Design and simulation of GaSb/InAs 2D Transmission enhanced TFET

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INTRODUCTION

Tunneling Field Effect Transistors (TFETs) have been widely analyzed for potential use in low-power applications because of its steep subthreshold swing (SS). However, the on-currents (I_{on}) of tunneling FETs are much lower than that of to conventional MOSFETs because of low tunneling probability [1].

Avci [2] reported a modified TFET, adding a second barrier to introduce a resonant, bound state. As this bound state is brought into resonance with the source, the transmission peaks sharply, thus deceasing (improving) the subthreshold swing. Here we show supplementary barriers added to a TFET can improve the electron transmission over a broad energy range, thus improving on-current.

Electron transmission enhancement is similar [3] to the design of optical anti-reflection coatings and of microwave impedance-matching networks. An electron wave incident on the PN tunnel barrier has some transmission probability less than unity, and hence a nonzero wave reflection probability. If a secondary reflector is added, the reflections from the PN junction and of the secondary reflector will add and interfere; with appropriate adjustment of the barrier thickness and position, the reflections will add destructively, giving zero reflectivity, and 100% transmission, at one particular energy. With multiple layers, the energy range of high transmission can be increased; there are, however, bounds [4] to energy range over which transmission is high.

MODEL

The device is based on a p-GaSb/n-InAs double gate TFET with 3.2nm thick body and 2.56nm thick gate oxide (ε_r =20), 20nm gate length, $5\cdot10^{19}$ cm^{-3} source doping and $2\cdot10^{19}$ cm^{-3} drain doping. The transmission enhanced TFETs are PN heterojunction TFETs with three GaSb barriers in the channel. The GaSb barriers are 3, 5.5, and 3 monolayers (ml) thickness, and are separated by InAs layers 9.5 ml thickness. The 3-barrier structure is 16.5ml away from GaSb/InAs tunnel junction..

Ballistic transport properties are simulated by Quantum transmitting boundary method (QTBM) and band structure described by sp3d5s* tight binding basis [5]. The QTBM and Poisson equations are solved self-consistently, using NEMO5 nanoelectronics modeling software [6].

RESULTS

The width of wells and barriers was adjusted empirically with a series of simulations to peak the transmission over a broad energy range, thus increasing the device I_{on}. With the addition of the 3-barrier structure, the transmission is increased to 71% at 210 meV incident energy range, and is greater than 7% over an energy range from 207 to 275 meV and from 316meV to 340meV (Fig. 2). Fig. 3 shows the energy resolved current density..

Transfer characteristics are shown in Fig. 4. Using the ITRS general purpose (GP) logic off-current specification of 10^{-3} μA/μm, and selecting a 0.3V supply voltage (hence V_{gs}=0.3V in the on-state), the SS improved from 32mV/dec. to 25mV/dec. and I_{on} is increased from 36 μA/μm to 102 μA/μm.

CONCLUSION

Supplementary barriers added to a TFET can be designed such that they introduce reflections which interfere destructively with the reflection from the main PN tunnel barrier, thereby reducing the net electron reflectivity. The tunnel barrier transmission coefficient, and hence TFET on-current, can thereby be increased. Multilayer

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designs permit the transmission to be enhanced over a broad energy range, thereby significantly increasing the TFET on-current.

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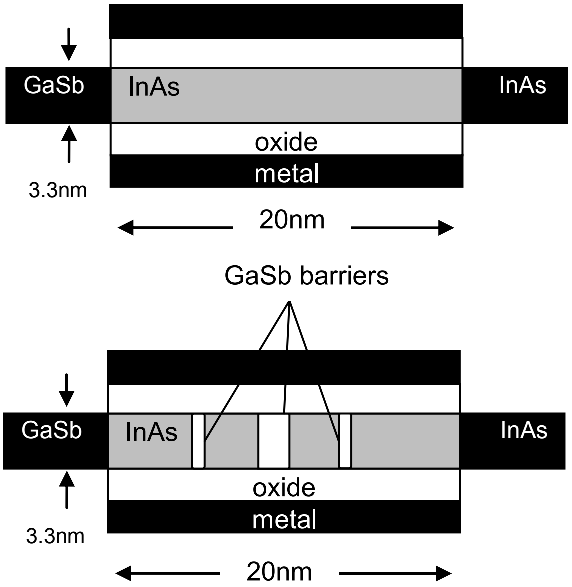

Fig. **1**. Cross-section view of aconventional Double Gate GaSb/InAs heterojunction TFET and transmission enhanced TFET, which has three supplementary reflectors inside the channel.

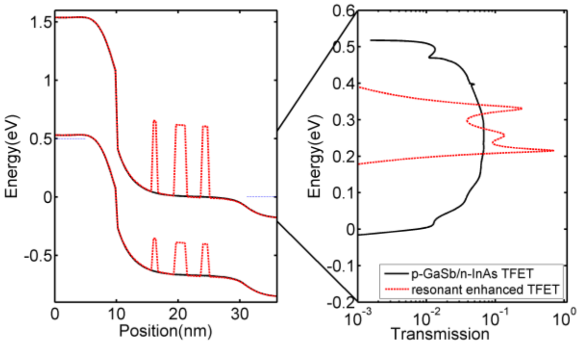

Fig. 2. Left: Band diagram of a transmission enhanced TFET and conventional TFET at ON-state. Right: Transmission probability at the zoomed-in energy range of BTBT at transverse wave vector k=0

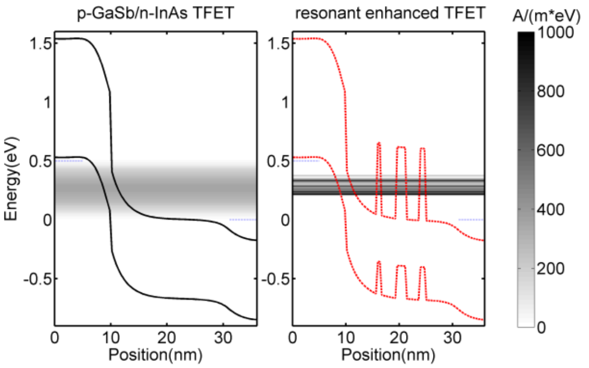

Fig. 3. Energy resolved current density at ON-state for conventional GaSb/InAs heterojunction TFET (left) and transmission enhanced TFET (right).

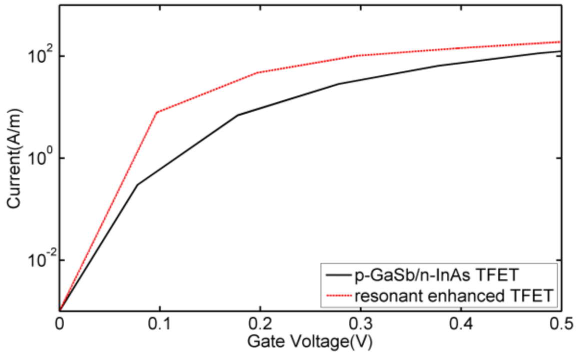

Fig. 4. Transfer characteristics of conventional GaSb/InAs heterojunction TFET compared with transmission enhanced TFET aligned at GP off-current specification of 10^{-3} μA/μm.