.

Dhawan, S.K., Kumar, D., and Chandra, S. (1997) Application of conducting polyaniline as sensor material for ammonia. Sensors and Actuators B, 40, 99-103.

Epstein, A.J., and MacDiarmid, A.G. (1995). Secondary doping: a new concept in conducting polymers. Macromolecule Symposium, 98, 835-842.

Epstein, A.J., Bredas, J.L., and Huang, W.S. (1987). Polaron lattice in highly conducting polyaniline: theoretical and optical studies. Physical Review Letters, 59(13), 1464-1467.

Epstein, A.J., Ginder, J.M., and Glatkowiski, P.J. (1991). Thermal process for orientation of polyaniline films. Macromolecules, 24, 4157-4161.

Gospodinova, N., Terlemezyan, P., and Mokreva, P. (1993). On the mechanism of oxidative polymerization of aniline. Polymer, 34(11), 2434-2437.

Haang, W.S., Humphrey, B.D., and MacDiarmid, A.G. (1986). Polyaniline , a novel conducting polymer. Journal of Chemical Society Faraday Translation, 82, 2385-2400.

Kratochvil, P., Jenkins, A.D., and Stejskal, J. (1996). The formation of polyaniline and the nature of its structures. Polymer, 37(2), 367-369.

Lee, H., Kwanyoung, L., and Kim, H.J. (1996). Transport studies of emeraldine salts protonated by phosphoric acids. Synthetic Metals, 81, 75-80.

Leven, K., Zheng, W.Y., and Laakso, J. (1995). Thermal doping of polyaniline with dodecylbenzene sulfonic acid without auxiliary solvents. Polymer, 36 (14), 2733-2738.

Liangyan, S., Zhang, T., and Changzhi, G. (1996). The design and characteristics of a porphyrin LB-FET film gas sensor. Thin Solid Films, 284-285, 863-865.

MacDiarmid, A.G., Yaniger, S.T., and Chaiang, J.C. (1985). Polyaniline: Interconversion of metallic and insulating forms. Molecular Crystal and Liquid Crystal, 121, 173-180.

Monkman, A.P., Petty, M.C., and Cresswell, J.P. (1997). An optical gas sensor based on polyaniline langmuir-blodgeet films. Sensors and Actuators B, 37, 137-141.

Palanlappan, S., and Narayana, B.H. (1994) Temperature effect on conducting polyaniline salts. Journal of Polymer Science: Part A: Polymer Chemistry, 32, 2431-2436.

Park, J.K., and Moon, H.S. (1998). Structural effect of polymeric acid dopants on the characteristics of doped polyaniline composites. Journal of Polymer Science: Part A: Polymer Chemistry, 36, 1431-1436.

Partridge, A.C., Harris, P., and Andrews, M.K. (1996). High sensitivity conducting polymer sensor. Analyst, 121, 1349-1353.

Perrin, D.D., and Armareg, W.L.F. (1985). Purification of laboratory chemicals. 3rd ed. USA: Pergamon Press.

Petty, M.C. (1995). Gas sensing using thin organic films. Biosensors & Bioelectronics, 10, 129-134.

Petty, M.C., Barker, P.S., and Monkman, A.P. (1996). A hybride phthalocyanine/silicon field-effect transistor sensor for NO_2. Thin Solid Films, 284-285, 94-97.

Piletsky, S.A., Shirshov, Y.M., and Kukla, A.L. (1996). Ammonia sensors based on sensitive polyaniline films. Sensors and Actuators B, 37, 135-140.

Rasmussen, P.G., Hopkins, A.R., and Basheer, R.A. (1996). Characterization of solutionand solid state properties of undoped and doped polyaniline processed from hexafluoro-2-propanol. Macromolecules, 29, 7838-7846.

Tandon, R.P., Arora, V., and Singh, R. (1997). Transport and structural properties of polyaniline doped with monovalent and multivalent ions. Polymer, 33(15), 4897-4902.

Usawa, M., Shimizu, S., and Saitoh, T. (1997) Charge transport properties of fully-sulfonated polyaniline. Synthetic Metals, 84, 807-808.

Weiss, R.A., and Fu, Y. (1997). Protonation of polyaniline with lightly sulfonated polystyrene. Synthetic Metals, 84, 103-104.

