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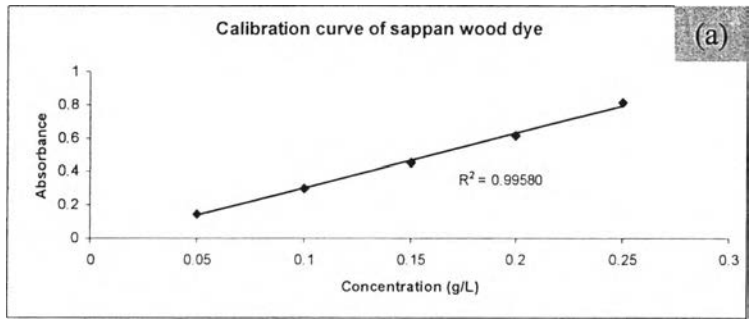
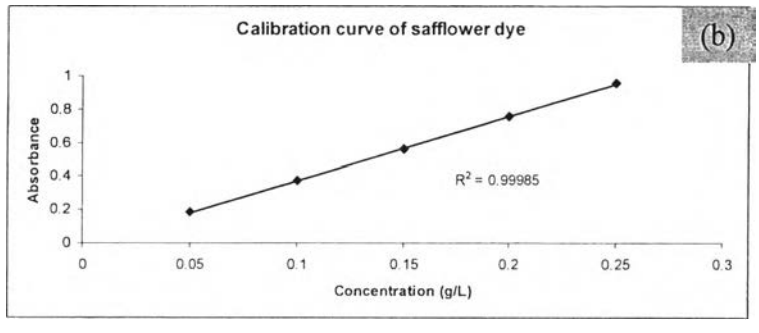
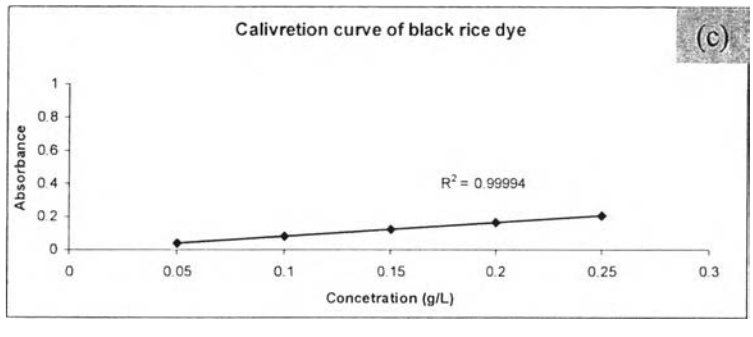
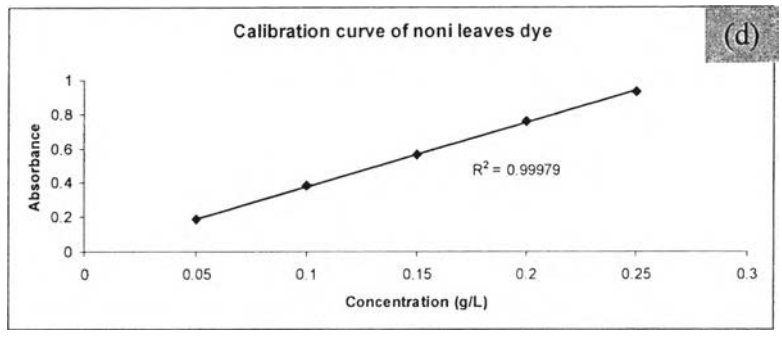
APPENDICES

