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APPENDICES

Appendix A Determination of Water Content in Bacterial Cellulose sheets

Table A1 Raw data of BC weight and water content in BC sheets

Sample No.	Wet weight (mg)	Dry weight (mg)	% Water content
1	7538.10	103.40	98.63
2	8530.60	104.20	98.78
3	9165.30	122.40	98.66
4	8564.20	113.90	98.67
5	8863.90	114.60	98.71
6	9037.80	119.20	98.68
7	8081.80	111.10	98.63
8	8321.50	115.10	98.62
9	8753.20	117.70	98.66
10	9001.10	119.90	98.67
11	8561.90	110.20	98.71
12	7329.90	100.10	98.63
13	8247.10	112.40	98.64
14	8569.90	116.10	98.65
15	8976.70	115.50	98.71
16	8488.80	114.30	98.65
17	7929.00	110.10	98.61
18	8199.30	114.10	98.61
19	8290.30	120.10	98.55
20	8998.50	120.00	98.67
Average			98.66
STD			0.05

Appendix B Determination of Ohmic Linear Regime

Linear regime or ohmic regime is the regime that applied voltage depends directly on the applied current according to ohmic law in equation (B1)

In this work, linear regime was determined by plotting applied voltage (V_0) versus current (I). The range that gives the straight line is acceptable for using in conductivity measurement. Figure B1 is the plot between V_0 versus I of the silicon wafer, as a standard material, using custom built two-point probe.

$$V_0 = IR \quad (\text{B1})$$

where V_0 = applied voltage (V)

I = current (A)

R = resistance (Ω)

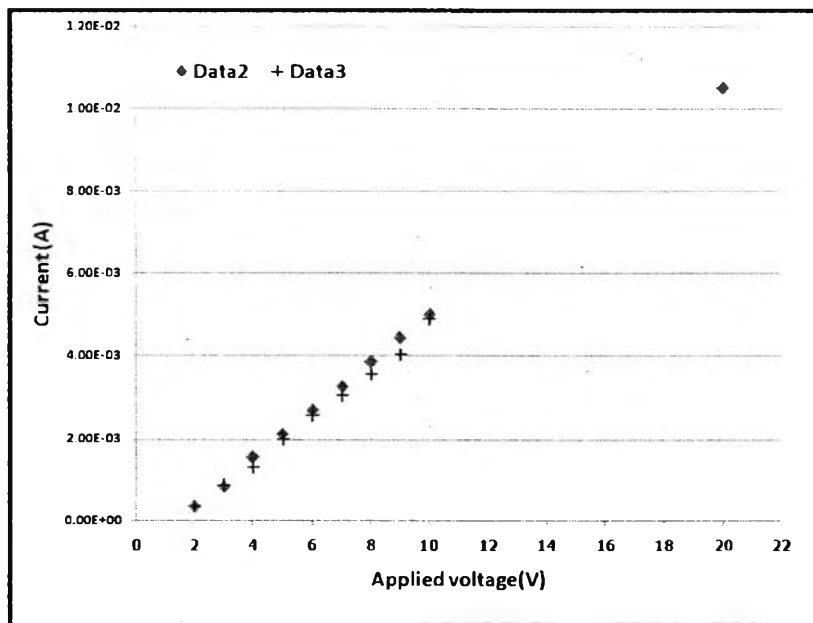


Figure B1 Linear regime of V_0 and I of the silicon wafer, which was used as a standard material, obtained by the custom built two-point probe.

According to Figure B1, straight line is indicated the range of applied voltage and current corresponding to the ohmic law. The accepted range of those for using in conductivity measurement are 2 to 20 Volt.

Table B1 Raw data of determination of linear regime from silicon wafer by using custom built two-point probe

Applied voltage (V)	Current (A ₂)	Current (A ₃)
20	0.010526	-
10	0.004999	0.004894
9	0.004446	0.004054
8	0.003873	0.00359
7	0.003295	0.003076
6	0.002717	0.002581
5	0.002143	0.002007
4	0.001567	0.001330
3	0.000869	0.000885
2	0.000345	0.000357

Appendix C Determination of Geometric Correlation Factor (K) of Custom Built Two-Point Probe

Geometric correction factor (K) is a correction that takes into account of geometric effects. K factor can be determined by using the following equation (C1).

$$K = \frac{\rho_{ref} \times I}{t \times V} \quad (C1)$$

Where	K	=	geometric correction factor
	ρ_{ref}	=	resistivity of standard material ($\Omega \cdot \text{cm}$)
	R	=	resistivity (Ω)
	t	=	sheet thickness (cm)
	V	=	applied voltage (V)
	I	=	current (A)

The silicon wafer with known resistivity per thickness of 107.373Ω was used as a standard material for the determination of geometric correction factor (K).

Table C1 Raw data of determination of the geometric correction factor (K) from silicon wafer, as a standard material

Applied voltage (V)	Current (A2)	Current (A3)	K2	K3	Average
20	1.0526×10^{-2}	-	4.9017×10^{-6}		4.9017×10^{-6}
10	4.9991×10^{-3}	4.8938×10^{-3}	4.6558×10^{-6}	4.5577×10^{-6}	4.6068×10^{-6}
9	4.4459×10^{-3}	4.0537×10^{-3}	4.6006×10^{-6}	4.1948×10^{-6}	4.3977×10^{-6}
8	3.8732×10^{-3}	3.5905×10^{-3}	4.5090×10^{-6}	4.1799×10^{-6}	4.3444×10^{-6}
7	3.2945×10^{-3}	3.0762×10^{-3}	4.3833×10^{-6}	4.0928×10^{-6}	4.2381×10^{-6}
6	2.7174×10^{-3}	2.5808×10^{-3}	4.2180×10^{-6}	4.0060×10^{-6}	4.1120×10^{-6}
5	2.1432×10^{-3}	2.0068×10^{-3}	3.9920×10^{-6}	3.7380×10^{-6}	3.8650×10^{-6}
4	1.5669×10^{-3}	1.3302×10^{-3}	3.6483×10^{-6}	3.0971×10^{-6}	3.3727×10^{-6}
3	8.6855×10^{-3}	8.8462×10^{-3}	2.6963×10^{-6}	2.7462×10^{-6}	2.7213×10^{-6}
2	3.4502×10^{-4}	3.5708×10^{-3}	1.6066×10^{-6}	1.6628×10^{-6}	1.6347×10^{-6}
Average					3.8194×10^{-6}
SD					9.9121×10^{-7}

According to Figure B1, the accepted range for using in conductivity measurement of silicon wafer covered the range of applied voltage from 2 to 20 V. Therefore, the geometric correction factor (K) for the conductive samples of custom built two-point probe is 3.8194×10^{-6}

Appendix D Conductivity Measurement of BC Sheets

Table D1 Raw data of conductivity measurement of bacterial cellulose

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (mm)	V(V)	I(A)	σ (S/cm)
1	6.833	4	2.02×10^{-11}	1.93×10^{-4}	2	6.500	4	2.62×10^{-11}	2.64×10^{-4}
		3	1.44×10^{-11}	1.84×10^{-4}			3	1.84×10^{-11}	2.47×10^{-4}
		2	8.92×10^{-11}	1.71×10^{-4}			2	1.13×10^{-11}	2.27×10^{-4}
		1	3.86×10^{-12}	1.48×10^{-4}			1	4.52×10^{-11}	1.82×10^{-4}
		0.9	3.41×10^{-12}	1.45×10^{-4}			0.9	3.90×10^{-12}	1.74×10^{-4}
		0.8	2.95×10^{-12}	1.41×10^{-4}			0.8	3.30×10^{-12}	1.66×10^{-4}
		0.7	2.46×10^{-12}	1.35×10^{-4}			0.7	2.70×10^{-12}	1.56×10^{-4}
		0.6	1.98×10^{-12}	1.26×10^{-4}			0.6	2.14×10^{-12}	1.43×10^{-4}
		0.5	1.51×10^{-12}	1.16×10^{-4}			0.5	1.46×10^{-12}	1.17×10^{-4}
		0.4	1.06×10^{-12}	1.02×10^{-4}			0.4	8.31×10^{-13}	8.36×10^{-5}
		0.3	6.51×10^{-13}	8.32×10^{-5}			0.3	3.50×10^{-13}	4.70×10^{-5}

