REFERENCES

[1] Ghosh, M. K., and Mittal, K. L. Polyimides foundamentals and applications. New York: Marcel Dekker, 1996.

[2] Chiron, D., Trigaud, T., and Moliton, J. P. Optical waveguides etched in 6FDA-ODA by focused ion beam. Synthetic Metals 124 (2001): 33-35.

[3] Cornic, C., Lucas, B., Moliton, A., Colombeau, B., and Mercier, R. Elaboration and characterization of 6FDA/MPDA polyimide-based optical waveguide. Synthetic Metals 127 (2002): 299-302.

[4] Kim, J. H., Koros, W. J., and Paul, D. R. Physical aging of thin 6FDA-based polyimide membranes containing carboxyl acid groups. Part II. Optical properties. Polymer 47 (2006): 3104–3111.

[5] Kim, H., et al. Doped ZnO thin films as anode materials for organic light-emitting diodes. Thin Solid Films 420–421 (2002): 539–543.

[6] Cembreroa, J., Elmanounib, A., Hartitib, B., Mollarc, M., and Mar´ıc, B. Nanocolumnar ZnO films for photovoltaic applications. Thin Solid Films 451–452 (2004): 198–202.

[7] Hirai, T., Harada, Y., Hashimoto, S., Itoh, T., and Ohno, N. Luminescence of excitons in mesoscopic ZnO particles. Journal of Luminescence 112 (2005): 196-199.

[8] Guo, L., et al. Synthesis and characterization of poly(vinylpyrrolidone)-modified zinc oxide nanoparticles. Chemistry of Materials 12 (2003): 2268-2274.

[9] Hung, C. H., and Whang, W. T. Effect of surface stabilization of nanoparticles on luminescent characteristics in ZnO/poly(hydroxyethyl methacrylate) nanohybrid films. Journal of Materials Chemistry 15 (2005): 267-274.

[10] Andelman, T., et al. Morphological control and photoluminescence of Zinc Oxide nanocrystals. Journal Physics Chemistry 109 (2005): 14314-14318.

[11] Tsukazaki, A., et al. Repeated temparature modulation epitaxy for p-type doping and light-emitting diode based on ZnO. Nature materials 4 (2004): 1-5.

[12] Wang, Z. J., et al. Room - temperature dual excitonic emission from amorphous ZnO. Chinese Physics Letters 20 (2003): 696-699.

[13] Winter, M. Web elements periodic table[online]. Department of Chemistry, University of Sheffield, England: Mark Winter, 1993. Available from: http://www.webelements.com/webelements/compounds/text/Zn/O1Zn1-1314132.html [January 2007]

[14] AOL. Remarkable zinc oxide[online]. Nanovation technical centre, France: Nanovation, 2000. Available from: http://hometown.aol.com/nanovation/ZnO.html [November 2005]

[15] Roy, V. A. L., et al. Luminescent and structural properties of ZnO nanorods prepared under different conditions. Applied Physics Letters 83 (2003): 141-143.

[16] Bendre, B. S., and Mahamuni, S. Luminescence in ZnO quantum particles. Journal of Materials Research 19 (2004): 737-740.

[17] Wang, Z., Zhang, H., Wang, Z., Zhang, L., and Yuan, J. Structure and strong ultraviolet emission characteristics of amorphous ZnO films grown by electrophoretic deposition. Journal of Materials Research 18 (2003): 151-155.

[18] Jeon, H. J., Chung, Y., Kim, S. Y., Yoon, C. S., and Kim, Y. H. Synthesis of ZnO nanoparticles embedded in a polymeric matrix; Effect of curing temperature. Materials Science Forum 449-452 (2004): 1145-1148.

[19] Sawada, T., and Ando, S. Synthesis, characterization, and optical properties of metal-containing fluorinated polyimide films. Chemistry of Materials 10 (1998): 3368-3378.

[20] Chiang, P. C., and Whang, W. T. The synthesis and morphology characteristic study of BAO-ODPA polyimide/TiO_2 nano hybrid films. Polymer 44 (2003): 2249-2254.

[21] Hsu, S. C., Whang, W. T., Hung, C. H., Chiang, P. C., and Hsiao, Y. N. Effect of the polyimide structure and ZnO concentration on the morphology and characteristics of polyimide/ZnO nanohybrid films. Macromolecular Chemistry and Physics 206 (2005): 291-298.

[22] Chae, D. W., and Kim, B. C. Characterization on polystyrene/zinc oxide nanocomposites prepared from solution mixing. Polymers for advanced technologies 16 (2005): 846-850.

[23] Savin, D. A., Pyun, J., Patterson, G. D., Kowalewski, T., and Matyjaszewski, K. Synthesis and characterization of silica-*graft*-polystyrene hybrid nanoparticles: Effect of constratint on the glass transition temperature of spherical polymer brushes. Journal of Polymer Science: Part B: Polymer Physics 40 (2002): 2667-2676.

[24] Guo, L., et al. Highly monodisperse polymer-capped ZnO nanoparticles:preparation and optical properties. Applied Physics Letters 76 (2000): 2901-2903.

[25] ลาวัลย์ ศรีพงษ์. การวิเคราะห์เชิงฟลูออโรเมตรี. นครปฐม: คณะเภสัชศาสตร์ มหาวิทยาลัยศิลปากร, 2544.

[26] Lin, B., Fu, Z., and Jia, Y. Green luminescent center in undoped zinc oxide films deposited on silicon substrates. Applied Physics Letters 79 (2001): 943-945.

[27] Lin, Y., et al. Green luminescent zinc oxide films prepared by polymer-assisted deposition with rapid thermal process. Thin Solid Films 492 (2005): 101-104.

[28] Masuda, Y., Kinoshita, N., Sato, F., and Koumoto, K. Site-selective deposition and morphology control of UV-and visible-light-emitting ZnO crystals. Crystal growth & design 6 (2006): 75-78.

APPENDICES

APPENDIX A

Calculation of ZnO in PI film

Table A-1 Molecular weight of materials

Type of materials	Molecular weight (M_w)
6FDA (dianhydride)	444.24
TFDB (diamine)	320.23
ZnO	81.41
Zinc nitrate hexahydrate	297.49

15 wt% of poly(amic acid) (PAA) in DMAc was obtained as follows.
Assume we required solution 70 g
Amount of solute PAA, equal (15*70)/100 = 10.5 g
Amount of solvent, DMAc = 70 – 10.5 = 59.5 g

Molecular weight of poly(amic acid) = M_w of 6FDA + M_w of TFDB
= 444.24 + 320.23
= 764.47

Mol of poly(amic acid) (PAA) = g / M_w
= 10.5 / 764.47
= 0.01374 mol

Amount of 6FDA dianhydride = mol of PAA / M_w of 6FDA
= 0.01374 / 444.24
= 6.10164 g

Amount of TFDB diamine = mol of PAA / M_w of TFDB
= 0.01374 / 320.23
= 4.39836 g

Assume we required concentration of ZnO at 5 mol% in PI film, the calculation was as follows.

Assume we require PAA solution 5 g

Amount of PAA in solution	= (15*5)/100
	= 0.75 g
Mol of PAA	= g / M_w of PAA
	= 0.75 / 764.47
	= 0.00098 mol
Mol of ZnO	= concentration of ZnO * mol of PAA / 100
	= (5 * 0.00098) / 100
	= 4.9054E-05 mol
Amount of ZnO	= mol of ZnO * M_w of ZnO
	= 0.00399 g

Therefore, concentration of ZnO at 5 mol% used 0.00399 grams in 5 grams of PAA solution.

APPENDIX B

The XRD reflection of crystal structure of ZnO

Table B-1 Relationship between plane reflection of crystal ZnO and 2 theta (degree)

Plane reflection of crystal ZnO	2 theta (degree)
100	31.42
002	34.04
101	35.88
102	47.16
110	56.28
103	62.52
112	67.66
201	68.80

APPENDIX C

The average size of the crystal ZnO in polyimide films

The average size of the crystal ZnO in polyimide films was calculated by Scherrer's formula equation as shown below.

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

Where D = average size of the ZnO crystallites

λ = the wavelength of the X-ray, 1.5418 °A

β = line width at half maximum of peak

θ = Bragg angle of the diffraction peaks

Diffraction angle of crystal ZnO was measured by XRD. The value of 2θ peak is 35.88° in which average size of ZnO crystal was calculated as follows.

D = (0.9 * 1.5418) / (0.12139 * cos 35.88)

= 135.2273 °A

= 13.5 nm

APPENDIX D

Effect of curing temperature on photoluminescence

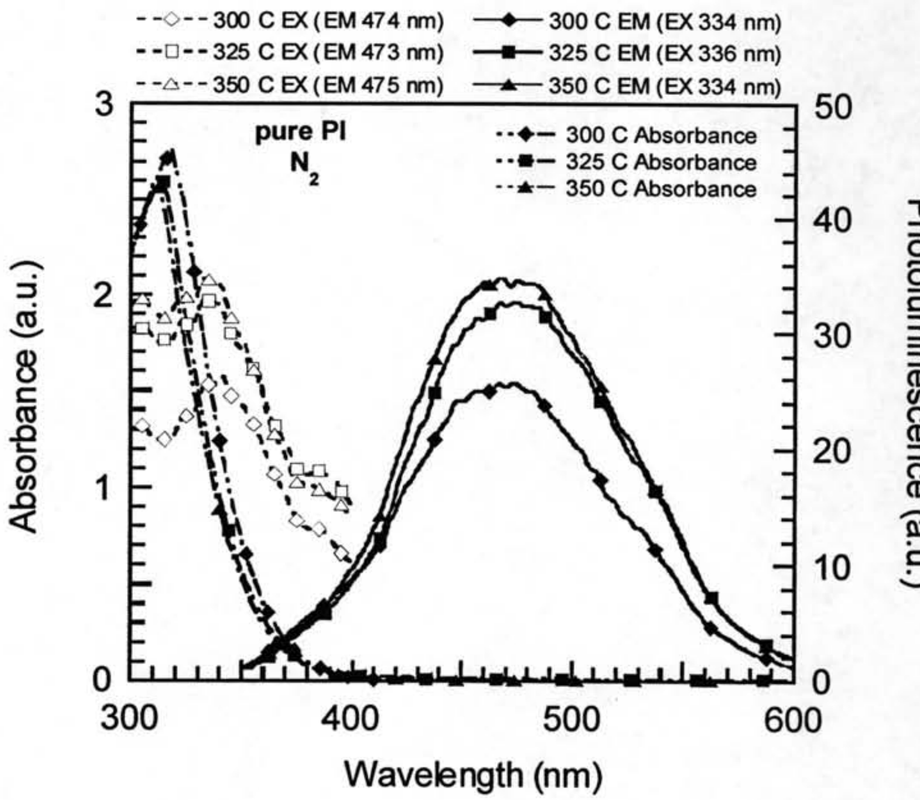

Figure D-1 Effect of curing temperature on photoluminescence of pure PI under nitrogen atmosphere.