Appendix A Extinction coefficient of natural dyes









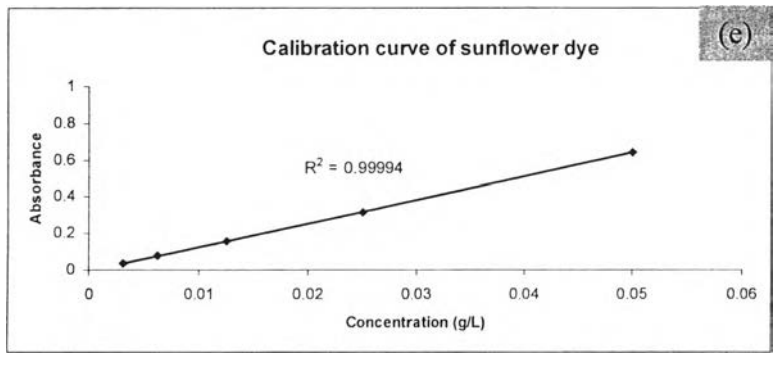


Figure A1 Calibration curve of natural dyes; sappan wood (a), safflower (b), black rice (c), noni leaves (d) and sunflower (e).

Table A1 Extinction coefficient of natural dyes

Natural dyes	**Extinction coefficient (L g^{-1} cm^{-1})**
Sappan wood	3.303
Safflower	3.848
Black rice	0.819
Noni leaves	3.747
Sunflower	12.923

From the Beer-Lambert Law relationship for absorbance of light:

$$A = \varepsilon cl,$$

Where A = absorbance

ε = extinction coefficient (L g^{-1} cm^{-1})

c = concentration of the dye (g/L)

l = path length of the cell, which is normally 1cm

The data of concentration and absorbance at a particular wavelength are used to draw the calibration curve as shown in figure 6.3. The slope of the curve is the extinction coefficient for each of the natural dyes.

Appendix B EDX of ZnO + polythiophene

Sample: 0.1 M Thiophene 0.2 M $LiClO_4$ 1 min

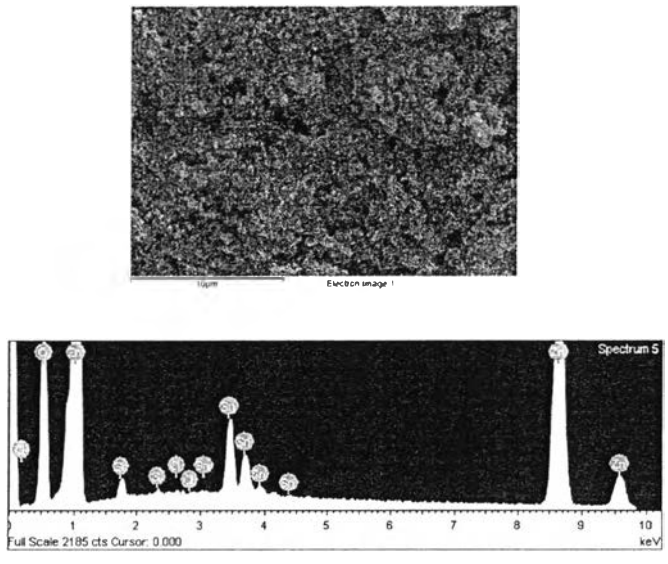


Figure B1 FE-SEM image and EDX spectrum of the hybrid of ZnO and polythiophene.

Table B1 EDX data of of the hybrid of ZnO and polythiophene.

Element	Weight%	Atomic%
O K	14.52	43.15
Si K	0.78	1.32
S K	0.19	0.28
Cl K	0.04	0.05
Zn L	65.40	47.56
Sn L	19.06	7.64
Totals	100.00	

