催化学报 » 2012, Vol. 33 » Issue (10) :1672-1680 DOI: 10.1016/S1872-2067(11)60446-4

LED Irradiation of a Photocatalyst for Benzene, Toluene, Ethyl Benzene, and Xylene Decomposition

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摘要 Studies on the use of gas phase applications of light emitting diodes (LEDs) in photocatalysis are scarce although their photocatalytic decomposition kinetics of environmental pollutants are likely different from those in aqueous solutions. The present study evaluated the use of chips of visible light LEDs to irradiate nitrogen doped titania (N-TiO_2) prepared by hydrolysis to decompose gaseous benzene, toluene, ethyl benzene, m-xylene, p-xylene, and o-xylene. Photocatalysts calcined at different temperatures were characterized by various analytical instruments. The degradation efficiency of benzene was close to zero for all conditions. For the other compounds, a conventional 8 W daylight lamp/N-TiO_2 unit gave a higher photocatalytic degradation efficiency as compared with that of visible-LED/N-TiO_2 units. However, the ratios of degradation efficiency to electric power consumption were higher for the photocatalytic units that used two types of visible-LED lamps (blue and white LEDs). The highest degradation efficiency was observed with the use of a calcination temperature of 350 ^{o}C. The average degradation efficiencies for toluene, ethyl benzene, m-xylene, p-xylene, and o-xylene were 35%, 68%, 94%, and 93%, respectively. The use of blue- and white-LEDs, high light intensity, and low initial concentrations gave high photocatalytic activities for the photocatalytic units using visible-LEDs. The morphological and optical properties of the photocatalysts were correlated to explain the dependence of photocatalytic activity on calcination temperature. The results suggest that visible-LEDs are energy efficient light source for photocatalytic gas phase applications, but the activity depends on the operational conditions.

关键词： light emitting diode energy efficiency gas phase degradation photocatalyst characterization calcination temperature

Abstract： Studies on the use of gas phase applications of light emitting diodes (LEDs) in photocatalysis are scarce although their photocatalytic decomposition kinetics of environmental pollutants are likely different from those in aqueous solutions. The present study evaluated the use of chips of visible light LEDs to irradiate nitrogen doped titania (N-TiO_2) prepared by hydrolysis to decompose gaseous benzene, toluene, ethyl benzene, m-xylene, p-xylene, and o-xylene. Photocatalysts calcined at different temperatures were characterized by various analytical instruments. The degradation efficiency of benzene was close to zero for all conditions. For the other compounds, a conventional 8 W daylight lamp/N-TiO_2 unit gave a higher photocatalytic degradation efficiency as compared with that of visible-LED/N-TiO_2 units. However, the ratios of degradation efficiency to electric power consumption were higher for the photocatalytic units that used two types of visible-LED lamps (blue and white LEDs). The highest degradation efficiency was observed with the use of a calcination temperature of 350 ^{o}C. The average degradation efficiencies for toluene, ethyl benzene, m-xylene, p-xylene, and o-xylene were 35%, 68%, 94%, and 93%, respectively. The use of blue- and white-LEDs, high light intensity, and low initial concentrations gave high photocatalytic activities for the photocatalytic units using visible-LEDs. The morphological and optical properties of the photocatalysts were correlated to explain the dependence of photocatalytic activity on calcination temperature. The results suggest that visible-LEDs are energy efficient light source for photocatalytic gas phase applications, but the activity depends on the operational conditions.

Keywords： light emitting diode, energy efficiency, gas phase degradation, photocatalyst characterization, calcination temperature

收稿日期: 2012-07-22; 出版日期: 2012-09-24

引用本文:

JO Wan-Kuen, KANG Hyun-Jung .LED Irradiation of a Photocatalyst for Benzene, Toluene, Ethyl Benzene, and Xylene Decomposition[J] 催化学报, 2012,V33(10): 1672-1680

JO Wan-Kuen, KANG Hyun-Jung .LED Irradiation of a Photocatalyst for Benzene, Toluene, Ethyl Benzene, and Xylene Decomposition[J] Chinese Journal of Catalysis, 2012,V33(10): 1672-1680

链接本文:

[1] Herrmann J-M, Duchamp C, Karkmaz M, Hoai B T, Lachheb H, Puzenat E, Guillard C. J Hazard Mater, 2007, 146: 624

[2] Xu J, Wang W, Shang M, Gao E, Zhang Z, Ren J. J Hazard Mater, 2011, 196: 426

[3] Gaya U I, Abdullah A H. J Photochem Photobiol C, 2008, 9: 1

[4] Paz Y. Appl Catal B, 2010, 99: 448

[5] Matsumoto T, Iyi N, Kaneko Y, Kitamura K, Ishihara S, Ta-kasu Y, Murakami Y. Catal Today, 2007, 120: 226