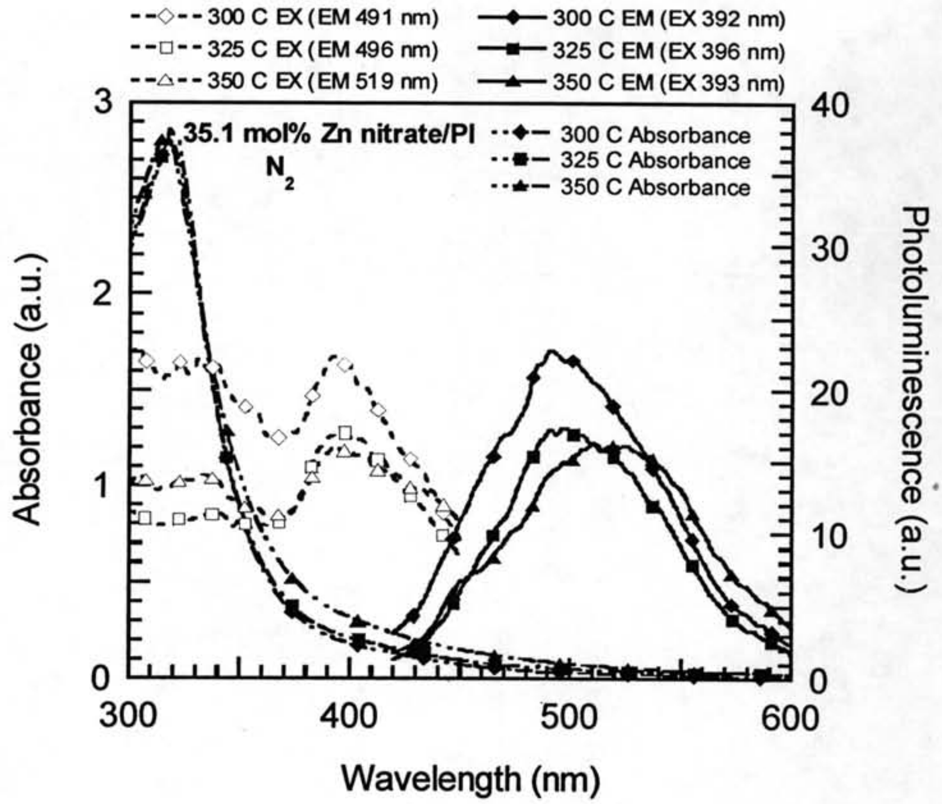

Figure D-2 Effect of curing temperature on photoluminescence of 35.1 mol% Zn nitrate/PI under nitrogen atmosphere.

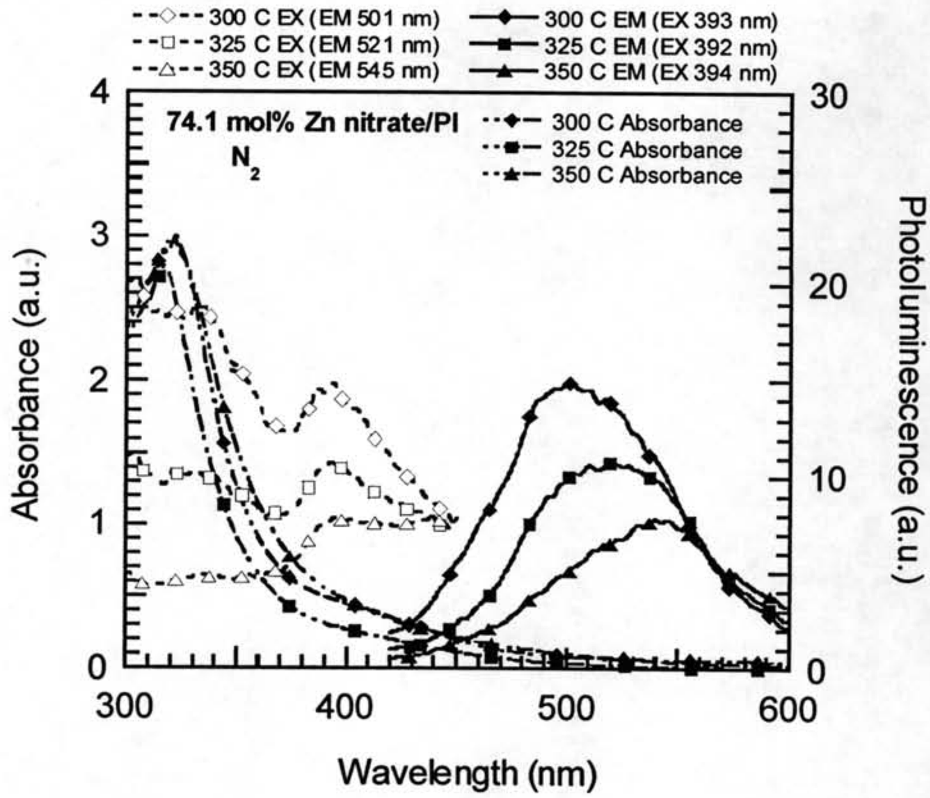

Figure D-3 Effect of curing temperature on photoluminescence of 74.1 mol% Zn nitrate/PI under nitrogen atmosphere.

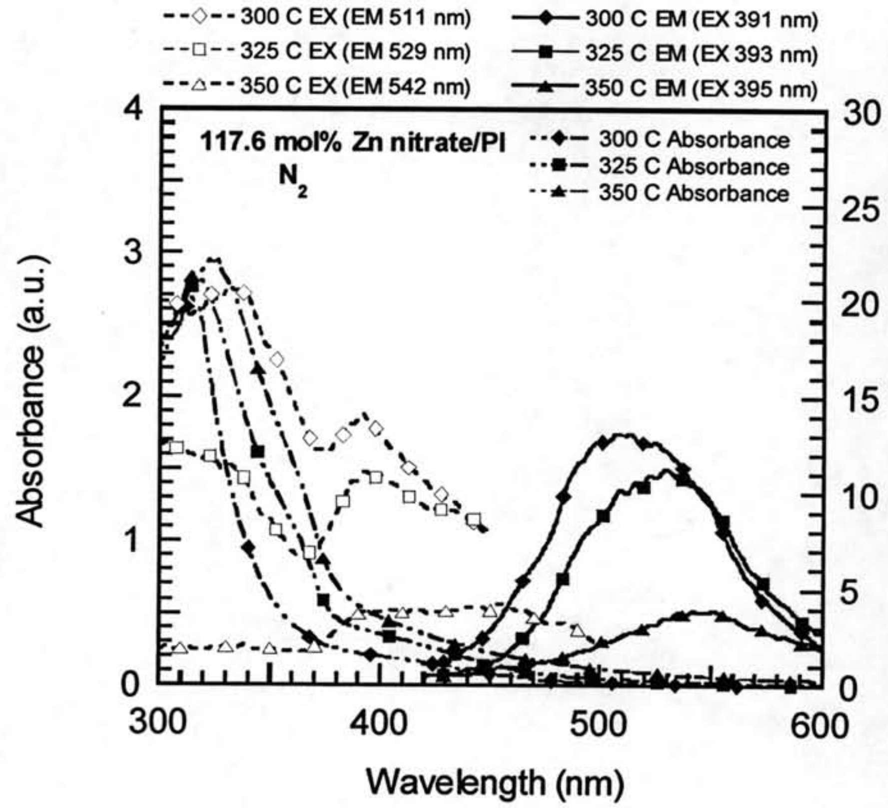

Figure D-4 Effect of curing temperature on photoluminescence of 117.6 mol% Zn nitrate/PI under nitrogen atmosphere.

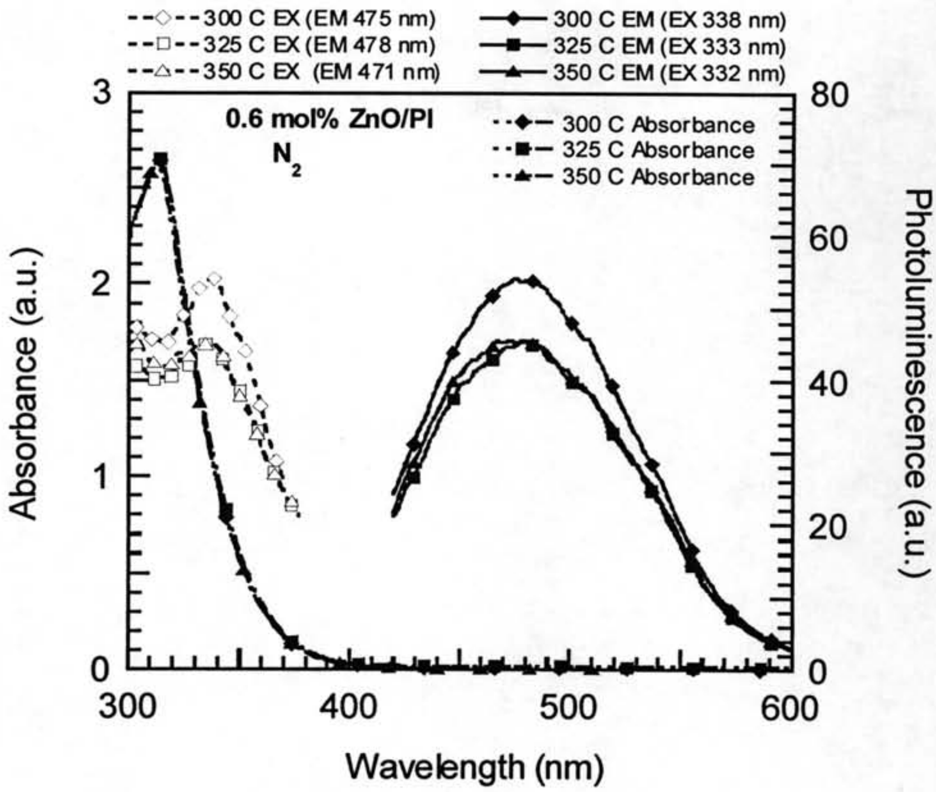

Figure D-5 Effect of curing temperature on photoluminescence of 0.6 mol% ZnO/PI under nitrogen atmosphere.

