MOSFET Channel Engineering And Scaling Study With Halo Implants Using COMSOL Multiphysics

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Abstract

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With the world continuously scaling MOSFETs into smaller submicron dimensions, subthreshold current and threshold voltage control are important challenges to ensure optimal device performance. This study explores the effects of halo implants on simulated MOSFETs by introducing p-type halo implants adjacent to the n-type doped source and drain regions. This was done using the COMSOL Multiphysics ® simulation software's Semiconductor Module. Using this, two-dimensional device models were constructed with silicon as the base material and then incorporated regions of varying doping concentrations for source, drain, and Indium halo implants to model and represent the halo architecture.
To capture a more realistic carrier transport, a chain made of different mobility models was used. The Arora mobility model simulates the effect of lattice and impurity scattering on the hole and electron mobilities. The Lombardi Surface mobility model was used to incorporate the effects of surface scattering into these models. The Caughey-Thomas mobility model was used to account for carrier mobility degradation due to high electric fields and high-field velocity saturation. These three models were used to properly simulate a more realistic scenario. The recombination effects were captured using the Trap Assisted Recombination Model to simulate carrier dynamics more realistically.
Different studies were conducted, and electrical characteristics such as current versus gate voltage (Id-Vg) and drain current versus drain voltage (Id-Vd) were analyzed for gate lengths of 397nm, 280nm, 196nm, and 140nm. Stationary studies were conducted with proper meshes to account for non-linear behavior introduced by mobility and recombination models. These values were chosen in accordance with Dennard's Scaling Law, or constant field scaling, where a factor of 0.7x was used to distinguish each generation of MOSFETs.
The simulation results indicate a significant reduction in the off-state leakage current in the halo-doped devices, which can be attributed to the suppressed subthreshold current. Additionally, an increase in threshold voltage was observed. These findings validate the importance and effectiveness of halo implants in improving the subthreshold current and improving threshold voltage stability, which could further contribute to the advancement of MOSFETs.

Reference

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Figures used in the abstract

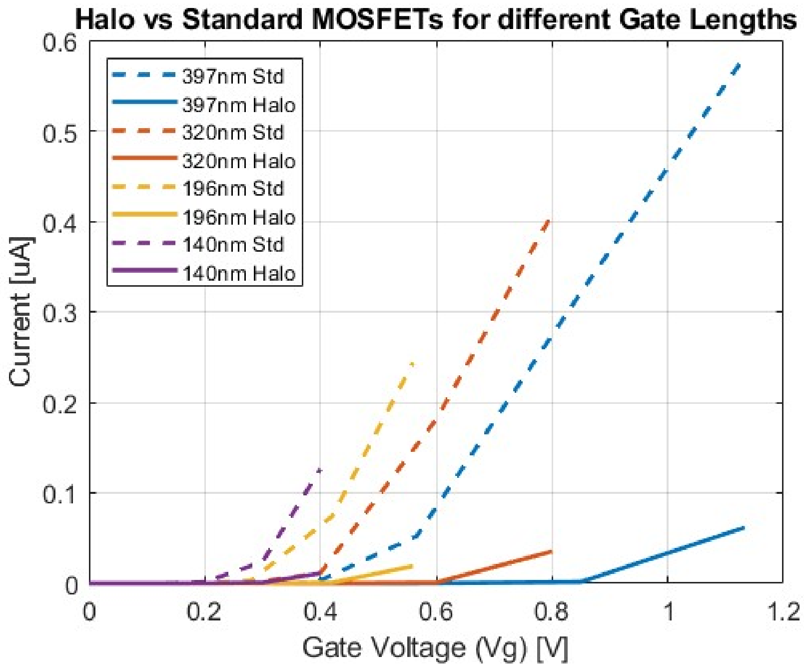

Figure 1 : Threshold Voltage Comparison for Halo- Implanted vs Standard MOSFETs with Different Gate Lengths

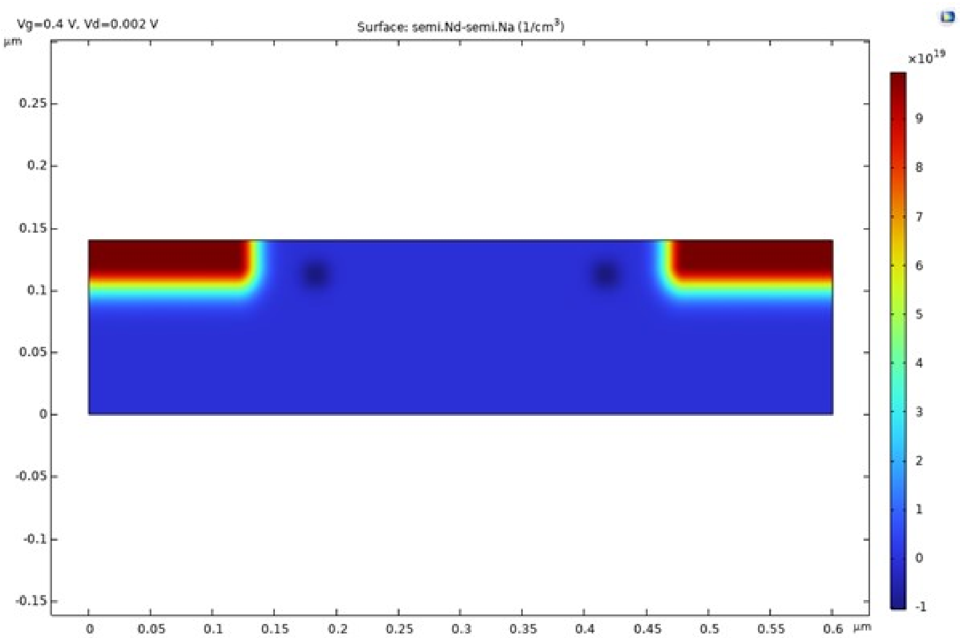

Figure 2 : Net Doping Concentration for a MOSFET of Gate Length 280nm with Indium Halo Implants