[6] Peng Y-P, Lo S-L, Ou H-H, Lai S-W. J Hazard Mater, 2010, 183: 754

[7] Seabra M P, Miranda Salvado I M, Labrincha J A. Ceram Int, 2011, 37: 3317

[8] Chatterjee D, Dasgupta S. J Photochem Photobiol C, 2005, 6: 186

[9] Asahi R, Morikawa T, Ohwaki T, Aoki K, Taga Y. Science, 2001, 293: 269

[10] Di Valentin C, Finazzi E, Pacchioni G, Selloni A, Livraghi S, Paganini M C, Giamello E. Chem Phys, 2007, 339: 44

[11] Peng F, Cai L, Yu H, Wang H, Yang J. J Solid State Chem, 2008, 181: 130

[12] Janus M, Choina J, Morawski A W. J Hazard Mater, 2009, 166: 1

[13] Jo W K, Kim J T. J Hazard Mater, 2009, 164: 360

[14] Wikipedia, Light-emitting diode, 2011. Accessed at http://en.wikipedia.org/wiki/Light-emitting_diode (accessed 07.02.11)

[15] Ran J, Yu J, Jaroniec M. Green Chem, 2011, 13: 2708

[16] Yu J, Ran J. Energy Environ Sci, 2011, 4: 1364

[17] Chen H-W, Ku Y, Irawan A. Chemosphere, 2007, 69: 184

[18] Ghosh J P, Sui R, Langford C H, Achari G, Berlinguette C P. Water Res, 2009, 43: 4499

[19] Shie J-L, Lee C-H, Chiou C-S, Chang C-T, Chang C-C, Chang C-Y. J Hazard Mater, 2008, 155: 164

[20] Liu Y, Liu J, Lin Y, Zhang Y, Wei Y. Ceramics Int, 2009, 35: 3061

[21] Nosaka Y, Matsushita M, Nishino J, Nosaka A Y. Sci Technol Adv Mater, 2005, 6: 143

[22] Xagas A P, Androulaki E, Hiskia A, Falaras P. Thin Solid Films, 1999, 357: 173

[23] Wang Z, Cai W, Hong X, Zhao X, Xu F, Cai C. Appl Catal B, 2005, 57: 223

[24] Liu S, Chen X, Chen X. Chin J Catal, 2006, 27: 697

[25] Xiong L, Sun W, Yang Y, Chen C, Ni J. J Colloid Interf Sci, 2011, 356: 211

[26] Xiang Q, Yu J, Jaroniec M. Phys Chem Chem Phys, 2011, 13: 4853.

[27] Geng J, Yang D, Zhu J, Chen D, Jiang Z. Mater Res Bull, 2009, 44: 146

[28] Araña J, Doña-Rodríguez J M, Portillo-Carrizo D, Fernández-Rodríguez C, Pérez-Peña J, González Diaz O, Navío J A, Macias M. Appl Catal B, 2010, 100: 346

[29] Peng T, Zhao D, Dai K, Shi W, Hirao K. J Phys Chem B, 2005, 109: 4947

[30] Wei F, Ni L, Cui P. J Hazard Mater, 2008, 156: 135

[31] Zhou M, Yu J, Liu S, Zhai P, Huang B. Appl Catal B, 2009, 89: 160

[32] Zhao J, Yang X D. Build Environ, 2003, 38: 645

[33] Strini A, Cassese S, Schiavi L. Appl Catal B, 2005, 61: 90

[34] Demeestere K, Dewulf J, Van Langenhove H. Crit Rev Envi-ron Sci Technol, 2007, 37: 489

[35] Liu B, Zhao X. Electrochim Acta, 2010, 55: 4062

[36] Chen Y, Lu A, Li Y, Yip H Y, An T, Li G, Jin P, Wong P K. Chemosphere, 2011, 84: 1276

[37] AFNOR, XP-B44-013 Standard, in Photocatalysis: Test & Analysis Method for Determining the Efficiency of Photo-catalytic Systems for Eliminating VOC/Odours in Recirculat-ing Indoor Air-Confined Chamber Test, 2009.

[38] Yu H, Zhang K, Rossi C. Indoor Built Environ, 2007, 16: 529

[39] Wang W, Ku Y. J Photochem Photobiol A, 2003, 159: 47

[40] Lim T H, Kim S D. Chemosphere, 2004, 54: 305

[41] Kim S B, Hong S C. Appl Catal B, 2002, 35: 305

[42] Zhang P Y, Liang F Y, Yu G, Chen Q, Zhu W P. J Photochem Photobiol A, 2003, 156: 189

[43] Hegedüs M, Dombi A. Appl Catal B, 2004, 53: 141

[44] Yu Q L, Brouwers H J H. Appl Catal B, 2009, 92: 454

[1] YANG S, YU M. S, KIM J. S, JO W. K.Alternative Use of Light Emitting Diodes in an Activated Charcoal-Supported Photocatalyst Reactor for the Control of Volatile Organic Compounds[J]. 催化学报, 2011,32(5): 756-761