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APPENDICES

APPENDIX A Determination of the Geometric Correction Factor (K)

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

Table A.1 The sheet resistivity and thickness of standard sheet (SiO)

Material	Sheet Resistivty, 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 A.2 Determination of K factor of the constructed four point meter by using SiO_A as the standard sheet at 25^{O}C

1st measurement			2nd measurement		
I (mA)	V (mV)	K	I (mA)	V (mV)	K
54.7	1.60	1.82	70.7	2.50	1.90
60.6	1.90	1.87	71.5	3.30	1.65
82.6	3.40	1.87	82.7	4.00	1.69
116	5.60	1.88	104	5.60	1.69
153	80.0	1.90	125	7.60	1.62
Average		1.86	Average		1.71
SD		0.04	SD		0.11

Table A.3 Determination of K factor of the constructed four point meter by using SiO_B as the standard sheet at 25^{O}C

1st measurement			2nd measurement		
I (mA)	V (mV)	K	I (mA)	V (mV)	K
69.7	3.80	1.51	66.9	3.90	1.42
69.4	3.40	1.61	76.3	4.50	1.48
90.5	5.00	1.63	97.1	6.20	1.50
88.6	4.90	1.62	118	8.00	1.51
110	6.60	1.62	123	8.30	1.52
Average		1.60	Average		1.49
SD		0.05	SD		0.04

APPENDIX B Elemental Analysis Data of Doped Polyaniline

The elemental analysis technique was used to determine the amounts of elements; carbon (C), hydrogen (H), nitrogen (N), and sulfer (S) atoms of doped polyaniline in order to calculate to % of H/N, the doping level. The doping level presents the amount of protons from an acid dopant protonating the nitrogen atoms in the polymer chain in the protonation doping process of polyaniline. The undoped and doped film samples were weighed at 1.5-2.5 mg and sealed in the tin capsules and put in the sample cell. The sample was dropped in the combustion zone at a temperature between 975-1100°C with helium as a carrier gas.The data from EA measurements of doped polyaniline films at various doping ratios (C_a/C_p and N_a/N_p) are shown in Table B.1.

Table B.1 The EA data of doped polyaniline films

Doped polyaniline	C_a/C_p	N_a/N_p	% H/N
HCl doped polyaniline film	0	0	5.64
	1	9.90	11.3
	10	99.3	13.4
	50	496	14.7
	100	993	13.7
	500	4963	10.4
CSA doped polyaniline films	0	0	5.64
	1	1.60	18.8
	5	7.80	27.6
	10	15.6	28.0
	50	78.1	42.7
	150	234	46.0
	500	781	53.3

APPENDIX C Electrical Conductivity Data of HCl Doped Polyaniline

C.1 Effect of Aging on the electrical conductivity of HCl doped polyaniline films at various doping ratios (figure 4.15)

Sample: $C_a/C_p = 1$, $N_a/N_p = 9.90$

Thickness (t) = 20.2, 21.2 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-70%

Moisture content = 3-5%

Table C.1.1 The electrical conductivity of HCl doped polyaniline films at $C_a/C_p = 1$, $N_a/N_p = 9.90$

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	1.35E-01	1.37E-01	1.36E-01	1.63E-03
5	1.25E-01	1.23E-01	1.24E-01	1.20E-03
10	8.37E-02	8.40E-02	8.39E-02	2.12E-04
20	7.28E-02	7.24E-02	7.26E-02	2.83E-04
30	8.40E-02	8.14E-02	8.27E-02	1.84E-03
40	5.31E-02	-	5.31E-02	-
50	6.00E-02	5.27E-02	5.64E-02	5.16E-03
80	5.10E-02	3.17E-02	4.14E-02	1.36E-02

Sample: $C_a/C_p = 10$, $N_a/N_p = 99.3$

Thickness (t) = 21.0, 72.8 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-70%

Moisture content = 3-5%

Table C-1.2 The electrical conductivity of HCl doped polyaniline films at $C_a/C_p = 10$, $N_a/N_p = 99.3$

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	2.37E-01	2.05E-01	2.21E-01	2.23E-02
5	1.13E-01	-	1.13E-01	-
10	5.90E-02	4.54E-02	5.22E-02	9.62E-03
20	4.15E-02	4.54E-02	4.35E-02	2.76E-03
30	1.10E-02	-	1.10E-02	-
40	5.35E-02	2.37E-02	3.86E-02	2.11E-02
50	4.62E-02	4.69E-02	4.66E-02	4.95E-04
80	4.28E-02	-	4.28E-02	-

