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Comparison Analysis of Tunnel Field Effect Transistor and Dopingless Tunnel Field Effect Transistor

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Abstract

In the present day, nm technology is highly significant. Along with the application of scaling down of devices, there are several obstacles that are confronted in this nano world due to the reduction in sizes. DLTFETs are a form of nano FET that can effectively address some of the problems. DLTFETs can lower the high temperature needs of traditional TFETs. They can also obtain a lower sub threshold swing. DLTFETs are synthesized utilizing charge plasma principles rather than high temperature annealing methods to form the source and drain. RDFs may be avoided in DLTFETs thanks to these creative approaches. In this research, we will give a comparative analysis on TFET and DLTFET varieties.

Key words: SCE, BTBT, RDF, S Sav, ION/IOFF, Vth, TFET, DLTFET, DODLTFET, HGDODLTFET, MLTFET, SCE, BTBT, RDF, S Sav, ION/IOFF, Vth.

1. Introduction

Scaling down the sizes of MOS devices to improve their performance has been increasingly common in recent years. Scaling down MOS device sizes boosts speed and packing density. It minimizes both power usage and chip cost. In addition to the benefits listed above, several hurdles must be overcome. When the devices are reduced in size, the leakage current rises, followed by the static power dissipation [1]. When the device is scaled down, the power supply should likewise be scaled down, which reduces the device's ON-state performance. These are some of the difficulties encountered by the scaled-down MOS device. In addition, the MOS device's sub threshold slope is restricted to 60mv/decade. In order to address these problems, TFETs outperform traditional MOS devices. TFETs are devices that operate according to the BTBT process rather than the thermionic emission of charge carriers. These TFETs have come into play because to their steep sub threshold slopes of less than 60mv/decade [2]. Short channel effects have less of an influence. TFETs are well-known for their low-power performance. However, these TFETs also have drawbacks such as low on current, SCEs [3], and the influence of random dopant oscillations [4]. Also, sharp connections are required for effective tunneling mechanisms to occur, but forming abrupt junctions using high heat annealing techniques is problematic.

Tunnelling Field-Effect-Transistors (TFETs) have become a prominent semiconductor device in the field of high sensitive biosensor-based scientific research and industry due to its advantages over other semiconductor devices in dealing with sub-threshold effects [5-8]. The combination of TFET and Nanowire architectures results in an optimal silicon device for biosensors [9-10]. Biosensors must be very sensitive to biomolecules while being small in size.

Tunnel field-effect transistors (TFETs) are a type of transistor that uses quantum tunneling to switch current flow. They are promising for low-power applications because they have a very low sub threshold swing (SS), which is the amount of voltage change required to change the current by a factor of 10. This means that TFETs can operate at much lower voltages than traditional metal-oxide-semiconductor field-effect transistors (MOSFETs), which can lead to significant power savings.

Dopingless TFETs are a type of TFET that does not require any doping in the channel region. This can make them easier to fabricate and can also improve their performance. However, dopingless TFETs also have some challenges, such as a lower ON-state current than doped TFETs.

In order to tackle the issues that TFETs confront more efficiently, fewer TFETs have been introduced. A doping-less TFET is created without the usage of any high thermal energy. The development of source and drain occurs as a result of the charge plasma idea, on intrinsic silicon, with the employment of metal electrodes with proper work functions [11]. There is already a charge plasma diode and a charge plasma transistor [12-13]. Because extreme temperature requirements are minimized in the design of DLTFETs, the influence of RDF„s is reduced. To avoid quantum mechanical effects in DLTFETs, the silicon wafer thickness must be kept at 10 nm [14]. The state performance of DLTFETs can be enhanced. Because high temperature requirements are avoided, abrupt connections may be made, increasing tunneling efficiency and the device's on-state current. The use of a high k dielectric at the gate can also boost the on state current, which raises the ION/IOF ratio. The operating frequency of a conventional MOSFET is around 200 KHz, and that of a TFET is also 200 KHz, but that of a DLTFET is 8 GHz. The performance of DLTFETs can also be increased in many ways. A DGDLTFET's on current can be effectively managed. Using different oxide materials as the source and drain, i.e. a DODGDLTFET, the performance may also be improved by lowering the S Sav to a lower level. Another form is the MLDLTFET, which employs a metal layer in the oxide layer between the gate and the source. The operating frequencies of DODLTFET and HGDODLTFET are 42.5 GHz and 103 GHz, respectively. All of these DLTFETs have their unique benefits with regard to parameter trading. However, without diminishing the performance of TFETs, DLTFETs can provide good parameters when compared to TFETs. In this work, we will show a comparison of TFET and DLTFETs based on research from many studies.

