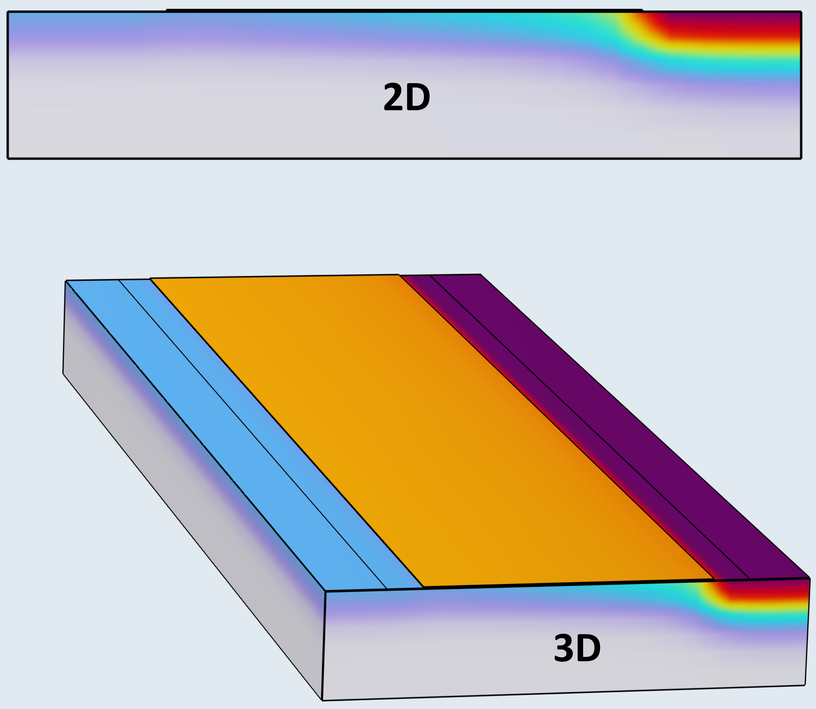

FEM-based Electrical Analysis of 3D-MOSFET

MOSFETs are popular in many sensing applications due to their low power consumption, compactness, and reliable operation. In this work, we delve into a 3D model of MOSFET using COMSOL Multiphysics to explore performance based on electrical characteristics. This work analyses the influence of aspect ratio and gate-insulating materials, specifically SiO_2 and Al_2O_3, on 3D-MOSFET performance.

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Introduction:

- MOSFETs are used as effective transducers in the bio/chemical sensors owing to their potential for miniaturization, rapid response, direct signal readout, and compatible manufacturing techniques.
- 1D or 2D simulations of MOSFET are not suitable for complex channel profile analysis because of its 3D geometry.
- Whereas 3D modelling helps in the accurate electrical analysis of various geometrical and operational characteristics.
- In this work, we studied MOSFET characteristics for short-channel effects (SCE), gate-insulating material, and aspect ratio in a 3D domain.

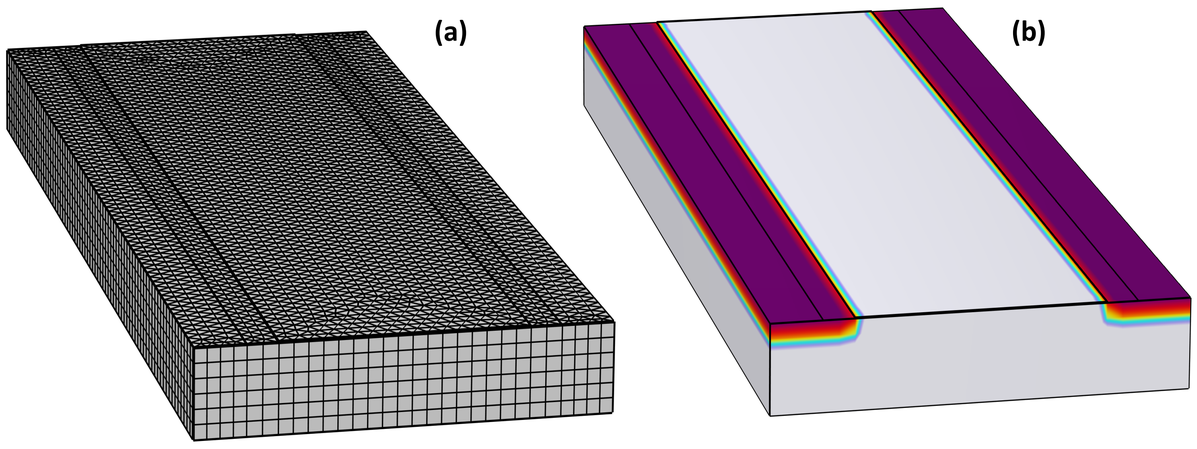

Figure 1: (a) Meshing and **(b)** Doping profile ($1/cm^3$) of 3D model of MOSFET.