Sample: $C_a/C_p = 50$, $N_a/N_p = 496$

Thickness (t) = 18.2, 69.6 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-70%

Moisture content = 3-5%

Table C.1.3 The electrical conductivity of HCl doped polyaniline films at $C_a/C_p = 50$, $N_a/N_p = 496$

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	4.55E-01	2.99E-01	3.77E-01	1.10E-01
5	1.71E-01	1.74E-01	1.73E-01	2.12E-03
10	2.04E-01	1.02E-01	1.53E-01	7.21E-02
20	1.69E-01	1.95E-01	1.82E-01	1.86E-02
30	8.13E-02	-	8.13E-02	-
40	7.58E-02	-	7.58E-02	-
80	8.76E-02	-	8.76E-02	-

Sample: $C_a/C_p = 500$, $N_a/N_p = 4963$

Thickness (t) = 20.0, 23.2 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-70%

Moisture content = 3-5%

Table C.1.4 The electrical conductivity of HCl doped polyaniline films at $C_a/C_p = 500$, $N_a/N_p = 4963$

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	9.73E-02	9.67E-02	9.70E-02	4.24E-04
5	2.70E-02	2.57E-02	2.64E-02	9.19E-04
10	1.10E-03	9.00E-04	1.00E-03	1.41E-04
20	2.10E-03	2.00E-03	2.10E-03	7.07E-05
40	3.20E-03	3.10E-03	3.20E-03	7.07E-05
50	2.10E-03	-	2.10E-03	-
80	1.70E-03	-	1.70E-03	-

C.2 Effect of acid concentrations on the electrical conductivity of HCl doped polyaniline films at various doping ratios (figure 4.21)

Sample: HCl doped polyaniline films

Thickness (t) ~ 20 μm

Testing conditions: K factor = 1.65

Temperature = 24-25 °C

Humidity = 64-75%, Moisture content = 3-5%

Table C.2.1 The electrical conductivity of HCl doped polyaniline films at different doping ratios

	Electrical Conductivity (S/cm)					
C_a/C_p	1	10	50	150	250	500
N_a/N_p	9.90	99.3	496	1489	2482	4963
	3.17E-02	5.31E-02	8.13E-02	4.97E-02	1.82E-02	3.20E-03
	2.37E-02	4.62E-02	7.58E-02	4.75E-02	1.77E-02	3.10E-03
		5.27E-02	8.76E-02			2.10E-03
		5.10E-02				1.70E-03
Average	2.77E-02	5.08E-02	8.16E-02	4.86E-02	1.80E-02	2.50E-03
SD	5.66E-03	3.17E-03	5.90E-03	1.60E-03	4.00E-04	7.00E-04

C.3 Effect of the percentage of humidity on the electrical conductivity of HCl doped polyaniline films (figure 4.19)

Sample: $C_a/C_p = 1$, $N_a/N_p = 9.90$

Thickness (t) = 21.2 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Table C.3.1 The electrical conductivity of HCl doped polyaniline films at different %humidity

	The electrical conductivity (S/cm)			
%humidity	36.5	43.0	54.8	70.0
	1.20E-03	1.52E-03	2.20E-03	2.59E-03
	1.20E-03	1.52E-03	2.18E-03	2.55E-03
	1.12E-03	1.52E-03	2.17E-03	
	1.17E-03		2.21E-03	
	1.17E-03		2.19E-03	
	1.17E-03			
Average	1.18E-03	1.52E-03	2.19E-03	2.57E-03
SD	8.95E-06	2.52E-06	1.39E-05	2.76E-05

C.4 Effect of 1000 ppm SO_2/N_2 mixture gas on the electrical conductivity of HCl doped polyaniline films (figure 4.22)

Sample: $C_a/C_p = 1$, $N_a/N_p = 9.9$

Thickness (t) = 39.4 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table C.4.1 The electrical conductivity of HCl doped polyaniline films at $C_a/C_p = 1$ when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)
-13	1.00E-02	575.5	2.729E-03
-8	1.00E-02	577.5	2.722E-03
-1	1.00E-02	577.5	2.722E-03
0	1.00E-02	578.5	2.723E-03
1	1.00E-02	568.5	2.733E-03
1	1.00E-02	570.5	2.729E-03
2	1.00E-02	572.5	2.724E-03
2	1.00E-02	573.5	2.721E-03
3	1.00E-02	572.5	2.727E-03
3	1.00E-02	570.5	2.737E-03
4	1.00E-02	574.5	2.720E-03
5	1.00E-02	573.5	2.730E-03
6	1.00E-02	572.5	2.738E-03
8	1.00E-02	575.5	2.726E-03
10	1.00E-02	573.5	2.736E-03
13	1.00E-02	576.5	2.722E-03
17	1.00E-02	579.5	2.718E-03
19	1.00E-02	578.5	2.723E-03
33	1.00E-02	579.5	2.718E-03
40	1.00E-02	577.5	2.720E-03
54	1.00E-02	577.5	2.725E-03

