Nano ZnO synthesis by modified sol gel method and its application in heterogeneous photocatalytic removal of phenol from water

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Zinc oxide nanoparticles were synthesized by precipitation and modified sol gel methods. The influence of calcination temperature on morphology and crystallite size of ZnO was studied by varying temperature from 400 to 700 °C. The nano-structured ZnO particles were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), energy dispersive X-ray spectroscopy (EDXS) and transmission electron microscopy (TEM). The photo catalytic activity of as-prepared ZnO was evaluated by degradation of phenol under UV laser irradiation. The Photocatalytic degradation (PCD) efficiency of ZnO was found to decrease with the increase in calcination temperature due to agglomeration of particles and the increase in particle size. In addition to the effect of calcination temperature, the influence of various other parameters such as photocatalyst concentration, initial pH and the initial phenol concentration was also investigated to achieve the maximum PCD of phenol. The operational parameters show the expected influence regarding the efficiency of the photocatalytic degradation process. The results follow the pseudo-first order rate kinetics.

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1. Introduction

Sol–gel preparation of solid catalysts has been reported by many research groups since the 1980s [1–5]. Within the broad family of functional materials, metal oxides are particularly attractive with respect to applications in catalysis, sensing, energy storage and conversion, optics, and electronic devices [6]. Although they have been extensively studied by materials scientists for many years but still research is going on to synthesize metal oxides with well-defined shape, size and composition. The soft-chemistry routes especially sol–gel procedures offer unique advantages such as the possibility of obtaining metastable materials, achieving superior purity and compositional homogeneity of the products at moderate temperatures with simple laboratory equipment [7].

Semiconductor photo-catalysts offer huge potential for elimination of toxic chemicals [8]. The photocatalytic degradation of organic pollutants in water and air, using semiconductors such as TiO2 and ZnO have been focus of research recently due to their unique ability in the environmental detoxification [9–12]. ZnO, with band gap = 3.37 eV, has become promising in the past few years because of its distinctive optoelectronic, catalytic, and photochemical properties [13,14]. The quantum efficiency of ZnO is also significantly larger than that of TiO2 [15]. In some cases, ZnO has revealed better activity than TiO2 [16]. The ZnO-mediated photocatalytic process has been successfully used to degrade organic pollutants [17,11]. ZnO is available at low cost and it absorbs over larger fraction of the solar spectrum than TiO2 [18]. For this reason, ZnO is considered to be more suitable material for photocatalytic degradation of organic pollutants.

Phenol and phenolic compounds are widely used in industry and daily life. The presence phenol and phenolic compounds in the resulting wastewaters is an issue of environmental concern. Their high toxicity, even at low concentrations, have motivated the search and improvement of many waste treatment techniques. They have caused considerable damage and threat to the ecosystem in water bodies and human health due to their high stability, high toxicity and carcinogenicity. Removal of phenol and phenolics in wastewater effectively is a burning issue worldwide. Traditional wastewater treatment techniques include activated carbon adsorption, chemical oxidation and biological digestion, in which photocatalytic degradation assisted by titanium dioxide under ultraviolet light is extensively studied. More research has been focused recently on the search for new catalysts beyond TiO2, modification of the catalyst and the factors influencing photocatalytic rate and the reaction kinetics [19–21]. A few studies regarding photo-oxidation of phenol are reported in the literature [22–25].