Influence of Eu\(^{3+}\) doping content on antioxidant properties of Lu\(_2\)O\(_3\) sol-gel derived nanoparticles

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Abstract

This paper presents the synthesis of pure and europium-doped lutetium oxide (Lu\(_2\)O\(_3\)) powders prepared by sol-gel method. The influence of europium ion concentration into Lu\(_2\)O\(_3\) nanocrystallites was investigated for the first time in an in vitro system using a modified ABTS radical cation decolorization assay to determine the antioxidant activity. The crystalline structure of Lu\(_2\)O\(_3\) and Eu:Lu\(_2\)O\(_3\) powders was elucidated by XRD obtaining cubic phase in all system without secondary products in accordance with FT-IR results. By TEM and Scherrer equation, it was determined that Lu\(_2\)O\(_3\) and Eu:Lu\(_2\)O\(_3\) powders presented nearly spherical particle morphology with crystallites sizes in the range of 8 to 13 nm. The antioxidant assays results revealed that europium ion enhance Lu\(_2\)O\(_3\) powders antioxidant properties, showing that 12.5 mol% of europium is sufficient to reach its maximum capacity.

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1. Introduction

Currently, in molecular biology and biotechnology, the study of antioxidant activity of different (diverse) materials and compounds is a large area of interest because of the important role of antioxidants in biosystems in scavenging free radicals [1]. Reactive chemical species that have one unpaired electron in an outer orbit [2]. Most free radicals that harm biological systems are oxygen-free radicals, known as “reactive oxygen species” (ROS), generated during natural biological processes. Furthermore, they can initiate a chain of damage [3]. In the search of new antioxidant materials, the use of metal oxide nanoparticles [4–6] has recently been proposed, since they are more stable and robust and have a longer shelf life compared to organic agents [7]. They have shown promising scavenging effect results, sparking consideration of these nanomaterials directly as therapeutic agents on some tumors treatment [8] or as antibacterial materials [7]. It has been suggested that the antioxidant properties of these materials are strongly dependent on crystal structure, oxygen vacancies distribution and particle size [9,10]. Nevertheless, a simple way to modify the antioxidant properties of these oxide nanoparticles is doping, as has been observed in Ag-doped Bi\(_2\)O\(_3\): Ag\(^{3+}\) [11] and SnO:Ag\(^{3+}\) nanoparticles [12].

Recently, the use of compounds doped with rare-earth ions as antibacterial agents has been proposed [13–15]. Y\(_2\)O\(_3\): Eu\(^{3+}\) host matrix has showed crystal defects in its crystalline structure such as oxygen vacancies, and as a consequence, it has demonstrated biological activities, particularly antioxidant property. Based on these findings, these materials could be proposed for potential biological applications. [9].

Lutetium sesquioxide (Lu\(_2\)O\(_3\)) is a very attractive host material for various activators because of its wide band gap (5.8 eV) and favorable properties such as phase stability, low thermal expansion, and chemical stability [16]. Lutetium oxide presents a cubic crystal phase [17] and has been synthesized by different ways, including sol-gel method [18], through a molten salt route [19], by the Pechini sol-gel method [20], and co-precipitation method [21]. The sol-gel method has been used to synthesize nanostructured powders and films because of its advantages, such as employing lower temperatures in the process, high homogeneity and purity of resulting materials, and the possibility of several forming processes [22]. It also offers the advantage that precursors such as alkoxides are often volatile and easy to purify. These advantages provide a highly porous material that can be amorphous or nanocrystalline [23]. The main objective of using the sol-gel method is to control material surfaces and interfaces during the early stages of