No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.700	4	2.26×10^{-11}	2.21×10^{-4}
		3	1.67×10^{-11}	2.18×10^{-4}
		2	1.07×10^{-11}	2.09×10^{-4}
		1	4.54×10^{-12}	1.78×10^{-4}
		0.9	4.11×10^{-12}	1.79×10^{-4}
		0.8	3.64×10^{-12}	1.78×10^{-4}
		0.7	3.10×10^{-12}	1.73×10^{-4}
		0.6	2.60×10^{-12}	1.69×10^{-4}
		0.5	2.45×10^{-12}	1.92×10^{-4}
		0.4	1.92×10^{-12}	1.88×10^{-4}
		0.3	8.07×10^{-13}	1.05×10^{-4}

Average electrical conductivity 1.65×10^{-4} S/cm

Standard deviation 5.18×10^{-5}

Appendix E Conductivity Measurement of Bacterial Cellulose Sheets Containing Polyaniline in Doped and Un-Doped states

Table E1 Raw data of conductivity measurement of BC sheets containing PANI with 15% wt aniline monomer in doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.867	1	4.9×10^{-8}	1.87	2	7.700	1	9.46×10^{-8}	3.22
		0.9	4.44×10^{-8}	1.88			0.9	7.7×10^{-8}	2.91
		0.8	3.98×10^{-8}	1.90			0.8	7.01×10^{-8}	2.98
		0.7	3.51×10^{-8}	1.91			0.7	6.57×10^{-8}	3.19
		0.6	2.94×10^{-8}	1.87			0.6	5.48×10^{-8}	3.10
		0.5	2.43×10^{-8}	1.85			0.5	3.85×10^{-8}	2.62
		0.4	1.91×10^{-8}	1.82			0.4	2.42×10^{-8}	2.06
		0.3	1.39×10^{-8}	1.76			0.3	1.72×10^{-8}	1.95
		0.2	8.94×10^{-9}	1.70			0.2	9.15×10^{-8}	1.56
		0.1	4.18×10^{-9}	1.59			0.1	2.02×10^{-8}	6.87×10^{-1}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.100	0.9	4.23×10^{-8}	2.02	4	5.533	1	5.51×10^{-8}	2.61
		0.8	3.86×10^{-8}	2.07			0.9	4.99×10^{-8}	2.62
		0.7	3.37×10^{-8}	2.06			0.8	4.46×10^{-8}	2.64
		0.6	2.86×10^{-8}	2.04			0.7	3.93×10^{-8}	2.65
		0.5	2.44×10^{-8}	2.09			0.6	3.43×10^{-8}	2.71
		0.4	1.96×10^{-8}	2.10			0.5	2.92×10^{-8}	2.76
		0.3	1.55×10^{-8}	2.21			0.4	2.39×10^{-8}	2.83
		0.2	1.07×10^{-8}	2.30			0.3	5.89×10^{-8}	9.30×10^{-1}
		0.1	6.23×10^{-9}	2.68			0.2	3.63×10^{-9}	8.59×10^{-1}

Average electrical conductivity 2.29 S/cm

Standard deviation 0.52

Table E2 Raw data of conductivity measurement of BC sheets containing PANI with 20% wt aniline monomer in doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	4.800	2	9.49×10^{-8}	2.59	2	7.933	2	2.28E-07	3.75
		1	5.02×10^{-8}	2.74			1	1.18E-07	3.90
		0.9	4.60×10^{-8}	2.79			0.9	1.08E-07	3.95
		0.8	4.10×10^{-8}	2.80			0.8	9.38E-08	3.87
		0.7	3.68×10^{-8}	2.87			0.7	8.10E-08	3.82
		0.6	3.20×10^{-8}	2.91			0.6	6.98E-08	3.84
		0.5	2.70×10^{-8}	2.95			0.5	5.92E-08	3.91
		0.4	2.19×10^{-8}	2.98			0.4	4.74E-08	3.91
		0.3	1.69×10^{-8}	3.08			0.3	3.65E-08	4.02
		0.2	1.28×10^{-8}	3.50			0.2	2.55E-08	4.20
0.1	8.48×10^{-9}	4.62	0.1	1.53E-08	5.05				

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	5.167	2	9.49×10^{-8}	2.59	4	5.933	2	2.28×10^{-7}	3.75
		1	5.02×10^{-8}	2.74			1	1.18×10^{-7}	3.90
		0.9	4.60×10^{-8}	2.79			0.9	1.08×10^{-7}	3.95
		0.8	4.10×10^{-8}	2.80			0.8	9.38×10^{-8}	3.87
		0.7	3.68×10^{-8}	2.87			0.7	8.10×10^{-8}	3.82
		0.6	3.20×10^{-8}	2.91			0.6	6.98×10^{-8}	3.84
		0.5	2.70×10^{-8}	2.95			0.5	5.92×10^{-8}	3.91
		0.4	2.19×10^{-8}	2.98			0.4	4.74×10^{-8}	3.91
		0.3	1.69×10^{-8}	3.08			0.3	3.65×10^{-8}	4.02
		0.2	1.28×10^{-8}	3.50			0.2	2.55×10^{-8}	4.20
0.1	8.48×10^{-9}	4.62	0.1	1.53×10^{-8}	5.05				

Average electrical conductivity 3.16 S/cm

Standard deviation 0.69

Table E3 Raw data of conductivity measurement of BC sheets containing PANI with 25% wt aniline monomer in doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	4.870	1	6.28×10^{-8}	3.38	2	7.430	1	9.97×10^{-8}	3.51
		0.9	5.87×10^{-8}	3.51			0.9	8.87×10^{-8}	3.47
		0.8	5.40×10^{-8}	3.63			0.8	7.91×10^{-8}	3.48
		0.7	5.15×10^{-8}	3.96			0.7	6.79×10^{-8}	3.42
		0.6	4.74×10^{-8}	4.25			0.6	5.87×10^{-8}	3.45
		0.5	4.24×10^{-8}	4.57			0.5	4.95×10^{-8}	3.49
		0.4	3.66×10^{-8}	4.93			0.4	4.01×10^{-8}	3.53
		0.3	3.02×10^{-8}	5.42			0.3	3.03×10^{-8}	3.56
		0.2	2.38×10^{-8}	6.40			0.2	2.12×10^{-8}	3.73
		0.1	1.66×10^{-8}	8.95			0.1	1.25×10^{-8}	4.41

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	4.433	1	7.75×10^{-8}	4.58	4	5.933	1	8.90×10^{-8}	4.51
		0.9	6.80×10^{-8}	4.46			0.9	8.10×10^{-8}	4.56
		0.8	5.90×10^{-8}	4.35			0.8	7.15×10^{-8}	4.53
		0.7	5.23×10^{-8}	4.41			0.7	6.38×10^{-8}	4.62
		0.6	4.21×10^{-8}	4.14			0.6	5.58×10^{-8}	4.71
		0.5	3.09×10^{-8}	3.65			0.5	4.68×10^{-8}	4.75
		0.4	2.25×10^{-8}	3.32			0.4	3.82×10^{-8}	4.84
		0.3	1.54×10^{-8}	3.03			0.3	3.01×10^{-8}	5.08
		0.2	8.60×10^{-8}	2.54			0.2	2.14×10^{-8}	5.42
		0.1	2.44×10^{-8}	1.44			0.1	1.29×10^{-8}	6.52

Average electrical conductivity 4.16 S/cm

Standard deviation 1.20

Table E4 Raw data of conductivity measurement of BC sheets containing PANI with 30 % wt aniline monomer in doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.233	1	1.49×10^{-7}	6.25	2	6.567	0.8	1.74×10^{-7}	8.66
		0.9	1.43×10^{-7}	6.67			0.7	1.52×10^{-7}	8.64
		0.8	1.31×10^{-7}	6.87			0.6	1.40×10^{-7}	9.28
		0.7	1.19×10^{-7}	7.14			0.5	1.22×10^{-7}	9.75
		0.6	1.05×10^{-7}	7.35			0.4	9.62×10^{-8}	9.59
		0.5	9.10×10^{-7}	7.64			0.3	7.03×10^{-8}	9.34
		0.4	7.48×10^{-8}	7.86			0.2	4.59×10^{-8}	9.15
		0.3	6.00×10^{-8}	8.40					
		0.2	4.19×10^{-8}	8.79					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	5.167	2	1.74×10^{-7}	3.55	4	6.300	2	2.33×10^{-7}	4.85
		1	7.85×10^{-8}	4.19			1	1.14×10^{-7}	4.74
		0.9	7.38×10^{-8}	4.38			0.9	1.05×10^{-7}	4.86
		0.8	6.66×10^{-8}	4.45			0.8	9.55×10^{-8}	4.96
		0.7	5.89×10^{-8}	4.50			0.7	8.47×10^{-8}	5.03
		0.6	5.03×10^{-8}	4.48			0.6	7.29×10^{-8}	5.05
		0.5	4.15×10^{-8}	4.43			0.5	6.17×10^{-8}	5.13
		0.4	3.30×10^{-8}	4.40			0.4	5.06×10^{-8}	5.25
		0.3	2.43×10^{-8}	4.32			0.3	3.88×10^{-8}	5.37
		0.2	1.57×10^{-8}	4.18			0.2	2.71×10^{-8}	5.63