Ziberman, M., Titelman, G.I., and Narkis, M. (1997). Conductive blends of thermally dodecylbenzene sulfonic acid doped polyaniline with thermoplastic polymers. Journal of Applied Polymer Science, 66, 243-253.

APPENDICES

APPENDIX A Caculation of Doping Level and Atom Mole Ratio from Elemental Analysis of the Doped Polyaniline

The doping levels of the doped polyaniline films at various ratios of Ca/Cp were determined by the determination of carbon (C), hydrogen (H), and nitrogen (N) atoms from elemental analysis. The amounts of oxygen (O) and chlorine (Cl) atoms in the doped film samples were calculated from Equation A1. The number of oxygen atoms in the doped films from water, NMP, and oxidant were determined from TGA measurement. The amounts of chlorine (Cl) atoms were calculated by subtract the number of oxygen atoms in the doped films from Equation A2. The number of nitrogen (N) atoms of the doped films was calculated by subtract the number of nitrogen atoms in NMP from Equation A3. The number of hydrogen atoms of the doped films was calculated from Equation A4.

$$(O+Cl) = 100 - \%C - \%H - \%N - \%S \quad (A1)$$

$$Cl = (O+Cl) - (\%O, H_2O) - (\%O, NMP) - (\%O, oxidant) \quad (A2)$$

$$N = \%N - (\%N, NMP) \quad (A3)$$

$$H = \%H - (\%H, H_2O) - (\%H, NMP) - (\%H, oxidant\ [HSO_4^-]) \quad (A4)$$

The number of chlorine and nitrogen atoms from the above calculation was used to determine the doping level of the doped films from Equation 2.2. The raw data of the doped films are shown in Table A-1.

Table A-1 The raw data from elemental analyzer and the doping level.

C_a/C_p	Sample No.	EA Data				Calculated Data			Doping Level
		% C	% H	% N	% S	% H	% N	% Cl	
0.73	1	72.13	6.12	14.67	0.72	5.04	15.91	2.41	5.97
	2	72.25	6.14	14.71	0.73	5.06	13.47	2.21	6.48
1.46	1	71.1	6.34	14.54	0.74	5.26	13.30	3.31	9.84
4	1	70.58	6.28	14.51	0.7	5.20	13.27	3.96	11.78
	2	70.41	6.46	14.61	0.75	5.38	13.37	3.83	11.31
7.3	1	69.22	6.25	14.37	0.74	5.17	13.13	5.45	16.41
	2	69.35	6.28	14.37	0.73	5.20	13.13	5.31	15.98
10.2	1	68.03	6.29	14.35	0.83	5.21	13.11	6.47	19.51
	2	68.16	6.42	14.23	0.77	5.34	12.99	6.43	19.57
14.6	1	66.54	6.35	13.91	0.71	5.27	12.67	8.54	26.64
	2	66.73	6.23	13.96	0.76	5.15	12.72	8.34	25.90
30	1	61.54	6.4	12.69	0.99	5.32	11.45	14.25	49.16
50	1	55.66	6.86	12.89	0.99	5.78	11.65	19.47	66.02
73	1	54.9	5.57	13.05	0.77	4.49	11.81	21.72	72.67
	2	55.56	6.37	13.13	0.91	5.29	11.89	19.95	66.30

The empirical formulas of the chemical structure of the doped polyaniline films were also determined from elemental analysis data. The mole ratio of carbon (C), hydrogen (H) and nitrogen (N) atoms of the doped films were calculated by the following:

1) Mole ratio of carbon (C), hydrogen (H) and nitrogen (N) were calculated by dividing weight ratio of each element with their molecular weight.

C	=	71.1/12.01	=	5.92 mole
H	=	5.26/1.01	=	5.21 mole
N	=	13.3/14.01	=	0.95 mole

2) The doped polyaniline have one nitrogen atom per repeating unit. Therefore, mole ratios of each elements normalized to nitrogen were calculated by dividing mole ratios of each atoms with mole ratio of nitrogen.

C	=	5.92/0.95	=	6.23
H	=	5.21/0.95	=	5.48
N	=	0.95/0.95	=	1

APPENDIX B Determination of Geometric Correction Factor (K)

The calibration of the constructed four point probe meter for measurement the electrical conductivity of thin film sample was performed by using silicon wafer chip (SiO). The sheet resistivity (ρ) and thickness of silicon wafer chips are shown in Table B.1.

