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Photocatalytic study of alumina–zirconia ceramic nanocomposite synthesized by spray pyrolysis

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Abstract

The alumina–zirconia (Al_2O_3–ZrO_2) ceramic nanocomposite was synthesized by spray pyrolysis technique. The as-prepared nanocomposite was characterized by X-ray diffraction, scanning electron microscope and ultraviolet–visible spectroscopy. The as-prepared nanocomposite has a optical band gap ~2.42 eV. The catalytic activity of Al_2O_3–ZrO_2 ceramic nanocomposite was studied against the degradation of methylene blue in natural light. The photocatalysts show extraordinary reusability after 4th cycle.

Keywords: Photocatalytic study; Alumina–zirconia nanocomposite; Spray pyrolysis

1. Introduction

Alumina–Zirconia (Al_2O_3–ZrO_2) is one of the most basic and extensively studied high-performance ceramics [1]. The ceramic system becomes a part of interest due to its extraordinary properties such as hardness, wear resistance and chemical stability [2,3]. The literature survey around the Al_2O_3–ZrO_2 ceramic system shows that many research groups focused on the mechanical and microstructural properties of this ceramic system.

Huang et al. studied the quantitative analysis of the residual stress and dislocation density distributions around indentations in alumina and zirconia toughened alumina ceramics. The fluorescence and Raman spectroscopy were employed to study the effect of indentation loads, phase transformation and plastic deformation [4]. Ye et al. investigated the microstructure and mechanical properties of yttria-stabilized Al_2O_3–ZrO_2 nanocomposite ceramics. In this work, yttria-stabilized Al_2O_3–ZrO_2 nanocomposite ceramics exhibits hardness of the order of 19.8 GPa without any pressureless sintering [5]. Naglieri et al. reported the mechanical properties of alumina–zirconia composites, which exhibits exhibited the maximum value of hardness [6]. Zhao et al. synthesized the Al_2O_3–ZrO_2 (Y_2O_3) self-growing ceramic composites prepared by combustion synthesis under high gravity and studied the microstructural and mechanical properties of composite ceramics [7]. Tuan et al. examined the mechanical properties of Al_2O_3–ZrO_2 composites. In this study, t-phase zirconia and m-phase zirconia particles are incorporated by sintering pressurelessly at 1600 °C strength and toughness determined [8]. The toughness of Al_2O_3–ZrO_2 composites were studied by tuning the ZrO_2 matrix composition under identical conditions. In this work, toughness is discussed as function of yttria content and the residual stress due to the presence of the Al_2O_3 particles [9]. Nouri et al. studied the effect of alumina content on the structural properties of ZrO_2–Al_2O_3 unstabilized composite nanopowders. This study shows that an increase in Al2O3 content shifted the tetragonal zirconia (t-ZrO_2)-phase crystallization to higher temperatures [10].

In the present work, we planned to study the photocatalytic study of Al_2O_3–ZrO_2 ceramic nanocomposite prepared by spray pyrolysis. To the best of our knowledge, it is unique report present on the photocatalytic study of Al_2O_3–ZrO_2 ceramic nanocomposite. The main accomplishment of present work is

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outstanding recycling capability and stability of Al_2O_3–ZrO_2 ceramic nanocomposite as a catalyst.

2. Experimental

The Al_2O_3–ZrO_2 ceramic nanocomposite was synthesized by a spray pyrolysis technique using the starting chemicals $Al(NO_3)_3$ and $Zr(NO_3)_4$ of AR grade (SD Fine, India). The solution of precursor was prepared by taking 1:1 M ratio of both chemicals in double distilled water under constant magnetic stirring for 20 min. Subsequent to this step, solution was subjected to the ultrasonic homogenizer for 30 min. The as-obtained solution was loaded in chamber of spray pyrolysis of specification mentioned in Ref. [11]. During the spray pyrolysis, substrate temperature was maintained at 300 °C. After this step, Al_2O_3–ZrO_2 ceramic nanocomposite deposited substrate kept for heating at 500 °C for 5 h. Finally, a light yellow Al_2O_3–ZrO_2 nanocomposite powder was obtained. The flow chart for the preparation of Al_2O_3–ZrO_2 ceramic nanocomposite is shown in Fig. 1.