Sample: 0.1M Th 0.2M $LiClO_4$ 2 min

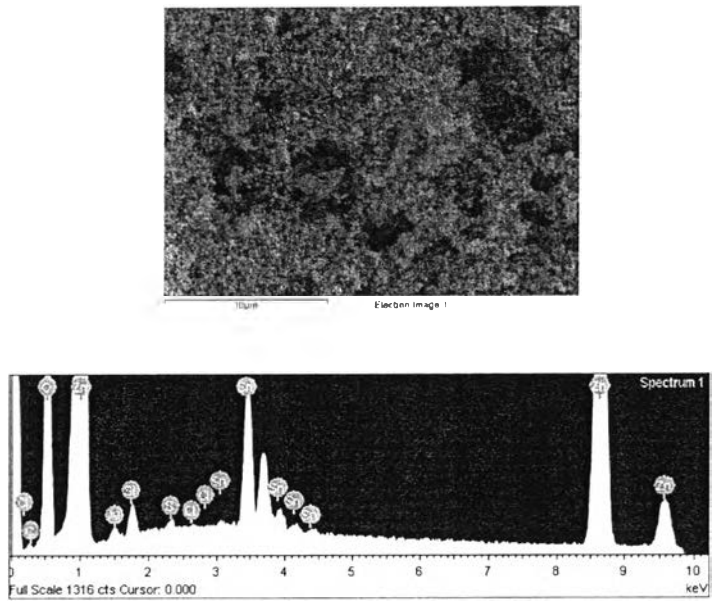


Figure B2 FE-SEM image and EDX spectrum of the hybrid of ZnO and polythiophene.

Table B2 EDX data of of the hybrid of ZnO and polythiophene.

Element	Weight%	Atomic%
C K	-0.13	-0.52
O K	14.37	43.22
Al K	0.24	0.43
Si K	0.72	1.23
S K	0.23	0.35
Cl K	0.11	0.14
Zn L	63.21	46.53
Sn L	21.26	8.62
Totals	100.00	

Sample: 0.1M Th 0.2M $LiClO_4$ 5 min

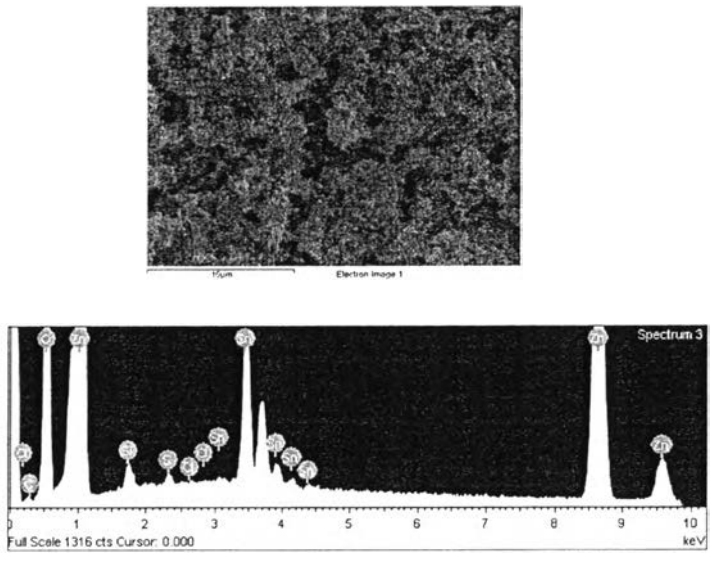


Figure B3 FE-SEM image and EDX spectum of the hybrid of ZnO and polythiophene.

Table B3 EDX data of of the hybrid of ZnO and polythiophene.

Element	Weight%	Atomic%
C K	-0.10	-0.41
O K	14.36	43.69
Si K	0.56	0.97
S K	0.37	0.57
Cl K	0.05	0.07
Zn L	60.79	45.28
Sn L	23.97	9.83
Totals	100.00	

Sample: 0.2M Th 0.2M $LiClO_4$ 1 min

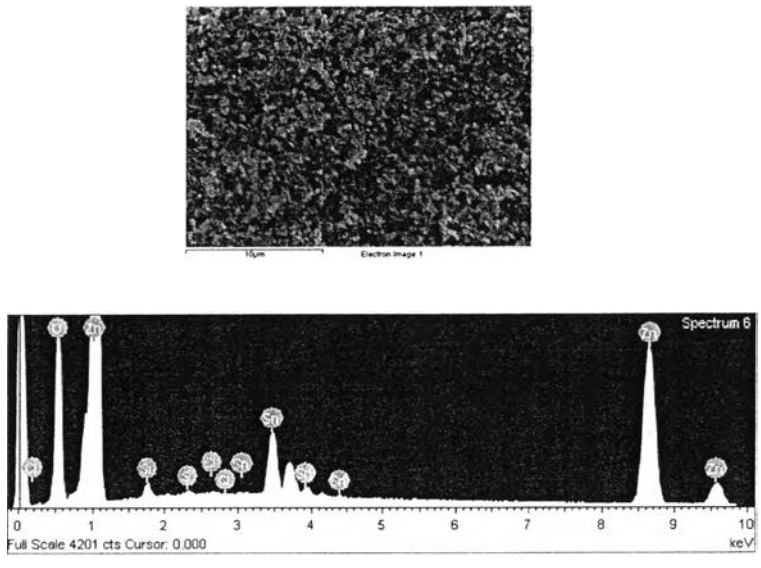


Figure B4 FE-SEM image and EDX spectrum of the hybrid of ZnO and polythiophene.