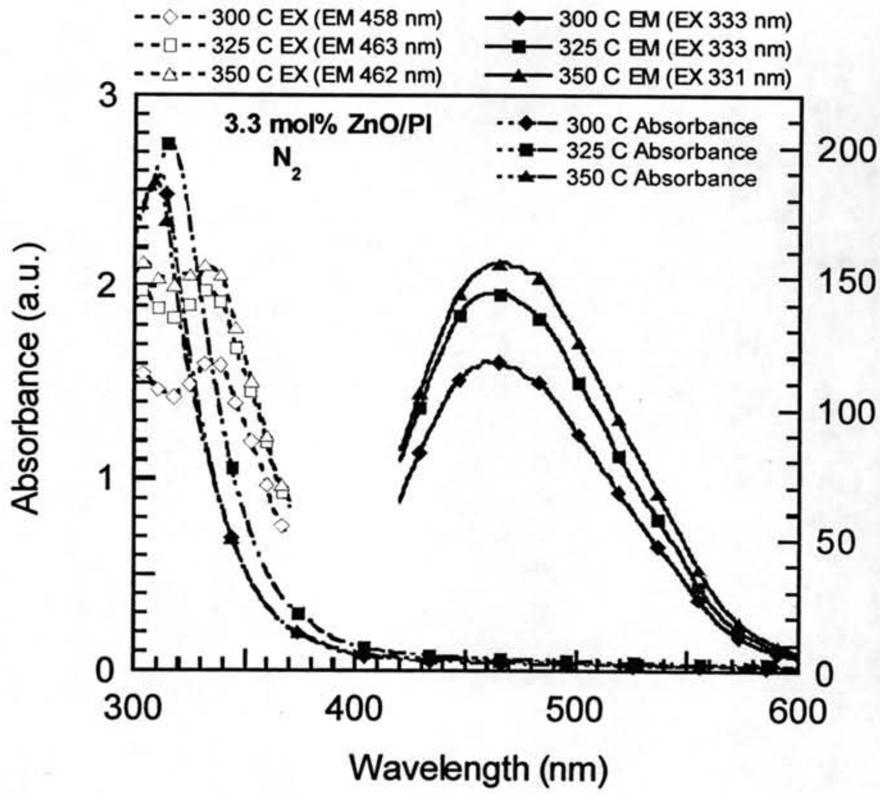

Figure D-6 Effect of curing temperature on photoluminescence of 3.3 mol% ZnO/PI under nitrogen atmosphere.

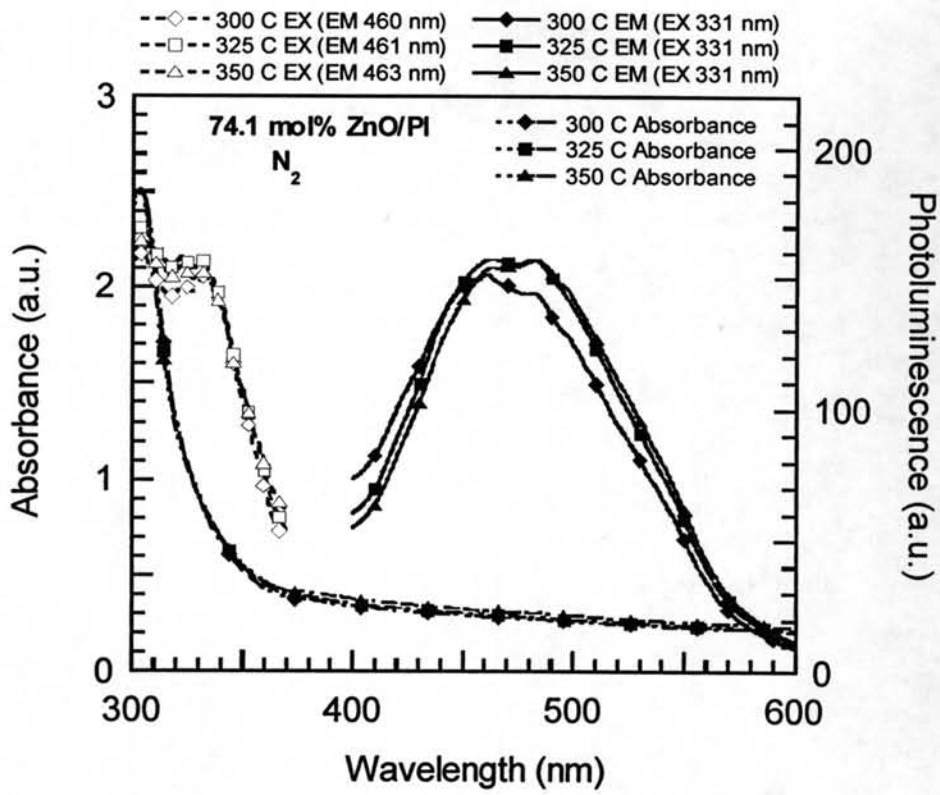

Figure D-7 Effect of curing temperature on photoluminescence of 74.1 mol% ZnO/PI under nitrogen atmosphere.

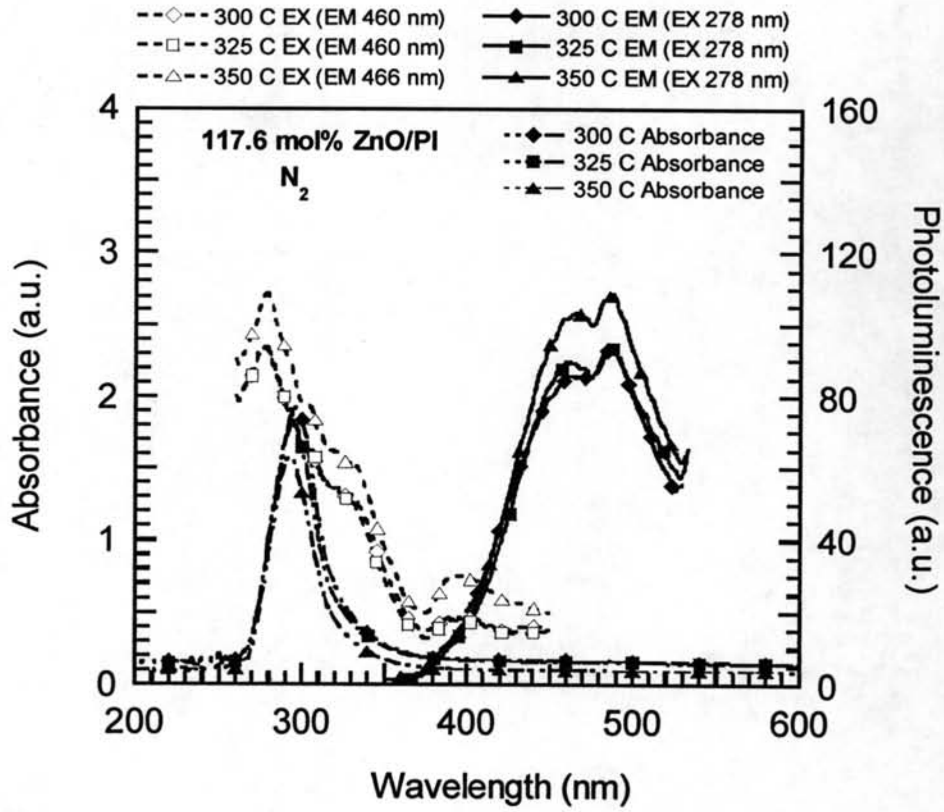

Figure D-8 Effect of curing temperature on photoluminescence of 117.6 mol% ZnO/PI under nitrogen atmosphere.

APPENDIX E

Effect of curing atmosphere on photoluminescence

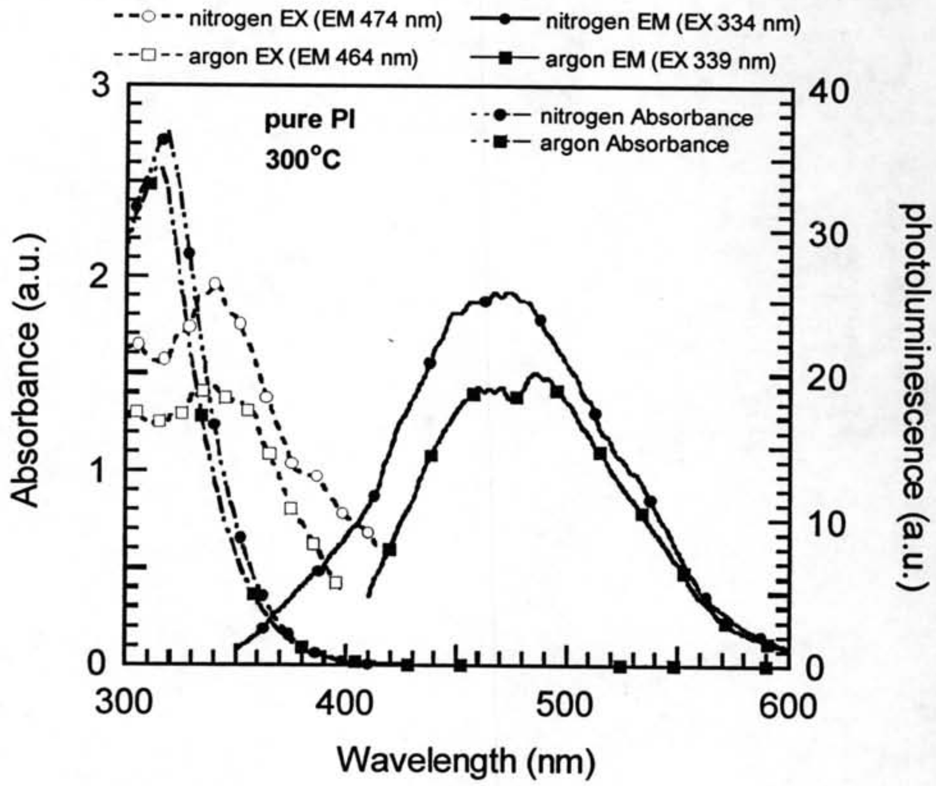

Figure E-1 Effect of curing atmosphere on photoluminescence of pure PI at 300°C curing temperature.