Sample: $C_a/C_p = 50$, $N_a/N_p = 496.3$

Thickness (t) = 69.6 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table C.4.2 The electrical conductivity of HCl doped polyaniline films at $C_a/C_p = 50$ when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)
-13	4.00E-03	59.2	2.385E-02
-9	4.00E-03	59.5	2.379E-02
-3	4.00E-03	58.5	2.386E-02
-1	4.00E-03	58.5	2.392E-02
0	4.00E-03	55.5	2.325E-02
0	4.00E-03	56.5	2.338E-02
2	4.00E-03	55.5	2.398E-02
3	4.00E-03	56.5	2.367E-02
4	4.00E-03	57.5	2.329E-02
5	4.00E-03	57.5	2.332E-02
8	4.00E-03	57.5	2.351E-02
11	4.00E-03	57.5	2.363E-02
14	4.00E-03	56.5	2.419E-02
19	4.00E-03	56.5	2.425E-02
24	4.00E-03	56.5	2.402E-02
29	4.00E-03	57.5	2.360E-02
34	4.00E-03	54.5	2.481E-02
39	4.00E-03	56.5	2.373E-02
44	4.00E-03	56.5	2.367E-02
48	4.00E-03	56.5	2.373E-02

APPENDIX D Electrical Conductivity Data of CSA Doped Polyaniline

D.1 Effect of Aging on the electrical conductivity of CSA doped polyaniline films at various doping ratios (figure 4.16)

Sample: C_a/C_p = 1, N_a/N_p = 1.60

Thickness (t) = 15.0 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table D.1.1 The electrical conductivity of CSA -doped polyaniline at C_a/C_p = 1, N_a/N_p = 1.60

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	6.58E-04	6.57E-04	6.58E-04	7.07E-07
5	5.59E-04	5.65E-04	5.62E-04	4.24E-06
10	4.93E-04	4.90E-04	4.92E-04	2.12E-06
15	4.85E-04	4.89E-04	4.87E-04	2.83E-06
20	5.81E-04	5.75E-03	3.17E-03	3.66E-03
30	7.35E-04	7.46E-04	7.41E-04	7.78E-06

Sample: $C_a/C_p = 5$, $N_a/N_p = 7.80$

Thickness (t) = 18.2 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table D.1.2 The electrical conductivity of CSA -doped polyaniline at C_a/C_p = 5 N_a/N_p = 7.80

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	2.55E-03	4.81E-03	3.68E-03	1.60E-03
5	2.40E-03	6.70E-03	4.55E-03	3.04E-03
10	3.32E-03	-	3.32E-03	-
15	4.50E-03	-	4.50E-03	-
20	2.50E-03	-	2.50E-03	-
30	4.32E-03	-	4.32E-03	-

Sample: C_a/C_p = 10, N_a/N_p = 15.6

Thickness (t) = 33.4 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table D.1.3 The electrical conductivity of CSA-doped polyaniline at C_a/C_p = 10, N_a/N_p = 15.6

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	1.90E-02	6.00E-03	3.68E-03	1.60E-03
5	1.73E-02	1.01E-02	4.55E-03	3.04E-03
10	7.71E-03	4.68E-03	3.32E-03	-
15	7.51E-03	-	4.50E-03	-
20	7.47E-03	4.42E-03	2.50E-03	-
30	3.35E-03	3.23E-03	4.32E-03	-

Sample: C_a/C_p = 100, N_a/N_p = 156

Thickness (t) = 33.0 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table D.1.4 The electrical conductivity of CSA -doped polyaniline at C_a/C_p = 100, N_a/N_p = 156

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	2.95E-02	4.33E-02	3.68E-03	1.60E-03
5	4.31E-02	5.12E-02	4.55E-03	3.04E-03
10	5.13E-02	3.00E-02	3.32E-03	-
15	4.38E-02	-	4.50E-03	-
20	3.84E-02	4.14E-02	2.50E-03	-
30	4.45E-02	4.26E-02	4.32E-03	-

Sample: C_a/C_p = 150, N_a/N_p = 234

Thickness (t) = 33.4 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table D.1.5 The electrical conductivity of CSA -doped polyaniline at C_a/C_p = 150, N_a/N_p = 234

