

P-3-6

Impact of Gate Overlap on the Performance of Schottky Barrier MOSFETs including GIBL Effect

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1. Introduction

Schottky-barrier source/drain (S/D) field-effect transistors (SBFETs) are promising substitutes for conventional doped S/D MOSFETs for sub-22-nm CMOS technology because silicide S/D can provide abrupt junctions with low series resistance [1-5]. The carriers which come through the Schottky barrier at source are mostly tunneling carriers. So the performance of SBFET is sensitive to the Schottky barrier height (SBH) and shape. The simulation studies have shown that SBFET would be competitive in terms of drivability only if the SBH < 100 meV [6]. The image-force can notably reduce the Schottky barrier height. The image-force SBH lowering is directly related to the electric field at the source-side Schottky barrier junction which can be controlled by the gate voltage and the distance between gate and channel strongly [7]. The misalignment (overlap) between the gate and the source/drain silicide due to the sidewall may influence the performance of SB FET. In this work, we simulated the SBFETs with various overlap structures by using two dimensional (2D) full-band self-consistent ensemble Monte Carlo (EMC) including gate-induced barrier lowering (GIBL) effect. The influence of scattering on the performance of SBFET is also evaluated.

2. Simulation Method

2D full-band self-consistent EMC simulation including SB contact model developed in-house is used [8]. The SB contact model, including thermal emission and tunneling effect, is verified by simulation of the SB diode [9]. The structure we simulated is shown in Fig. 1. The parameters of the structure are listed in Table. 1. The overlap is chosen to be 0, 2, 5 nm respectively, to compare the impact of overlap to the performance of SB FET. The channel length is calculated by $L_{ch} = L_g + 2 * \text{overlap}$. The image-force SBH lowering as shown in Fig. 4 is calculated from the electric field value, following the image-force model $\Delta\phi_B = 2\sqrt{qE/(16\pi\epsilon_0\epsilon_s)}$, where q is the electron charge, E is the transverse electric field at the Schottky junction and ϵ_s is the relative permittivity. The acoustic and optical phonon scattering, the ionized impurity scattering, the impact ionization scattering and the surface roughness scattering are included.

3. Results And Discussion

Fig. 2 plots the simulated I_{ds} - V_{ds} of SB FETs with and without GIBL effect. It is obviously shown that the drain current with GIBL effect has a very significant increase comparing with that without GIBL. In Fig. 3, we can see that when the overlap is 2nm, the ratio of on current with and without GIBL is higher than that when overlap is 0nm, especially when V_{ds} is 1.0V. The explanation of this result is shown in Fig. 4. When overlap is 2nm, the channel length L_{ch} increases and the transverse electric field at source side is smaller than the case of overlap=0nm, thus

$\Delta\Phi_B$ is smaller. But the barrier region is wider when overlap=2nm, thus ΔL is bigger than the case of overlap=0nm. Since the tunneling probability has a form of integral with distance as integral variable, the change of barrier shape plays a more important role than the change of barrier height. Thus the effect of GIBL is more obvious when overlap is 2nm. Fig. 5 and Fig. 6 plot the potential distribution along the channel at $x=1\text{nm}$ with GIBL and without GIBL respectively. Although the difference of potential distribution when overlap is 0nm and 2nm is little, the ratio of on current of the two cases is about 2 as shown in Fig. 3. Fig. 7 plots the electron density distribution along the channel at $x=1\text{nm}$ both with and without GIBL when overlap is 2nm and 0nm. From the figure, it can be seen that the electron density near source side is sensitive to the gate overlap and GIBL due to their influence on tunneling probability. However, the electron density in channel is almost same since the gate voltage is the dominate issue in this region. Fig. 8 plots the electron velocity distribution along the channel at $x=1\text{nm}$ with and without GIBL when overlap is 2nm and 0nm. It is shown in the figure that near the source side the average velocity is almost the same for four cases, since electrons near the source are all high energy tunneling electrons. But in the channel the average velocity is quite different and this can be understood from the view point of current continuity. The electron energy distribution at $x=1\text{nm}$ along the channel with and without GIBL is shown in Fig. 9. From the figure, it can be seen that electrons with high energy are almost located near source region and the average energy reduces most slowly when overlap is zero with GIBL effect.

Fig. 10 plots the ratio of on current with and without GIBL and the ratio of on current with and without scattering when overlap is 0nm, 2nm and 5nm. The ratio of on current with and without GIBL increases with the increase of overlap. The ratio of on current with and without scattering is almost same (a little bigger than 1) which indicates that the electrons which transport across the channel are almost ballistic and less dependent to overlap. This can be understood that tunneling electrons are high velocity carriers with little scattering happening in channel. However, scattering plays a more important role if GIBL effect is not considered.

3. Conclusions

The impact of overlap on the performance of SB FET including GIBL effect is investigated by MC simulation. The result shows that the performance of SBFETs is less sensitive to overlap due to GIBL effect. The influence of scattering on the performance of SBFETs is negligible since the electrons across the channel are nearly ballistic.

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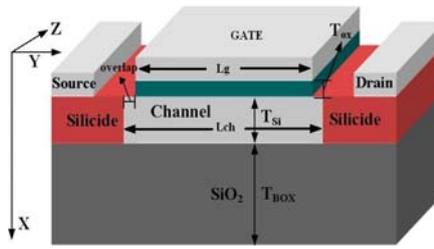


Fig. 1 The schematic of a UTB SOI SBFET with overlap.

PARAMETERS	VALUE
L_g	45 nm
T_{ox}	1 nm
T_{Si}	12 nm
T_{BOX}	20 nm
Φ_B	0.3 eV
$N_{channel}$	10^{16} cm^{-3}
overlap	0, 2, 5 nm
L_{ch}	45, 49, 55 nm

Table. 1 The parameters of the UTB SOI SBFET with overlap.