Average electrical conductivity 6.17 S/cm

Standard deviation 1.84

Table E5 Raw data of conductivity measurement of BC sheets containing PANI with 35% wt aniline monomer in doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.900	6	1.68×10^{-6}	10.64	2	6.733	6	7.35×10^{-7}	4.76
		5	1.34×10^{-6}	10.19			5	6.01×10^{-7}	4.68
		4	1.03×10^{-6}	9.72			4	4.83×10^{-7}	4.69
		3	7.23×10^{-7}	9.14			3	3.58×10^{-7}	4.64
		2	4.56×10^{-7}	8.65			2	2.41×10^{-7}	4.68
		1	1.84×10^{-7}	7.00			1	1.18×10^{-7}	4.59
		0.9	1.66×10^{-7}	6.99			0.9	1.10×10^{-7}	4.75
		0.8	1.48×10^{-7}	7.02			0.8	9.97×10^{-7}	4.84
		0.7	1.26×10^{-7}	6.84			0.7	9.18×10^{-8}	5.10
		0.6	1.08×10^{-7}	6.82			0.6	8.18×10^{-8}	5.30
		0.5	9.41×10^{-8}	7.14			0.5	6.92×10^{-8}	5.38
		0.4	6.93×10^{-8}	6.57			0.4	5.61×10^{-8}	5.45
0.3	4.94×10^{-8}	6.25	0.3	4.42×10^{-8}	5.74				

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.633	6	1.46×10^{-6}	9.59	4	4.467	6	3.23×10^{-7}	3.15
		5	1.25×10^{-6}	9.87			5	2.76×10^{-7}	3.24
		4	1.01×10^{-6}	9.93			4	2.28×10^{-7}	3.34
		3	7.49×10^{-7}	9.85			3	1.79×10^{-7}	3.50
		2	4.78×10^{-7}	9.43			2	1.15×10^{-7}	3.36
		1	2.21×10^{-7}	8.73			1	5.19×10^{-8}	3.04
		0.9	1.94×10^{-7}	8.51			0.9	4.63×10^{-8}	3.02
		0.8	1.68×10^{-7}	8.28			0.8	4.16×10^{-8}	3.05
		0.7	1.43×10^{-7}	8.05			0.7	3.64×10^{-8}	3.05
		0.6	1.18×10^{-7}	7.75			0.6	3.11×10^{-8}	3.03
		0.5	9.46×10^{-8}	7.47			0.5	2.56×10^{-8}	3.00
		0.4	7.35×10^{-8}	7.25			0.4	2.02×10^{-8}	2.96
0.3	5.37×10^{-8}	7.07	0.3	1.46×10^{-8}	2.85				

Average electrical conductivity 6.00 S/cm

Standard deviation 2.46

Table E6 Raw data of conductivity measurement of BC sheets containing PANI with 40% wt aniline monomer in doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.600	6	7.29×10^{-7}	5.68	2	6.400	6	7.97×10^{-7}	5.43
		5	6.05×10^{-7}	5.65			5	6.40×10^{-7}	5.24
		4	4.81×10^{-7}	5.63			4	4.81×10^{-7}	4.92
		3	3.59×10^{-7}	5.60			3	3.48×10^{-7}	4.74
		2	2.31×10^{-7}	5.40			2	1.91×10^{-7}	3.92
		1	9.51×10^{-8}	4.45			1	1.48×10^{-7}	6.04
		0.9	9.31×10^{-8}	4.84			0.9	1.34×10^{-7}	6.10
		0.8	7.76×10^{-8}	4.54			0.8	1.25×10^{-7}	6.40
		0.7	6.60×10^{-8}	4.41			0.7	1.03×10^{-7}	6.05
		0.6	5.18×10^{-8}	4.03			0.6	8.32×10^{-8}	5.67

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.100	4	5.79×10^{-7}	6.21	4	5.200	1	1.13×10^{-7}	5.68
		3	4.36×10^{-7}	6.23			0.9	9.97×10^{-8}	5.58
		2	3.07×10^{-7}	6.59			0.8	8.73×10^{-8}	5.49
		1	1.62×10^{-7}	6.97			0.7	7.63×10^{-8}	5.49
		0.9	1.43×10^{-7}	6.83			0.6	6.71×10^{-8}	5.63
		0.8	1.25×10^{-7}	6.71			0.5	5.59×10^{-8}	5.63
		0.7	1.11×10^{-7}	6.83			0.4	4.43×10^{-8}	5.58
		0.6	9.93×10^{-8}	7.10			0.3	3.37×10^{-8}	5.66
		0.5	8.77×10^{-8}	7.53			0.2	2.30×10^{-8}	5.80
		0.4	7.42×10^{-8}	7.97			0.1	1.14×10^{-8}	5.76

Average electrical conductivity 5.73 S/cm

Standard deviation 0.86

Table E7 Raw data of conductivity measurement of BC sheets containing PANI with 15% wt aniline monomer in un-doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.667	10	9.88×10^{-11}	4.56×10^{-4}	2	5.533	10	1.90×10^{-10}	8.99×10^{-4}
		9	9.98×10^{-11}	5.12×10^{-4}			9	1.62×10^{-10}	8.51×10^{-4}
		8	8.59×10^{-11}	4.96×10^{-4}			8	1.34×10^{-10}	7.92×10^{-4}
		7	7.47×10^{-11}	4.93×10^{-4}			7	1.06×10^{-10}	7.14×10^{-4}
		6	6.30×10^{-11}	4.85×10^{-4}			6	8.50×10^{-10}	6.70×10^{-4}
		5	5.36×10^{-11}	4.96×10^{-4}			5	6.38×10^{-10}	6.04×10^{-4}
		4	3.82×10^{-11}	4.41×10^{-4}			4	4.70×10^{-10}	5.56×10^{-4}
		3	3.09×10^{-11}	4.75×10^{-4}			3	2.02×10^{-10}	3.18×10^{-4}
		2	1.90×10^{-11}	4.38×10^{-4}			2	1.12×10^{-10}	2.65×10^{-4}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.233	10	1.07×10^{-10}	4.49×10^{-4}	4	3.633	9	3.61×10^{-11}	2.89×10^{-4}
		9	9.39×10^{-11}	4.38×10^{-4}			8	3.14×10^{-11}	2.83×10^{-4}
		8	7.96×10^{-11}	4.18×10^{-4}			7	2.44×10^{-11}	2.52×10^{-4}
		7	7.09×10^{-11}	4.25×10^{-4}			6	1.93×10^{-11}	2.32×10^{-4}
		6	5.53×10^{-11}	3.87×10^{-4}			5	1.40×10^{-11}	2.02×10^{-4}
		5	4.66×10^{-11}	3.91×10^{-4}			4	1.10×10^{-11}	1.98×10^{-4}
		4	3.50×10^{-11}	3.68×10^{-4}					
		3	2.58×10^{-11}	3.62×10^{-4}					
		2	1.41×10^{-11}	2.96×10^{-4}					

