

Simulation of DIBL effect in 25 nm SOI-FinFET with the different body shapes

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Short channel effects, such as DIBL are compared for SOI-FinFETs with different silicon body geometries. The original device considered was straight without narrowing at the top and a set of devices that exhibit the mentioned narrowing, up to the extreme case where the top of the gate has no surface and so the body cross-section is essentially a triangle. We have studied five different variations from the original geometry of a 25 nm gate length SOI-FinFET device with 1.5 nm thick oxide layer. The P-type channel had a doping concentration of 10^{15} cm^{-3} and n-type S/D areas are doped at concentrations of 10^{20} cm^{-3} . The silicon body of the device accordingly had a height of 30 nm and a width of 12 nm. Simulation results show the source-drain barrier decreasing with increasing the upper body thickness. The DIBL effect of the considered FinFETs depends on upper body thickness, tending to increase with thicker upper body widths. Results of a comparison of two devices with different shapes but with the same cross-sectional area shows the relationship mainly depends on the shape rather than the cross-section area of the device body.

Keywords: FinFET, DIBL, potential barrier.

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1. Introduction

MOSFET scaling induces different effects that tend to degrade device performance. Among the most important are: technological variability of parameters [1], short channel effects (SCEs) [2], influence of single defects in oxide or oxide-semiconductor interface [3]. The use of multiple-gate topologies significantly enhances the electrostatic integrity of the device and provides increased immunity from SCEs [4]. As the devices are scaled down, new sources of variability appear, while other ones might gain more importance [5, 6]. One type of variability is the narrowing of the body which might appear in a multiple-gate FinFET. Previous works on SOI-FinFET [1] have investigated the impact of the device body shape on the electric characteristics, such as threshold voltage, subthreshold swing, on-current, and off-current. In this work, we analyze the influence of body width narrowing in FinFET on short channel effects such as DIBL. The impact of the device body shape on the DIBL of a 25 nm SOI-FinFET was studied using Sentaurus TCAD simulations [7].

2. Device structure

SOI-FinFETs are currently considered one of the most promising solutions to avoid SCEs of MOSFETs, but because the body is aligned in a vertical fashion which allows self-aligned gate contacts, a body narrowing appears at the top of the gate. This will have an effect on the channel, as well as the threshold voltage, off-current, on-current and subthreshold swing [5]. We have studied five different variations from the original geometry of a 25 nm gate length SOI-FinFET device with oxide thickness 1.5 nm. The P-type channel has a doping concentration of 10^{15} cm^{-3} and n-type S/D areas are doped with concentrations 10^{20} cm^{-3} . The silicon body of the device has height and width of 30 nm and 12 nm accordingly. For each device, we had simulated the device using Synopsys Sentaurus software in a local computation cluster. Our objective was to modify the original device, which is straight without narrowing at the top, with a set of devices that exhibit the mentioned narrowing, up to the extreme case where the top of the gate has no surface and so the body cross-section is triangular in shape (Fig. 1).

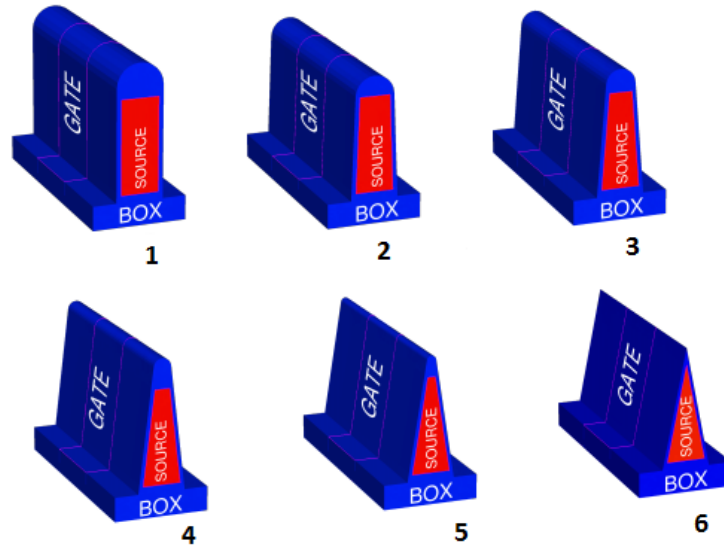


FIG. 1. Cross-section of SOI-FinFETs simulated, with different body top thickness, silicon body cross-section is modified from rectangle shape (a structure 1 with maximal body top thickness) up to triangle geometry (structure 6 with zero body top thickness)