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	4.01E-02	-	3.68E-03	1.60E-03
5	6.31E-02	-	4.55E-03	3.04E-03
10	5.40E-02	-	3.32E-03	-
15	6.30E-02	4.03E-02	4.50E-03	-
20	7.66E-02	4.89E-02	2.50E-03	-
30	5.44E-02	-	4.32E-03	-

D.2 Effect of acid concentrations on the electrical conductivity of CSA doped polyaniline films at various doping ratios (figure 4.21)

Sample: CSA doped polyaniline films

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%, Moisture content = 3-5%

Table D.2.1 The electrical conductivity of CSA doped polyaniline films at different doping ratios

	Specific Electrical Conductivity (S/cm)				
C_a/C_p	1	5	10	100	150
N_a/N_p	1.60	7.80	15.6	156	234
	6.58E-04	2.55E-03	1.90E-02	2.95E-02	4.01E-02
	6.57E-04	4.81E-03	6.00E-03	4.33E-02	6.31E-02
	5.59E-04	2.39E-03	1.73E-02	4.31E-02	5.40E-02
	5.65E-04	6.70E-03	1.01E-02	5.12E-02	6.30E-02
	4.93E-04	3.32E-03	7.71E-03	5.13E-02	4.03E-02
	4.90E-04	4.50E-03	4.68E-03	3.00E-02	7.66E-02
	4.85E-04	2.50E-03	7.51E-03	4.38E-02	4.89E-02
	4.89E-04	4.32E-03	7.47E-03	3.84E-02	5.44E-02
	5.81E-04		4.42E-03	4.14E-02	
	5.75E-04		3.35E-03	4.45E-02	
	7.35E-04		3.23E-03	4.26E-02	
	7.46E-04				
Average	5.86E-04	3.89E-03	8.25E-03	2.91E-03	1.16E-02
SD	9.38E-05	1.49E-03	5.33E-03	7.05E-03	1.24E-02

D.3 Effect of the percentage of humidity on the electrical conductivity of CSA doped polyaniline films (figure 4.19)

Sample: $C_a/C_p = 10$, $N_a/N_p = 15.6$

Thickness (t) = 39.2 μm

Testing conditions: K factor = 1.65

Temperature = 25-28 °C

Moisture content = 4%

Table D.3.1 The electrical conductivity of CSA doped polyaniline films at different % humidity

	Specific Electrical Conductivity (S/cm)						
% humidity	36	41	47	58	66	75.8	88
	1.16E-04	3.53E-04	1.11E-03	3.30E-03	6.10E-03	2.43E-02	3.46E-02
	1.14E-04	3.53E-04	1.04E-03	3.36E-03	6.06E-03	2.50E-02	3.48E-02
	1.10E-04	3.53E-04	9.50E-04	3.36E-03	5.93E-03	2.36E-02	3.53E-02
	1.12E-04		9.40E-04			2.44E-02	
	1.16E-04					2.41E-02	
	1.12E-04						
Average	1.13E-04	3.53E-04	1.01E-03	3.34E-03	6.03E-03	2.43E-02	3.49E-02
SD	2.28E-06	3.06E-07	7.98E-05	3.40E-05	8.54E-05	5.10E-04	3.80E-04

D.4 Effect of 1000 ppm SO_2/N_2 mixture gas on the electrical conductivity of CSA doped polyaniline films (figure 4.23)

Sample: $C_a/C_p = 1$, $N_a/N_p = 1.60$ (first sample)

Thickness (t) = 24.9 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.4.1 The electrical conductivity of CSA doped polyaniline films at $C_a/C_p = 1$ (first sample) when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)	Δσ	%Δσ
-11	1.00E-03	870.5	4.89E-04		
-10	1.00E-03	877.5	4.85E-04		
-8	1.00E-03	882.5	4.82E-04		
-5	1.00E-03	880.5	4.83E-04		
-3	1.00E-03	917.5	4.83E-04		
0	1.00E-03	982.5	4.87E-04	2.32E-06	0.48
2	1.00E-03	1005.5	4.94E-04	8.78E-06	1.82
3	1.00E-03	1011.5	4.91E-04	5.84E-06	1.21
4	1.00E-03	1012.5	4.90E-04	5.36E-06	1.11
5	1.00E-03	1014.5	4.89E-04	4.39E-06	0.91
6	1.00E-03	1012.5	4.90E-04	5.36E-06	1.11
7	1.00E-03	1010.5	4.91E-04	6.32E-06	1.31
8	1.00E-03	1013.5	4.90E-04	4.87E-06	1.01
10	1.00E-03	1011.5	4.91E-04	5.84E-06	1.21
12	1.00E-03	1011.5	4.91E-04	5.84E-06	1.21
15	1.00E-03	1005.5	4.94E-04	8.78E-06	1.82
18	1.00E-03	1002.5	4.95E-04	1.02E-05	2.12
21	1.00E-03	976.5	4.90E-04	5.26E-06	1.09
23	1.00E-03	975.5	4.91E-04	5.79E-06	1.20
27	1.00E-03	972.5	4.92E-04	7.29E-06	1.51
30	1.00E-03	975.5	4.91E-04	5.79E-06	1.20