Average electrical conductivity 4.53×10^{-4} S/cm

Standard deviation 1.78×10^{-4}

Table E8 Raw data of conductivity measurement of BC sheets containing PANI with 20% wt aniline monomer in un-doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.633	10	3.76×10^{-11}	1.75×10^{-4}	2	5.367	20	2.27×10^{-10}	5.54×10^{-4}
		9	3.53×10^{-11}	1.82×10^{-4}			10	1.04×10^{-10}	5.06×10^{-4}
		8	3.39×10^{-11}	1.97×10^{-4}			9	9.55×10^{-11}	5.18×10^{-4}
		7	3.06×10^{-11}	2.03×10^{-4}			8	8.41×10^{-11}	5.13×10^{-4}
		6	2.76×10^{-11}	2.14×10^{-4}			7	7.35×10^{-11}	5.12×10^{-4}
		5	2.45×10^{-11}	2.28×10^{-4}			6	6.29×10^{-11}	5.11×10^{-4}
		4	2.25×10^{-11}	2.62×10^{-4}			5	5.19×10^{-11}	5.06×10^{-4}
		3	2.02×10^{-11}	3.13×10^{-4}			4	4.11×10^{-11}	5.01×10^{-4}
		2	1.74×10^{-11}	4.05×10^{-4}			3	3.24×10^{-11}	5.28×10^{-4}
		1	1.57×10^{-11}	7.28×10^{-4}			2	2.08×10^{-11}	5.08×10^{-4}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.267	30	2.52×10^{-10}	3.51×10^{-4}	4	4.167	40	6.66×10^{-10}	1.05×10^{-3}
		20	1.45×10^{-10}	3.02×10^{-4}			30	4.54×10^{-10}	9.50×10^{-4}
		10	6.66×10^{-11}	2.78×10^{-4}			20	3.14×10^{-10}	9.85×10^{-4}
		9	6.19×10^{-11}	2.87×10^{-4}			10	1.40×10^{-10}	8.82×10^{-4}
		8	5.70×10^{-11}	2.98×10^{-4}			9	1.27×10^{-10}	8.84×10^{-4}
		7	5.16×10^{-11}	3.08×10^{-4}			8	1.05×10^{-10}	8.23×10^{-4}
		6	4.60×10^{-11}	3.21×10^{-4}			7	8.64×10^{-11}	7.75×10^{-4}
		5	3.99×10^{-11}	3.33×10^{-4}			6	6.68×10^{-11}	7.00×10^{-4}
		4	3.30×10^{-11}	3.45×10^{-4}			5	5.03×10^{-11}	6.32×10^{-4}
		3	2.64×10^{-11}	3.67×10^{-4}			4	3.65×10^{-11}	5.73×10^{-4}
		2	2.09×10^{-11}	4.36×10^{-4}			3	2.60×10^{-11}	5.45×10^{-4}

Average electrical conductivity 4.89×10^{-4} S/cm

Standard deviation 2.34×10^{-4}

Table E9 Raw data of conductivity measurement of BC sheets containing PANI with 25% wt aniline monomer in un-doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.967	60	1.21×10^{-9}	8.82×10^{-4}	2	5.833	60	1.11×10^{-9}	8.29×10^{-4}
		50	8.51×10^{-10}	7.47×10^{-4}			50	7.58×10^{-10}	6.80×10^{-4}
		40	5.29×10^{-10}	5.81×10^{-4}			40	4.98×10^{-10}	5.59×10^{-4}
		30	3.09×10^{-10}	4.51×10^{-4}			30	2.94×10^{-10}	4.40×10^{-4}
		20	1.58×10^{-10}	3.46×10^{-4}			20	1.55×10^{-10}	3.47×10^{-4}
		10	3.36×10^{-11}	1.48×10^{-4}			10	2.67×10^{-11}	1.20×10^{-4}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	5.133	60	9.75×10^{-10}	8.29×10^{-4}	4	5.000	60	1.10×10^{-9}	9.63×10^{-4}
		50	6.37×10^{-10}	6.50×10^{-4}			50	7.72×10^{-10}	8.08×10^{-4}
		40	3.95×10^{-10}	5.03×10^{-4}			40	4.96×10^{-10}	6.49×10^{-4}
		30	2.29×10^{-10}	3.89×10^{-4}			30	2.99×10^{-10}	5.22×10^{-4}
		20	1.11×10^{-10}	2.83×10^{-4}			20	1.59×10^{-10}	4.16×10^{-4}
		10	1.51×10^{-11}	7.72×10^{-5}			10	3.42×10^{-11}	1.79×10^{-4}

Average electrical conductivity 5.17×10^{-4} S/cm

Standard deviation 2.54×10^{-4}

Table E10 Raw data of conductivity measurement of BC sheets containing PANI with 30% wt aniline monomer in un-doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	4.633	90	1.08×10^{-9}	6.84×10^{-4}	2	4.767	90	1.06×10^{-9}	6.50×10^{-4}
		80	9.47×10^{-10}	6.69×10^{-4}			80	7.92×10^{-10}	5.44×10^{-4}
		70	7.84×10^{-10}	6.33×10^{-4}			70	5.91×10^{-10}	4.64×10^{-4}
		60	6.22×10^{-10}	5.86×10^{-4}			60	4.27×10^{-10}	3.91×10^{-4}
		50	5.16×10^{-10}	5.83×10^{-4}			50	2.94×10^{-10}	3.23×10^{-4}
		40	3.98×10^{-10}	5.62×10^{-4}			40	2.07×10^{-10}	2.85×10^{-4}
		30	2.97×10^{-10}	5.60×10^{-4}			30	1.84×10^{-10}	3.37×10^{-4}
		20	1.82×10^{-10}	5.14×10^{-4}			20	1.25×10^{-10}	3.43×10^{-4}
		10	1.02×10^{-10}	5.76×10^{-4}					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.100	60	1.23×10^{-9}	8.78×10^{-4}	4	5.467	80	1.05×10^{-9}	6.29×10^{-4}
		50	8.38×10^{-10}	7.20×10^{-4}			70	9.15×10^{-10}	6.26×10^{-4}
		40	6.49×10^{-10}	6.96×10^{-4}			60	7.96×10^{-10}	6.36×10^{-4}
		30	6.89×10^{-10}	9.86×10^{-4}			50	6.89×10^{-10}	6.60×10^{-4}
		20	3.52×10^{-10}	7.56×10^{-4}			40	4.64×10^{-10}	5.56×10^{-4}
		10	1.26×10^{-10}	5.41×10^{-4}			30	3.36×10^{-10}	5.37×10^{-4}
				20			2.04×10^{-10}	4.89×10^{-4}	
				10			1.01×10^{-10}	4.82×10^{-4}	

Average electrical conductivity 5.75×10^{-4} S/cm

Standard deviation 1.55×10^{-4}

Table E11 Raw data of conductivity measurement of BC sheets containing PANI with 35% wt aniline monomer in un-doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.400	100	1.18×10^{-9}	4.83×10^{-4}	2	6.167	100	1.85×10^{-9}	7.86×10^{-4}
		90	1.12×10^{-9}	5.09×10^{-4}			90	1.63×10^{-9}	7.71×10^{-4}
		80	9.71×10^{-10}	4.96×10^{-4}			80	1.35×10^{-9}	7.15×10^{-4}
		70	8.25×10^{-10}	4.82×10^{-4}			70	1.06×10^{-9}	6.43×10^{-4}
		60	6.61×10^{-10}	4.51×10^{-4}			60	7.97×10^{-10}	5.64×10^{-4}
		50	5.13×10^{-10}	4.20×10^{-4}			50	5.79×10^{-10}	4.92×10^{-4}
		40	3.57×10^{-10}	3.65×10^{-4}			40	3.89×10^{-10}	4.13×10^{-4}
		30	2.32×10^{-10}	3.16×10^{-4}			30	2.35×10^{-10}	3.32×10^{-4}
		20	1.24×10^{-10}	2.54×10^{-4}			20	1.16×10^{-10}	2.46×10^{-4}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	4.967	100	1.50×10^{-9}	7.93×10^{-4}	4	6.367	100	2.15×10^{-9}	8.83×10^{-4}
		90	1.32×10^{-9}	7.74×10^{-4}			90	1.79×10^{-9}	8.19×10^{-4}
		80	1.14×10^{-9}	7.50×10^{-4}			80	1.50×10^{-9}	7.69×10^{-4}
		70	9.20×10^{-10}	6.93×10^{-4}			70	1.20×10^{-9}	7.05×10^{-4}
		60	7.24×10^{-10}	6.36×10^{-4}			60	9.37×10^{-10}	6.42×10^{-4}
		50	5.44×10^{-10}	5.74×10^{-4}			50	6.84×10^{-10}	5.63×10^{-4}
		40	3.80×10^{-10}	5.01×10^{-4}			40	4.62×10^{-10}	4.75×10^{-4}
		30	2.41×10^{-10}	4.24×10^{-4}			30	2.85×10^{-10}	3.91×10^{-4}
		20	1.29×10^{-10}	3.41×10^{-4}			20	1.60×10^{-10}	3.30×10^{-4}
		10	5.13×10^{-11}	2.71×10^{-4}			10	8.23×10^{-11}	3.38×10^{-4}