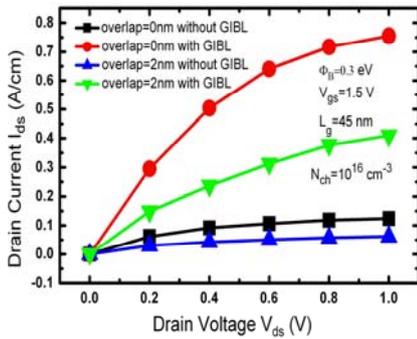


Fig. 2 The output characteristics of a UTB SOI SBFET with and without GIBL effect for overlap= 0nm and 2nm.

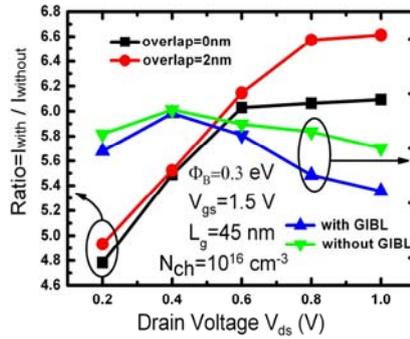


Fig. 3 The ratio of current with GIBL and without GIBL and the ratio of on current for overlap= 0nm and 2nm.

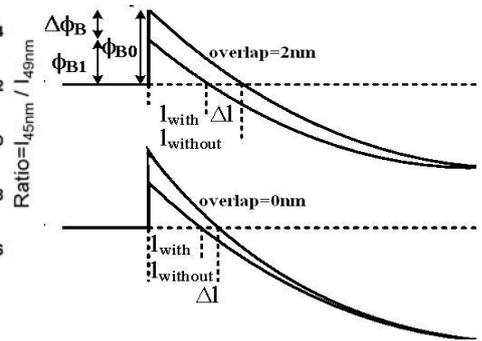


Fig. 4 The explanation for the ratio of current with GIBL and without GIBL for overlap= 0nm and 2nm.

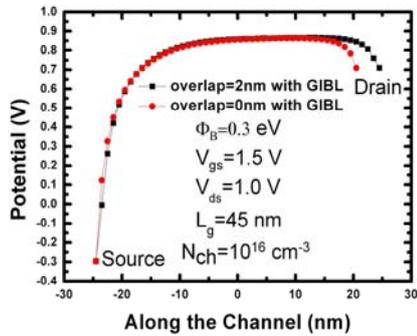


Fig. 5 The potential distribution along the channel at x=1nm with GIBL for overlap= 0nm and 2nm.

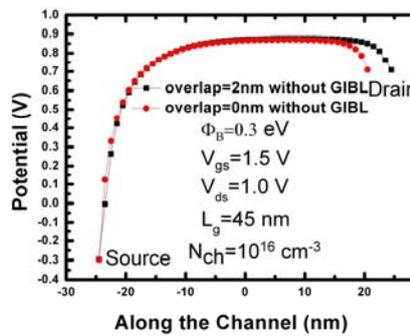


Fig. 6 The potential distribution along the channel at x=1nm without GIBL for overlap= 0nm and 2nm.

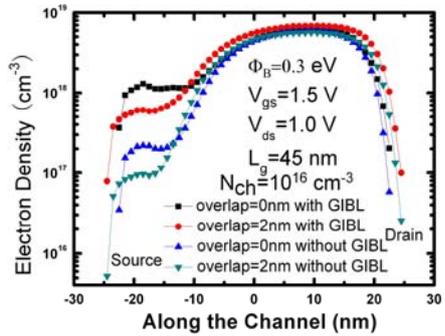


Fig. 7 The average electron density distribution along the channel at x= 1nm with and without GIBL for overlap= 0nm and 2nm.

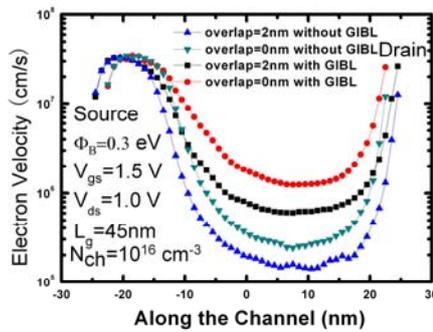


Fig. 8 The average electron velocity distribution along the channel at x=1nm with and without GIBL for overlap= 0nm and 2nm.

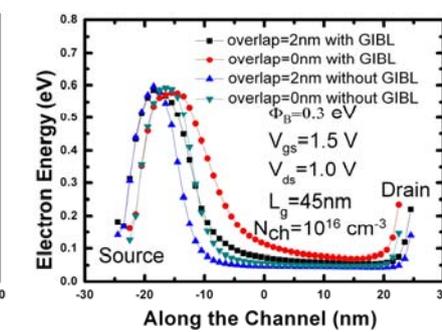


Fig. 9 The average electron energy distribution along the channel at x=1nm with and without GIBL for overlap= 0nm and 2nm.

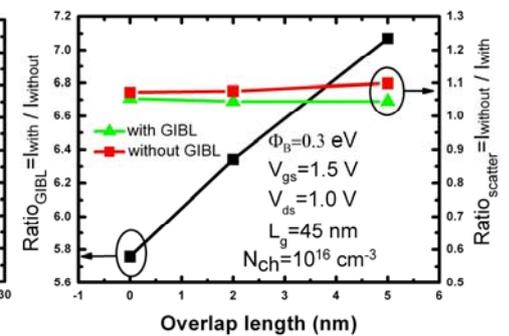


Fig. 10 The influence of channel length on GIBL and the influence of scattering with and without GIBL for overlap= 0nm, 2nm and 5nm.