Sample: $C_a/C_p = 1$, $N_a/N_p = 1.60$ (second sample)

Thickness (t) = 17.1 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.4.2 The electrical conductivity of CSA doped polyaniline films at $C_a/C_p = 1$ (second sample) when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)	Δσ	%Δσ
-14	2.00E-03	1159.5	5.20E-04		
-13	2.00E-03	1158.5	5.20E-04		
-11	2.00E-03	1164.5	5.17E-04		
-6	2.00E-03	1168.5	5.16E-04		
-4	2.00E-03	1170.5	5.15E-04		
-2	2.00E-03	1170.5	5.15E-04		
0	2.00E-03	1176.5	5.27E-04	1.16E-05	2.24
1	2.00E-03	1177.5	5.27E-04	1.11E-05	2.15
2	2.00E-03	1169.5	5.30E-04	1.47E-05	2.85
3	2.00E-03	1180.5	5.25E-04	9.75E-06	1.89
4	2.00E-03	1178.5	5.26E-04	1.07E-05	2.07
5	2.00E-03	1173.5	5.29E-04	1.29E-05	2.50
7	2.00E-03	1181.5	5.25E-04	9.34E-06	1.81
8	2.00E-03	1185.5	5.23E-04	7.53E-06	1.46
10	2.00E-03	1183.5	5.24E-04	8.46E-06	1.64
12	2.00E-03	1188.5	5.22E-04	6.23E-06	1.21
15	2.00E-03	1190.5	5.21E-04	5.36E-06	1.04
17	2.00E-03	1188.5	5.22E-04	6.23E-06	1.21
20	2.00E-03	1185.5	5.23E-04	7.52E-06	1.46
25	2.00E-03	1184.5	5.24E-04	7.98E-06	1.55
28	2.00E-03	1189.5	5.21E-04	5.77E-06	1.12
30	2.00E-03	1190.5	5.21E-04	5.36E-06	*1.04*

Sample: C_a/C_p = 10, N_a/N_p = 15.6 (first sample)

Thickness (t) = 27.0 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.4.3 The electrical conductivity of CSA doped polyaniline films at C_a/C_p = 10 (first sample) when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)	Δσ	%Δσ
-10	7.30E-01	1270	1.20E-03		
-8	7.55E-01	1310	1.20E-03		
-5	8.20E-01	1460	1.17E-03		
-3	7.45E-01	1290	1.21E-03		
0	7.75E-01	1340	1.21E-03		
2	7.65E-01	1310	1.22E-03	2.38E-05	1.99
3	7.65E-01	1300	1.23E-03	3.32E-05	2.77
4	7.80E-01	1310	1.24E-03	4.78E-05	3.99
5	7.80E-01	1300	1.25E-03	5.74E-05	4.79
6	7.75E-01	1300	1.25E-03	4.94E-05	4.12
7	7.55E-01	1280	1.23E-03	3.62E-05	3.02
8	7.65E-01	1280	1.25E-03	5.25E-05	4.38
10	7.45E-01	1270	1.23E-03	2.94E-05	2.45
12	7.60E-01	1280	1.24E-03	4.43E-05	3.70
15	7.90E-01	1340	1.23E-03	3.55E-05	2.96
18	7.70E-01	1300	1.24E-03	4.13E-05	3.45
21	7.85E-01	1320	1.24E-03	4.62E-05	3.86
23	7.70E-01	1300	1.24E-03	4.13E-05	3.45
27	8.10E-01	1360	1.25E-03	4.82E-05	4.02
30	8.00E-01	1350	1.24E-03	4.19E-05	3.50

Sample: C_a/C_p = 10, N_a/N_p = 15.6 (second sample)