Average electrical conductivity 5.37×10^{-4} S/cm

Standard deviation 1.81×10^{-4}

Table E12 Raw data of conductivity measurement of BC sheets containing PANI with 40% wt aniline monomer in un-doped state

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	7.100	10	2.49×10^{-10}	9.17×10^{-4}	2	6.367	8	1.37×10^{-10}	7.05×10^{-4}
		9	2.11×10^{-10}	8.64×10^{-4}			7	9.36×10^{-11}	5.50×10^{-4}
		8	1.71×10^{-10}	7.88×10^{-4}			6	6.28×10^{-11}	4.30×10^{-4}
		7	1.38×10^{-10}	7.28×10^{-4}			5	3.98×10^{-11}	3.27×10^{-4}
		6	1.06×10^{-10}	6.50×10^{-4}			4	2.42×10^{-11}	2.48×10^{-4}
		5	8.18×10^{-11}	6.03×10^{-4}			3	1.33×10^{-11}	1.83×10^{-4}
		4	5.65×10^{-11}	5.21×10^{-4}			2	6.25×10^{-12}	1.29×10^{-4}
		3	3.70×10^{-11}	4.55×10^{-4}					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.200	8	1.33×10^{-10}	7.04×10^{-4}	4	5.167	7	7.71×10^{-11}	5.48×10^{-4}
		7	9.44×10^{-11}	5.69×10^{-4}			6	6.64×10^{-11}	5.50×10^{-4}
		6	6.46×10^{-11}	4.55×10^{-4}			5	5.37×10^{-11}	5.34×10^{-4}
		5	4.10×10^{-11}	3.46×10^{-4}			4	4.39×10^{-11}	5.46×10^{-4}
		4	2.13×10^{-11}	2.25×10^{-4}			3	3.50×10^{-11}	5.79×10^{-4}
		3	1.02×10^{-11}	1.43×10^{-4}			2	2.61×10^{-11}	6.49×10^{-4}

Average electrical conductivity 5.32×10^{-4} S/cm

Standard deviation 2.01×10^{-4}

Appendix F Conductivity Measurement of Bacterial Cellulose Sheets Containing Polyaniline at Different Impregnation Time

Table F1 Raw data of conductivity measurement of BC sheets containing PANI at impregnation time 0.5 h

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.233	1	1.49×10^{-7}	6.25	2	6.567	0.8	1.74×10^{-7}	8.66
		0.9	1.43×10^{-7}	6.67			0.7	1.52×10^{-7}	8.64
		0.8	1.31×10^{-7}	6.87			0.6	1.40×10^{-7}	9.28
		0.7	1.19×10^{-7}	7.14			0.5	1.22×10^{-7}	9.75
		0.6	1.05×10^{-7}	7.35			0.4	9.62×10^{-8}	9.59
		0.5	9.10×10^{-8}	7.64			0.3	7.03×10^{-8}	9.34
		0.4	7.48×10^{-8}	7.86			0.2	4.59×10^{-8}	9.15
		0.3	6.00×10^{-8}	8.40					
		0.2	4.19×10^{-8}	8.79					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.400	2	1.74×10^{-7}	3.55	4	6.300	2	2.33×10^{-7}	4.85
		1	7.85×10^{-8}	4.19			1	1.14×10^{-7}	4.74
		0.9	7.38×10^{-8}	4.38			0.9	1.05×10^{-7}	4.86
		0.8	6.66×10^{-8}	4.45			0.8	9.55×10^{-8}	4.96
		0.7	5.89×10^{-8}	4.50			0.7	8.47×10^{-8}	5.03
		0.6	5.03×10^{-8}	4.48			0.6	7.29×10^{-8}	5.05
		0.5	4.15×10^{-8}	4.43			0.5	6.17×10^{-8}	5.13
		0.4	3.30×10^{-8}	4.40			0.4	5.06×10^{-8}	5.25
		0.3	2.43×10^{-8}	4.32			0.3	3.88×10^{-8}	5.37
		0.2	1.57×10^{-8}	4.18			0.2	2.71×10^{-8}	5.63

Average electrical conductivity 6.17 S/cm

Standard deviation 1.84

Table F2 Raw data of conductivity measurement of BC sheets containing PANI at impregnation time 3 h

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	7.133	0.7	1.94×10^{-7}	10.19	2	6.300	0.3	1.25×10^{-7}	17.29
		0.6	1.60×10^{-7}	9.78			0.2	7.17×10^{-8}	14.91
		0.5	1.31×10^{-7}	9.65			0.1	2.64×10^{-8}	10.96
		0.4	1.00×10^{-7}	9.20			0.09	2.32×10^{-8}	10.71
		0.3	6.82×10^{-8}	8.34			0.08	1.94×10^{-8}	10.07
		0.2	3.83×10^{-8}	7.03			0.07	1.44×10^{-8}	8.55
		0.1	1.01×10^{-8}	3.69			0.06	1.08×10^{-8}	7.51
		0.09	8.35×10^{-9}	3.40			0.05	6.97×10^{-8}	5.79
		0.08	5.56×10^{-9}	2.55			0.04	4.48×10^{-8}	4.65
						0.03	1.80×10^{-9}	2.50	

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	7.000	0.09	2.18×10^{-8}	9.04	4	7.033	0.1	2.37×10^{-8}	8.84
		0.08	1.82×10^{-8}	8.51			0.09	2.07×10^{-8}	8.58
		0.07	1.55×10^{-8}	8.28			0.08	1.74×10^{-8}	8.08
		0.06	1.29×10^{-8}	8.03			0.07	1.47×10^{-8}	7.83
		0.05	9.62×10^{-9}	7.20			0.06	1.20×10^{-8}	7.46
		0.04	7.24×10^{-9}	6.77			0.05	8.91×10^{-9}	6.63
		0.03	4.45×10^{-9}	5.54			0.04	6.91×10^{-9}	6.43
		0.02	1.63×10^{-9}	3.05			0.03	5.15×10^{-9}	6.39
						0.02	2.81×10^{-9}	5.23	

Average electrical conductivity 7.74 S/cm

Standard deviation 3.08

Table F3 Raw data of conductivity measurement of BC sheets containing PANI at impregnation time 6 h

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.767	0.08	2.63×10^{-8}	14.94	2	6.300	0.3	1.23×10^{-7}	16.98
		0.07	2.20×10^{-8}	14.30			0.2	6.74×10^{-8}	14.01
		0.06	1.83×10^{-8}	13.85			0.1	2.14×10^{-8}	8.88
		0.05	1.28×10^{-8}	11.61			0.09	1.41×10^{-8}	6.50
		0.04	9.23×10^{-9}	10.47			0.08	1.09×10^{-8}	5.68
		0.03	6.28×10^{-9}	9.51			0.07	8.92×10^{-9}	5.29
		0.02	3.61×10^{-9}	8.18			0.06	6.41×10^{-9}	4.44
		0.01	1.95×10^{-9}	8.83			0.05	3.84×10^{-9}	3.19

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.733	0.1	2.42×10^{-8}	9.41	4	6.300	0.3	1.21×10^{-7}	16.83
		0.09	2.00×10^{-8}	8.64			0.2	6.74×10^{-8}	14.02
		0.08	1.67×10^{-8}	8.14			0.1	2.16×10^{-8}	8.98
		0.07	1.34×10^{-8}	7.43			0.09	1.81×10^{-8}	8.36
		0.06	1.13×10^{-8}	7.34			0.08	1.22×10^{-8}	6.35
		0.05	6.45×10^{-8}	5.01			0.07	7.99×10^{-9}	4.74
		0.04	3.01×10^{-9}	2.93			0.06	5.59×10^{-9}	3.87
		0.03	5.19×10^{-10}	0.67			0.05	1.15×10^{-9}	0.95

Average electrical conductivity 8.45 S/cm

Standard deviation 4.37

Appendix G Conductivity Measurement of BC Sheets Containing PANI, which was Polymerized from 30 % wt of Aniline Monomer in Different Relative Humidity

Table G1 Raw data of conductivity measurement of BC sheets containing PANI at 11.3 %RH

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	4.225	0.09	3.55×10^{-9}	1.84	2	5.525	0.09	3.89×10^{-9}	2.05
		0.08	3.20×10^{-9}	1.87			0.08	3.21×10^{-9}	1.90
		0.07	2.76×10^{-9}	1.85			0.07	2.66×10^{-9}	1.80
		0.06	2.44×10^{-9}	1.90			0.06	2.16×10^{-9}	1.70
		0.05	2.17×10^{-9}	2.03			0.05	1.61×10^{-9}	1.53
		0.04	1.93×10^{-9}	2.26			0.04	1.12×10^{-9}	1.32
		0.03	1.76×10^{-9}	2.74			0.03	8.14×10^{-10}	1.28
						0.02	5.87×10^{-10}	1.39	
						0.01	4.57×10^{-10}	2.17	