Table B-1 The sheet resisitivity and thickness of standard sheet (SiO).

Material	Sheet Resistivity (ρ, Ωcm)	Thickness (cm)
SiO_A	9.09×10^{-3}	7.18×10^{-2}
SiO_B	9.23×10^{-3}	7.16×10^{-2}

Table B-2 Determination of K factor of the left probe by using SiO_A as the standard sheet at 27° C.

Time (min)	1st measurement			2nd measurement		
	I (A)	V (V)	K	I (A)	V (V)	K
1	6.1×10^{-5}	2.5×10^{-3}	3.1×10^{-3}	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}
5	6.0×10^{-5}	2.4×10^{-3}	3.2×10^{-3}	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}
10	6.0×10^{-5}	2.2×10^{-3}	3.4×10^{-3}	5.9×10^{-5}	2.2×10^{-3}	3.4×10^{-3}
15	6.0×10^{-5}	2.2×10^{-3}	3.4×10^{-3}	5.9×10^{-5}	2.2×10^{-3}	3.4×10^{-3}
20	6.0×10^{-5}	2.2×10^{-3}	3.4×10^{-3}	5.9×10^{-5}	2.1×10^{-3}	3.6×10^{-3}
25	-	-	-	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}
30	-	-	-	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}
Average			3.3×10^{-3}	Average		3.4×10^{-3}
SD			1.7×10^{-4}	SD		1.2×10^{-4}

Table B-3 Determination of K factor of the right probe by using SiO_A as the standard sheet at 27° C.

Time (min)	1st measurement			2nd measurement		
	I (A)	V (V)	K	I (A)	V (V)	K
1	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}
5	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	1.9×10^{-3}	3.9×10^{-3}
10	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	1.9×10^{-3}	3.9×10^{-3}
15	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}
20	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}
25	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}
30	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.7×10^{-3}
average			3.7×10^{-3}	average		3.8×10^{-3}
SD			0	SD		9.6×10^{-5}

Table B-4 Determination of K factor of the left probe by using SiO_B as the standard sheet at 27° C.

Time (min)	1st measurement			2nd measurement		
	I (A)	V (V)	K	I (A)	V (V)	K
1	5.94×10^{-5}	2.1×10^{-3}	3.6×10^{-3}	5.9×10^{-5}	2.5×10^{-3}	2.99×10^{-3}
5	5.94×10^{-5}	2.1×10^{-3}	3.6×10^{-3}	5.9×10^{-5}	2.5×10^{-3}	2.99×10^{-3}
10	5.9×10^{-5}	2.2×10^{-3}	3.4×10^{-3}	5.9×10^{-5}	2.5×10^{-3}	2.99×10^{-3}
15	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}	5.9×10^{-5}	2.5×10^{-3}	2.99×10^{-3}
20	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}	5.9×10^{-5}	2.4×10^{-3}	3.13×10^{-3}
25	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}	5.9×10^{-5}	2.4×10^{-3}	3.13×10^{-3}
30	5.9×10^{-5}	2.3×10^{-3}	3.3×10^{-3}	5.9×10^{-5}	2.4×10^{-3}	3.13×10^{-3}
average			3.5×10^{-3}	average		3.05×10^{-3}
SD			9.8×10^{-5}	SD		7.48×10^{-5}

Table B-5 Determination of K factor of the right probe by using SiO_B as the standard sheet at 27° C.

Time (min)	1st measurement			2nd measurement		
	I (A)	V (V)	K	I (A)	V (V)	K
1	5.9×10^{-5}	1.9×10^{-3}	4.0×10^{-3}	5.9×10^{-5}	1.9×10^{-3}	4.0×10^{-3}
5	5.9×10^{-5}	1.9×10^{-3}	4.0×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}
10	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}
15	5.9×10^{-5}	2.1×10^{-3}	3.6×10^{-3}	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}
20	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}	5.9×10^{-5}	2.1×10^{-3}	3.6×10^{-3}
25	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}	5.9×10^{-5}	2.1×10^{-3}	3.6×10^{-3}
30	5.9×10^{-5}	2.0×10^{-3}	3.8×10^{-3}	5.9×10^{-5}	2.1×10^{-3}	3.6×10^{-3}
average			3.8×10^{-3}	average		3.7×10^{-3}
SD			1.3×10^{-4}	SD		1.3×10^{-4}

APPENDIX C Electrical Property Data

C-1 Effect of Aging on the doped polyaniline films at different ratio of C_a/C_p

Sample : C_a/C_p = 14.6 Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no.2, Left probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-1.1 Data from the conductive measurement of the doped film at C_a/C_p equal to 14.6 on the effect of aging.