3. Results of simulation and discussion

We have analyzed the influence of varying the geometry of a 25 nm gate length FinFET device to DIBL. This study has been done via drift-diffusion simulations that include quantum corrections.

For calculating DIBL, we simulated I_d - V_g characteristics of FinFET devices with the geometrical parameters mentioned in Section 2. The DIBL was calculated as the change of threshold voltage per 1 V change of drain voltage. The characteristics were simulated for $V_{ds} = 0.05$ V and 0.75 V. In Fig. 2, the I_d - V_g characteristics, normalized to cross-section area for FinFET, with different upper body widths, are shown.

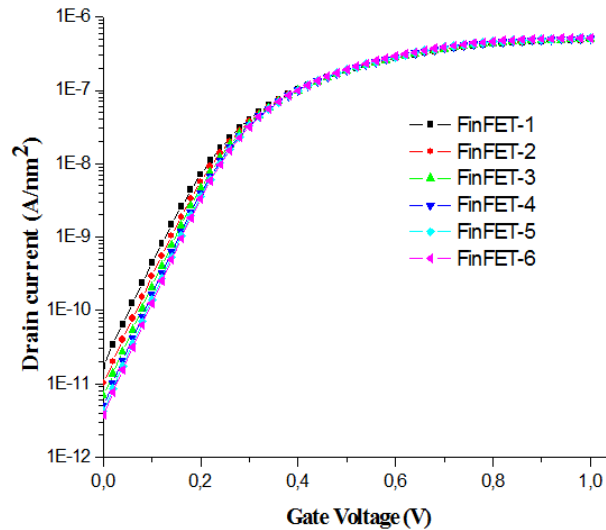


FIG. 2. The normalized transfer characteristics for FinFETs with different body top thickness at $V_{ds} = 0.75$ V

The DIBL effect had a strong influence on the device geometry of FinFET and increased with increased upper body thickness (Fig. 3). This means that the threshold voltage was controlled more by the gate voltage than by the drain voltage for devices with narrower upper bodies.

Such behavior of DIBL for FinFETs with different upper body widths may be connected with changing of parasitic capacitive coupling between source (drain) and gate of the device structure; this results in a changing of potential distribution between the source and the drain for devices with different upper body widths (Fig. 4).

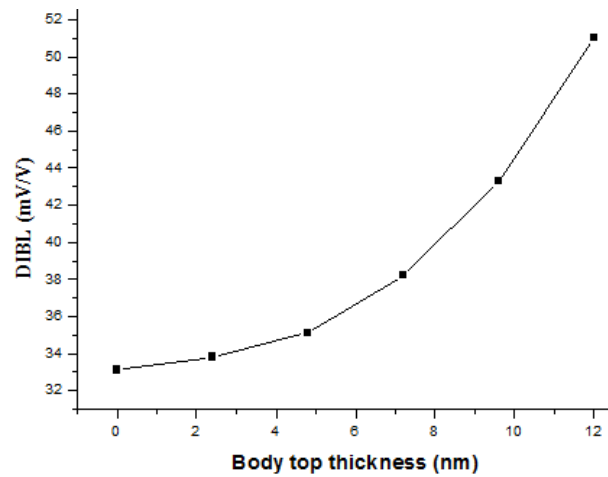
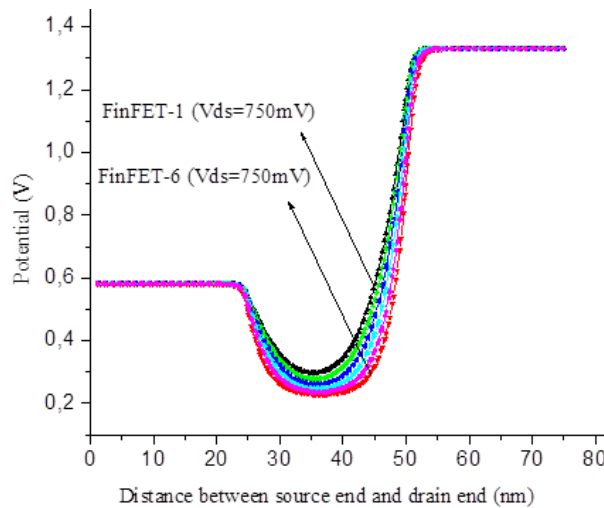