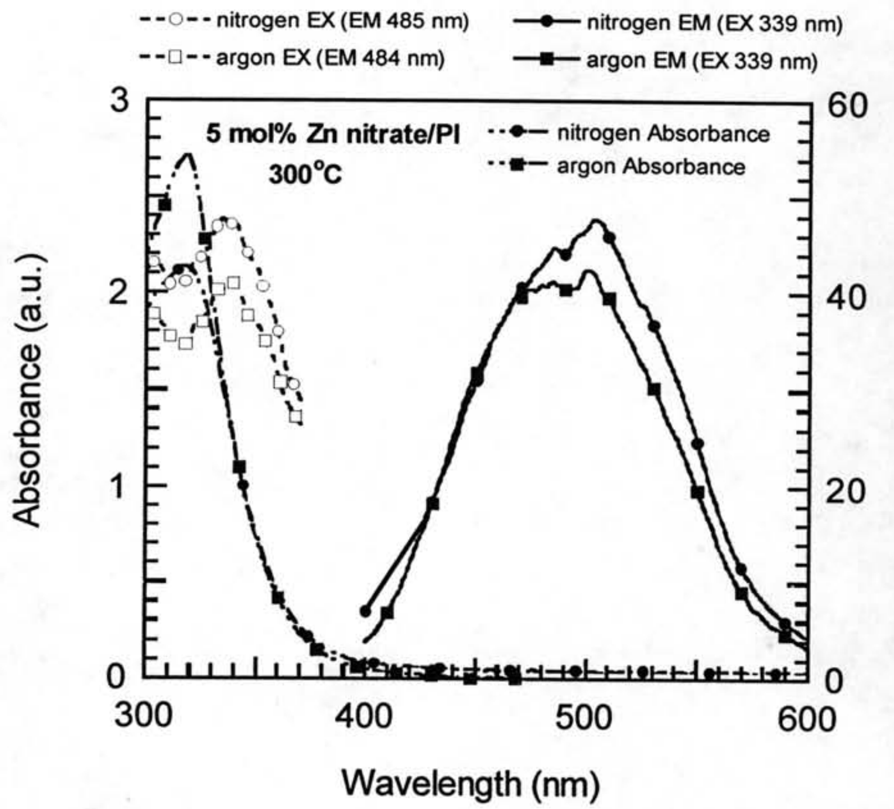

Figure E-2 Effect of curing atmosphere on photoluminescence of 5 mol% Zn nitrate/PI at 300°C curing temperature.

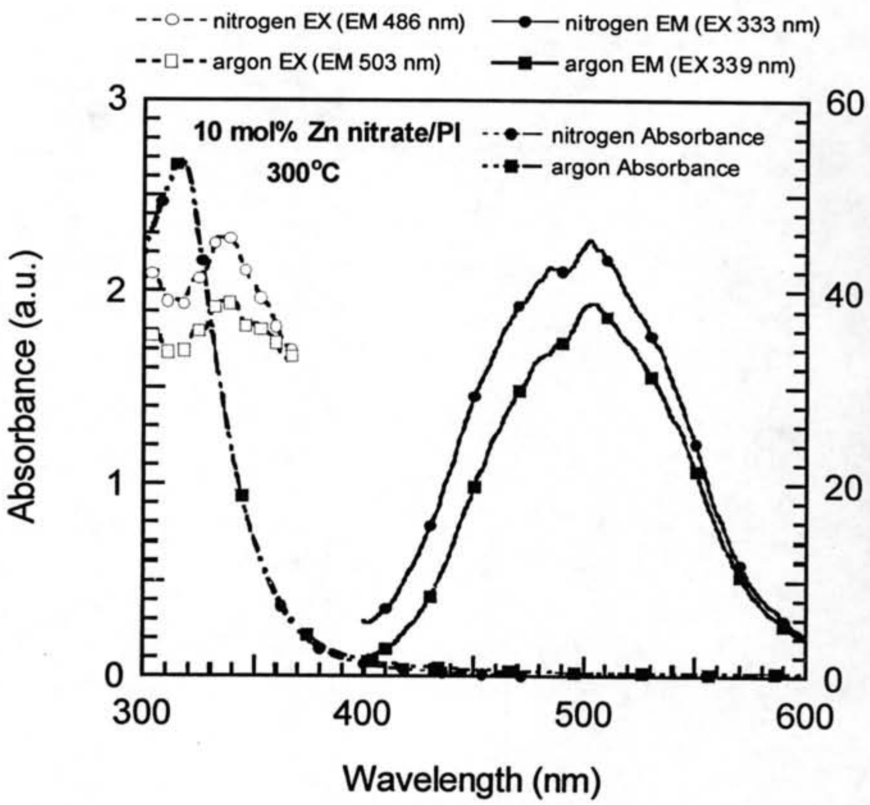

Figure E-3 Effect of curing atmosphere on photoluminescence of 10 mol% Zn nitrate/PI at 300°C curing temperature.

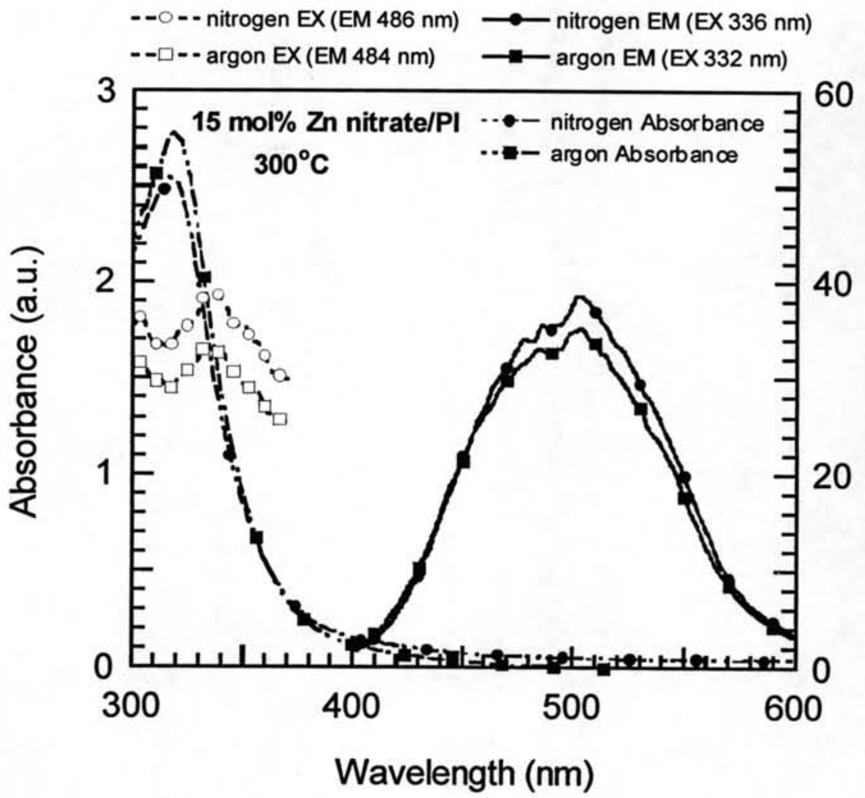

Figure E-4 Effect of curing atmosphere on photoluminescence of 15 mol% Zn nitrate/PI at 300°C curing temperature.

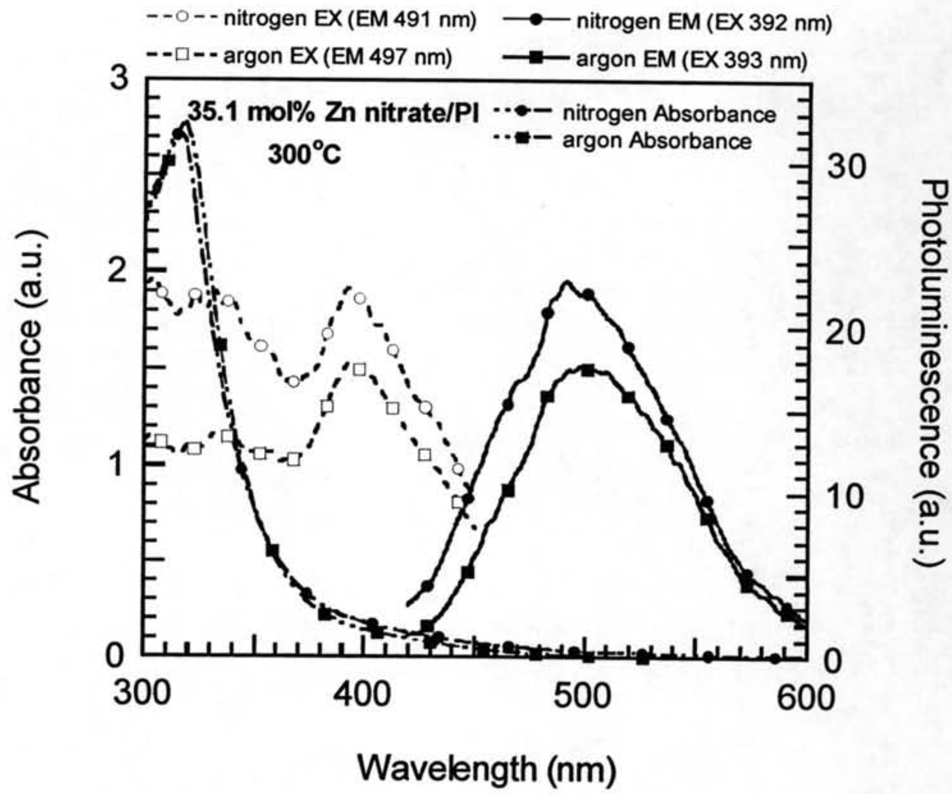

Figure E-5 Effect of curing atmosphere on photoluminescence of 35.1 mol% Zn nitrate/PI at 300°C curing temperature.