Time (days)	Sample No. 1			Sample No. 2		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	1.52×10^{-3}	0.25	6.72×10^{2}	1.53×10^{-3}	0.28	6.04×10^{2}
5	1.50×10^{-3}	0.33	5.03×10^{2}	1.52×10^{-3}	0.29	5.90×10^{2}
10	1.50×10^{-3}	0.31	5.35×10^{2}	1.50×10^{-3}	0.27	6.14×10^{2}
20	1.50×10^{-3}	0.64	2.59×10^{2}	1.50×10^{-3}	0.60	2.76×10^{2}
30	1.50×10^{-3}	0.60	2.75×10^{2}	1.50×10^{-3}	0.74	2.24×10^{2}
40	1.52×10^{-3}	0.62	2.70×10^{2}	1.52×10^{-3}	0.73	2.29×10^{2}
50	1.51×10^{-3}	0.53	3.15×10^{2}	1.51×10^{-3}	0.48	3.43×10^{2}
60	1.51×10^{-3}	0.55	3.04×10^{2}	1.51×10^{-3}	0.52	3.19×10^{2}

Sample : C_a/C_p = 50 Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no.1, Left probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-1.2 Data from the conductive measurement of the doped film at C_a/C_p equal to 50 on the effect of aging.

Time (days)	Sample No. 1			Sample No. 2		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	3.76×10^{-5}	4.17×10^{-2}	9.97×10^{1}	3.73×10^{-5}	3.88×10^{-2}	1.06×10^{2}
5	3.70×10^{-5}	4.22×10^{-2}	9.69×10^{1}	3.68×10^{-5}	3.94×10^{-2}	1.03×10^{2}
10	3.61×10^{-5}	4.75×10^{-2}	8.40×10^{1}	3.50×10^{-5}	4.42×10^{-2}	8.75×10^{1}
20	3.64×10^{-5}	9.13×10^{-2}	4.41×10^{1}	3.66×10^{-5}	8.34×10^{-2}	4.85×10^{1}
30	3.60×10^{-5}	9.33×10^{-2}	4.27×10^{1}	3.30×10^{-5}	9.0×10^{-2}	4.05×10^{1}
40	3.70×10^{-5}	8.61×10^{-2}	4.75×10^{1}	3.53×10^{-5}	8.28×10^{-2}	4.71×10^{1}
50	3.65×10^{-5}	7.52×10^{-2}	5.37×10^{1}	3.68×10^{-5}	8.47×10^{-2}	4.85×10^{1}
60	3.68×10^{-5}	7.75×10^{-2}	5.30×10^{1}	3.66×10^{-5}	7.32×10^{-2}	5.59×10^{1}

Sample : C_a/C_p = 73 Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no.1, Left probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-1.3 Data from the conductive measurement of the doped film at C_a/C_p equal to 73 on the effect of aging.

Time (days)	Sample No. 1			Sample No. 2		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	3.79×10^{-5}	3.72×10^{-2}	1.13×10^{2}	3.82×10^{-5}	3.81×10^{-2}	1.11×10^{2}
5	3.75×10^{-5}	3.67×10^{-2}	1.13×10^{2}	3.69×10^{-5}	3.94×10^{-2}	1.04×10^{2}
10	3.72×10^{-5}	4.03×10^{-2}	1.02×10^{2}	3.70×10^{-5}	4.15×10^{-2}	9.86×10^{1}
20	3.73×10^{-5}	6.43×10^{-2}	6.41×10^{1}	3.60×10^{-5}	6.45×10^{-2}	6.17×10^{1}
30	3.68×10^{-5}	9.19×10^{-2}	4.43×10^{1}	3.65×10^{-5}	9.33×10^{-2}	4.33×10^{1}
40	3.58×10^{-5}	8.27×10^{-2}	4.79×10^{1}	3.69×10^{-5}	9.67×10^{-2}	4.23×10^{1}
50	3.71×10^{-5}	7.68×10^{-2}	5.34×10^{1}	3.67×10^{-5}	7.76×10^{-2}	5.13×10^{1}
60	3.66×10^{-5}	8.04×10^{-2}	5.04×10^{1}	3.73×10^{-5}	7.89×10^{-2}	5.25×10^{1}

C-2 Effect of acid concentrations on the doped polyaniline films at different ratio of C_a/C_p

Sample : C_a/C_p = 7.3 Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no. 2, Left probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-2.1 Data from the conductive measurement of the doped film at C_a/C_p equal to 7.3 on the effect of acid concentrations.