Table B4 EDX data of of the hybrid of ZnO and polythiophene.

Element	Weight%	Atomic%
O K	14.87	43.92
Si K	0.63	1.06
S K	0.23	0.34
Cl K	0.13	0.17
Zn L	64.65	46.74
Sn L	19.50	7.76
Totals	100.00	

Sample: 0.3M Th 0.2M $LiClO_4$ 1 min

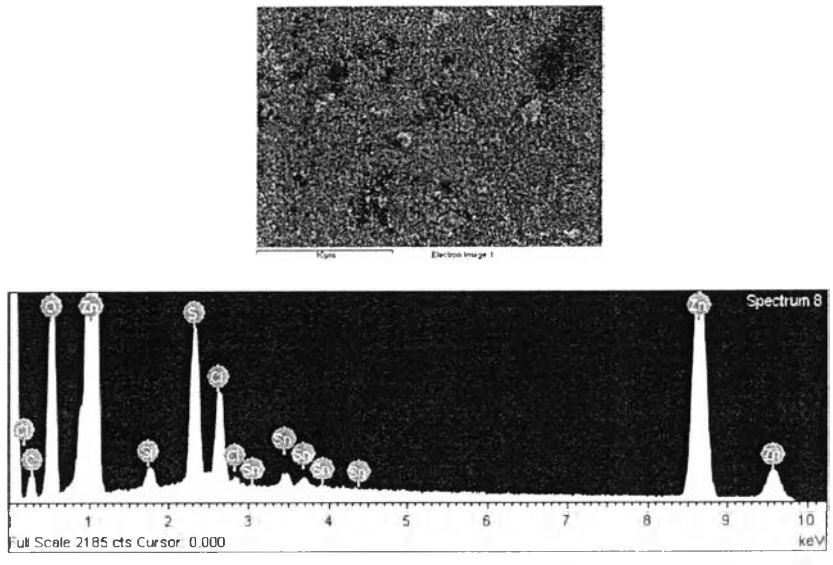


Figure B5 FE-SEM image and EDX spectrum of the hybrid of ZnO and polythiophene.

Table B5 EDX data of of the hybrid of ZnO and polythiophene.

Element	Weight%	Atomic%
C K	4.34	12.91
O K	16.19	36.12
Si K	0.91	1.15
S K	8.83	9.83
Cl K	6.31	6.36
Zn L	59.34	32.40
Sn L	4.07	1.23
Totals	100.00	

Sample: 0.1 M Th 0.2 M $LiClO_4$ 1 min (EPD)

