L형 터널 트랜지스터의 트랩-보조-터널링 현상 조사

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Investigation of Trap-Assisted-Tunneling Mechanism in L-Shaped Tunneling Field-Effect-Transistor at Low Bias

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요 약

L형 터널링 전계 효과 트랜지스터 (LTFET)는 종래의 터널링 전계 효과 트랜지스터 (TFET)보다 우수한 소자로 고려된다. 그러나, 실험적으로 입증 된 LTFET은 트랩 상태의 존재로 인한 트랩-보조-터널링 (Trap-Assisted-Tunneling; TAT)에 기인한 열악한 임계 이하 기울기(SS) 특성을 나타내었다. 본 논문에서는 실험적으로 시연 된 LTFET의 저전압 바이어스에 TAT 메커니즘을 밴드 다이어그램과 TAT 재조합률 (GTAT)을 사용하여 조사한다.

ABSTRACT

L-shaped tunneling field-effect-transistor (LTFET) is considered a superior device over conventional TFETs. However, experimentally demonstrated LTFET demonstrated poor subthreshold characteristics which was attributed to trap-assisted-tunneling (TAT) caused by presence of trap states. In this paper, TAT mechanism in the experimentally demonstrated LTFET is investigated with the help of band diagram and TAT recombination rate (G_{TAT}).

키워드

Interface traps, LTFET, traps, trap assisted tunneling

Ⅰ. Introduction

L-shaped tunnel field-effect transistor (LTFET) is considered a superior device over conventional TFETs. However, the experimentally demonstrated [1] LTFET exhibited significantly degraded subthreshold slope which was attributed to presence of trap states. Traps states caused trap-assisted tunneling (TAT) which offers higher current in subthreshold region than the band-to-band-tunneling current thus degrading LTFET's transfer characteristics. Subthreshold characteristics of LTFET have not been reported in terms of TAT mechnism in detail.

In this abstract, TAT mechanism in the experimentally demonstrated LTFET is investigated with the help of band diagram and TAT recombination rate.

Ⅱ. Trap-Assisted-Tunneling

Fig. 1(a) shows schematic of LTFET. Bulk trap states are assumed. The channel region is very small, that is, only 10 nm in the x-direction. TAT is a two-step process. First, electrons from the valence band is captured by a trap states. In the second step, the trapped electron moves to

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conduction band. Both these steps may require phonon (thermal) assistance or direct tunneling between the bands.

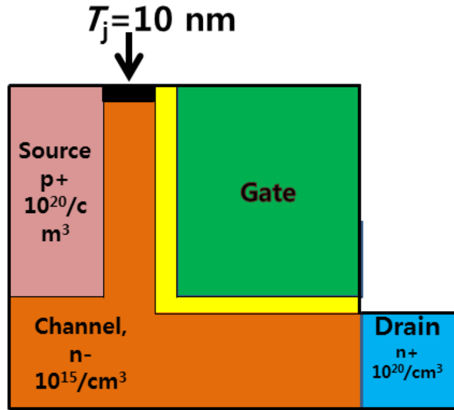

그림 1. LTFET structure.

III. Results

Dynamic nonlocal TAT model was used as well as Fermi statistics, and constant mobility model [2]. Fig. 2 shows band diagram in the 1D region in LTFET. $E_c/E_v/E_{trap}$ are given by blue, red and green symbols respectively. Left axis shows TAT generation rate (G_{TAT}). At high bias, electron directly tunnel from E_v to E_{trap} and then tunnel from E_{trap} to E_c without requiring any phonon assistance.

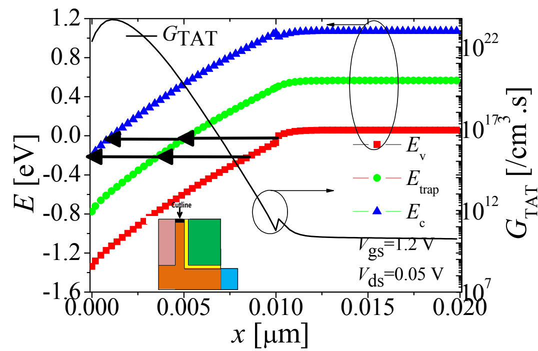

그림 2. Band diagram in 1D region of LTFET showing $E_c/E_v/E_{trap}$ (blue, red, and green symbols, respectively, at V_{gs}=0.0 V. E_{trap} is at midgap level. G_{TAT} (black line) is shown on the left axis. Direct E_v to E_{trap} and E_{trap} to E_c transition is possible without requiring any phonon assistance.

Ⅳ. Conclusion

TAT mechanism was demonstrated in LTFET for different trap levels at high bias. It was found that at high bias, direct tunneling possibility exists between E_v to E_{trap} and E_{trap} to E_c without the need for any phonon assistance. The better electrostatics of LTFET as compared to conventional TFET also makes it worst for TAT induced performance degradation.

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.