Dielectric Influence On A 2D Lateral Gallium Oxide (Ga2O3) MOSFET Using COMSOL Multiphysics

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Abstract

Gallium Oxide (β-Ga2O3) is an emerging wide bandgap oxide semiconductor that has garnered attention for power electronic applications because of its large 4.8 eV bandgap energy and critical electric field strength of ~ 8 MV/cm [1]. However, due to Gallium Oxides' poor thermal conductivity k = 27 W/mK, the self-heating effects can severely limit device performance and reliability. This work aims to study the electrical and thermal response of a 2D lateral Gallium Oxide MOSFET using different gate dielectric oxide materials to investigate the dielectric effect of dissipating heat in the gallium oxide layer. The three gate dielectrics selected were Silicon Oxide (SiO2), Aluminum Oxide (Al2O3), and Hafnium Oxide (HfO2), as these are the three most commonly used gate oxides in conjunction with Gallium Oxide for power electronic applications. The simulations were carried out by employing the Semiconductor and Heat Transfer in Solids modules in COMSOL Multiphysics to simulate the phonon generation in the gallium oxide layer of the MOSFET structure.

A convective heat flux domain was defined for the source, drain, and gate components of the MOSFET, and defining the semiconductor layer as the heat source. In addition, the gate was held at a constant 5 V bias while the drain was swept from -1 V to 12 V with a 0.1 V step. The results show that aluminum oxide helps dissipate heat more effectively than silicon oxide and hafnium oxide as a gate dielectric. A peak temperature of 718.2 K was observed for aluminum oxide as the gate dielectric, while silicon oxide had a peak temperature of 996.6 K and 1025.4 K for hafnium oxide. Aluminum oxide shows a 27.94% and 29.96% reduction in temperature compared to silicon oxide and hafnium oxide, respectively.

This work considers three gate dielectrics and their effect on the thermal and electrical response of a 2D lateral gallium oxide MOSFET. The results showed that aluminum oxide helps dissipate heat more effectively than silicon oxide and hafnium oxide. This work adds further insights to the ongoing research on mitigating the self-heating effects of gallium oxide due to its poor thermal conductivity.

Reference

J. Y. Tsao et al. S. Chowdhury, M. A. Hollis, D. Jena, N. M. Johnson, K. A. Jones, R. J. Kaplar, S. Rajan, C. G. Van de Walle, "Ultrawide-Bandgap Semiconductors: Research Opportunities and Challenges," Adv. Electron. Mater., vol. 4, no. 1, p. 1600501, Jan. 2018, doi: 10.1002/aelm.201600501.

M. Higashiwaki, "β-Ga2O3 material properties, growth technologies, and devices: a review," AAPPS Bull., vol. 32, no. 1, p. 3, Jan. 2022, doi: 10.1007/s43673-021-00033-0.

B. R. Tak et al. S. Kumar, A. K. Kapoor, D. Wang, X. Li, H. Sun, R. Sing, "Recent advances in the growth of gallium oxide thin films employing various growth techniques—a review," J. Phys. Appl. Phys., vol. 54, no. 45, p. 453002, Nov. 2021, doi: 10.1088/1361-6463/ac1af2.

N. P. Sepelak, “Demonstration of High-Temperature Operation of Beta-Gallium Demonstration of High-Temperature Operation of Beta-Gallium Oxide (β-Ga2O3) Metal-Oxide-Semiconductor Field Effect Oxide (-Ga2O3) Metal-Oxide-Semiconductor Field Effect Transistors (MOSFET) with Electrostatic Model in COMSOL”.

P. Kachhawa et al., N. Chaturvedi, “High-k Dielectric Influence on Recessed-Gate Gallium Oxide MOSFETs,” in Micro and Nanoelectronics Devices, Circuits and Systems. Singapore: Springer Nature Singapore, 2023, pp. 21–29.