2. Construction

The TFET source and drain are produced using the traditional approach of doping the impurities, which demands extremely high temperatures. The schematic and band diagrams of an n-channel TFET are shown in Figure (1). This may be solved by employing a different sort of FET known as DLTFET (doping less TFET), in which the source and drain areas are produced by a change in plasma idea. The source and drain of a DLTFET are produced by inducing metal electrodes with appropriate work functions. Figure 2 depicts a cross section of a double gate doping less TFET. Because of the lack of sudden functions, normal TEFT has a lower BTBT efficiency. It is not feasible to build an abrupt function when the source and drain are produced using the doping approach. The problem with DLTFET tunneling that traditional TFETs confront is that they are influenced by RDF owing to the use of costly thermal annealing procedures. They have an influence on the device's off-state performance by raising the leaking current. Because they eschew doping procedures, these RDFs can be minimized to some amount in DLTFET. It is clear from the above construction features that DLTFET has more benefits than standard TFET. When compared to DLTFET, a DODLTFET has a higher K gate dielectric on the source side, which results in a smaller tunneling width and a higher ON current. Figure 3 depicts a DODLTFET design with several oxide materials beneath the source and drain. The dielectric layer underneath the gate is equally filled by both oxides. As shown in Figure 4, the HGDODLTFET employs a metal with a low work function on the top of the tunneling junction and a high K dielectric on the source side, which increases the devices ON state performance [15]. Figures 9, 10 demonstrate the energy band diagrams and transfer characteristics of the HG-DODLTFET, indicating that the device outperforms the standard DLTFET [26, 18].Figure 5 depict the ML-TFET design. The inclusion of a metal layer in the oxide area between the gate and source electrodes improves the band steepness at the source channel interface in an MLTFET. This lowers the tunneling barrier and improves Ion, SS, and Vth. Figures 10 and 11 depict the ML-TFET's energy band diagrams and transfer curve. The inclusion of the metal layer increases the tunneling rate, resulting in a high switching rate for an ML-TFET.

3. Working

Figure 6 depicts the energy band diagrams of the TFET and DLTFET. The threshold voltage was determined to be 0.12V, which is nearly same for both devices. Both are nearly identical. In the off state situation, the source's conduction band edge lies above the channel's valence band edge, leaving no room for tunneling. As a result, the off state current is lower. Because TFETs function in reverse bias, when the device is turned on, the source is grounded and a positive voltage is provided across the drain. When the gate voltage is zero, no current flows through the device. As the gate voltage increases, the tunneling width narrows and a large ON current flows through the device. DLTFET operates in a manner similar to TFET. If a dual gate is employed in either a TFET or a DLTFET, the gate potential may be adjusted more effectively [16, 17]. As a result, although having the same SS and Ion/Ioff ratio as traditional TFETs, the DLTFET may be seen as an enhanced TFET with no sacrifice in any of the features, i.e. in functioning or construction.