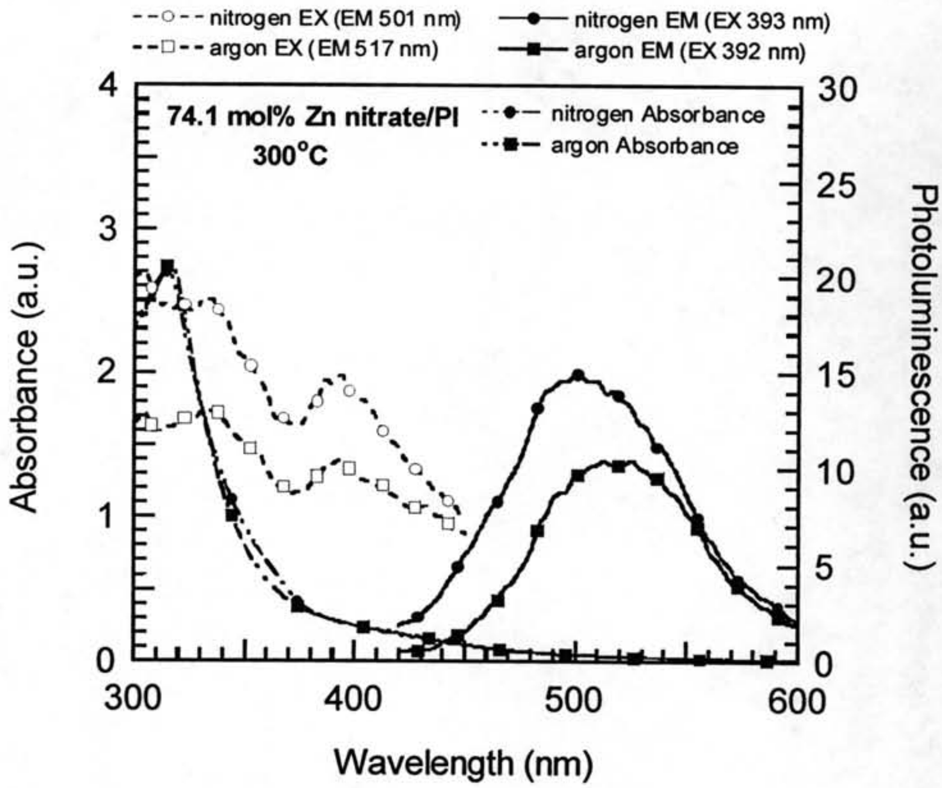

Figure E-6 Effect of curing atmosphere on photoluminescence of 74.1 mol% Zn nitrate/PI at 300°C curing temperature.

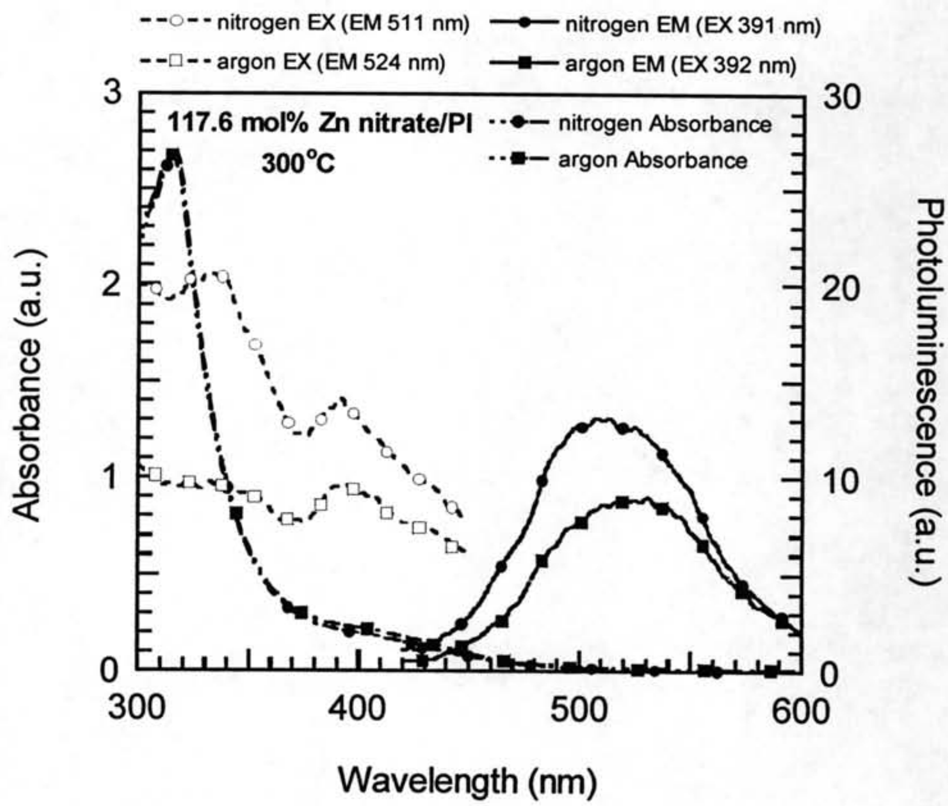

Figure E-7 Effect of curing atmosphere on photoluminescence of 117.6 mol% Zn nitrate/PI at 300°C curing temperature.

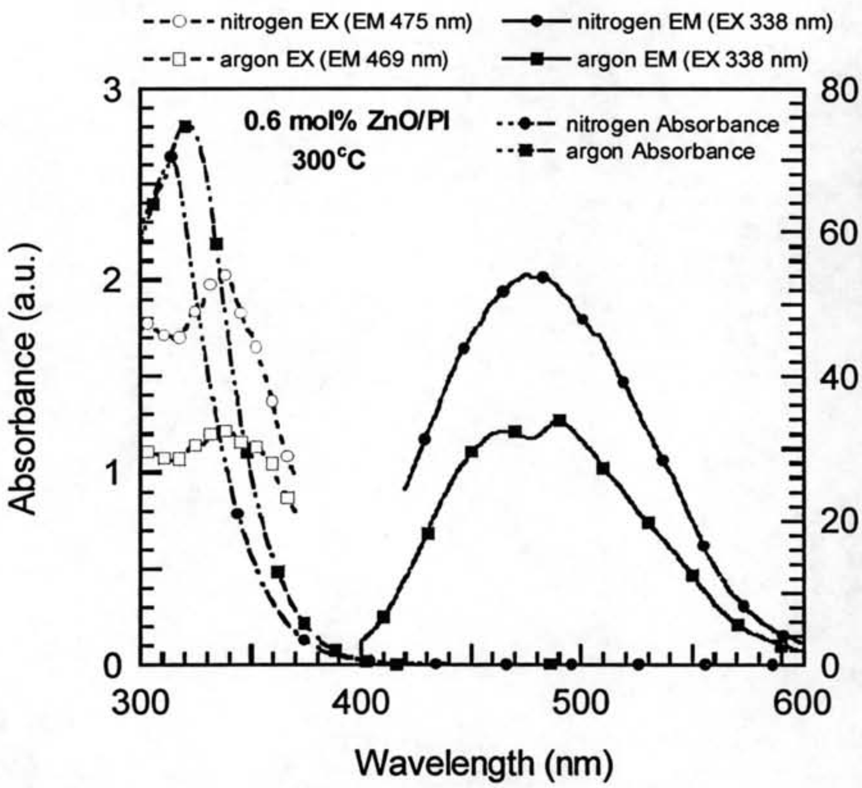

Figure E-8 Effect of curing atmosphere on photoluminescence of 0.6 mol% ZnO/PI at 300°C curing temperature.

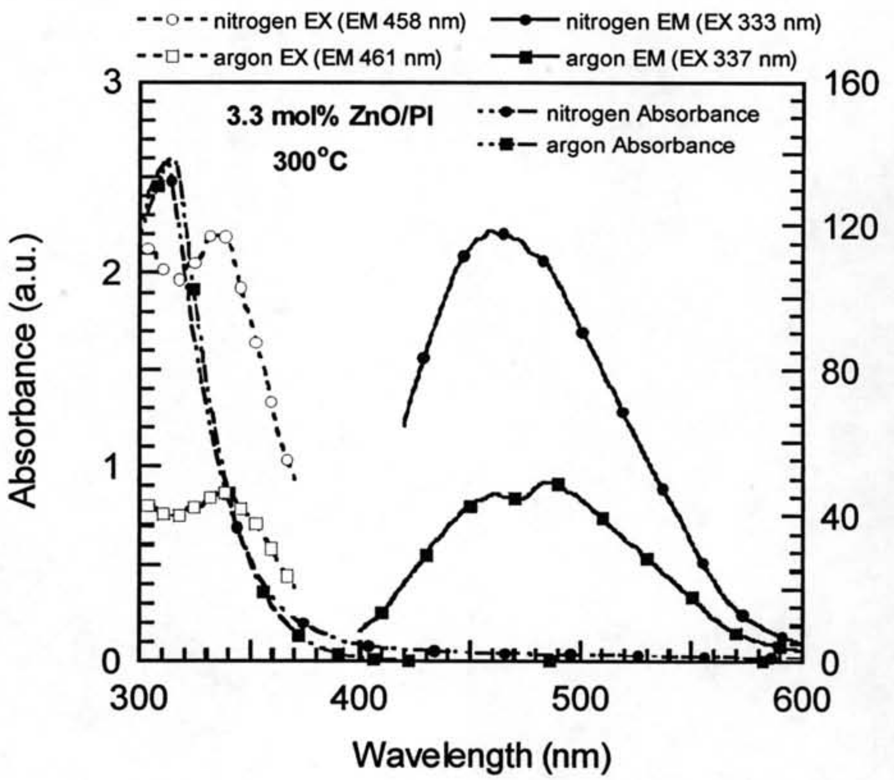

Figure E-9 Effect of curing atmosphere on photoluminescence of 3.3 mol% ZnO/PI at 300°C curing temperature.

