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ORIGINAL PAPER

Simple Hydrothermal Synthesis of Ultra-Small Cerium Oxide Nanoparticles

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Abstract

Cerium oxide, CeO_2 nanoparticles (NPs) have been synthesized through various methods to achieve the desired physicochemical properties. However, high temperatures, pressure and long reaction time were involved. In this study, ultra-small CeO_2 NPs were successfully synthesized using the hydrothermal method but under a favourably low temperature (70 ℃) for 4 hours using cerium nitrate hexahydrate, $Ce(NO_3)_3 \bullet 6\ H_2O$ and sodium hydroxide, NaOH as the precursors while deionized water was used as the solvent. The synthesized ultra-small CeO_2 NPs were characterized using field emission scanning electron microscope (FESEM), transmission electron microscope (TEM), energy dispersive X-ray (EDX), ultraviolet visible (UV-Vis) spectrometer, Fourier transform infrared (FTIR) spectroscopy, X-Ray Diffraction (XRD) and Brunauer-Emmett-Teller (BET) method. The synthesized ultra-small CeO_2 NPs were determined to have an average particle size of 3.54 nm, crystallite size of 3.05 nm and a high specific surface area of 185 $m^2\ g^{-1}$. UV-Vis spectrum also showed absorption peak at 310 nm and FTIR spectrum intense peak at 447.20 cm^{-1} indicating the presence of CeO_2 NPs. FTIR, EDX and XRD diffraction pattern have proved that the synthesized CeO_2 NPs is of high purity. This study has successfully synthesized ultra-small CeO_2 NPs with optimal conditions of hydrothermal treatment at 70℃ for 4 hours and a percent yield of ~99%.

Keywords Cerium oxide nanoparticles · Ultra-small · Hydrothermal synthesis · Low temperature · Short- reaction time

Introduction

Nanoparticles are three-dimensional (3-D) particles with the size range of 1 to 100 nm. They are composed of either carbon, silicon and metals [1]. These NPs are synthesized in various ways and the large surface area of these particles allows them to have novel properties and to be highly reactive [2]. Due to these reasons, nanotechnology has been widely used in many fields including medicine, energy, industrial, environmental and commercial [3]. However, NPs consequently are constantly being produced and released to the environment especially into the aquatic life.

Cerium, Ce is a naturally occurring lanthanides and is the most abundant rare-earth metal found in the Earth's crust. It consists of four stable isotopes which are ^{136}Ce, ^{138}Ce, ^{140}Ce and ^{142}Ce with the ^{140}Ce being the most abundant (88.5%) [4]. This soft and ductile metal exists in the trivalent state (Ce^{3+}) and the tetravalent state (Ce^{4+}) while forming oxides of cerium dioxide (CeO_2) and cerium sesquioxide (Ce_2O_3) through oxidation [5]. Cerium oxide, CeO_2, NPs are metal oxides NPs used in various industries including in solar cells, fuel oxidation catalysis and chemical mechanical polarization [6] Since the last 40 years, the catalytic activity of this NP has also been used in automobile engines. This is due to their ability to reduce hydrocarbons and nitrous oxide emissions [5]. Furthermore, CeO_2 NPs are also useful in protecting cells against damage by free radicals and reactive oxygen species (ROS) because of the large surface area of these NPs that are available for oxygen storage.

However, different sizes of CeO_2 NPs behave differently and are used in different type of applications [7]. Ultra-small CeO_2 NPs possess a higher UV absorbance compared to bigger NPs which give them a higher energy band gap and photocatalytic

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