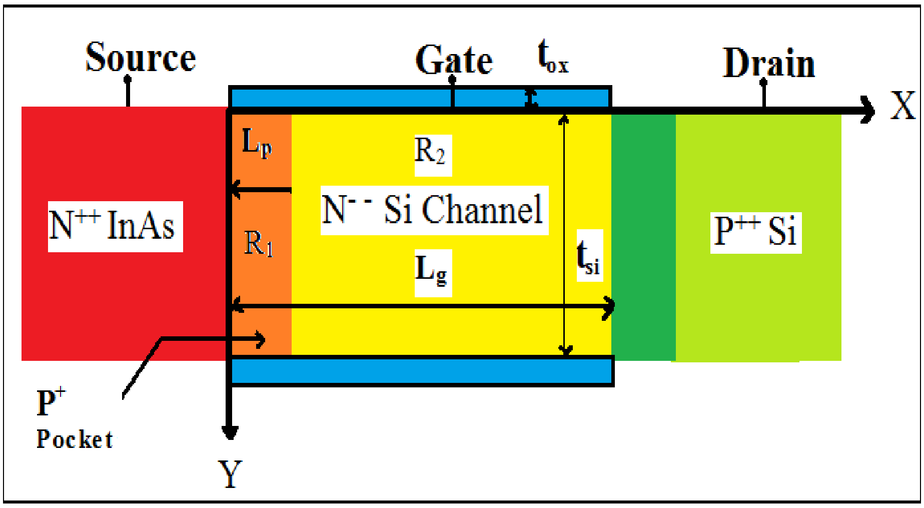

Fig.1 A cross-section of a double gate doping-less TFET.

The energy band diagram of a DODLTFET is shown in Figure 7.The conduction band energy levels of the channel are aligned with the valence band energy levels of the source side in both DL-TFET and DO-DL-TFET, however the tunneling width is shorter in the DODLTFET than in the conventional DLTFET due to the use of high -k dielectric material on the source side. Figure compares the transfer properties of DODGDLTFET to those of DL-TFET and shows that the ON current of a DGDODLTFET is enhanced, as is the sub-threshold slope and Ion/Ioff ratio [20].

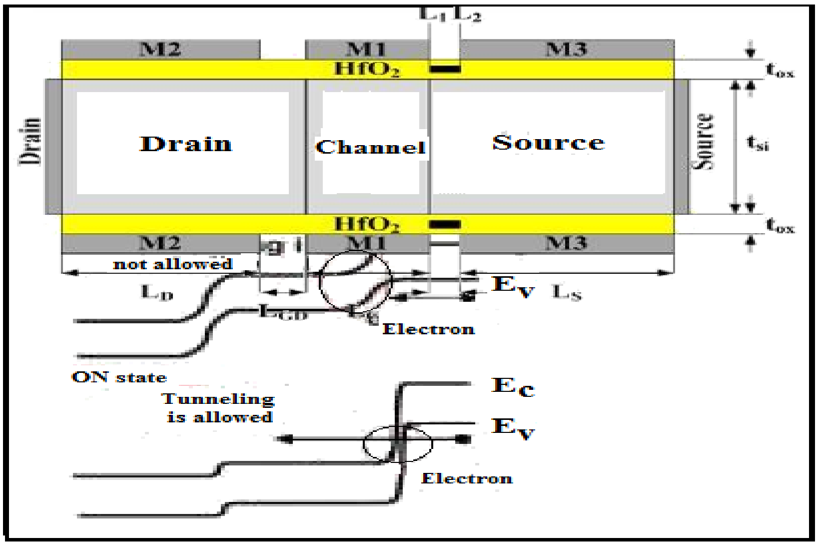

Fig. 2 The n-channel TFET's ON/OFF states are depicted schematically.

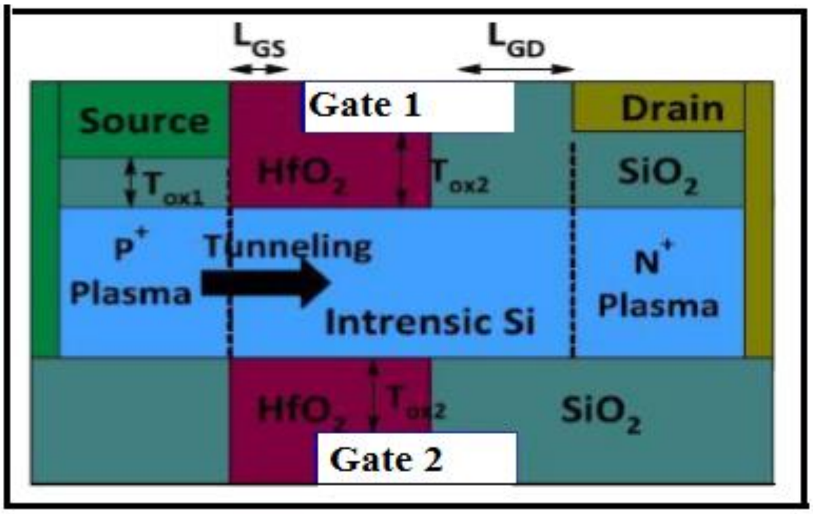

Fig 3: Diagram of the DG-DO-DL-TFET.