Figures used in the abstract

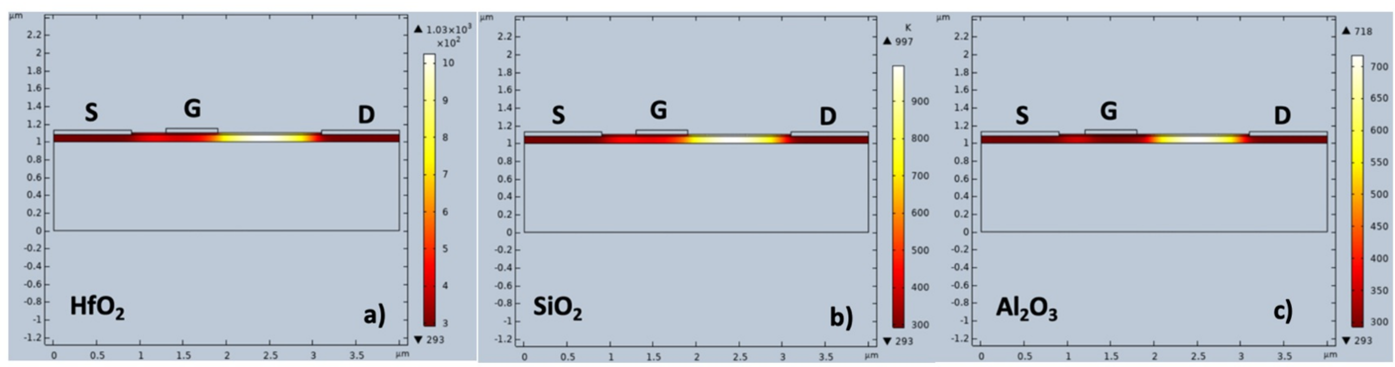

Figure 1 : Figure 1: Phonon generation plot of the Lateral Ga2O3 MOSFET for all three dielectrics considered: a) HfO2, b) SiO2, and c) Al2O3.

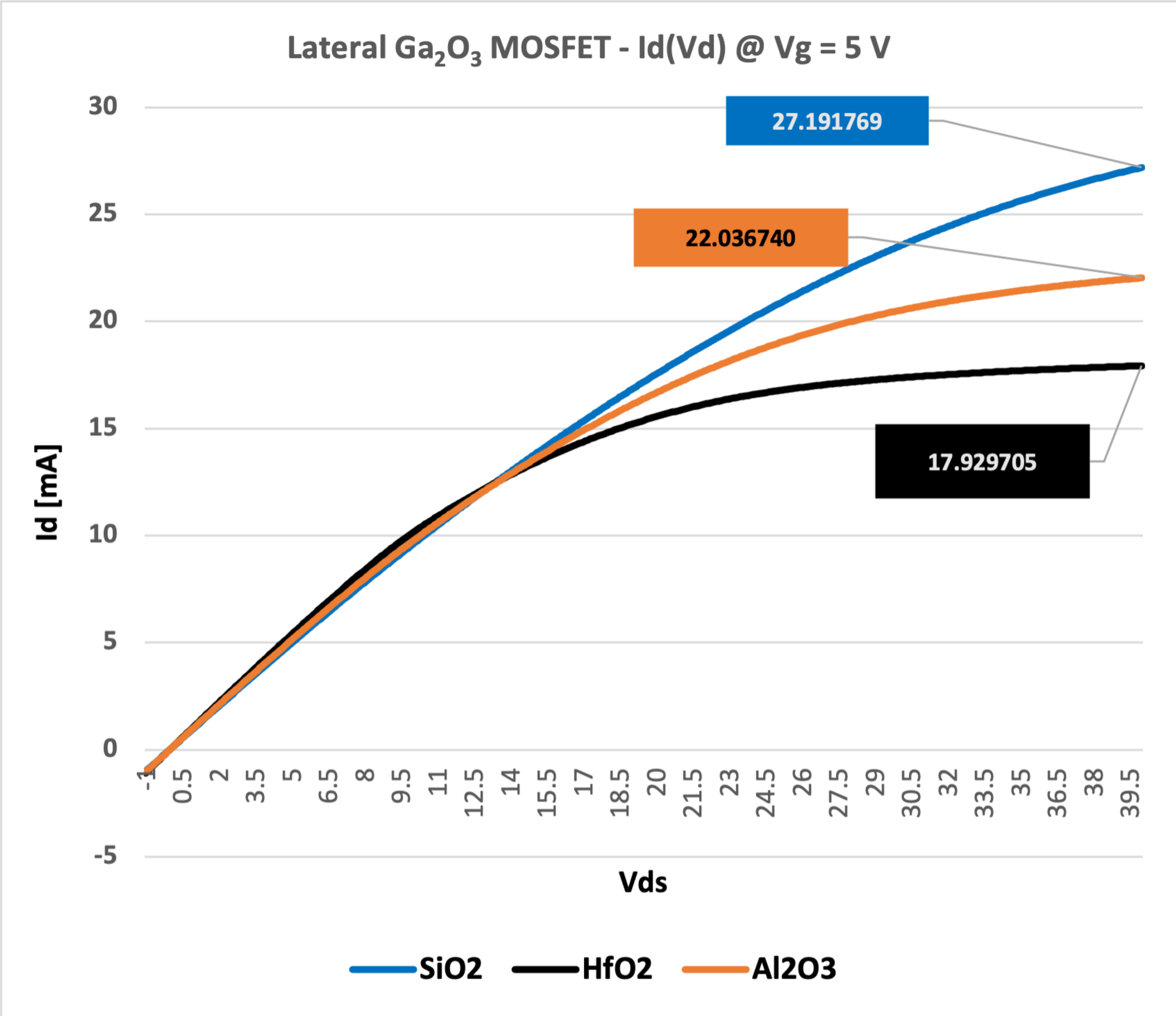

Figure 2 : Figure 2: Comparison of output drain current Id(Vd) of 2D Lateral Ga2O3 MOSFET for three dielectrics SiO2, HfO2, and Al2O3 evaluated.

