Ultrathin Zirconium Dioxide for Future MOS Technology

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Recently ZrO_2 attracted much attention as a possible high-k gate dielectric in microelectronic metal-oxide-semiconductor (MOS) devices, promising to overcome the tunneling limits of SiO_2 and thus allowing further reduction of device dimensions [1]. An effective dielectric constant of thin and ultrathin films in the range of $k = 18$, a wide band-gap of more than 5 eV, favorable band mismatch to silicon and finally high thermodynamic stability on silicon led to increasing interest in the growth and electrical characterization of ZrO_2 thin films. We focus our research activities in the high-k field on the deposition and integration of ZrO_2 in MOS technology using low-temperature processes. This takes the inevitable need for continual reduction of the thermal budget during processing into consideration. The deposition process utilizes MOCVD (Metal Organic Chemical Vapor Deposition) from tetrakistrifluoro-acetylacetonate zirconium as precursor followed by a post-deposition annealing step. Overall goal is to avoid temperatures above 650 °C in the gate insulator preparation while taking full advantage of the favorable properties of ZrO_2.

The outlined approach interlinks the two promising research topics high-k materials and MOCVD in the field of semiconductor technology, opening up an entirely new area of application.

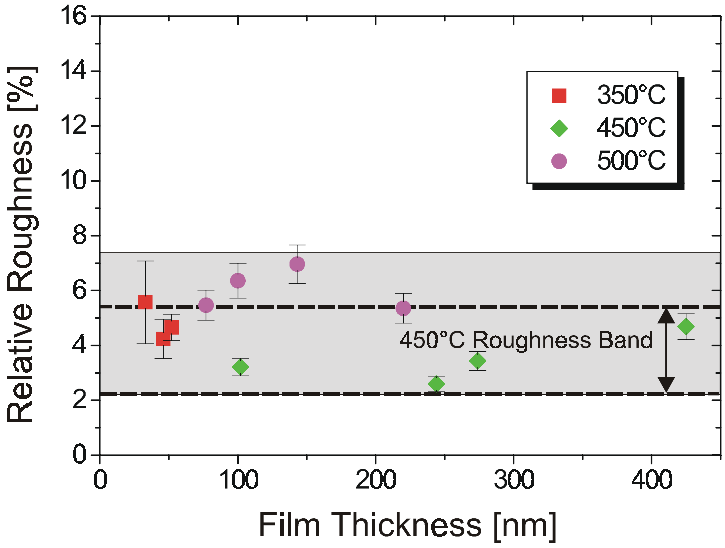

Fig. 1: Relative surface roughness of ZrO_2 thin films.

Morphological analysis using AFM and REM showed the deposited films to be polycrystalline with a relative roughness between 2 and 5% (Fig. 1). Moreover it was shown that the relative roughness is largely independent of the absolute film thickness [2]. The chemical composition of the deposited layers was examined by Auger-electron spectroscopy (Fig. 2). Besides the elements zirconium and oxygen also the presence of carbon is unveiled, while no fluorine contamination is observed. The carbon content can be reduced to the limit of detection by spike-annealing to temperatures between 650 and 850 °C. This thermal treatment results in an almost stoichiometric composition of the thin film.