Methodology:

- 3D modelling using semiconductor module based on drift and diffusion equations.
- Suitable meshing and boundary conditions for reliable 3D simulation.
- Parametric sweep analysis to get MOSFET characteristics.
- SCE analysis for varying aspect ratio (W/L).
- Study of gate-insulating material effect, specifically SiO_2 and high-k dielectric- Al_2O_3 on the 3D-MOSFET model using material sweep analysis.

Results and Conclusion:

- 3D modelling of MOSFET enabled the study of aspect ratio effect on the electric potential and electron concentration profiles.
- The gate insulating material, Al_2O_3 (high-k dielectric material) has shown better output characteristics than SiO_2 owing to the higher electron concentration and surface potential in MOSFET.
- SCE and decreased transconductance caused by the velocity saturation effect was observed with reduction in gate channel length. This phenomenon is confirmed through S-shape of the transfer characteristics.

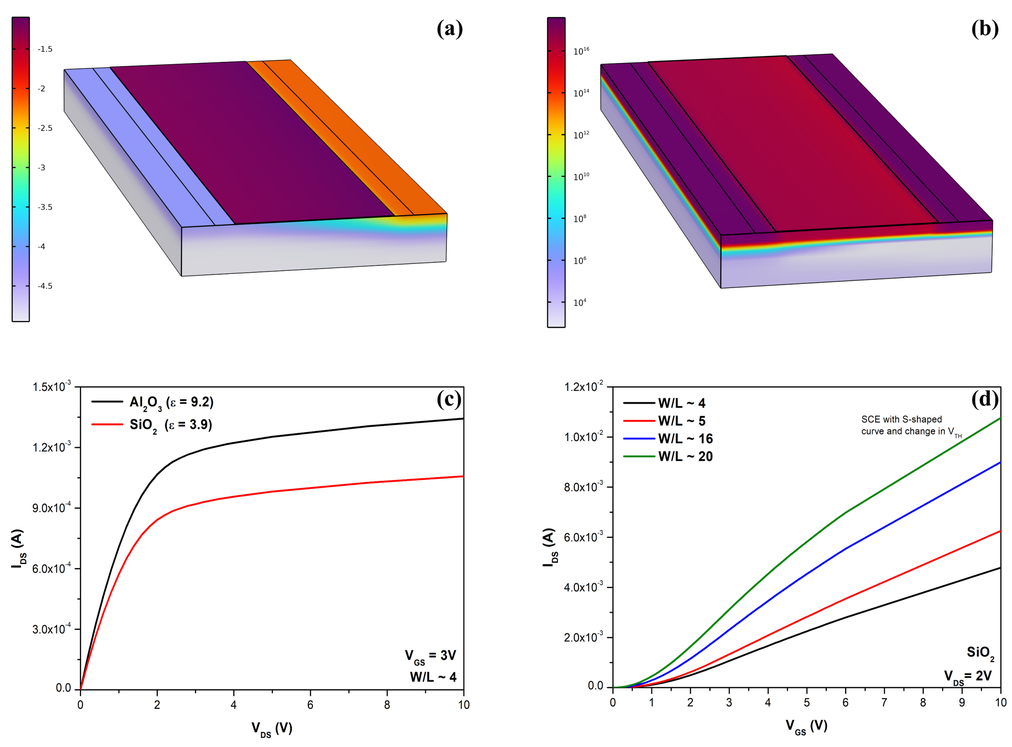

Figure 2: (a) Electric potential (V), **(b)** Electron concentration ($1/cm^3$) profiles of 3D model of MOSFET at V_{DS} = 2V & V_{GS} = 3V, **(c)** Output characteristics for Al_2O_3 and SiO_2 as gate-insulating material, **(d)** Transfer characteristics of 3D-MOSFET for variation in aspect ratio.

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