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Synthesis, characterization and photocatalytic properties of lanthanum oxy-carbonate, lanthanum oxide and lanthanum hydroxide nanoparticles

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ABSTRACT

A simple thermal decomposition route has been developed to prepare La_2O_3 and $La_2O_2CO_3$ nanoparticles. Sonication of La_2O_3 nanoparticles in water at room temperature is accompanied to the formation of $La(OH)_3$ nanoparticles. The effect of addition of citric acid, as disperser, was also investigated on the phase formation and particle size distribution of the products. It is observed that citric acid has no effect on the particle size of the samples. The prepared nanoparticles were characterized by Fourier transform infrared spectroscopy (FT-IR), X-ray diffraction (XRD), transmission electron microscopy (TEM) and atomic force microscopy (AFM) analyses. Photocatalytic activity of the products was examined for degradation of methyl orange, a common reactive dye, as a pollutant under ultraviolet irradiation in the wastewater. The results show that $La_2O_2CO_3$ nanoparticles are promising materials in this photocatalytic degradation with no significant loss of activity even after four cycles of successive uses. A pseudo-first-order kinetic is obtained for the photocatalytic degradation of methyl orange over $La_2O_2CO_3$ nanoparticles according to the Langmuir–Hinshelwood analysis.

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1. Introduction

Particles of metal oxides that are in the nanometer size regime have attracted significant interests because of their atom-like size dependent properties [1]. Many improved pathways for the synthesis of such nanomaterials with tunable properties have been reported [2,3]. Recently, synthesis of metal oxide nanoparticles with new inorganic precursor has been interested, taking profit of the tools of organometallic chemistry [4–7]. A major interest at the moment is in the development of organometallic or inorganic compounds for preparation of nanoparticles [8, 9]. Using of the novel compound can be useful and open a new way for preparing nanomaterials to control nanocrystal size, shape and distribution size. A reduction in particle size to nanometer scale results in various interesting properties compared with the bulk properties. Having a large surface area, metal oxide and hydroxide nanomaterials show great advantages over conventional materials in many applications. For example, lanthanum oxide has different applications such as synthesis of ferroelectric and optical materials [10]. It has the lowest lattice energy of the rare earth oxides, with very high dielectric constant of 27 [11]. It is widely used in industrial applications and research projects. It shows a p-type semi-conducting property. Its resistivity at ambient temperature is equal to 10 kΩ·cm [12]. Lanthanum oxide is used to make optical glasses, which increases their density, refractive index, and hardness. In combination with oxides of tungsten, tantalum, and thorium, La_2O_3 improves the resistance of the glass against alkali compounds and is known as one of the ingredients for production of piezoelectric and thermoelectric materials. It is also used as a catalyst for the oxidative coupling of methane [13,14]. Owing to its excellent physical and chemical properties, $La(OH)_3$ has been extensively used as high-potential oxide ceramic, hydrogen storage materials, superconductive materials and, etc [15]. Until quite recently, the catalytic and sorbet properties of $La(OH)_3$ have been concerned intensively for their potential applications [16].

Different metal oxides, hydroxides and carbonates were examined as photocatalysts for wastewater treatment [17–19]. The effluents of textile and dye industries are the main pollutants in wastewater. This causes serious environmental problems such as increase of toxicity of environment, chemical oxygen demand (COD), biochemical oxygen demand (BOD), bad smell, and color of the wastewater [20]. The colored organic dyes are heavily polluted the water system [18]. The complete remediation of these dyes into less harmful chemicals is required to overcome these problems [21]. Among various dye remediation process, the heterogeneous photocatalytic process is well known method for the decomposition of hazardous waste materials especially organic compounds into less harmful chemicals [22]. In general, the semiconducting materials are required to facilitate the heterogeneous photocatalytic reaction. So far, many semiconductor materials such as TiO_2, ZnO, Fe_2O_3, CdS, and ZnS are effectively used as photocatalysts [18,19,23]. The aim of the present work is to prepare and characterize nanocrystals of $La_2O_2CO_3$, La_2O_3 and $La(OH)_3$ using an easily obtained precursor; [tris(salicylaldehydeato)Lanthanum(III)]; $La(sal)_3$. This is the first report on the synthesis of La_2O_3 nanoparticles from $La(sal)_3$. The photocatalytic activities were also evaluated using methyl orange degradation as a model of the organic pollutant in the wastewater under ultraviolet irradiation.

2. Experimental

2.1. Materials and physical measurements

All the chemicals and solvents were purchased from Merck and used as received without further purification. The FT-IR spectra of samples were recorded in a Perkin–Elmer FT-IR spectrometer. DR UV–Vis spectra were recorded by an Analytikjena UV–Vis spectrometer. Elemental analyses for C, H and N were performed on a LECO 600 CHN elemental analyzer. The Inductively coupled plasma (ICP) analysis was implemented for La content, using an INTEGRA model of GBC Company. Thermogravimetric-differential thermal analysis (TG-DTA) was carried out using a thermal gravimetric analysis instrument (TG/DTA6300 Japan) with a heating rate of 10 °C/min in the air atmosphere from ambient temperature to 750 °C. A single wave ultrasonic generator (Parsonic 2600s), operating at 28 ± 5% kHz with a maximum power output of 50 W, was used for the ultrasonic irradiation. The ultrasonic generator automatically adjusted the power level. X-ray diffraction patterns of the freshly calcined samples