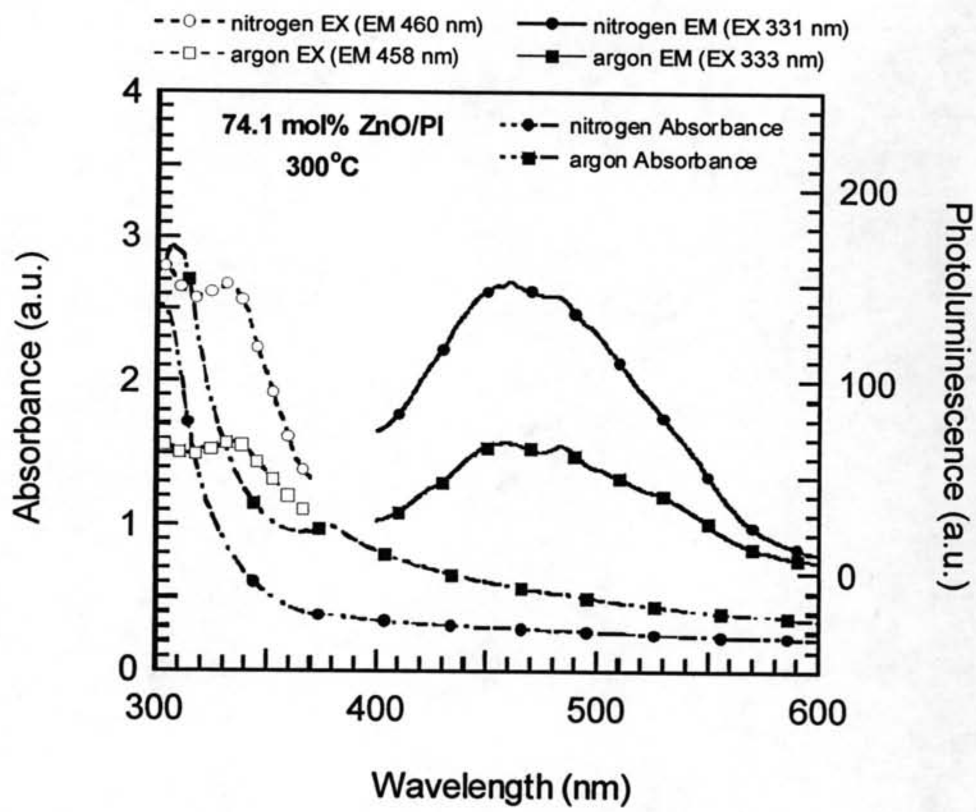

Figure E-10 Effect of curing atmosphere on photoluminescence of 74.1 mol% ZnO/PI at 300°C curing temperature.

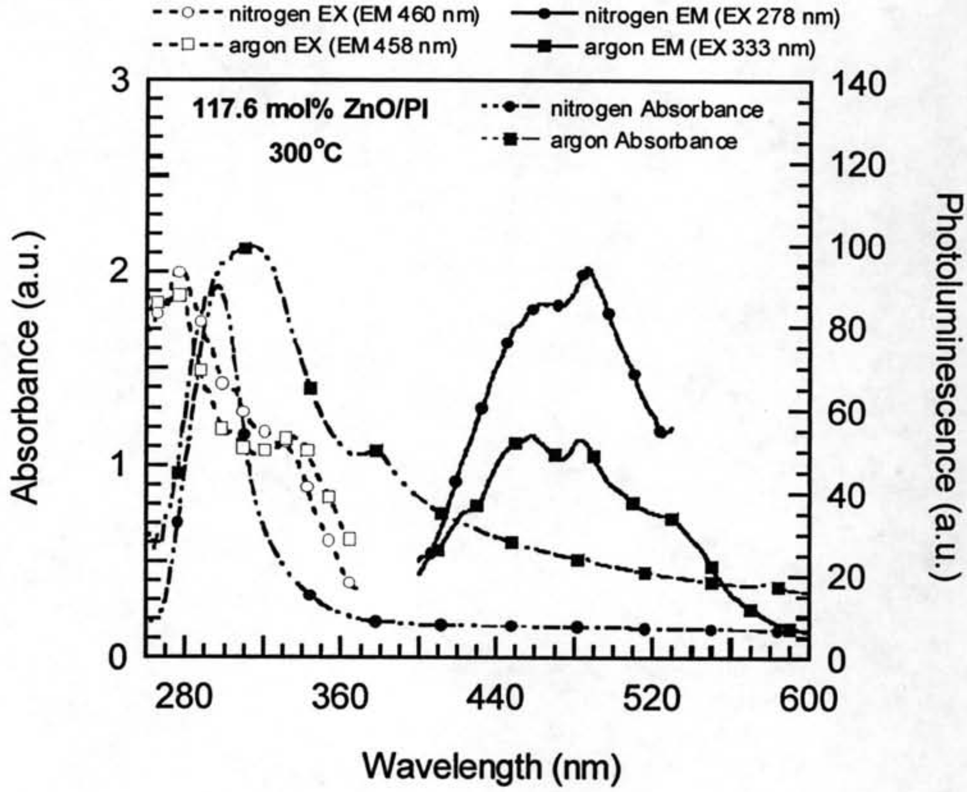

Figure E-11 Effect of curing atmosphere on photoluminescence of 117.6 mol% ZnO/PI at 300°C curing temperature.

APPENDIX F

Effect of ZnO concentration on photoluminescence

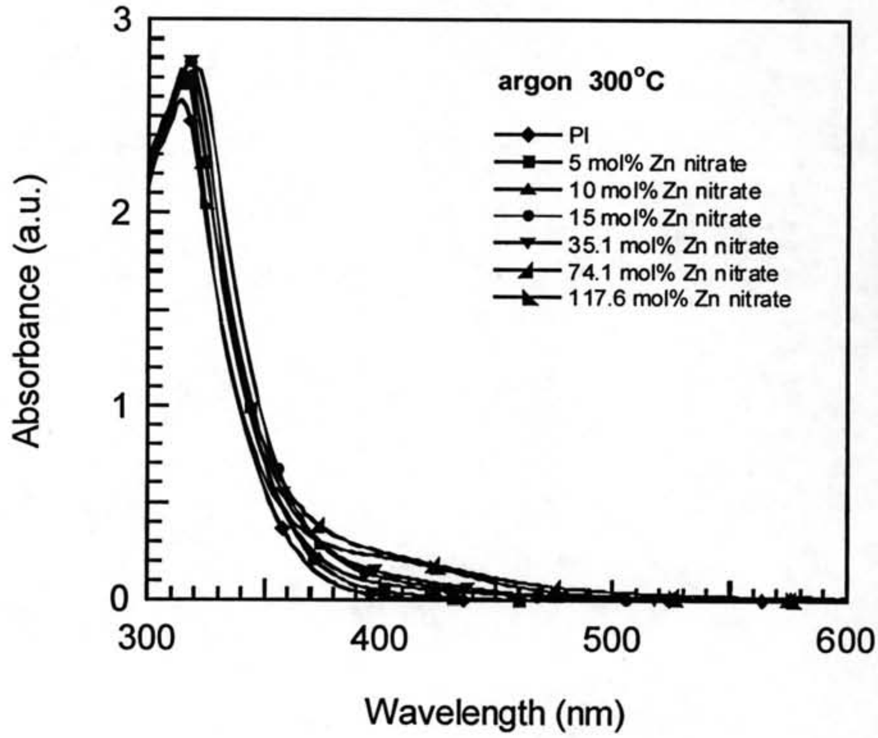

Figure F-1 Effect of ZnO concentration on absorbance of Zn nitrate/PI under argon atmosphere at 300°C curing temperature.

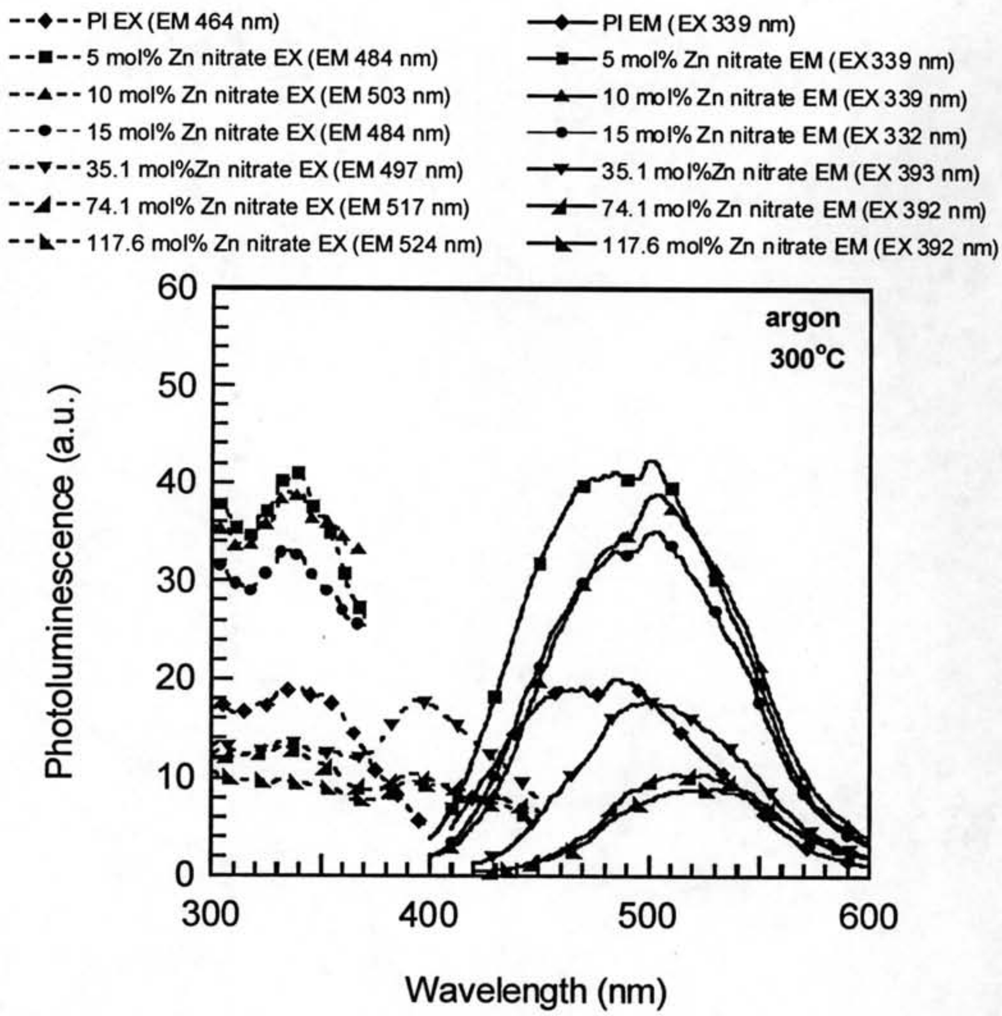

Figure F-2 Effect of ZnO concentration on photoluminescence of Zn nitrate/PI under argon atmosphere at 300°C curing temperature.