Thickness (t) = 29.0 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.4.4 The electrical conductivity of CSA doped polyaniline films at C_a/C_p = 10 (second sample) when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)	Δσ	%Δσ
-12	4.30E-01	840	1.07E-03		
-10	4.40E-01	850	1.08E-03		
-9	4.40E-01	870	1.06E-03		
-8	4.40E-01	860	1.07E-03		
-7	4.50E-01	890	1.06E-03		
-6	4.45E-01	880	1.06E-03		
-5	4.45E-01	870	1.07E-03		
-3	4.45E-01	880	1.06E-03		
-1	4.55E-01	890	1.07E-03		
0	4.50E-01	870	1.08E-03		
1	4.50E-01	880	1.07E-03	6.70E-06	0.63
2	4.35E-01	850	1.07E-03	7.55E-06	0.71
3	4.40E-01	840	1.10E-03	3.28E-05	3.08
4	4.40E-01	830	1.11E-03	4.60E-05	4.32
5	4.45E-01	830	1.12E-03	5.86E-05	5.51
6	4.35E-01	810	1.12E-03	6.04E-05	5.68
7	4.35E-01	820	1.11E-03	4.67E-05	4.39
8	4.40E-01	820	1.12E-03	5.95E-05	5.59
11	4.40E-01	820	1.12E-03	5.95E-05	5.59
14	4.45E-01	830	1.12E-03	5.86E-05	5.51
19	4.35E-01	810	1.12E-03	6.04E-05	5.68
25	4.40E-01	830	1.11E-03	4.60E-05	4.32
29	4.45E-01	830	1.12E-03	5.86E-05	5.51
33	4.45E-01	835	1.11E-03	5.19E-05	4.88

Sample: C_a/C_p = 150, N_a/N_p = 234 (first sample)

Thickness (t) = 50.1 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.4.5 The electrical conductivity of CSA doped polyaniline films at C_a/C_p = 150 (first sample) when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I(mA)	V(mV)	σ (S/cm)	Δσ	%Δσ
-14	2.00E-03	1.3270	1.42E-02		
-11	2.00E-03	1.3420	1.40E-02		
-7	2.00E-03	1.3550	1.43E-02		
-4	2.00E-03	1.3770	1.41E-02		
0	2.00E-03	1.3930	1.39E-02		
0	2.00E-03	1.2990	2.01E-02		
1	2.00E-03	1.3140	1.98E-02	5.76E-03	40.7
3	2.00E-03	1.3550	1.88E-02	4.71E-03	33.3
4	2.00E-03	1.3720	1.77E-02	3.59E-03	25.4
5	2.00E-03	1.3860	1.75E-02	3.41E-03	24.1
6	2.00E-03	1.3950	1.74E-02	3.30E-03	23.3
7	2.00E-03	1.4060	1.72E-02	3.16E-03	22.3
9	2.00E-03	1.4230	1.70E-02	2.96E-03	20.9
10	2.00E-03	1.4300	1.69E-02	2.87E-03	20.3
12	2.00E-03	1.4450	1.76E-02	3.54E-03	25.0
15	2.00E-03	1.4590	1.82E-02	4.16E-03	29.4

Sample: C_a/C_p = 150, N_a/N_p = 234 (second sample)

Thickness (t) = 32.7 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.4.4 The electrical conductivity of CSA doped polyaniline films at C_a/C_p = 150 (second sample) when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I(mA)	V(mV)	σ (S/cm)	Δσ	%Δσ
-6	2.00E-01	0.3800	8.25E-02		
-5	2.00E-01	0.3800	8.25E-02		
-3	2.00E-01	0.3800	8.25E-02		
-1	2.00E-01	0.3800	8.25E-02		
0	2.00E-01	0.3400	9.18E-02	9.32E-03	11.3
1	2.00E-01	0.3500	8.93E-02	6.77E-03	8.2
2	2.00E-01	0.3300	9.45E-02	1.20E-02	14.5
3	2.00E-01	0.3400	9.18E-02	9.32E-03	11.3
4	2.00E-01	0.3300	9.45E-02	1.20E-02	14.5
5	2.00E-01	0.3300	9.45E-02	1.20E-02	14.5
6	2.00E-01	0.3100	1.00E-01	1.77E-02	21.5
7	2.00E-01	0.3200	9.73E-02	1.48E-02	17.9
8	2.00E-01	0.2900	1.07E-01	2.43E-02	29.5
9	2.00E-01	0.2900	1.07E-01	2.43E-02	29.5
10	2.00E-01	0.2800	1.11E-01	2.80E-02	33.9
12	2.00E-01	0.2750	1.12E-01	2.99E-02	36.2
14	1.50E-01	0.2300	9.98E-02	1.72E-02	20.9
16	1.60E-01	0.2300	1.06E-01	2.39E-02	29.0
17	1.50E-01	0.2300	9.98E-02	1.72E-02	20.9
18	1.50E-01	0.2200	1.04E-01	2.15E-02	26.1
20	1.50E-01	0.2200	1.04E-01	2.15E-02	26.1
22	1.50E-01	0.2300	9.98E-02	1.72E-02	20.9
24	1.50E-01	0.2100	1.09E-01	2.62E-02	31.7
27	1.50E-01	0.2200	1.04E-01	2.15E-02	26.1