Sample No.	1st measurement			2nd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	2.0×10^{-5}	1.4×10^{-1}	1.58×10^{1}	2.0×10^{-5}	1.46×10^{-1}	1.52×10^{1}
	2.0×10^{-5}	1.37×10^{-1}	1.61×10^{1}	2.0×10^{-5}	1.40×10^{-1}	1.58×10^{1}
	2.0×10^{-5}	1.33×10^{-1}	1.66×10^{1}	2.0×10^{-5}	1.38×10^{-1}	1.60×10^{1}
	2.0×10^{-5}	1.27×10^{-1}	1.75×10^{1}	2.0×10^{-5}	1.30×10^{-1}	1.70×10^{1}
	2.0×10^{-5}	1.27×10^{-1}	1.74×10^{1}	2.0×10^{-5}	1.33×10^{-1}	1.66×10^{1}
	2.0×10^{-5}	1.30×10^{-1}	1.70×10^{1}	2.0×10^{-5}	1.29×10^{-1}	1.71×10^{1}
				2.0×10^{-5}	1.28×10^{-1}	1.73×10^{1}
	Average		1.67×10^{1}	Average		1.64×10^{1}
	SD		0.68	SD		0.79
2	2.0×10^{-5}	1.20×10^{-1}	1.8×10^{1}	2.0×10^{-5}	1.23×10^{-1}	1.79×10^{1}
	2.0×10^{-5}	1.15×10^{-1}	1.9×10^{1}	2.0×10^{-5}	1.29×10^{-1}	1.72×10^{1}
	2.0×10^{-5}	1.19×10^{-1}	1.9×10^{1}	2.0×10^{-5}	1.14×10^{-1}	1.94×10^{1}
	2.0×10^{-5}	1.08×10^{-1}	2.0×10^{1}	2.0×10^{-5}	1.16×10^{-1}	1.91×10^{1}
	2.0×10^{-5}	1.16×10^{-1}	1.9×10^{1}	2.0×10^{-5}	1.17×10^{-1}	1.89×10^{1}
	2.0×10^{-5}	1.07×10^{-1}	2.1×10^{1}	2.0×10^{-5}	1.22×10^{-1}	1.81×10^{1}
				2.0×10^{-5}	1.20×10^{-1}	1.84×10^{1}
	Average		1.94×10^{1}	Average		1.84×10^{1}
	SD		0.92	SD		0.76

Sample : C_a/C_p = 10.2 Thickness (t) = 2.65×10^{-3} cm

Testing conditions : Conductive meter no. 2, Left probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-2.2 Data from the conductive measurement of the doped film at C_a/C_p equal to 10.2 on the effect of acid concentrations.