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	4.200	0.09	3.95×10^{-9}	2.74	4	4.275	0.09	2.94×10^{-9}	2.00
		0.08	3.27×10^{-9}	2.55			0.08	2.38×10^{-9}	1.82
		0.07	2.79×10^{-9}	2.48			0.07	1.90×10^{-9}	1.66
		0.06	2.38×10^{-9}	2.47			0.06	1.48×10^{-9}	1.51
		0.05	2.00×10^{-9}	2.49			0.05	1.09×10^{-9}	1.33
		0.04	1.72×10^{-9}	2.68			0.04	8.22×10^{-10}	1.26
		0.03	1.50×10^{-9}	3.11			0.03	6.06×10^{-10}	1.23
		0.02	1.30×10^{-9}	4.04			0.02	4.32×10^{-10}	1.32
						0.01	3.29×10^{-10}	2.01	

Average electrical conductivity 2.02 S/cm

Standard deviation 0.61

Table G2 Raw data of conductivity measurement of BC sheets containing PANI at 43.2 %RH

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	3.875	0.7	2.93×10^{-8}	2.82	2	3.575	0.9	2.02×10^{-7}	16.43
		0.6	2.41×10^{-8}	2.71			0.8	1.58×10^{-7}	14.43
		0.5	2.00×10^{-8}	2.70			0.7	1.24×10^{-7}	12.94
		0.4	1.55×10^{-8}	2.62			0.6	8.91×10^{-8}	10.86
		0.3	1.11×10^{-8}	2.49			0.5	6.25×10^{-8}	9.15
		0.2	6.45×10^{-8}	2.17			0.4	4.15×10^{-8}	7.60
		0.1	2.59×10^{-9}	1.74			0.3	2.43×10^{-8}	5.93
		0.09	2.25×10^{-9}	1.69			0.2	1.08×10^{-8}	3.96

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	3.175	0.3	2.27×10^{-8}	6.24	4	3.575	0.3	7.98×10^{-8}	12.44
		0.2	1.41×10^{-8}	5.82			0.2	4.43×10^{-8}	10.35
		0.1	6.35×10^{-9}	5.23			0.1	1.80×10^{-8}	8.42
		0.09	5.54×10^{-9}	5.07			0.09	1.37×10^{-8}	7.11
		0.08	4.74×10^{-9}	4.88			0.08	1.01×10^{-8}	5.89
		0.07	3.97×10^{-9}	4.67			0.07	7.45×10^{-8}	4.98
		0.06	3.20×10^{-9}	4.38			0.06	5.48×10^{-8}	4.27
		0.05	2.29×10^{-9}	3.77			0.05	3.75×10^{-9}	3.51
		0.04	1.73×10^{-9}	3.56			0.04	2.63×10^{-9}	3.08

Average electrical conductivity 4.80 S/cm

Standard deviation 2.65

Table G3 Raw data of conductivity measurement of BC sheets containing PANI at 75.6 %RH

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	3.400	0.2	2.61×10^{-8}	10.06	2	4.075	0.2	4.17×10^{-8}	13.38
		0.1	1.14×10^{-8}	8.77			0.1	1.75×10^{-8}	11.24
		0.09	9.07×10^{-9}	7.76			0.09	1.34×10^{-8}	9.58
		0.08	7.36×10^{-9}	7.09			0.08	1.01×10^{-8}	8.07
		0.07	6.02×10^{-9}	6.62			0.07	7.32×10^{-9}	6.71
		0.06	4.93×10^{-9}	6.33			0.06	5.29×10^{-9}	5.66
		0.05	3.87×10^{-9}	5.96			0.05	3.66×10^{-9}	4.70
		0.04	3.14×10^{-9}	6.04			0.04	2.67×10^{-9}	4.28
		0.03	2.51×10^{-9}	6.44					
		0.02	1.98×10^{-9}	7.60					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	4.650	0.2	2.34×10^{-8}	6.60	4	4.575	0.4	4.27×10^{-8}	6.11
		0.1	1.03×10^{-8}	5.79			0.3	3.24×10^{-8}	6.17
		0.09	8.17×10^{-9}	5.11			0.2	2.25×10^{-8}	6.43
		0.08	6.43×10^{-9}	4.53			0.1	1.53×10^{-8}	8.74
		0.07	5.08×10^{-9}	4.08			0.09	1.53×10^{-8}	9.69
		0.06	3.91×10^{-9}	3.67			0.08	1.48×10^{-8}	10.59
		0.05	2.76×10^{-9}	3.11			0.07	1.42×10^{-8}	11.57
		0.04	2.02×10^{-9}	2.85			0.06	1.38×10^{-8}	13.12
		0.03	1.43×10^{-9}	2.69			0.05	1.39×10^{-8}	15.92

Average electrical conductivity 7.06 S/cm

Standard deviation 2.78

Appendix H Conductivity Measurement of BC Sheets Containing Fe₃O₄ at Different Initial Concentration of Iron Precursors (Fe²⁺ and Fe³⁺)

Table H1 Raw data of conductivity measurement of BC sheets containing containing Fe₃O₄ at 0.01 M initial concentration

No.	L (μm)	V (V)	I (A)	σ(S/cm)	No.	L (μm)	V (V)	I (A)	σ(S/cm)
1	4.900	10	1.03×10 ⁻¹⁰	5.52×10 ⁻⁴	2	5.433	9	9.62×10 ⁻¹¹	5.15×10 ⁻⁴
		9	8.24×10 ⁻¹¹	4.89×10 ⁻⁴			8	6.55×10 ⁻¹¹	3.94×10 ⁻⁴
		8	6.83×10 ⁻¹¹	4.56×10 ⁻⁴			7	4.60×10 ⁻¹¹	3.17×10 ⁻⁴
		7	5.70×10 ⁻¹¹	4.35×10 ⁻⁴			6	3.59×10 ⁻¹¹	2.88×10 ⁻⁴
		6	4.71×10 ⁻¹¹	4.19×10 ⁻⁴			5	2.10×10 ⁻¹¹	2.03×10 ⁻⁴
		5	3.96×10 ⁻¹¹	4.23×10 ⁻⁴			4	1.34×10 ⁻¹¹	1.61×10 ⁻⁴
		4	3.13×10 ⁻¹¹	4.18×10 ⁻⁴			3	8.70×10 ⁻¹²	1.40×10 ⁻⁴
		3	2.28×10 ⁻¹¹	4.06×10 ⁻⁴					
		2	1.48×10 ⁻¹¹	3.96×10 ⁻⁴					
		1	6.73×10 ⁻¹²	3.60×10 ⁻⁴					

No.	L (μm)	V (V)	I (A)	σ(S/cm)	No.	L (μm)	V (V)	I (A)	σ(S/cm)
3	5.567	10	1.95×10 ⁻¹⁰	9.16×10 ⁻⁴	4	5.900	8	1.04×10 ⁻¹⁰	5.79×10 ⁻⁴
		9	1.67×10 ⁻¹⁰	8.71×10 ⁻⁴			7	7.84×10 ⁻¹¹	4.97×10 ⁻⁴
		8	1.39×10 ⁻¹⁰	8.17×10 ⁻⁴			6	5.83×10 ⁻¹¹	4.31×10 ⁻⁴
		7	1.17×10 ⁻¹⁰	7.87×10 ⁻⁴			5	4.25×10 ⁻¹¹	3.77×10 ⁻⁴
		6	9.73×10 ⁻¹¹	7.62×10 ⁻⁴			4	2.98×10 ⁻¹¹	3.30×10 ⁻⁴
		5	7.95×10 ⁻¹¹	7.48×10 ⁻⁴			3	1.45×10 ⁻¹¹	2.14×10 ⁻⁴
		4	6.18×10 ⁻¹¹	7.27×10 ⁻⁴			2	9.46×10 ⁻¹²	2.10×10 ⁻⁴
		3	4.63×10 ⁻¹¹	7.26×10 ⁻⁴			1	3.89×10 ⁻¹²	1.73×10 ⁻⁴
		2	2.94×10 ⁻¹¹	6.90×10 ⁻⁴			0.9	3.29×10 ⁻¹²	1.62×10 ⁻⁴
		1	9.38×10 ⁻¹²	4.41×10 ⁻⁴			0.8	2.59×10 ⁻¹²	1.44×10 ⁻⁴
		0.9	8.49×10 ⁻¹²	4.44×10 ⁻⁴			0.7	1.92×10 ⁻¹²	1.22×10 ⁻⁴