FIG. 3. SOI-FinFET DIBL dependence on body top thickness

FIG. 4. Potential distribution in the center of the body between source and drain ends of FinFETs with different body top thickness. $V_{ds} = 750$ mV

In Fig. 4, the potential barrier between source and drain is shown to be lowered with increasing upper body thickness. The potential distribution and the potential barrier between the source and drain depend on the drain-source voltage (Fig. 5), which shows the DIBL effect.

In the considered FinFET devices, under conditions of constant height with decreasing upper body thickness, the cross section area also decreased. In order to verify the effect that the change in cross section area had on DIBL, the value was obtained for the initial device with rectangle top and compared to that of a device with triangle top, but with the same cross-section area (i.e. different height). The results showed that the DIBL value for the triangular device was 34 mV/V, which was less than the value obtained for the rectangular geometry device (51 mV/V). This indicates that the change in shape had more of an effect on the DIBL than the change of cross-section area of the device.

4. Conclusion

Simulation of SOI-FinFETs was performed with different upper body widths, starting with the original device, which was straight without narrowing at the top and a set of devices that exhibit the mentioned narrowing, up to the extreme case where the top of the gate had no surface and so the body cross-section was a triangle. These results showed source-drain barrier decreasing with increased upper body thickness. The DIBL effect of the considered FinFETs depended on upper body thickness, increasing with increased upper body width. Such behavior of the dependence is mainly connected with the shape rather than the cross-section area of the device's body.

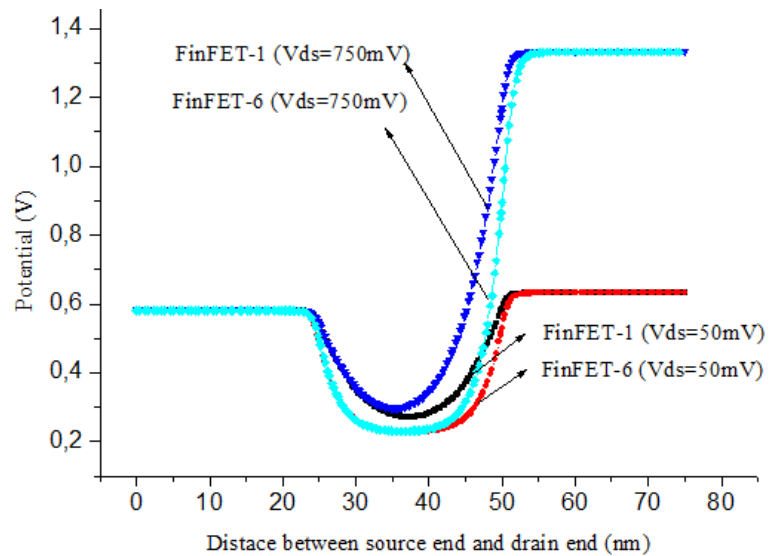


FIG. 5. Potential distribution in the center of body between source and drain ends of FinFETs with body top thickness 12 nm and 0 nm for $V_{ds} = 750$ mV and 50 mV

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