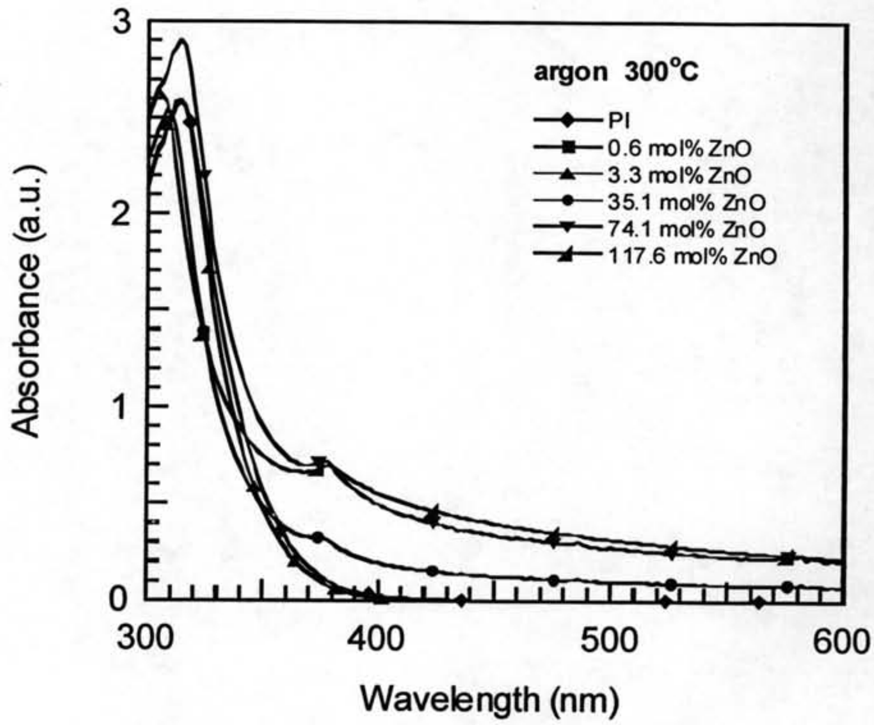

Figure F-3 Effect of ZnO concentration on absorbance of ZnO/PI under argon atmosphere at 300°C curing temperature.

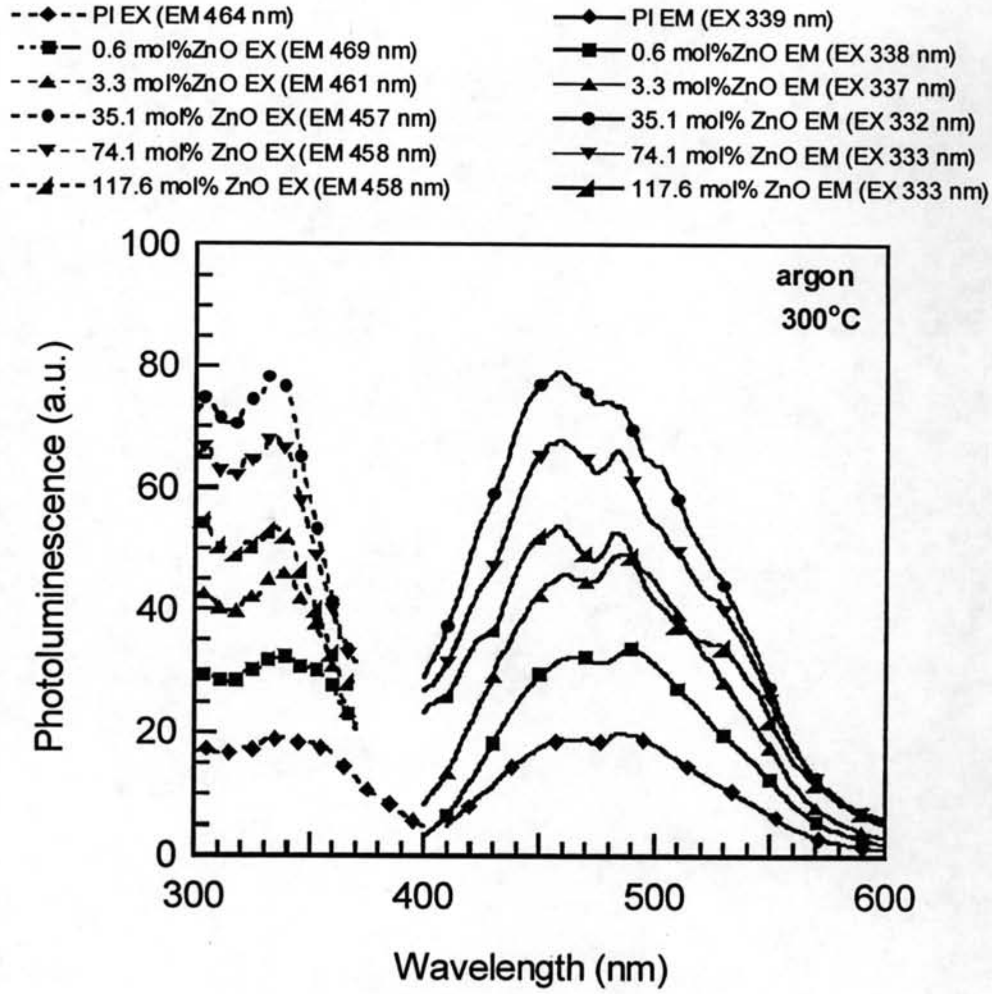

Figure F-4 Effect of ZnO concentration on photoluminescence of ZnO/PI under argon atmosphere at 300°C curing temperature.

APPENDIX G

Effect of the origin of ZnO on photoluminescence

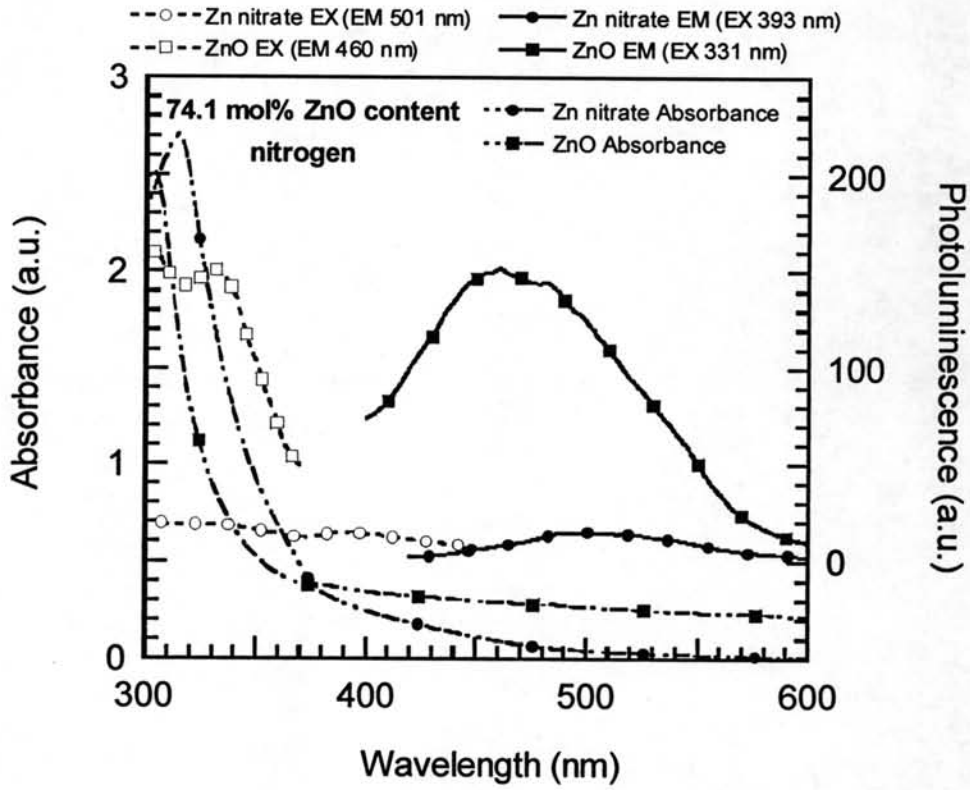

Figure G-1 Effect of the origin of ZnO at concentration of 74.1 mol% on photoluminescence under nitrogen atmosphere at 300°C curing temperature.