Sample No.	1st measurement			2nd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	1.0×10^{-5}	1.61×10^{-2}	7.00×10^{1}	1.0×10^{-5}	3.68×10^{-2}	3.06×10^{1}
	1.0×10^{-5}	1.02×10^{-2}	1.10×10^{2}	1.0×10^{-5}	2.30×10^{-2}	4.90×10^{1}
	1.0×10^{-5}	9.6×10^{-3}	1.17×10^{2}	1.0×10^{-5}	1.80×10^{-2}	6.26×10^{1}
	1.0×10^{-5}	1.31×10^{-2}	8.60×10^{1}	1.0×10^{-5}	2.50×10^{-2}	4.51×10^{1}
	1.0×10^{-5}	1.59×10^{-2}	7.08×10^{1}	1.0×10^{-5}	1.91×10^{-2}	5.90×10^{1}
	1.0×10^{-5}	8.9×10^{-3}	1.27×10^{2}	1.0×10^{-5}	3.40×10^{-2}	3.31×10^{1}
	1.0×10^{-5}	9.7×10^{-3}	1.16×10^{2}	1.0×10^{-5}	3.50×10^{-2}	3.22×10^{1}
	Average		9.96×10^{1}	Average		4.45×10^{1}
	SD		23.5	SD		13.1
2	2.0×10^{-5}	9.0×10^{-2}	2.50×10^{1}	2.0×10^{-5}	1.13×10^{-1}	1.99×10^{1}
	2.0×10^{-5}	7.54×10^{-2}	2.99×10^{1}	2.0×10^{-5}	1.31×10^{-1}	1.72×10^{1}
	2.0×10^{-5}	6.38×10^{-2}	3.53×10^{1}	2.0×10^{-5}	1.35×10^{-1}	1.67×10^{1}
	2.0×10^{-5}	7.22×10^{-2}	3.12×10^{1}	2.0×10^{-5}	1.23×10^{-1}	1.84×10^{1}
	2.0×10^{-5}	6.91×10^{-2}	3.26×10^{1}	2.0×10^{-5}	1.39×10^{-1}	1.63×10^{1}
	2.0×10^{-5}	5.92×10^{-2}	3.81×10^{1}	2.0×10^{-5}	1.07×10^{-1}	2.10×10^{1}
	2.0×10^{-5}	8.02×10^{-2}	2.81×10^{1}	2.0×10^{-5}	1.09×10^{-1}	2.07×10^{1}
	Average		3.51×10^{1}	Average		1.86×10^{1}
	SD		4.4	SD		2.0

Sample : C_a/C_p = 14.6 Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no. 2, Left probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-2.3 Data from the conductive measurement of the doped film at C_a/C_p equal to 14.6 on the effect of acid concentrations.

Sample No.	1st measurement			2nd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	1.52×10^{-3}	5.77×10^{-1}	2.91×10^{2}	1.51×10^{-3}	5.40×10^{-1}	3.09×10^{2}
	1.52×10^{-3}	5.76×10^{-1}	2.92×10^{2}	1.51×10^{-3}	5.39×10^{-1}	3.10×10^{2}
	1.52×10^{-3}	5.78×10^{-1}	2.91×10^{2}	1.51×10^{-3}	5.44×10^{-1}	3.07×10^{2}
	1.52×10^{-3}	5.82×10^{-1}	2.89×10^{2}	1.51×10^{-3}	5.36×10^{-1}	3.11×10^{2}
				1.51×10^{-3}	5.39×10^{-1}	3.10×10^{2}
				1.51×10^{-3}	5.35×10^{-1}	3.12×10^{2}
				1.51×10^{-3}	5.46×10^{-1}	3.06×10^{2}
	Average		2.91×10^{2}	Average		3.09×10^{2}
	SD		1.3	SD		2.3
2	1.52×10^{-3}	6.43×10^{-1}	2.61×10^{2}	1.51×10^{-3}	4.95×10^{-1}	3.37×10^{2}
	1.52×10^{-3}	6.44×10^{-1}	2.61×10^{2}	1.51×10^{-3}	4.96×10^{-1}	3.37×10^{2}
	1.52×10^{-3}	6.45×10^{-1}	2.61×10^{2}	1.51×10^{-3}	4.97×10^{-1}	3.36×10^{2}
	1.52×10^{-3}	6.43×10^{-1}	2.61×10^{2}	1.51×10^{-3}	4.98×10^{-1}	3.35×10^{2}
	Average		2.61×10^{2}	Average		3.36×10^{2}
	SD		0.4	SD		0.9

Sample No.	1st measurement			2nd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
3	1.51×10^{-3}	4.47×10^{-1}	3.73×10^{2}	1.52×10^{-3}	6.43×10^{-1}	2.61×10^{2}
	1.51×10^{-3}	4.46×10^{-1}	3.74×10^{2}	1.52×10^{-3}	6.44×10^{-1}	2.61×10^{2}
	1.51×10^{-3}	4.48×10^{-1}	3.73×10^{2}	1.52×10^{-3}	6.45×10^{-1}	2.61×10^{2}
				1.52×10^{-3}	6.43×10^{-1}	2.61×10^{2}
	Average		3.73×10^{2}	Average		3.59×10^{2}
	SD		0.8	SD		0.99
4	1.53×10^{-3}	4.65×10^{-1}	3.63×10^{2}	1.50×10^{-3}	5.03×10^{-1}	3.30×10^{2}
	1.53×10^{-3}	4.69×10^{-1}	3.59×10^{2}	1.50×10^{-3}	5.02×10^{-1}	3.30×10^{2}
	1.53×10^{-3}	4.68×10^{-1}	3.60×10^{2}	1.50×10^{-3}	5.04×10^{-1}	3.29×10^{2}
	1.53×10^{-3}	4.66×10^{-1}	3.62×10^{2}			
	1.53×10^{-3}	4.67×10^{-1}	3.61×10^{2}			
	Average		3.61×10^{2}	Average		3.30×10^{2}
	SD		1.22	SD		0.66