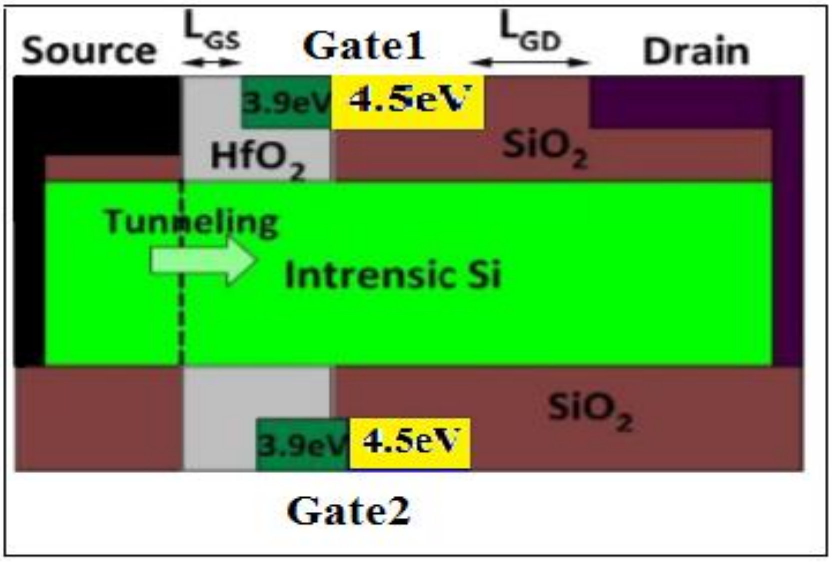

Fig 4: HG-DLTFET schematic.

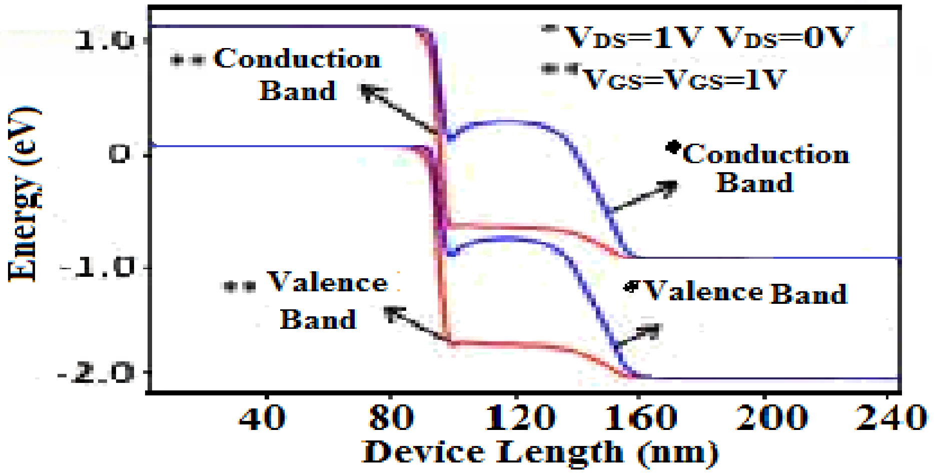

Fig. 5: ML-DLTFET Schematic.

