Rapid Thermal Process Atomic Layer Deposition of High Dielectric Constant Ultra Thin ZrO$_2$ for sub 65 nm Silicon CMOS Technology

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Processing and manufacturing a high performance and reliable high $\kappa$ gate material will be one of the most critical issues for sub 65 nm CMOS technology. Process integration of a new dielectric material with the existing CMOS process sequence will also be a major challenge. Rapid thermal process atomic layer deposition (RTPALD) [1] offers the most viable solution for the processing of ultra-thin gate dielectric materials. Rapid thermal processing is a short time processing technique, which introduces less bulk, and surface defects [2,3]. On the other hand, atomic layer deposition offers the possibility of depositing one atomic layer at a time by utilizing the binding energy difference between chemisorption and physisorption. Combining these two processes, we were able to process excellent quality ZrO$_2$ ($\kappa = ~25$) thin films. For this study, we deposited ZrO$_2$ films on n-type Si $<$100$>$ substrates. The thickness of the films was around 2.5 nm. Thermally evaporated gold dots were deposited to fabricate metal-insulator-semiconductor (MIS) capacitors.

At 1 V, we obtained leakage current density of $1.83\times10^{-11}$ A/cm$^2$ and capacitance per unit area of 8.07 µF/cm$^2$. These values demonstrate the excellent performance of RTPALD process. Up to 20 MV/cm, leakage current remained relatively low which indicates the good dielectric strength of the material. It was also observed that up to 95°C, the leakage current density decreases slightly with respect to the increase in temperature. After that, at a certain transition temperature, the leakage current started to increase as the temperature was increased for up to 115°C. Trap densities in the films were between $10^{17}$ cm$^{-3}$ and $10^{18}$ cm$^{-3}$ and for up to 9MV/cm field, the trap density remained constant. These measurements indicate the good reliability properties of the ZrO$_2$ thin films.

In this paper, complete electrical and structural characterization of ZrO$_2$ films processed on silicon substrates by RTPALD will be presented.

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