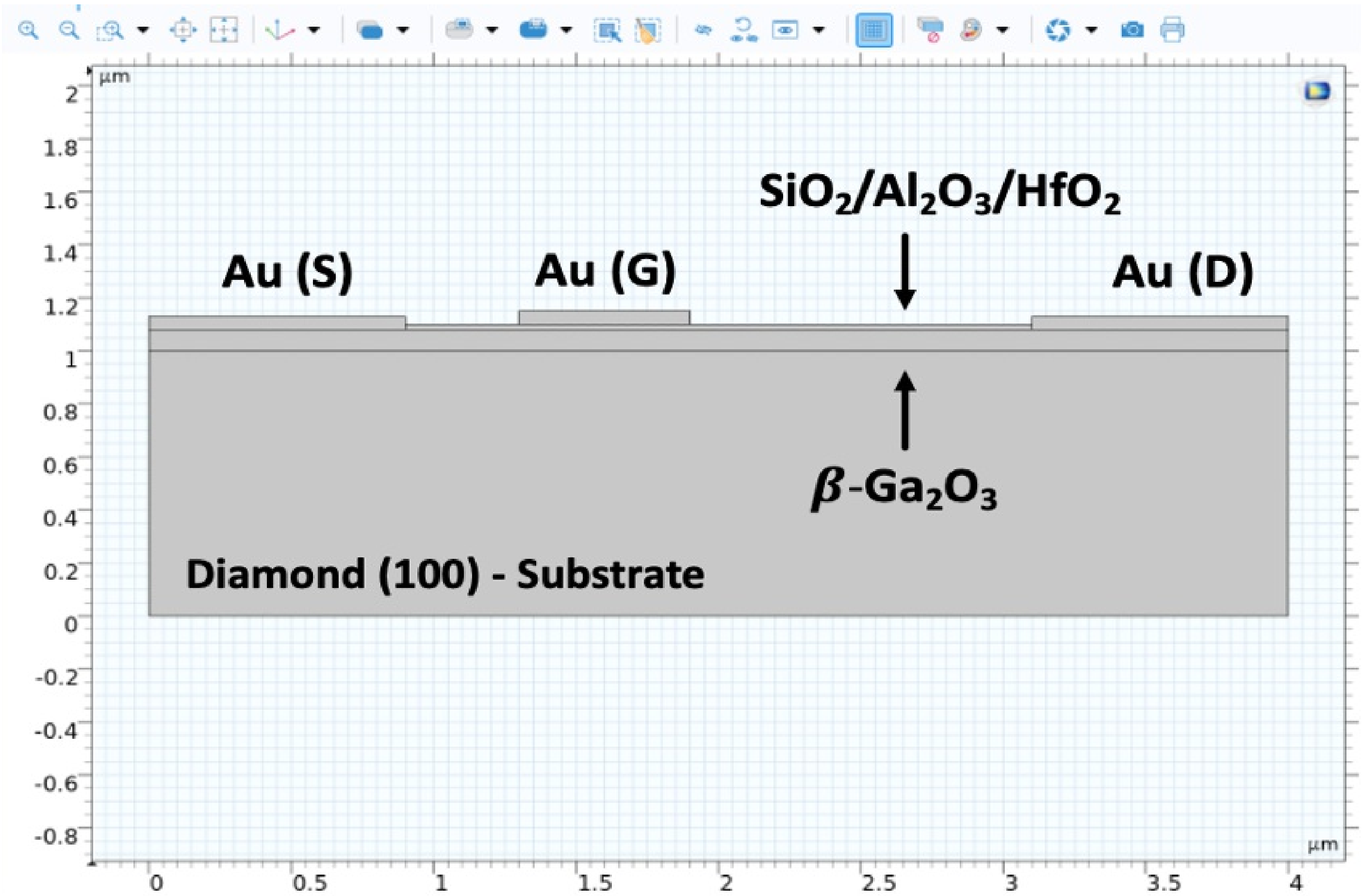

Figure 3 : Figure 3: Model geometry of a 2D Lateral Ga2O3 MOSFET built in COMSOL Multiphysics