# 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

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## 요 약

트랩-보조-터널링(Trap-Assisted-Tunneling; TAT)은 실제 터널링 전계 효과 트랜지스터 (TFET)의 임계 이하 기울기를 저하시키고 시뮬레이션에서 고려되어야한다. 그러나, 그 메커니즘은 라인 터널링 타입 L형 TFET(LTFET)에서는 잘 알려져 있지 않았다. 본 연구는 dynamic nonlocal Schenk 모델을 이용한 LTFET의 TAT 메커니즘을 연구한다. 이 연구에서는 터널링 이벤트를 위해서 phonon assisted and direct band가 모두 고려되었다.

## ABSTRACT

Trap-assisted-tunneling (TAT) degrades subthreshold slope of real-world tunneling field-effect-transistors (TFET) and it should be considered in the simulation. However, its mechanism is not very well understood in line tunneling type L-shaped TFET (LTFET). This study investigates TAT mechanism in LTFETs using dynamic nonlcoal Schenk model. Both phonon assisted and direct band to trap tunneling events are considered in this study.

키워드

Interface traps, LTFET, traps, trap assisted tunneling

## Ⅰ. Introduction

L-shaped tunnel field-effect transistor (LTFET) has been experimentally reported to exhibit significant trap-assisted-tunneling (TAT) current [1]. However, its mechanism has not been investigated yet. This study investigates TAT mechanism using dynamic nonlocal Schenk model in Sentaurus. Sentaurus considers both lateral and vertical tunneling mechanisms and is the most accurate simulation tool for this study.

## Ⅱ. Trap-Assisted-Tunneling

Fig. 1(a) shows schematic of LTFET. TAT is caused by presence of interface trap states present at the interface between the gate dielectric and silicon channel. These states originates during the fabrication process and are highly dependent on fabrication process used.

## 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. Trap states are represented by black stars. Conduction/valence band Ec/Ev are represented by black/blue symbols, respectively. Fig. 2 shows that both thermal excitation and direct Ev to Et transitions are possible for some trap levels. Fig. 3 shows TAT rate GTAT contour plot. It shows that both lateral and vertical TAT are present.

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## Ⅳ. Conclusion

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. Trap states are represented by black stars. Conduction/valence band Ec/Ev are represented by black/blue symbols, respectively. Fig. 2 shows that both thermal excitation and direct Ev to Et transitions are possible for some trap levels. Fig. 3 shows TAT rate GTAT contour plot. It shows that both lateral and vertical TAT are present.

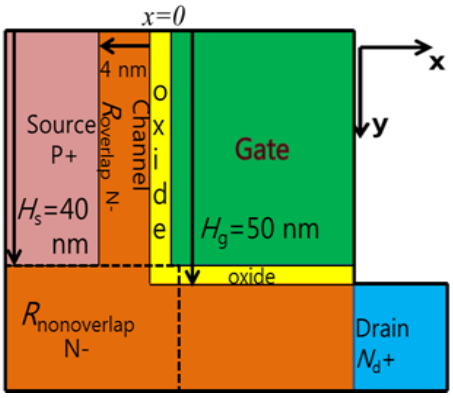


Fig 1. LTFET structure.

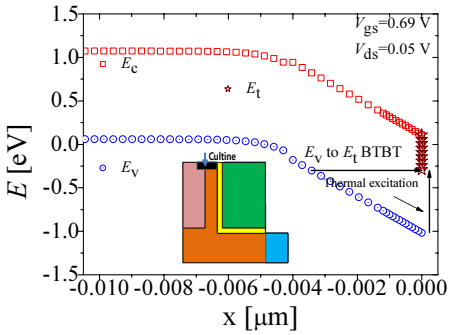


Fig 2. Band diagram in 1D region of LTFET showing $E_c/E_v$ (red and blue symbols, respectively) and $E_t$ (black stars). Thermal excitation and direct $E_v$ to $E_t$ transitions are indicated by vertical and horizontal arrows, respectively. $E_t$ to $E_c$ transition is a thermal event.

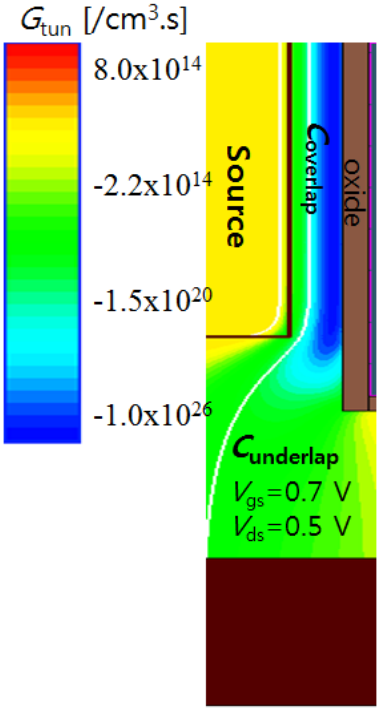


Fig 3. $G_{TAT}$ contour plot at $V_{gs}$=0.7 V. Both lateral and vertical TAT are present.

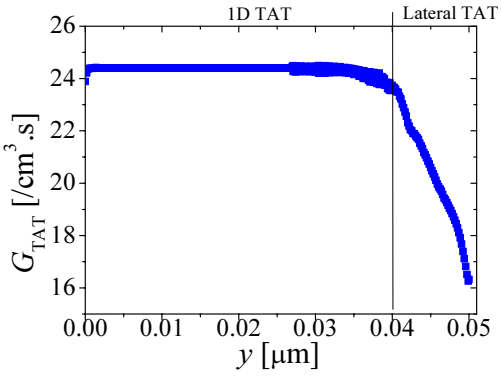


Fig 4. $G_{TAT}$ extracted from the countour plot above. It clearly shows both lateral and 1D TAT are present.

## 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.