Chapter 1

Introductory Chapter: Cerium Oxide - Applications and Attributes

Sher Bahadar Khan and Kalsoom Akhtar

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.82757

1. Introduction

Cerium belongs to lanthanide series and available most abundantly in the crust of the earth with an average concentration of 50 ppm as a rare earth element. Elemental cerium is a flexible and malleable lustrous metal. Cerium metal is iron-gray in color and is highly reactive. It is also known as a strong oxidizing agent and exists as cerium oxide in association with oxygen atoms. It exists as either cerous (Ce^{3+}, trivalent state) or ceric (Ce^{4+}, tetravalent state) in the form of compounds [1].

It is clear from the title that this book is related to cerium oxide (CeO_2) which is one of the important transition metal oxides acting as n-type semiconductor materials. It possesses several features resulted from the combination of high amount of oxygen in its structure and the facile change between the reduced and oxidized states (Ce^{3+} and Ce^{4+}) [2]. The CeO_2 has cubic fluorite structure, in which each cerium atom is surrounded by eight equivalent oxygen atoms and each oxygen atom is surrounded by a tetrahedron of four cerium atoms. Ideally, CeO_2 should have a formal charge of −2 and distance between oxygen–oxygen atoms should be 2.705 Å, in which the formal charge of cerium ions is +4 [3].

The main unique characteristics of cerium oxide involve a band gap of 3–3.6 eV, high value of dielectric constant up to $\kappa = 23–26$, high refractive index of n: 2.2–2.8, and high dielectric strength reached to 2.6 MV cm^{-1} [4]. Such properties qualify cerium oxide-based materials to be employed in various applications, especially when they are in nanosized particles. The cerium oxide is a famous member of nanostructured materials having a wide range of applications. Cerium oxide materials/nanomaterials have been utilized in numerous fields including adsorption, catalysis, photocatalysis, sensing, fuel cells, hydrogen production, semiconductor devices as well as biomedical uses [5–10].

Commercial uses of CeO_2 could be utilized in the pure form or in a concentrated dose as a polishing powder for glasses as well as ophthalmic lenses or precision optics. Cerium oxide is also employed as a glass constituent for preventing solarization and discoloration, particularly in television screens. The CeO_2 contributes in heat-resistant alloy and ceramic coatings. Cerium oxide is also used in petroleum refining and emission controlling system in gasoline engines as well as a diesel fuel-borne catalyst to reduce particulate matter emissions. In recent years, CeO_2 nanoparticles have gained more consideration in biomedical research community since they could be used as inhibiting cellular agent along with their antimicrobial and antioxidant activity [1, 5].

Owing to the dramatical and widespread industrial uses of cerium oxide materials, the National Institute of Environmental Health Sciences is suggested and nominated CeO_2 for toxicological characterization because of its limited toxicity data, and a lack of toxicological studies for nanoscale CeO_2. CeO_2, which is one of important transition metal oxides, acts as n-type semiconductor materials that have diverse applications such as adsorption, catalysis, photocatalysis, sensing, fuel cells, hydrogen production, semiconductor devices as well as biomedical uses.

Author details

Sher Bahadar Khan[1,2]* and Kalsoom Akhtar[1]

*Address all correspondence to: sbkhan@kau.edu.sa

1 Chemistry Department, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia

2 Center of Excellence for Advanced Materials Research (CEAMR), King Abdulaziz University, Jeddah, Saudi Arabia

References

[1] EPA. Cerium Oxide and Cerium Compounds, Washington, DC, 2009

[2] Nakagawa K, Tezuka Y, Ohshima T, Katayama M, Ogata T, Sotowa K-I, et al. Formation of cerium carbonate hydroxide and cerium oxide nanostructures by self-assembly of nanoparticles using surfactant template and their catalytic oxidation. Advanced Powder Technology. 2016;**27**:2128-2135

[3] Arunkumar P, Meena M, Babu KS. A review on cerium oxide-based electrolytes for ITSOFC. Nanomaterials and Energy. 2012;**1**:288-305

[4] Vangelista S, Piagge R, Ek S, Sarnet T, Ghidini G, Martella C, et al. Structural, chemical and optical properties of cerium dioxide film prepared by atomic layer deposition on TiN and Si substrates. Thin Solid Films. 2017;**636**:78-84

[5] Rajeshkumar S, Naik P. Synthesis and biomedical applications of cerium oxide nanoparticles–A review. Biotechnology Reports. 2018;**17**:1-5

[6] Dhall A, Self W. Cerium oxide nanoparticles: A brief review of their synthesis methods and biomedical applications. Antioxidants. 2018;**7**:97-109

[7] Khan SB, Faisal M, Rahman MM, Jamal A. Exploration of CeO_2 nanoparticles as a chemi-sensor and photo-catalyst for environmental applications. Science of the Total Environment. 2011;**409**:2987-2992

[8] Faisal M, Khan SB, Rahman MM, Jamal A, Akhtar K, Abdullah MM. Role of ZnO-CeO_2 nanostructures as a photo-catalyst and chemi-sensor. Journal of Materials Science & Technology. 2011;**27**:594-600

[9] Khan SB, Faisal M, Rahman MM, Akhtar K, Asiri AM, Khan A, et al. Effect of surfactant on the particle size, photocatalytic activity and sensing properties of CeO_2 nanoparticles. International Journal of Electrochemical Sciences. 2013;**8**:7284-7297

[10] Khan SB, Karimov KS, Chani MTS, Asiri AM, Akhtar K, Fatima N. Impedimetric sensing of humidity and temperature using CeO_2–Co_3O_4 nanoparticles in polymer hosts. Microchimica Acta. 2015;**182**:2019-2026