Succinic acid as a precursor for synthesis of nano cerium oxide

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Abstract:

Applying succinic acid as a versatile bidentate ligand to coordinate to cerium, resulted to a complex. The obtained crystalline complex was characterized by IR and melting point, then calcined at a certain temperature which was found by TGA method. Since in the first step, altering organic ligand type will affect on shape of precursor and as a result on the nano oxide, and in the next step, calcination time and temperature results in different morphologies of cerium oxide, we examine all these changes and conclude the optimum conditions and the best ligand to be succinic acid. Characterization of the nanorods of CeO_2 was performed by XRD, SEM and IR. Cerium oxide in nano-scale has many applications such as oxygen reservation capacity, conductivity, high UV absorption, high hardness, catalysis, fuel cells, sensors.

Keywords: Succinic acid, Cerium oxide, Nanorods

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1. Introduction

Ceria, CeO_2, is a well-known functional rare earth oxide and nanostructured ceria has been extensively used in many areas including high-storage capacitor devices, buffer layer for conductors, fuel cells, polishing materials, UV blocks and optical devices [1-3]. In addition, CeO_2 has been widely used in atumotative catalysts[1-2] due to its unique characteristics of facile Ce(IV) and Ce(III) switching. Simulated by both their promising application and their fantastic properties, much attention has been directed to the controlled synthesis of CeO_2 nanostructured materiales. Over the past few years, a remarkable process has been developed for the synthesis of CeO_2 with different morphologies and sizes due to its size/shape-dependent properties.

The physical/chemical properties of cerium oxides are strongly dependent on their microstructures, including size, morphology, and specific surface area [3]; therefore, the preparation of nanocrystalline ceria has been drawing much attention by the material scientists and chemists. A variety of chemical techniques have been utilized to prepare ceria nanomaterials, including hydrothermal [4–5], microemulsion, precipitation, sol–gel, and solvothermal synthesis [6–7].

Recently, Taniguchi et al. reported the synthesis of organophilic CeO_2 nanoparticles by a single step reaction of cerium oleate complex with NH_4OH[8]. The reaction was carried out at room temperature in an aqueous medium. The authors claimed that the oleate links to the surface of CeO_2 particles by chemical bonding and render the particles' surface an organophilic nature.

The same research group performed supercritical hydrothermal synthesis of hydrophilic polymer-modified CeO_2 nanoparticles.

2. Experimental

2.1 Materials

All reagents used in this work were of analytical grade, purchased from Merck Chemical Co. and used without further purification.

2.2 Synthesis method

Cerium nitrate hexahydrate and cerium choloride heptahydrate was used as the metal source. In a typical procedure, 1 mmol of $Ce(NO_3)_3 \cdot 6H_2O$ was dissolved in deionized water under stirring to form a homogeneous solution. Subsequently,1 mmol of succinic acid was dissolved in 30 ml of deionized water with a few drops 0.01 M NaOH solution. The obtained solution was introduced into the above homogeneous solution under continuous stirring. After 30 minutes, the solution was transferred into a Teflon-lined stainless steel autoclave, sealed, and maintained for 36 h. The supernatant liquid was discarded and the remaining product was washed with deionized water and ethanol in sequence several times, and then separated by centrifugation.and then the solution was poured into a Teflon-lined autoclave. The product was dried in a vacuum oven.

2.3 Characterization

The powder X-ray diffraction (XRD) patterns of products were obtained on a JEOL diffractometer with monochromatized CuKα radiation (l = 1.5418 Å). Fourier transform infrared (FT-IR) spectra were recorded on a Shimadzu-8400S spectrometer in the range of 400–4000 cm^{-1} using KBr pellets. Scanning electron microscopy (SEM) images were taken on a Philips XL-30 with gold coating and finally thermogravimetric analysis (TGA) were on a 931 TA Instruments analyzer.

3. Results and discussion

3.1 XRD pattern

Chemical compositions of generated nanoparticles are verified by powder X-ray diffaraction analysis. Figure 1a, b shows the XRD pattern for the fcc CeO_2.Diffraction peaks along (111), (200), (220), (311) and (222) planes confirm the cubic fluorite structure (JCPDS:34-0394) of CeO_2.

