Rapid Thermal Process Atomic Layer Deposition of High Dielectric Constant Ultra Thin ZrO_2 for sub 65 nm Silicon CMOS Technology

M. Fakhruddin, [1] R. Singh, [1] K. F. Poole, [1] S. V. Kondapi [1] and S. Kar[2]

[1]Holcombe Department of Electrical and Computer Engineering
Center for Silicon Nanoelectronics
Clemson University
Clemson, SC 29634-0915
U. S. A
[2]Department of Electrical Engineering
Indian Institute of Technology
Kanpur-208016
India

Processing and manufacturing a high performance and reliable high κ 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 (κ= ~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 meal-insulator-semiconductor (MIS) capacitors.

At 1 V, we obtained leakage current density of 1.83×10^{-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^{0}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^{o}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.

References

1. M. Fakhruddin, R. Singh, K. F. Poole and S. Kar, in Proceedings of the 10th IEEE International Conference on Advanced Thermal Processing of Semiconductors-RTP 2002, p. 89 (2002).
2. R. Singh, J. Appl. Phys., 63, R69, (1988)
3. R. Singh and R. P. S. Thakur, The Electrochemical Society Interface, 4(3), 38 (1995).