D.5 Effect of SO_2/N_2 mixture gas at various concentrations on the electrical conductivity of CSA doped polyaniline films (figure 4.26)

Sample: CSA doped polyaniline films at C_a/C_p = 150, N_a/N_p =234

Thickness (t) = 18.1, 32.6, 47.7, 51.4 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table D.5.1 The electrical conductivity of CSA doped polyaniline films (C_a/C_p = 150, N_a/N_p =234) at various SO_2/N_2 mixture gas concentrations

SO_2 concentration (ppm)	I		II		III		Average		SD	
	Δσ	Δσ (%)	Δσ	Δσ (%)	Δσ	Δσ (%)	Δσ	Δσ (%)	Δσ	Δσ (%)
1000	27.9	5.17E-03	18.6	5.13E-02	23.1	1.26E-02	23.2	2.30E-02	4.65	2.48E-02
750	11.9	3.37E-03	13.9	4.77E-03	-	-	12.9	4.07E-03	1.41	9.90E-04
500	3.29	1.88E-03	6.86	2.63E-03	4.09	6.90E-04	4.75	1.73E-03	1.87	9.78E-04
375	3.72	6.50E-04	-	-	-	-	3.72	6.50E-04	-	-
250	1.76	2.57E-04	3.81	6.47E-04	2.33	3.69E-04	2.31	4.24E-04	1.09	2.01E-04
187.5	0	0	0	0	-	-	0		-	
125	0	0	0	0	-	-	0		-	
62.5	0	0	0	0	-	-	0		-	

APPENDIX F Electrical Conductivity Data of ESA Doped Polyaniline

F.1 Effect of Aging on the electrical conductivity of ESA doped polyaniline films at various doping ratios (figure 4.17)

Sample: $C_a/C_p = 1$, $N_a/N_p = 3.30$

Thickness (t) = 26.8 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table F.1.1 The electrical conductivity of CSA -doped polyaniline at C_a/C_p = 1, N_a/N_p = 3.30

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	2.83E-02	2.82E-02	2.83E-02	7.07E-05
10	2.67E-02	2.68E-02	2.68E-02	7.07E-05
20	2.65E-02	2.66E-02	2.66E-02	7.07E-05
35	1.69E-02	-	1.69E-02	-
50	-	1.46E-02	1.46E-02	-

Sample: $C_a/C_p = 10$, $N_a/N_p = 32.9$

Thickness (t) = 23.0 μm

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table F.1.2 The electrical conductivity of CSA -doped polyaniline at $C_a/C_p =$ 10, $N_a/N_p = 32.9$

# aging day	Specific conductivity (S/cm)		Average	SD
	1st sample	2nd sample		
1	1.85E-01	-	1.85E-01	-
10	1.30E-01	-	1.30E-01	-
20	1.51E-01	9.50E-02	1.23E-01	3.97E-02
35	1.12E-01	1.52E-01	1.32E-01	2.82E-02
50	1.20E-01	1.30E-01	1.25E-01	7.00E-03

F.2 Effect of acid concentrations on the electrical conductivity of ESA doped polyaniline films at various doping ratios (figure 4.21)

Sample: ESA doped polyaniline films

Testing conditions: K factor = 1.65

Temperature = 25 °C

Humidity = 65-72%

Moisture content = 3-5%

Table F.2.1 The electrical conductivity of ESA doped polyaniline films at different doping ratios

	Specific Electrical Conductivity (S/cm)		
C_a/C_p	1	5	10
N_a/N_p	3.30	16.5	32.9
	2.83E-02	6.64E-02	1.85E-01
	2.68E-02	6.66E-02	1.30E-01
	2.66E-02	6.64E-02	1.23E-01
	1.69E-02	6.63E-02	1.32E-01
	1.46E-02	6.65E-02	1.25E-01
Average	2.26E-02	6.64E-02	1.39E-01
SD	6.38E-03	1.20E-04	2.60E-02

F.3 Effect of 1000 ppm SO_2/N_2 mixture gas on the electrical conductivity of ESA doped polyaniline films (figure 4.24)