Average electrical conductivity 4.38×10⁻⁴ S/cm

Standard deviation 2.15×10⁻⁴

Table H2 Raw data of conductivity measurement of BC sheets containing containing Fe_3O_4 at 0.05 M initial concentration

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.700	80	2.28×10^{-9}	1.11×10^{-3}	2	7.067	80	1.29×10^{-9}	5.97×10^{-4}
		70	1.76×10^{-9}	9.82×10^{-4}			70	1.25×10^{-9}	6.62×10^{-4}
		60	1.34×10^{-9}	8.74×10^{-4}			60	1.15×10^{-9}	7.12×10^{-4}
		50	9.94×10^{-10}	7.77×10^{-4}			50	8.46×10^{-10}	6.27×10^{-4}
		40	7.23×10^{-10}	7.07×10^{-4}			40	5.62×10^{-10}	5.21×10^{-4}
		30	5.25×10^{-10}	6.83×10^{-4}			30	4.28×10^{-10}	5.29×10^{-4}
		20	3.27×10^{-10}	6.39×10^{-4}			20	3.81×10^{-10}	7.06×10^{-4}
		10	1.63×10^{-10}	6.39×10^{-4}			10	2.16×10^{-10}	7.98×10^{-4}
		9	1.50×10^{-10}	6.53×10^{-4}			9	1.71×10^{-10}	7.05×10^{-4}
		8	1.35×10^{-10}	6.58×10^{-4}			8	1.30×10^{-10}	6.01×10^{-4}
		7	1.20×10^{-10}	6.73×10^{-4}			7	1.19×10^{-10}	6.28×10^{-4}
		6	1.04×10^{-10}	6.78×10^{-4}			6	1.20×10^{-10}	7.39×10^{-4}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	7.100	80	7.67×10^{-10}	3.54×10^{-4}	4	6.800	80	6.68×10^{-10}	3.22×10^{-4}
		70	5.76×10^{-10}	3.03×10^{-4}			70	6.86×10^{-10}	3.77×10^{-4}
		60	4.14×10^{-10}	2.55×10^{-4}			60	5.91×10^{-10}	3.79×10^{-4}
		50	2.92×10^{-10}	2.15×10^{-4}			50	5.41×10^{-10}	4.17×10^{-4}
		40	2.50×10^{-10}	2.31×10^{-4}			40	4.55×10^{-10}	4.38×10^{-4}
		30	1.98×10^{-10}	2.44×10^{-4}			30	3.56×10^{-10}	4.58×10^{-4}
		20	1.38×10^{-10}	2.54×10^{-4}			20	2.57×10^{-10}	4.96×10^{-4}
		10	6.34×10^{-11}	2.34×10^{-4}			10	1.50×10^{-10}	5.79×10^{-4}
		9	5.10×10^{-11}	2.09×10^{-4}			9	1.78×10^{-10}	7.60×10^{-4}
		8	3.96×10^{-11}	1.82×10^{-4}			8	1.86×10^{-10}	8.93×10^{-4}
		7	3.71×10^{-11}	1.95×10^{-4}			7	1.75×10^{-10}	9.63×10^{-4}
		6	3.58×10^{-11}	2.20×10^{-4}			6	1.46×10^{-10}	9.38×10^{-4}

Average electrical conductivity 5.75×10^{-4} S/cm

Standard deviation 2.98×10^{-4}

Table H3 Raw data of conductivity measurement of BC sheets containing containing Fe_3O_4 at 0.10 M initial concentration

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.467	10	1.95×10^{-10}	7.89×10^{-4}	2	5.867	10	1.19×10^{-10}	5.32×10^{-4}
		9	1.78×10^{-10}	8.00×10^{-4}			9	1.09×10^{-10}	5.39×10^{-4}
		8	1.58×10^{-10}	8.00×10^{-4}			8	9.53×10^{-11}	5.32×10^{-4}
		7	1.41×10^{-10}	8.16×10^{-4}			7	8.21×10^{-11}	5.23×10^{-4}
		6	1.21×10^{-10}	8.15×10^{-4}			6	7.08×10^{-11}	5.26×10^{-4}
		5	1.03×10^{-10}	8.31×10^{-4}			5	5.74×10^{-11}	5.13×10^{-4}
		4	7.53×10^{-11}	7.62×10^{-4}			4	4.54×10^{-11}	5.06×10^{-4}
		3	4.04×10^{-11}	5.45×10^{-4}			3	3.37×10^{-11}	5.02×10^{-4}
		2	2.69×10^{-11}	5.45×10^{-4}			2	1.73×10^{-11}	3.86×10^{-4}
		1	1.25×10^{-11}	5.07×10^{-4}			1	8.27×10^{-12}	3.69×10^{-4}

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	5.600	10	1.13×10^{-10}	5.27×10^{-4}	4	5.033	10	1.90×10^{-10}	9.86×10^{-4}
		9	1.00×10^{-10}	5.20×10^{-4}			9	1.62×10^{-10}	9.36×10^{-4}
		8	8.67×10^{-11}	5.07×10^{-4}			8	1.26×10^{-10}	8.21×10^{-4}
		7	7.50×10^{-11}	5.01×10^{-4}			7	9.83×10^{-11}	7.31×10^{-4}
		6	6.23×10^{-11}	4.86×10^{-4}			6	7.24×10^{-11}	6.28×10^{-4}
		5	5.21×10^{-11}	4.88×10^{-4}			5	4.02×10^{-11}	4.18×10^{-4}
		4	4.00×10^{-11}	4.67×10^{-4}			4	2.95×10^{-11}	3.84×10^{-4}
		3	2.84×10^{-11}	4.42×10^{-4}			3	2.11×10^{-11}	3.65×10^{-4}
		2	1.43×10^{-11}	3.35×10^{-4}			2	1.72×10^{-11}	4.47×10^{-4}
		1	6.57×10^{-12}	3.07×10^{-4}			1	9.07×10^{-12}	4.72×10^{-4}

Average electrical conductivity 5.06×10^{-4} S/cm

Standard deviation 1.84×10^{-4}

Table H4 Raw data of conductivity measurement of BC sheets containing containing Fe_3O_4 at 0.20 M initial concentration

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	6.400	9	1.20×10^{-10}	5.47×10^{-4}	2	5.967	10	1.55×10^{-10}	6.81×10^{-4}
		8	1.02×10^{-10}	5.24×10^{-4}			9	1.30×10^{-10}	6.33×10^{-4}
		7	8.87×10^{-11}	5.18×10^{-4}			8	1.07×10^{-10}	5.87×10^{-4}
		6	8.01×10^{-11}	5.46×10^{-4}			7	8.85×10^{-11}	5.55×10^{-4}
		5	6.91×10^{-11}	5.65×10^{-4}			6	7.19×10^{-11}	5.26×10^{-4}
		4	6.10×10^{-11}	6.24×10^{-4}			5	5.38×10^{-11}	4.72×10^{-4}
		3	5.43×10^{-11}	7.40×10^{-4}			4	3.73×10^{-11}	4.09×10^{-4}
		2	4.84×10^{-11}	9.89×10^{-4}			3	2.71×10^{-11}	3.97×10^{-4}
		1	4.39×10^{-11}	1.80×10^{-3}					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	5.067	9	7.90×10^{-11}	4.53×10^{-4}	4	5.667	9	2.21×10^{-10}	1.13×10^{-3}
		8	6.55×10^{-11}	4.23×10^{-4}			8	1.79×10^{-10}	1.03×10^{-3}
		7	5.57×10^{-11}	4.11×10^{-4}			7	1.42×10^{-10}	9.39×10^{-4}
		6	4.75×10^{-11}	4.09×10^{-4}			6	1.11×10^{-10}	8.54×10^{-4}
		5	4.00×10^{-11}	4.13×10^{-4}			5	8.15×10^{-11}	7.53×10^{-4}
		4	3.44×10^{-11}	4.44×10^{-4}			4	6.16×10^{-11}	7.11×10^{-4}
		3	2.99×10^{-11}	5.16×10^{-4}			3	4.54×10^{-11}	6.99×10^{-4}
		2	2.59×10^{-11}	6.70×10^{-4}			2	3.24×10^{-11}	7.47×10^{-4}