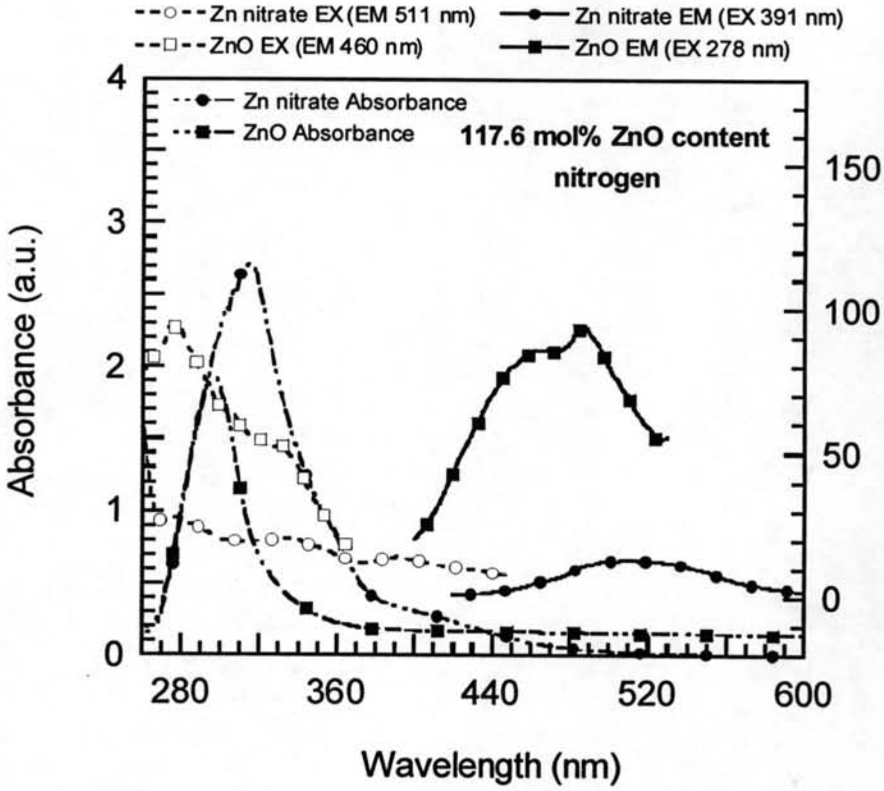

Figure G-2 Effect of the origin of ZnO at concentration of 117.6 mol% on photoluminescence under nitrogen atmosphere at 300°C curing temperature.

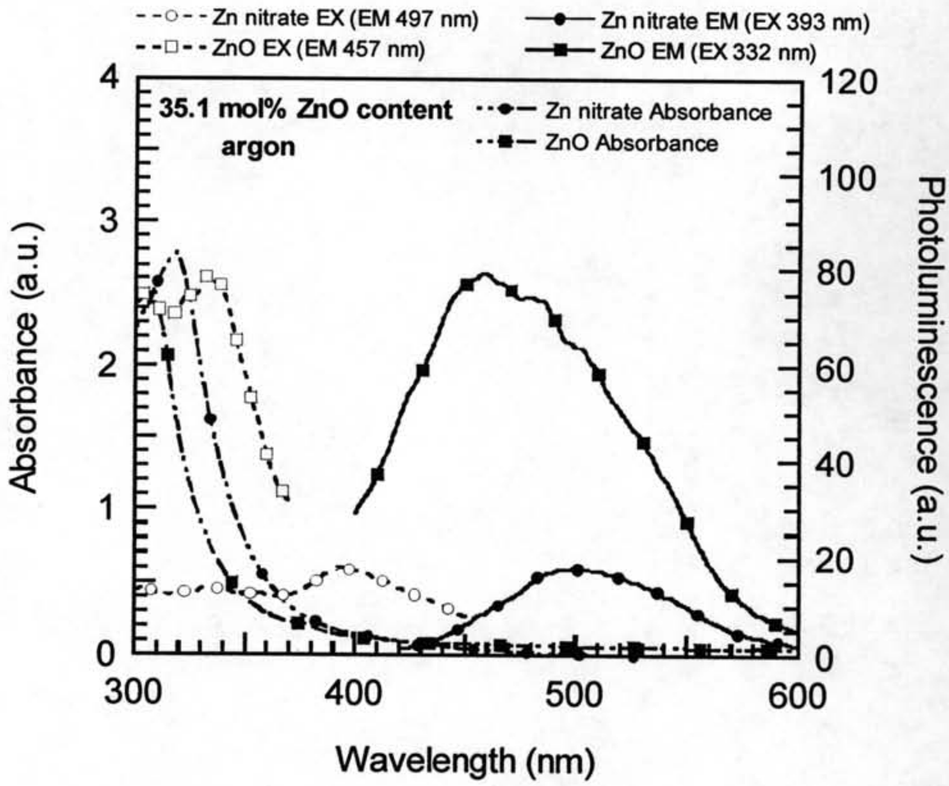

Figure G-3 Effect of the origin of ZnO at concentration of 35.1 mol% on photoluminescence under nitrogen atmosphere at 300°C curing temperature.

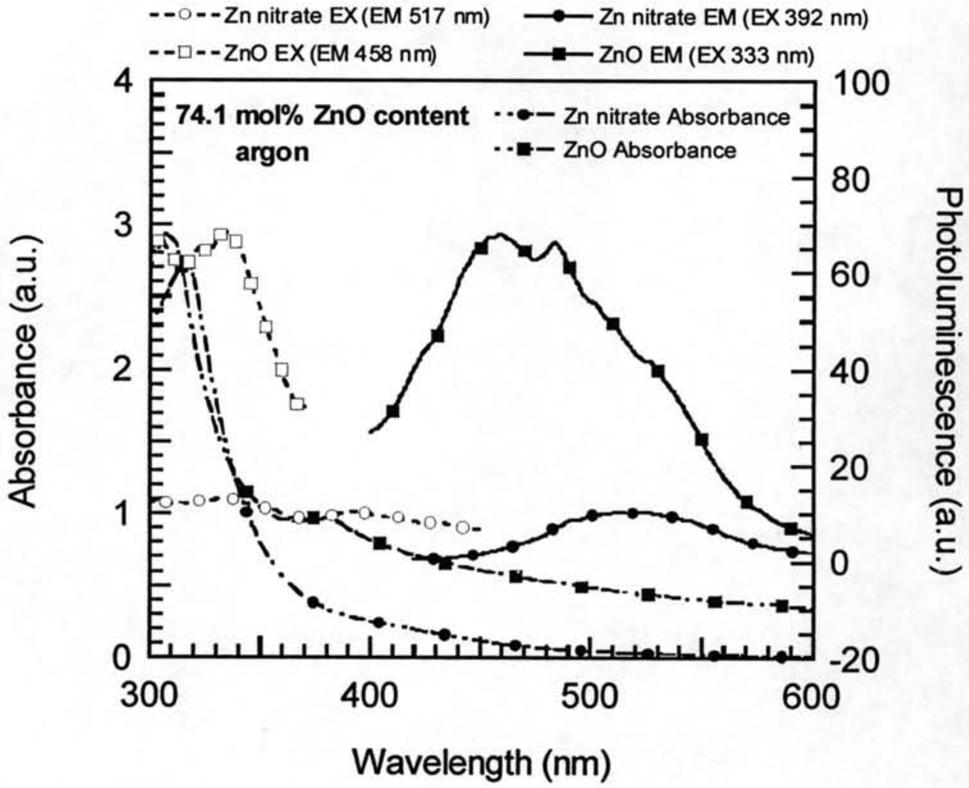

Figure G-4 Effect of the origin of ZnO at concentration of 74.1 mol% on photoluminescence under nitrogen atmosphere at 300°C curing temperature.

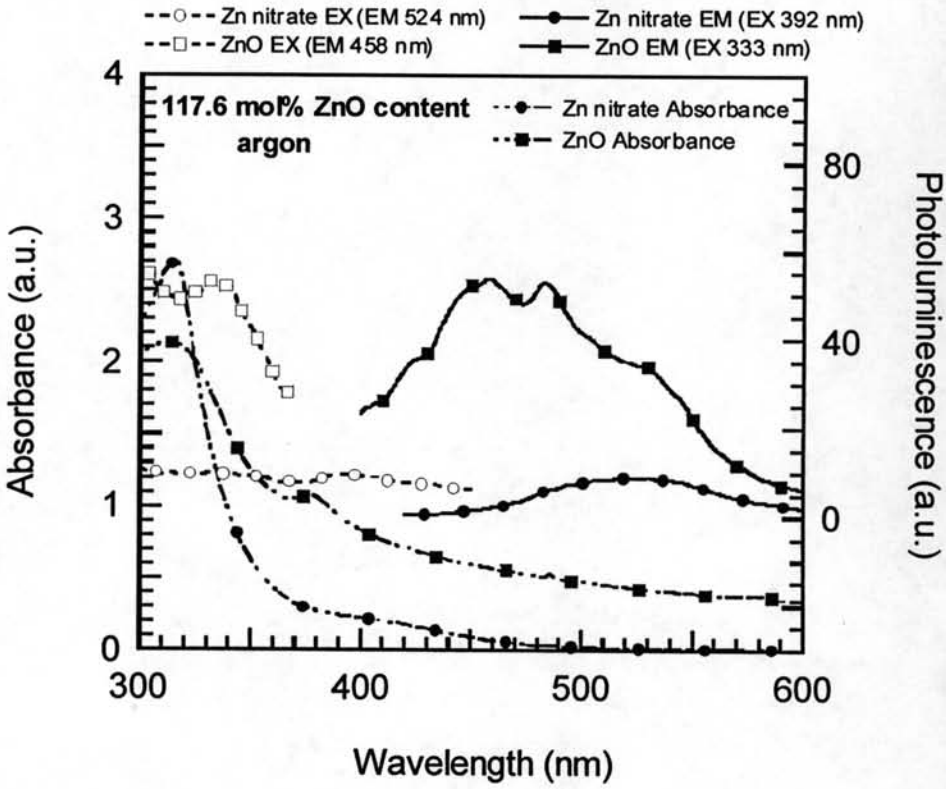

Figure G-5 Effect of the origin of ZnO at concentration of 117.6 mol% on photoluminescence under nitrogen atmosphere at 300°C curing temperature.

VITA

Miss Chuthatai Phanthawonge was born in Bangkok, Thailand on September 8, 1983. She completed senior high school at Samsenwittayalai School, Thailand in 2000 and received Bachelor degree from the Department of Chemical Engineering, Faculty of Engineering, Burapha University, Thailand in 2004. She continued her study for Master degree at Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University Bangkok, Thailand.

In addition, she was invited for oral presentation in 13th Regional Symposium on Chemical Engineering 2006 (RSCE 2006). This conference was held during 3-5 December, 2006 at Nanyang technological University, Singapore.