Sample: $C_a/C_p = 1$, $N_a/N_p = 3.3$

Thickness (t) = 48.6 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table F.3.1 The electrical conductivity of ESA doped polyaniline films at $C_a/C_p = 1$ when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)	Δσ	%Δσ
-24	1.10	4.08E-01	3.31E-02		
-13	1.10	4.08E-01	3.31E-02		
-9	1.10	3.95E-01	3.35E-02		
-4	1.80	6.40E-01	3.35E-02		
0	1.60	5.40E-01	3.36E-02		
0	1.40	4.91E-01	3.55E-02		
1	1.30	4.63E-01	3.49E-02	1.32E-03	3.96
2	1.20	4.40E-01	3.39E-02	2.80E-04	0.84
3	1.20	4.30E-01	3.47E-02	1.06E-03	3.18
5	1.15	4.07E-01	3.51E-02	1.48E-03	4.43
6	1.10	4.05E-01	3.37E-02	1.27E-04	0.38
8	1.10	4.03E-01	3.40E-02	3.33E-04	1.00
9	1.10	4.00E-01	3.42E-02	5.43E-04	1.63
10	1.10	4.00E-01	3.42E-02	5.43E-04	1.63
12	1.10	3.99E-01	3.42E-02	6.26E-04	1.88
14	1.10	4.01E-01	3.41E-02	4.60E-04	1.38
15	1.10	4.02E-01	3.40E-02	3.73E-04	1.12
17	1.15	4.20E-01	3.40E-02	4.06E-04	1.22
20	1.20	4.39E-01	3.40E-02	3.96E-04	1.19

Sample: C_a/C_p = 10, N_a/N_p = 32.9

Thickness (t) = 48.6 μm

Testing conditions: K factor = 1.65

Temperature = 25-26 °C

Moisture content = 2%

Humidity = 28-32%

Table F.3.2 The electrical conductivity of ESA doped polyaniline films at C_a/C_p = 10 when exposed to 1000 ppm SO_2/N_2 mixture gas

Time (min)	I (mA)	V (mV)	σ (S/cm)	Δσ	%Δσ
-5	1.00E-01	180.5	6.54E-02		
-4	1.00E-01	181.5	6.50E-02		
-3	1.05E-01	186.5	6.64E-02		
-3	1.05E-01	190.5	6.50E-02		
-1	1.10E-01	198.5	6.54E-02		
0	1.10E-01	199.5	6.50E-02		
1	1.25E-01	189.5	7.78E-02	1.23E-02	18.73
2	1.20E-01	202.5	6.99E-02	4.36E-03	6.66
3	1.20E-01	196.5	7.20E-02	6.49E-03	9.92
4	1.10E-01	184.5	7.03E-02	4.78E-03	7.31
6	1.10E-01	180.5	7.19E-02	6.34E-03	9.69
8	1.10E-01	180.5	7.19E-02	6.34E-03	9.69
10	1.10E-01	189.5	6.85E-02	2.93E-03	4.48
12	1.15E-01	196.5	6.90E-02	3.49E-03	5.34
14	1.20E-01	206.5	6.86E-02	3.00E-03	4.59
16	1.20E-01	205.5	6.89E-02	3.34E-03	5.10
18	1.30E-01	219.5	6.99E-02	4.32E-03	6.60
21	1.30E-01	220.5	6.96E-02	4.00E-03	6.12
23	1.30E-01	221.5	6.92E-02	3.69E-03	5.64
25	1.35E-01	230.5	6.91E-02	3.55E-03	5.42

F.4 Effect of SO_2/N_2 mixture gas at various concentrations on the electrical conductivity of ESA doped polyaniline films (figure 4.26)

Sample: ESA doped polyaniline films at $C_a/C_p = 10$,
$N_a/N_p = 32.9$
Thickness (t) = 11.2, 21.3 μm
Testing conditions: K factor = 1.65
Temperature = 25-26 °C
Moisture content = 2%
Humidity = 28-32%

Table F.4.1 The electrical conductivity of ESA doped polyaniline films ($C_a/C_p = 10$, $N_a/N_p = 32.9$) at various SO_2/N_2 mixture gas concentrations

SO_2 concentration (ppm)	I		II		Average		SD	
	Δσ	Δσ (%)	Δσ	Δσ (%)	Δσ	Δσ (%)	Δσ	Δσ (%)
1000	5.41	3.55E-03	-	-	5.41	3.55E-03	-	-
750	3.46	1.23E-04	1.43	4.82E-04	2.45	3.03E-04	1.44	2.54E-04
500	0		0		0		-	
375	0		0		0		-	
250	0		-		0		-	
187.5	0		-		0		-	

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