Sample : C_a/C_p = 30 Thickness (t) = 2.67×10^{-3} cm

Testing conditions : Conductive meter no. 2, Right probe

K factor = 3.35×10^{-3}

Testing temperature = 26-28° C

Table C-2.4 Data from the conductive measurement of the doped film at C_a/C_p equal to 30 on the effect of acid concentrations.

Sample No.	1st measurement			2nd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	1.55×10^{-3}	5.46×10^{-1}	3.18×10^{2}	1.57×10^{-3}	5.39×10^{-1}	3.26×10^{2}
	1.53×10^{-3}	5.44×10^{-1}	3.15×10^{2}	1.56×10^{-3}	5.38×10^{-1}	3.24×10^{2}
	1.52×10^{-3}	5.4×10^{-1}	3.15×10^{2}	1.54×10^{-3}	5.35×10^{-1}	3.22×10^{2}
	Average		3.16×10^{2}	Average		3.24×10^{2}
	SD		1.66	SD		2.15

Sample : $C_a/C_p = 50$ Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no.1, Left probe K factor = 3.35×10^{-3}

Testing temperature = 26-28^{0}C

Table C-2.5 Data from the conductivity measurement of the doped film at C_a/C_p equal to 50 on the effect of acid concentrations.

Sample No.	1st measurement			2nd measurement			3rd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	3.63×10^{-5}	7.37×10^{-2}	5.45×10^{1}	3.75×10^{-5}	7.72×10^{-2}	5.37×10^{1}	3.25×10^{-5}	7.20×10^{-2}	4.99×10^{1}
	3.51×10^{-5}	7.11×10^{-2}	5.46×10^{1}	3.90×10^{-5}	7.42×10^{-2}	5.81×10^{1}	3.62×10^{-5}	7.43×10^{-2}	5.39×10^{1}
	3.59×10^{-5}	7.30×10^{-2}	5.44×10^{1}	3.60×10^{-5}	6.92×10^{-2}	5.75×10^{1}	3.78×10^{-5}	8.24×10^{-2}	5.07×10^{1}
	3.72×10^{-5}	7.44×10^{-2}	5.53×10^{1}	3.30×10^{-5}	6.52×10^{-2}	5.60×10^{1}	3.66×10^{-5}	7.97×10^{-2}	5.08×10^{1}
	Average		5.47×10^{1}	3.50×10^{-5}	6.50×10^{-2}	5.95×10^{1}	Average		5.13×10^{1}
	SD		0.41	Average		5.70×10^{1}	SD		1.75
				SD		2.23			
2	3.72×10^{-5}	7.00×10^{-2}	5.88×10^{1}	3.65×10^{-5}	6.80×10^{-2}	5.93×10^{1}	3.88×10^{-5}	7.98×10^{-2}	5.38×10^{1}
	3.30×10^{-5}	6.90×10^{-2}	5.29×10^{1}	3.68×10^{-5}	6.94×10^{-2}	5.86×10^{1}	3.75×10^{-5}	8.52×10^{-2}	4.87×10^{1}
	3.50×10^{-5}	6.74×10^{-2}	5.74×10^{1}	3.75×10^{-5}	7.70×10^{-2}	5.38×10^{1}	3.68×10^{-5}	7.13×10^{-2}	5.71×10^{1}
	3.83×10^{-5}	7.64×10^{-2}	5.54×10^{1}	3.71×10^{-5}	7.31×10^{-2}	5.61×10^{1}	3.55×10^{-5}	7.37×10^{-2}	5.33×10^{1}
	3.79×10^{-5}	8.25×10^{-2}	5.08×10^{1}	3.55×10^{-5}	6.45×10^{-2}	6.08×10^{1}	3.58×10^{-5}	7.45×10^{-2}	5.31×10^{1}
	3.78×10^{-5}	8.28×10^{-2}	5.05×10^{1}	3.43×10^{-5}	6.30×10^{-2}	6.02×10^{1}	3.66×10^{-5}	7.26×10^{-2}	5.57×10^{1}
	Average		5.43×10^{1}	Average		5.82×10^{1}	Average		5.36×10^{1}
	SD		3.46	SD		2.68	SD		2.87