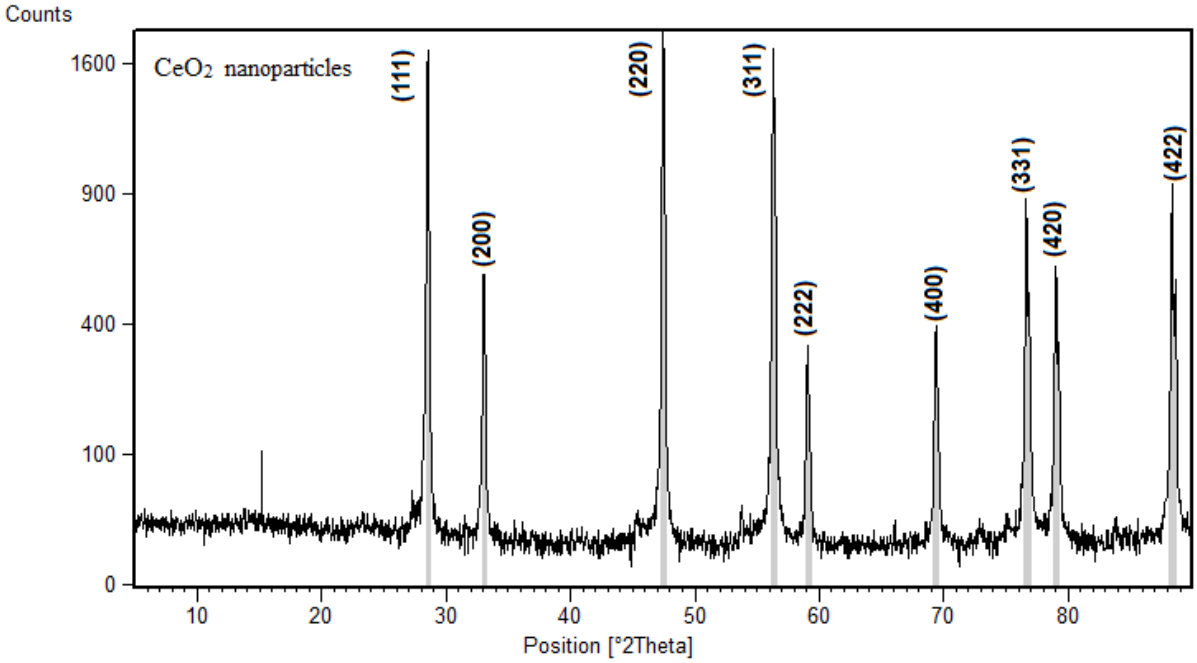

Fig. 1 The XRD pattern of the obtained CeO_2 particles

3.2 SEM studies

The morphological studies of the synthesized cerium oxide have been carried out by scanning electron microscopy. Fig. 2 displays the SEM image of the product. As it can be observed, the product is consistedof agglomerated nanoparticles constructing nanostructures in the range of 1-100nm.

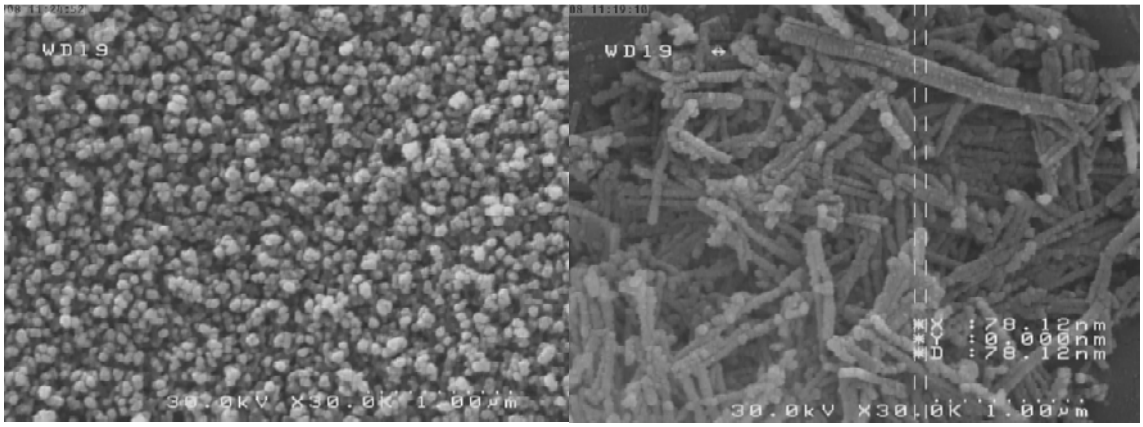

Fig. 2 The SEM image of the obtained CeO_2 particles

3.3 TGA

Thermal behavior of the prepared CeO_2 nanomaterial was monitored by thermogravimetric analyses. As can be seen in Fig. 3, the TGA curve shows a two step process and there is 6.7% weight loss below 200 °C due to the removal of associated water which is in good agreement with the results of FT-IR spectroscopy. The second step of weight loss about 400 °C is ascribed to the thermal decomposition of organic compounds in the DTA curve; an exothermic peak at 400 °C confirms this explanation.