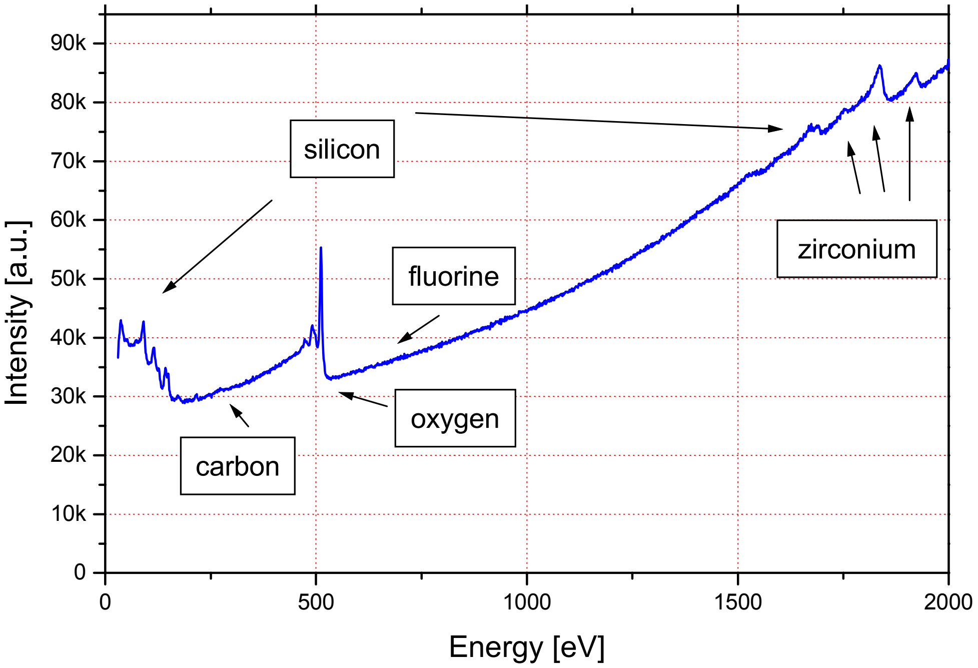

Fig. 2: Auger spectrum of a MOCVD ZrO_2 thin film.

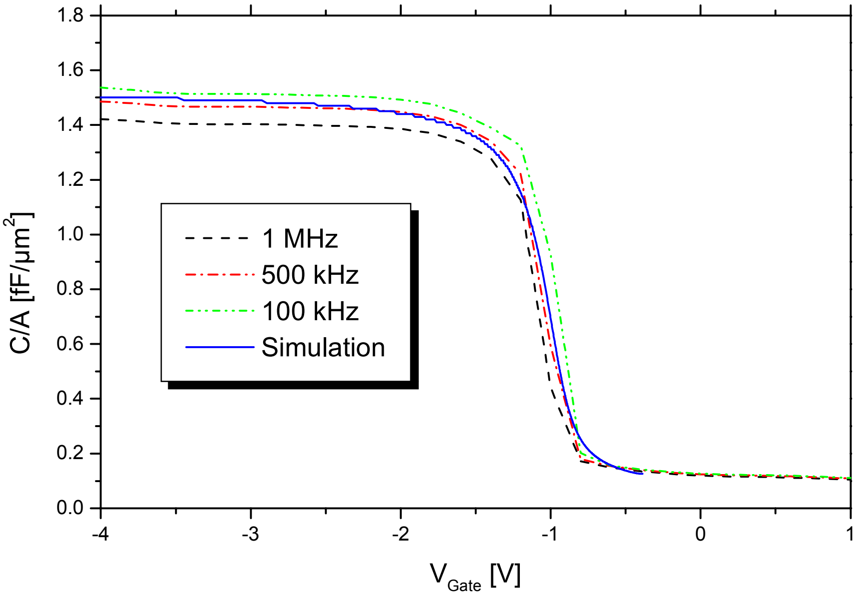

Fig. 3: Capacitance-voltage curve of a ZrO2 MOSCAP.

Electrical characterization of the layers is accomplished employing capacitance-voltage and current-voltage measurements on MOSCAP structures. EOT of the examined films reached down to about 3 nm. Fig. 3 gives an example of the achieved capacitance-voltage curves. The striking agreement between simulation and experimental results indicates a low interface trap density as well as low volume charges. The promising characteristics described are obtained by low-temperature processing not exceeding 650 °C.

References

[1] "*International Technology Roadmap for Semiconductors*", SIA, San Jose 1999

[2] S. Harasek, H.D. Wanzenboeck, B. Basnar, J. Smoliner, J. Brenner, H. Stoeri, E. Gornik, and E. Bertagnolli; "*MOCVD Growth and Nanoscale Characterization of Zirconium Oxide Thin Films*", submitted to *Thin Solid Films*