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Optical and structural characteristics of Y_2O_3 thin films synthesized from yttrium acetylacetonate

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Abstract Yttrium oxide thin films are deposited on silicon substrates using the ultrasonic spray pyrolysis technique from the thermal decomposition of a β-diketonate, yttrium acetylacetonate (Y(acac)$_3$). The decomposition of Y(acac)$_3$ was studied by thermogravimetry, differential scanning calorimetry, mass spectrometry, and infrared spectroscopy. It was found that a β-diketone ligand is lost during the initial steps of decomposition of the Y(acac)$_3$. The rest of the complex is then dissociated or degraded partially until Y_2O_3 is obtained in the final step with the presence of carbon related residues. Then the Y(acac)$_3$ was used to synthesize Y_2O_3 thin films using the spray pyrolysis technique. The films were deposited on silicon substrates at temperatures in the range of 400–550 °C. The films were characterized by ellipsometry, infrared spectroscopy, atomic force microscopy, and X-ray diffraction. The films presented a low surface roughness with an index of refraction close to 1.8. The crystalline structure of the films depended on the substrate temperature; films deposited at 400 °C were mainly amorphous, but higher deposition temperatures (450–550 °C), resulted in polycrystalline with a cubic crystalline phase.

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Introduction

Metallic and rare-earth oxides thin films such as ZrO_2, HfO_2, Y_2O_3, La_2O_3, Al_2O_3, etc., have been studied due to their applications in several areas of technological interest. For example, because of their wide energy band gap, some of these oxides are used as host matrix on the fabrication of luminescent materials [1]. Also, they are studied as optical layers [2], as protective or antireflection layers, as well as detectors [3–6]. Thin films of materials such as ZrO_2, Y_2O_3, and Al_2O_3 have shown an energy band gap higher than 5 eV [7]. Furthermore, the different applications above mentioned require thin and uniform films with a low surface roughness [8]. Most techniques that involve a deposition from a chemical vapor lead in general to films with a low surface roughness and with excellent adherence on the substrates used [9]. The chemical decomposition of the reagents used to get the films then becomes very important, to predict their properties. Among the wide variety of these chemical techniques used to deposit thin films, the spray pyrolysis technique is considered a low cost and simple deposition technique that leads to thin films and coatings with good optical, structural, and electrical properties [10, 11].

Yttrium oxide (Y_2O_3), is considered an interesting material for different technological applications due to its unique properties such as a high melting point (2,410 °C) [12], wide energy band gap (5.5 eV) [13], high resistivity of 10^{11}–10^{12} Ω-m, high dielectric strength, and high dielectric constant (up to 13) [9, 14]. Because of its transparency (in the ultraviolet and visible range of the electromagnetic spectrum), Y_2O_3 is a prospective material to be used as antireflection and protective layer [15]. In addition, recent studies consider Y_2O_3, as a good candidate to replace SiO_2 in the microelectronic industry because of