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Chapter 1

Introductory Chapter: Cerium Oxide - Applications and Attributes

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Additional information is available at the end of the chapter

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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.

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