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Photocatalytic activity of Lu^{3+}/TiO_2 prepared by ball milling method

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Abstract：Ball milling method was applied to prepare Lu^{3+}/TiO_2 photocatalysts. The catalysts were characterized with X-ray powder diffraction (XRD), X-ray photoelectron spectroscopy (XPS), UV-Visible diffuse reflectance spectra (UV-vis DRS), energy dispersive X-ray spectrometer (EDS),transmission electron microscopy (TEM) and Brunauer-Emmett-Teller (BET) method. The photocatalytic activities were determined by the degradation of methylene blue (MB)equipped with a 300 W medium pressure mercury lamp. Results show that the first order reaction rate constants of Lu^{3+}/TiO_2 and pure TiO_2 are 0.0565 and 0.0263 min^{-1}, respectively, which both were evaluated under the condition of catalysts loading of 0.2 g/L, initial concentration of 25 mg/L for MB, mole ratio of Lu^{3+}/TiO_2 of 1.5% and milling time of 4 h. The average crystal sizes of 1.5 mol% Lu^{3+}/TiO_2 and pure TiO_2 are 18.7 and 19.3 nm, respectively.

Keywords：ball milling method; rare earth; lutetium; titanium dioxide; methylene blue

In recent years, TiO_2 has been extensively studied and applied to sewage treatment and air purification.[1-2] It has been generally regarded as a low-price, high-efficiency, non-poisonous and stable semiconductor catalyst which could entirely destroy persistent organic contaminant.[3-4] However, only UV light can be absorbed by TiO_2 due to its wide band gap while the visible light can not be absorbed for the reaction and its low quantum yield also restricts the application of this technology.[5-6] Thus, researchers tried lots of methods to handle these problems in order to improve the photocatalytic activity of TiO_2, such as other elements doping, semiconductors coupling,[7-8] noble metalsdepositing and dye sensitization.[9-11] These methods could increase the photocatalytic efficiency of TiO_2 to a certain degree. Nevertheless, some technology problems still remain to be resolved. For instance, the improvement of materials preparation process needs to be studied.

Lots of study results showed that photocatalytic activity of TiO_2 can be improved efficiently while doped with rare earth elements.[12]A study conducted by Song et al. showed a remarkable example in the area of rare earth doping. It was demonstrated that RE ions (La^{3+}, Ce^{3+}, Pr^{3+}, Sm^{3+}, Eu^{3+}, Tb^{3+}, or Er^{3+}) doped TiO_2nanorods hadnarrowed band gap energy and improved photocatalytic activity in degrading methyl orange.[13,14]

Ball milling method has been an appealing technology recently which can make balls and raw materials fierce collided, squeezed and ground in a jar at a quite high speed rotation to prepare micro-nano composite materials.[15]In contrast to traditional chemical method, ball millingmethod has potential applications in industrial production synthesizing large numbers of catalysts. It has been considered to be a process that the materials are synthesized by the cyclic sheer cracking action and deformation at a specified time. In this process, the formation of nano-crystalline is the result of structural evolution under mechanical interaction through particle-ball, particle-wall and particle-particle instantaneous collision.[16] The grain defects are constantly generated in the interior of the particles. The grain size decreases and the strain increases with the increase of the milling time.[17]Ball milling method is widely applied to prepare nanometer materials, alloys, magnetic materials, superconducting materials and supersaturated solid solution materials.[18]Compared with sol-gel, hydrothermal and other chemical methods, the ball milling method has advantages of simple process, available raw materials, continuous production, etc.[19] In this

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