I. INTRODUCTION

High-κ dielectric thin films are being studied for a variety of applications. Several materials have been studied for this purpose. In particular, metal oxides such as ZrO₂, HfO₂, Al₂O₃, as well as rare-earth oxides such as Y₂O₃, La₂O₃, Pr₂O₃, and Gd₂O₃ have been proposed to replace SiO₂ because their high dielectric constant (10 < κ < 30), thermal stability, a relatively high conduction band offset, and a high dielectric breakdown.¹ Yttrium oxide (Y₂O₃) has a dielectric constant between 14 and 18,² a high crystalline stability,³ and mechanical strength,⁴ and a high refractive index (n ≈ 2).⁵ Epitaxial growth of rare-earth oxides has been reported to be achieved using molecular beam epitaxy (MBE).⁶ Several other deposition methods have been used to obtain Y₂O₃ thin films, such as pulsed laser deposition,⁷ rf-magnetron sputtering,⁸ spray pyrolysis,⁹ and sol gel.¹⁰ In the present work we report the deposition and characterization of Y₂O₃ thin films obtained by ultrasonic spray pyrolysis. These films were deposited from a spraying solution of yttrium acetylacetonate [Y(acac)₃] in N,N-dimethylformamide (N,N-DMF). The mist of a second spraying solution, consisting of a mixture of H₂O–NH₄OH, supplied simultaneously, and in parallel to the yttrium spraying solution, improved dramatically the optical, structural, and dielectric properties of the Y₂O₃ films. Specifically, the formation of a high quality interfacial layer of SiO₂ improved the interface characteristics with the silicon substrate.

II. EXPERIMENTAL PROCEDURE

The ultrasonic spray pyrolysis technique was used to deposit the Y₂O₃ films on c-Si wafers with (100) orientation and low resistivity or (111) and high resistivity, for electrical and optical measurements, respectively. The silicon wafers were previously cleaned with a well established procedure.¹¹ Spray pyrolysis is considered a simple and low cost deposition method for film deposition. This technique has been used to obtain high quality metallic oxides.¹²⁻¹⁵ It consists of an ultrasonic generator used for mist production from a spraying solution containing the proper reactive materials. The mist is transported through a glass tube to the substrate surface which is being heated to achieve a pyrolytic chemical reaction. This deposition process is performed in an atmospheric pressure air ambient. In this work, a 0.03 M yttrium spraying solution was prepared by dissolving Y(acac)₃ in N,N-DMF, from Alfa AESAR and J.T. Baker, respectively. In addition, the mist of a second spraying solution, consisting of a mixture of 1H₂O–1NH₄OH (J.T. Baker), was also carried, during the deposition process, to the surface of the silicon wafers, used as substrates. The mists of both spraying solutions were sprayed in parallel during the deposition process to improve the optical, structural, and electrical properties of the deposited films. The growth of a SiO₂ layer between the yttrium oxide and the Si substrate during this deposition process resulted in interface state density values as low as 10¹⁰ eV⁻¹ cm⁻². An effective refractive index value of 1.86, and deposition rates close to 1 Å/s were obtained. The Y₂O₃ films were polycrystalline with a crystalline cubic phase highly textured with the (400) direction normal to the Si surface. An effective dielectric constant up to 13, as well as a dielectric strength of the order of 0.2 MV/cm was obtained for ~1000 Å thick as-deposited films incorporated in a metal-oxide-semiconductor structure. © 2006 American Vacuum Society. [DOI: 10.1116/1.2214710]

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