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Analytic Models for Electric Potential and Subthreshold Swing of Dual–Material Double–Gate MOSFET

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As metal–oxide–semiconductor field–effect transistor (MOSFET) scales down to the nanometers, short channel effect (SCE), current tunneling through the gate oxide, and gate induced drain leakage (GIDL), will affect the device reliability severely. A MOSFET with a double–gate (DG) can control the channel more effectively, and can suppress the SCE. The control gate, usually the top gate, is made of dual materials (DM), of different work–functions, to alleviate GIDL effect.

A MOSFET with a DM DG has been proposed and studied to some extent. Several models for this device have been proposed before however, these models usually divide the different material region into two parts. Thus it is necessary to solve Poisson equation (PE) in two regions respectively and to describe eight boundary conditions. This results in complication of the calculation.

Here we present the model for potential distribution and subthreshold swing through the entire channel region. Poisson Equation (PE) is solved through the entire channel region so that the analytic relation for the channel potential can be derived and the subthreshold swing is calculated on the basis of the potential model. It enables us to avoid the complication in the calculation. Our model results and Medici simulation agree well with each other. Besides, this method is applicable to more complicated cases, for instance, the case that three different work–functions is used in considering the gate structure. The results will also provide some reference for the integrated circuit design.

The physical insights are as follows:

i) Owing to the reduction of the peak electric field near the drain end, a DMDG MOSFET can suppress the SCEs, improve the DIBL effects and increase the breakdown voltage significantly.

ii) In order to achieve a desirable subthreshold swing, it is recommended that the thickness of the gate oxide, and/or the channel thickness be small, especially when the device with a small channel length.

iii) The analytical model presented in this work can be embedded in circuit simulation tools, facilitating the application of the DMDG MOSFETs.