Role of Quantum Confinement Effect on Tunneling Operation of LTFET Devices

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ABSTRACT

Part of the channel in L-shaped tunnel field-effect transistor (LTFET) is very thin and suffers from quantum confinement effect. Role of quantum confinement effect on band-to-band-tunneling (BTBT) of LTFET was investigated using numerical simulation and band diagram analysis. It was found that quantum confinement effect significantly affects the BTBT mechanism of LTFET devices.

Keywords

BTBT, LTFET, potential, quantum confinement

Ⅰ. Introduction

L-shaped tunnel field-effect transistor (LTFET) has been introduced[1] to overcome the low on current I_{ON} problem of conventional TFETs. In this work, the effect of quantum confinement (QC) on band-to-band-tunneling (BTBT) mechanism of LTFET is investigated using numerical simulation[2].

Ⅱ. Quantum Confinement Effect

Fig. 1 shows schematic of LTFET. As can be seen in Fig. 1, there is a part of the channel labelled as region II in Fig. 1 that is very thin that is only 4 nm. This part of the channel suffers from QC effect. Whereas, region III which is also part of the chanel does not suffer from QC effect.

QC effect increases the bandgap near the surface where all the BTBT paths terminate. As a result, it becomes difficult for the BTBT condition E_c=E_v (E_v valence band) to be met in region II. because conduction band edge E_c is raised around surface whereas, within the source which does not suffer from QC it remains unchanged; a more raised E_c needs an equivalent E_v for BTBT to take place. Hence, for a majority of the gate bias swing, region II does not conduct. However, region III which does not suffer from QC conducts for all bias values. Region II only conducts when the gate bias is very high.

Ⅲ. Results

Fig. 2(a) and (b) show BTBT contour plots when quantum model is not selected and when quantum model is selected, respectively, at a gate-source voltage V_{gs}=0.4 V and drain-source voltage V_{ds}=0.25 V. With quantum model selected BTBT is not present. With no quantum model selected, a finite BTBT is observed in region II.

Fig. 3 shows the band diagram extracted from the simulator in region II along -0.010 μm $\leq x \leq 0.0$ μm, y=0.0 μm in x, and y directions respectively at V_{gs}=0.4 V and V_{ds}=0.25 V with quantum model selected (Fig. 3(a)) and with no quantum model selected (Fig. 3(b)). eQuantumpotential is the correction added to E_c when positive [2]. It can clearly be seen in Fig. 3(a) that E_c increases around the surface with quantum model selected, hence BTBT cannot take place in region II.

Ⅳ. Conclusion

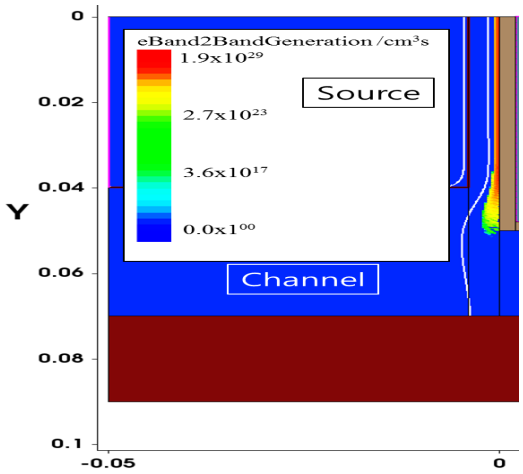
It was found that due to quantum confinement, BTBT does not take place in region II until V_{gs} bias is very high. Whereas,

BTBT takes place in region III for all biases.

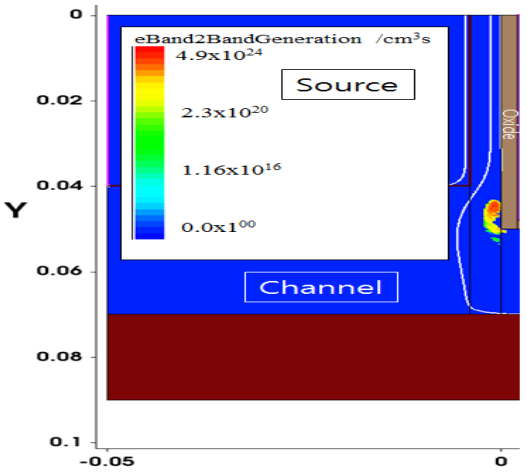
References

[1] S. W. Kim, J. H. Kim, T. J. K. Liu, W. Y. Choi, and B. G. Park, "Demonstration of L-shaped tunnel field-effect transistor," *IEEE Trans. Electron Devices*, vol. 63, no. 4, pp. 1774-1778, Apr. 2016.

[2] Sentaurus User Manual, version L-2016.03, Mar. 2016.



(a)



(b)

Fig. 2. BTBT contour plots extracted from the simulator at V_{gs}=0.40 V and V_{ds}=0.25 V. (a) No quantum model selected. (b) Quantum model selected.

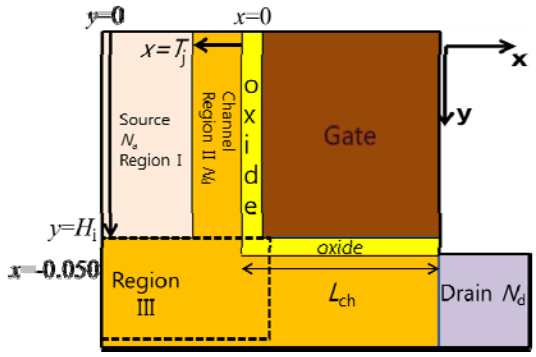
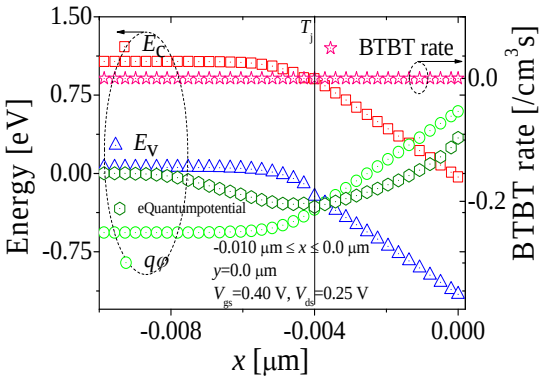
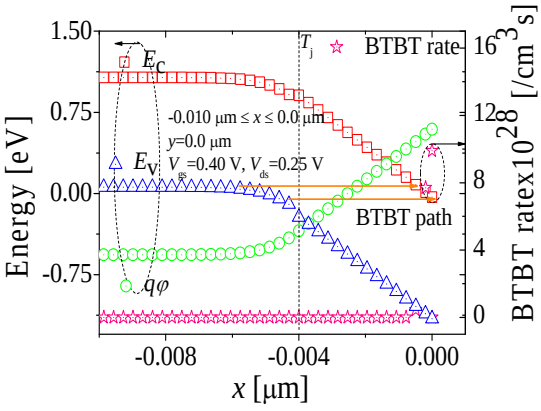


Fig. 1. Schematic of LTFET.



(a)



(b)

Fig. 3 Band diagram extracted from the simulator at V_{gs}=0.40 V. (a) Quantum model selected. (b) No quantum model selected.