Sample : $C_a/C_p = 73$ Thickness (t) = 2.7×10^{-3} cm

Testing conditions : Conductive meter no.1, Left probe K factor = 3.35×10^{-3}

Testing temperature = 26-28^{0}C

Table C-2.6 Data from the conductivity measurement of the doped film at C_a/C_p equal to 73 on the effect of acid concentrations.

Sample No.	1st measurement			2nd measurement			3rd measurement		
	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)	I (A)	V (V)	σ (S/cm)
1	3.96×10^{-5}	7.19×10^{-2}	6.09×10^{1}	3.98×10^{-5}	7.42×10^{-2}	5.93×10^{1}	3.59×10^{-5}	6.74×10^{-2}	5.89×10^{1}
	3.83×10^{-5}	7.43×10^{-2}	5.70×10^{1}	3.83×10^{-5}	7.21×10^{-2}	5.87×10^{1}	3.36×10^{-5}	6.57×10^{-2}	5.65×10^{1}
	3.77×10^{-5}	7.30×10^{-2}	5.71×10^{1}	3.85×10^{-5}	6.59×10^{-2}	6.46×10^{1}	3.73×10^{-5}	7.46×10^{-2}	5.53×10^{1}
	3.65×10^{-5}	6.78×10^{-2}	5.95×10^{1}	3.91×10^{-5}	7.48×10^{-2}	5.78×10^{1}	3.78×10^{-5}	7.71×10^{-2}	5.42×10^{1}
	3.68×10^{-5}	7.10×10^{-2}	5.73×10^{1}	3.72×10^{-5}	7.03×10^{-2}	5.85×10^{1}	3.81×10^{-5}	8.02×10^{-2}	5.25×10^{1}
	3.72×10^{-5}	7.14×10^{-2}	5.76×10^{1}	3.65×10^{-5}	6.26×10^{-2}	6.45×10^{1}	3.69×10^{-5}	7.08×10^{-2}	5.76×10^{1}
	Average		5.82×10^{1}	3.59×10^{-5}	6.41×10^{-2}	6.19×10^{1}	3.65×10^{-5}	6.43×10^{-2}	6.28×10^{1}
	SD		1.60	Average		6.19×10^{1}	Average		5.68×10^{1}
				SD		2.88	SD		3.37
2	3.79×10^{-5}	9.24×10^{-2}	4.53×10^{1}	3.87×10^{-5}	8.24×10^{-2}	5.19×10^{1}	3.94×10^{-5}	8.36×10^{-2}	5.21×10^{1}
	3.64×10^{-5}	9.42×10^{-2}	4.27×10^{1}	3.75×10^{-5}	7.94×10^{-2}	5.22×10^{1}	3.92×10^{-5}	8.57×10^{-2}	5.06×10^{1}
	3.65×10^{-5}	8.27×10^{-2}	4.88×10^{1}	3.72×10^{-5}	7.52×10^{-2}	5.47×10^{1}	3.76×10^{-5}	7.91×10^{-2}	5.26×10^{1}
	3.51×10^{-5}	8.01×10^{-2}	4.84×10^{1}	3.61×10^{-5}	6.91×10^{-2}	5.78×10^{1}	3.87×10^{-5}	7.98×10^{-2}	5.36×10^{1}
	3.45×10^{-5}	7.86×10^{-2}	4.85×10^{1}	3.50×10^{-5}	6.67×10^{-2}	5.80×10^{1}	3.69×10^{-5}	7.21×10^{-2}	5.66×10^{1}
	3.81×10^{-5}	9.35×10^{-2}	4.51×10^{1}	3.27×10^{-5}	6.52×10^{-2}	5.54×10^{1}	3.65×10^{-5}	6.98×10^{-2}	5.78×10^{1}
	Average		4.65×10^{1}	Average		5.50×10^{1}	3.54×10^{-5}	6.67×10^{-2}	5.87×10^{1}
	SD		2.48	SD		2.62	Average		5.46×10^{1}
							SD		3.12

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