High Quality ZrO$_2$ Thin Films on $<100>$ Si Substrates as a Gate Dielectric Material: Processing and Characterization

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High dielectric constant gate materials offer the possibility of pushing the CMOS technology in the realm of 10-20 nm feature sizes. Among various potential high $\kappa$ materials, ZrO$_2$ fulfills most of the stringent criterions, in terms of device performance and manufacturing requirements, to be considered as a gate material replacement for SiO$_2$. As the dielectric constant of ZrO$_2$ is higher (for bulk ZrO$_2$, $\kappa \approx 25$) than that of SiO$_2$, it will provide a significant increase in capacitance without scaling down the oxide thickness.

We have used Rapid Photothermal [1] assisted deposition of ZrO$_2$ films. In this study, we deposited ZrO$_2$ films on n-type Si $<100>$ substrates. The thickness of the films was between 5-8 nm. Metal-Insulator-Semiconductor (MIS) capacitors were fabricated by evaporating aluminum dots for front contact. The backside of the wafer was then cleaned by diluted HF and after that aluminum was deposited for back contact.

Rapid thermally processed ZrO$_2$ film showed a leakage current density of $6.03 \times 10^{-7}$ A/cm$^2$ and capacitance per unit area of 0.235 µF/cm$^2$ at 1V. For rapid photothermal processing, the leakage current density of ZrO$_2$ at 1V was $3.19 \times 10^{-9}$ A/cm$^2$ and the capacitance per unit area was 1.12 µF/cm$^2$ at 1V. We also processed ZrO$_2$ film with leakage current density of $9.17 \times 10^{-9}$A/cm$^2$ and capacitance per unit area of 4.76 µF/cm$^2$ at 1V. Fig. 1 shows the clear advantage of ZrO$_2$ over SiO$_2$ as gate dielectrics. Our results also indicate a significant improvement of leakage and capacitance characteristics over other high $\kappa$ materials reported so far [2] [3].

In this paper, a complete characterization of ZrO$_2$ films processed on silicon substrates will be presented.

References