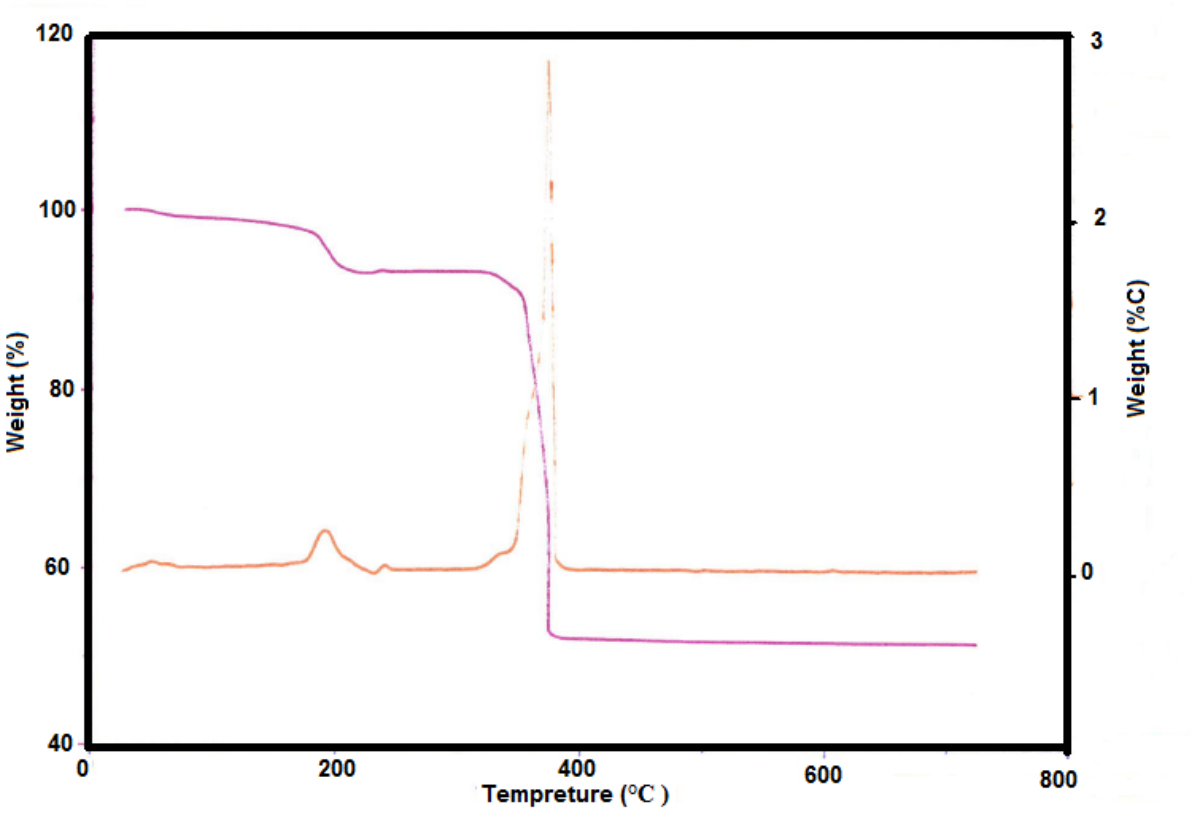

Fig. 3 The TGA analysis of CeO_2 particles

4. Conclusion

In a summary, our novel method of synthesis based on succinic acid was proven to be facile, highly economical and environmentally friendly. CeO_2 nanostructure has been synthesized by hydrothermal decomposition reaction with succinic acid as an available and affordable ligand. The XRD spectrum shows the presence of CeO_2. It is expected that as-prepared ceria nanostructure have potential applications in several fields as catalysts, catalyst supports, chemical sensors, storage hydrogen devices and optical or electrical materials.

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