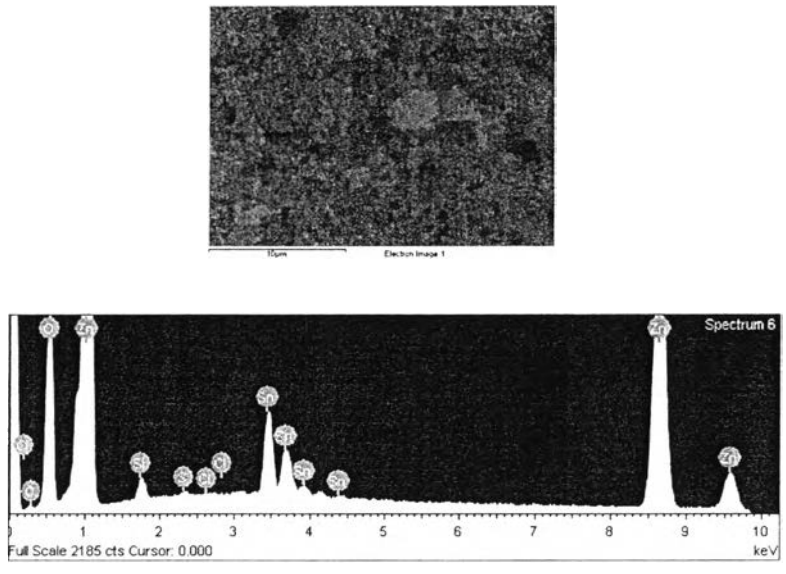


Figure B6 FE-SEM image and EDX spectrum of the hybrid of ZnO and polythiophene.

Table B6 EDX data of of the hybrid of ZnO and polythiophene.

Element	Weight%	Atomic%
C K	0.02	0.10
O K	14.48	43.10
Si K	0.77	1.30
S K	0.20	0.29
Cl K	0.04	0.05
Zn L	64.93	47.31
Sn L	19.57	7.85
Totals	100.00	

Appendix C BET data of the ZnO film with various conditions.

Table C1 BET data of the ZnO film with various voltages.

Conditions	Surface area (m^2/g)	Pore volume (cc/g)	Pore size (A^o)
15V 5 min	6.17	0.0302	195.6
18V 5 min	55.19	0.1543	109.8
21V 5 min	50.64	0.1247	98.53
24V 5 min	106.3	0.1904	71.65

Table C2 BET data of the ZnO film with various deposition times.

Conditions	Surface area (m^2/g)	Pore volume (cc/g)	Pore size (A^o)
15V 5 min	6.17	0.0302	195.6
15V 10 min	31.28	0.1270	162.3
15V 15 min	29.35	0.1159	158.1
15V 20 min	29.37	0.1671	227.6

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2006–2009 Bachelor Degree of Chemistry (1st Class Honours), Faculty of Science, Prince of Songkla University, Songkhla, Thailand

Proceedings:

1. Magaraphan, R.; and Joothamongkhon, J. (2012, December) Performance of Dye-Sensitized Solar Cells Using ZnO-Natural Dyes from Sappan Wood, Noni Leaves, Safflower and Black Rice. International Conference on Materials and Manufacturing Research (ICMMR 2012), Hong Kong.
2. Joothamongkhon, J.; and Magaraphan, R. (2013, April) Performance of Polythiophene-ZnO Dye-Sensitized Solar Cell Prepared Via Electrophoretic Deposition (EPD). Proceeding of the 4th Research Symposium on Petrochemical and Materials Technology and the 19th PPC Symposium on Petroleum, Petrochemicals and Polymers, Bangkok, Thailand.

Presentations:

1. Joothamongkhon, J.; and Magaraphan, R. (2012, December 11-15) The Effect of Plasma Treatment on Structural, Optical and Electrical Properties of Polythiophene/ZnO-Coated FTO Glass as a DSSC Application. Poster presentation at the 28th International Conference of The Polymer Processing Society (PPS-28), Pattaya, Thailand.
2. Joothamongkhon, J.; and Magaraphan, R. (2013, March 22) The Effect of ZnO Thickness on the Efficiency of Natural Dye-Sensitized Solar Cell. Oral presentation at the 8th Science and Technology Conference for Youths, Bangkok, Thailand.

3. Joothamongkhon, J.; and Magaraphan, R. (2013, April 23) Performance of Polythiophene-ZnO Dye-Sensitized Solar Cell Prepared Via Electrophoretic Deposition (EPD). Poster presentation at the 4th Research Symposium on Petrochemical and Materials Technology and the 19th PPC Symposium on Petroleum, Petrochemicals and Polymers, Bangkok, Thailand.
4. Joothamongkhon, J.; and Magaraphan, R. (2013, May 21-23) Fabrication of polythiophene/ZnO hybrid dye-sensitized solar cell that sensitized with noni leaves and sappan wood. Poster presentation at the 3rd International Symposium Frontiers in Polymer Science in association with Journal Polymer, Sitges, Spain.