Average electrical conductivity 6.58×10^{-4} S/cm

Standard deviation 2.81×10^{-4}

Appendix I Conductivity Measurement of BC Sheets Containing Fe₃O₄ at Different Initial Concentration of Iron Precursors (Fe²⁺ and Fe³⁺) and Coated with PANI, which was Polymerized from 30 % wt of Aniline Monomer

Table II Raw data of conductivity measurement of BC sheets containing Fe₃O₄ at 0.01 M initial concentration and coated with PANI

No.	L (μm)	V (V)	I (A)	σ(S/cm)	No.	L (μm)	V (V)	I (A)	σ(S/cm)
1	5.633	10	2.43×10 ⁻⁷	1.13	2	5.133	10	2.22×10 ⁻⁷	1.13
		9	2.02×10 ⁻⁷	1.04			9	1.92×10 ⁻⁷	1.09
		8	1.63×10 ⁻⁷	0.95			8	1.74×10 ⁻⁷	1.11
		7	1.42×10 ⁻⁷	0.94			7	1.47×10 ⁻⁷	1.07
		6	1.23×10 ⁻⁷	0.95			6	1.33×10 ⁻⁷	1.13
		5	9.81×10 ⁻⁸	0.91			5	1.14×10 ⁻⁷	1.16
		4	6.74×10 ⁻⁸	0.78			4	9.47×10 ⁻⁸	1.21
		3	4.31×10 ⁻⁸	0.67			3	7.47×10 ⁻⁸	1.27
		2	3.35×10 ⁻⁸	0.78			2	3.88×10 ⁻⁸	0.99
		1	1.62×10 ⁻⁸	0.75			1	1.74×10 ⁻⁸	0.88

No.	L (μm)	V (V)	I (A)	σ(S/cm)	No.	L (μm)	V (V)	I (A)	σ(S/cm)
3	5.833	10	2.71×10 ⁻⁷	1.22	4	5.600	10	2.99×10 ⁻⁷	1.40
		9	2.34×10 ⁻⁷	1.17			9	2.73×10 ⁻⁷	1.42
		8	2.16×10 ⁻⁷	1.21			8	2.35×10 ⁻⁷	1.38
		7	1.90×10 ⁻⁷	1.22			7	2.03×10 ⁻⁷	1.35
		6	1.60×10 ⁻⁷	1.19			6	1.71×10 ⁻⁷	1.34
		5	1.36×10 ⁻⁷	1.22			5	1.46×10 ⁻⁷	1.36
		4	1.10×10 ⁻⁷	1.24			4	1.12×10 ⁻⁷	1.31
		3	8.17×10 ⁻⁸	1.22			3	8.52×10 ⁻⁸	1.33
		2	4.96×10 ⁻⁸	1.11			2	6.46×10 ⁻⁸	1.51
		1	3.71×10 ⁻⁸	1.66			1	2.52×10 ⁻⁸	1.18

Average electrical conductivity 1.15 S/cm

Standard deviation 0.21

Table 12 Raw data of conductivity measurement of BC sheets containing Fe₃O₄ at 0.05 M initial concentration and coated with PANI

No.	L (μm)	V (V)	I (A)	σ(S/cm)	No.	L (μm)	V (V)	I (A)	σ(S/cm)
1	6.500	10	2.38×10^{-7}	0.96	2	6.600	10	2.47×10^{-7}	0.98
		9	2.17×10^{-7}	0.97			9	2.17×10^{-7}	0.95
		8	1.85×10^{-7}	0.93			8	1.92×10^{-7}	0.95
		7	1.70×10^{-7}	0.98			7	1.69×10^{-7}	0.96
		6	1.43×10^{-7}	0.96			6	1.42×10^{-7}	0.94
		5	1.18×10^{-7}	0.95			5	1.15×10^{-7}	0.91
		4	9.73×10^{-8}	0.98			4	8.68×10^{-8}	0.86
		3	7.37×10^{-8}	0.99			3	6.97×10^{-8}	0.92
		2	5.17×10^{-8}	1.04			2	5.48×10^{-8}	1.09
		1	3.33×10^{-8}	1.34			1	2.12×10^{-8}	0.84

No.	L (μm)	V (V)	I (A)	σ(S/cm)	No.	L (μm)	V (V)	I (A)	σ(S/cm)
3	6.933	10	5.88×10^{-7}	2.22	4	6.067	8	3.28×10^{-7}	1.77
		9	5.28×10^{-7}	2.22			7	2.24×10^{-7}	1.38
		8	4.44×10^{-7}	2.09			6	1.58×10^{-7}	1.14
		7	3.65×10^{-7}	1.97			5	1.07×10^{-7}	0.92
		6	2.95×10^{-7}	1.85			4	8.15×10^{-8}	0.88
		5	2.29×10^{-7}	1.73			3	6.12×10^{-8}	0.88
		4	1.69×10^{-7}	1.59			2	3.59×10^{-8}	0.77
		3	1.13×10^{-7}	1.42			1	1.94×10^{-8}	0.84
		2	6.66×10^{-8}	1.26					
		1	3.78×10^{-8}	1.43					

Average electrical conductivity 1.21 S/cm

Standard deviation 0.42

Table I3 Raw data of conductivity measurement of BC sheets containing Fe_3O_4 at 0.10 M initial concentration and coated with PANI

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.467	7	1.67×10^{-7}	1.14	2	5.800	7	2.47×10^{-7}	1.60
		6	1.37×10^{-7}	1.09			6	1.99×10^{-7}	1.50
		5	1.09×10^{-7}	1.04			5	1.56×10^{-7}	1.41
		4	8.58×10^{-8}	1.03			4	1.15×10^{-7}	1.30
		3	6.44×10^{-8}	1.03			3	6.98×10^{-8}	1.05
		2	4.40×10^{-8}	1.05			2	3.51×10^{-8}	0.79
		1	2.40×10^{-8}	1.15			1	1.16×10^{-8}	0.52
		0.9	2.39×10^{-8}	1.27					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	5.967	8	3.86×10^{-7}	2.12	4	5.233	8	2.52×10^{-7}	1.57
		7	3.08×10^{-7}	1.93			7	2.06×10^{-7}	1.47
		6	2.30×10^{-7}	1.69			6	1.72×10^{-7}	1.43
		5	1.73×10^{-7}	1.52			5	1.26×10^{-7}	1.26
		4	1.11×10^{-7}	1.21			4	8.44×10^{-8}	1.06
		3	5.96×10^{-8}	0.87			3	7.51×10^{-8}	1.25
		2	4.12×10^{-8}	0.90			2	5.23×10^{-8}	1.31
		1	9.83×10^{-9}	0.43					

Average electrical conductivity 1.23 S/cm

Standard deviation 0.36

Table I4 Raw data of conductivity measurement of BC sheets containing Fe_3O_4 at 0.20 M initial concentration and coated with PANI

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
1	5.933	10	4.46×10^{-7}	1.97	2	6.367	7	2.77×10^{-7}	1.63
		9	3.88×10^{-7}	1.90			6	2.02×10^{-7}	1.38
		8	3.08×10^{-7}	1.70			5	1.35×10^{-7}	1.11
		7	2.01×10^{-7}	1.27			4	9.17×10^{-8}	0.94
		6	1.31×10^{-7}	0.97			3	5.67×10^{-8}	0.78
		5	8.56×10^{-8}	0.76			2	2.80×10^{-8}	0.58
		4	5.03×10^{-8}	0.55					
		3	2.15×10^{-8}	0.32					

No.	L (μm)	V (V)	I (A)	σ (S/cm)	No.	L (μm)	V (V)	I (A)	σ (S/cm)
3	6.100	10	5.47×10^{-7}	2.35	4	6.400	9	3.54×10^{-7}	1.61
		9	4.78×10^{-7}	2.28			8	2.61×10^{-7}	1.33
		8	4.09×10^{-7}	2.19			7	1.93×10^{-7}	1.13
		7	3.42×10^{-7}	2.10			6	1.42×10^{-7}	0.97
		6	2.75×10^{-7}	1.97			5	9.71×10^{-8}	0.79
		5	1.97×10^{-7}	1.69			4	6.81×10^{-8}	0.70
		4	1.49×10^{-7}	1.60			3	4.45×10^{-8}	0.61
		3	9.64×10^{-8}	1.38			2	2.45×10^{-8}	0.50
		2	5.12×10^{-8}	1.10					

Average electrical conductivity 1.29 S/cm

Standard deviation 0.58

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