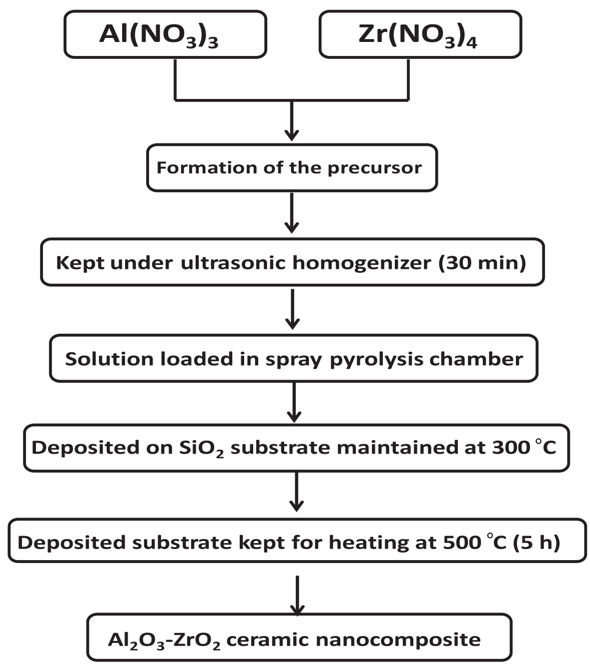

Fig. 1. Flow chart for the formation of Al_2O_3–ZrO_2 ceramic nanocomposite by spray pyrolysis technique.

The structural purity of the material was analyzed by a Rigaku Miniflex-II instrument in the scanning range 2θ from 10–70°. The microstructure of the Al_2O_3–ZrO_2 ceramic nanocomposite was observed in a JEOL JSM-7500F scanning electron microscope maintained at an accelerating voltage of 15 kV. The optical properties of the Al_2O_3–ZrO_2 ceramic nanocomposite were ascertained using Perkin Elmer ultraviolet–visible spectrophotometer (Lambda 850).

In the present work, photocatalytic degradation activity of as-prepared Al_2O_3–ZrO_2 ceramic nanocomposite catalyst was analyzed by most popular molecular probe methylene blue (MB). For the assessment of photocatalytic activity, base solution was prepared by taking 3 mL H_2O_2 and 3 mL MB solution in 100 mL of double distilled water. Subsequent to this step, Al_2O_3–ZrO_2 ceramic nanocomposite deposited SiO_2 substrate was immersed in the base solution under at ambient temperature for 30 min in dark. This complete assembly was irradiated by natural light. At fixed interval of time, single substrate was separated from assembly. The absorption spectrums of Al_2O_3–ZrO_2 ceramic nanocomposite deposited SiO_2 substrates were recorded and monitored around 608 nm peak.

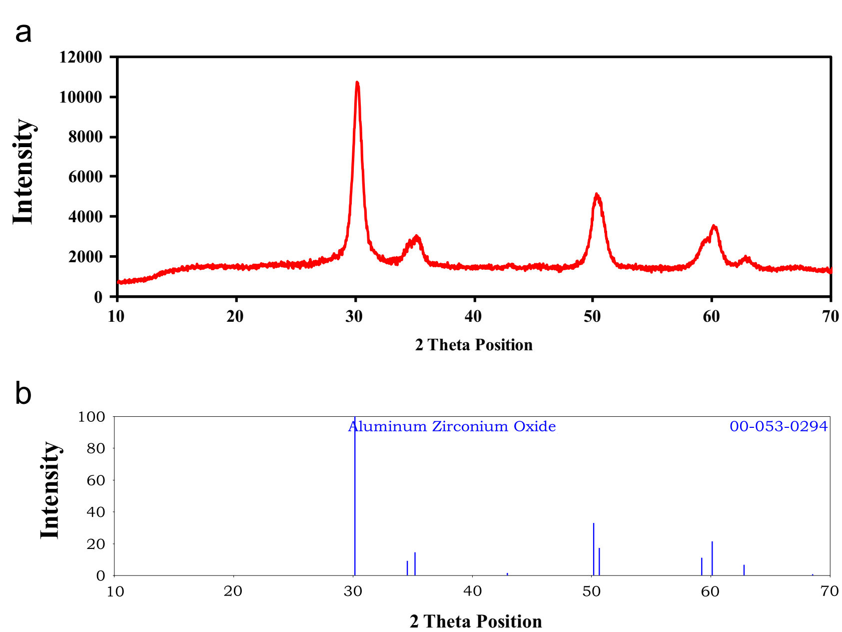

Fig. 2. (a) XRD spectra of as-prepared Al_2O_3–ZrO_2 ceramic nanocomposite and (b) diffraction peaks of Al_2O_3–ZrO_2 composite correspond to PDF-Card-00-053-0294.