UNIVERSITI TEKNOLOGI MARA

NOVEL SYNTHESIS OF $Al_{2-x}Hf_xO_3$ MATERIALS AND THE FABRICATION OF GATE DIELECTRIC THIN FILMS FOR METAL OXIDE SEMICONDUCTOR APPLICATIONS

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Developments of new materials for MOS applications are important due to the problems of downscaling of SiO_2. In this work, Hf doped Al_2O_3 materials were studied as a possible new material for use in metal oxide semiconductor (MOS) application. Novel $Al_{2-x}Hf_xO_3$ (x = 0.001, 0.002 and 0.003) materials were successfully prepared by a self-propagating combustion synthesis method. The synthesized materials were characterized by simultaneous thermogravimetric analysis (STA). From the analysis, the synthesis mechanism of the materials were proposed. X-ray diffraction (XRD) results reveal that hafnium doped materials correspond to the hexagonal crystal structure of Al_2O_3. Quantitative analysis *via* Rietveld refinements showed that Hf was successfully substituted in the hexagonal Al_2O_3 crystal structure. The field emission scanning electron microscope (FESEM) micrographs shown that the Hf doped samples have a quite similar morphology as the pure α-Al_2O_3 powder; however, as the Hf content increases, the small spherical crystallites embedded in the chunks are larger. The Hf content was confirmed, where the synthesized stoichiometry of all materials were perfectly identical to the obtained stoichiometry from energy dispersive X-Ray spectroscopy (EDS). UV-visible spectroscopy showed that $Al_{2-x}Hf_xO_3$ materials exhibited band gap narrowing with respect to pure Al_2O_3 materials and it is dependent on the Hf content following an exponential function. The optimized Al_2O_3 and novel $Al_{1.997}Hf_{0.003}O_3$ materials were used as targets in the pulsed laser deposition (PLD) technique for thin film fabrication. By controlling the parameters of PLD technique, high quality ultra-thin Al_2O_3 and novel $Al_{1.997}Hf_{0.003}O_3$ thin films were deposited at various thicknesses. The XRD patterns of thin film samples were obtained *via* the grazing incidence diffraction (GID) technique. The XRD patterns of thin film samples were indexed to the ICDD reference pattern number 01-088-0826 for Al_2O_3 hexagonal structure and the crystal growth orientation occurred in the (110) and (024) crystal direction. The RMS surface roughness obtained from the atomic force microscopy (AFM) show that thinner films are smoother compared to thicker ones attributed to the increased crystal defects. The FESEM cross-sections of the thin film samples show very high quality uniform thin films that was very smooth and highly dense. It was found that the band gap energies of the thinner samples have larger band gaps attributable to the quantum confinement effect of low dimensional structures. The MOS capacitor structures were fabricated in order to show the significance and suitability of $Al_{1.997}Hf_{0.003}O_3$ gate oxide thin film for the next generation of MOS devices. From the I-V and C-V characteristics, it was observed that $Al_{1.997}Hf_{0.003}O_3$ thin films have lower leakage current, higher capacitance and higher dielectric constant compared to Al_2O_3 thin films. According to the experimental results, $Al_{1.997}Hf_{0.003}O_3$ thin films were found to be more useful for MOS application compared to Al_2O_3 thin films.

TABLE OF CONTENTS