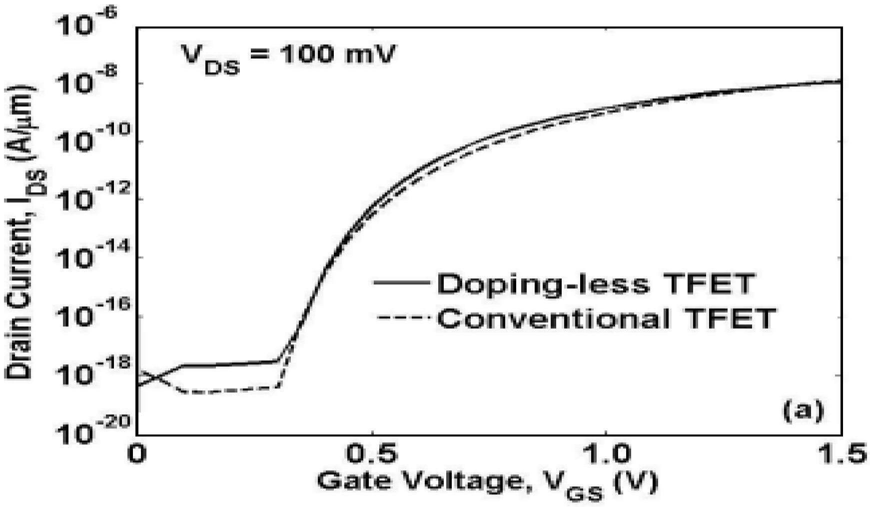

Fig.6: For VDS = 100 mV, the transfer properties of the doping-less TFET were compared to those of the comparable conventional TFET.

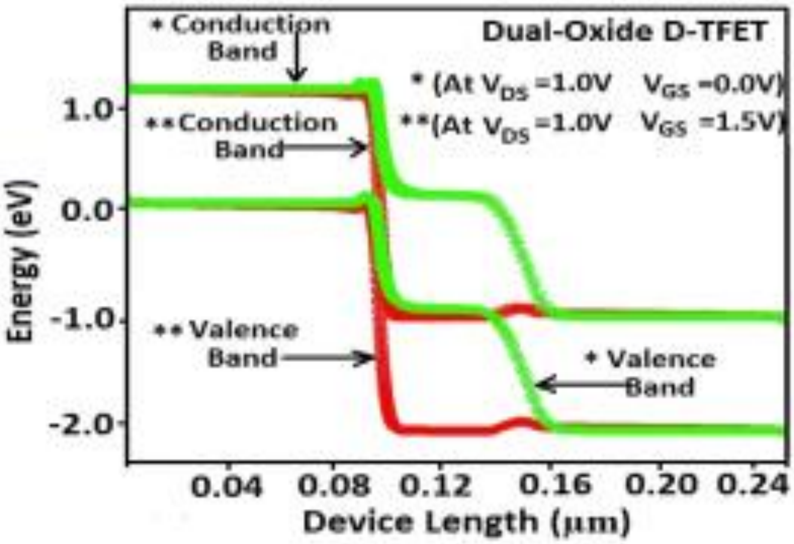

Fig.7: DO-DG-DL-TFET energy band diagram in thermal nnnnequilibrium and ON-state.

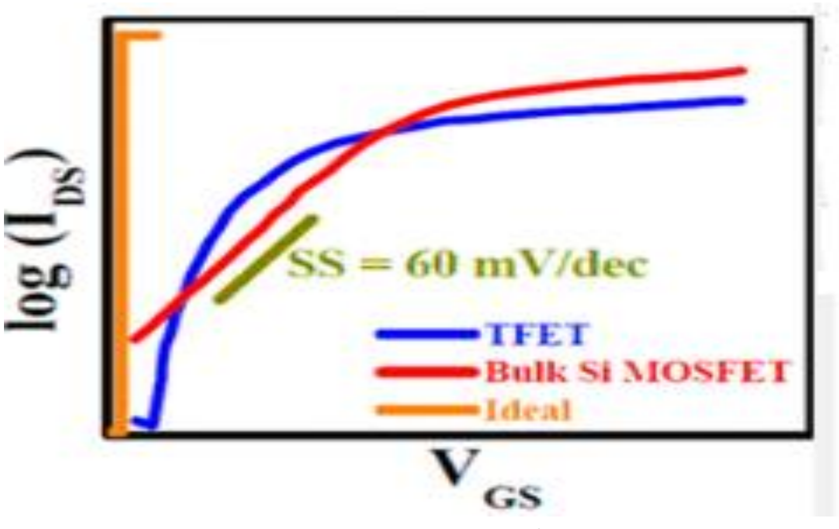

Fig. 8: The proposed DG-DO-DL-TFET transformer characteristics.

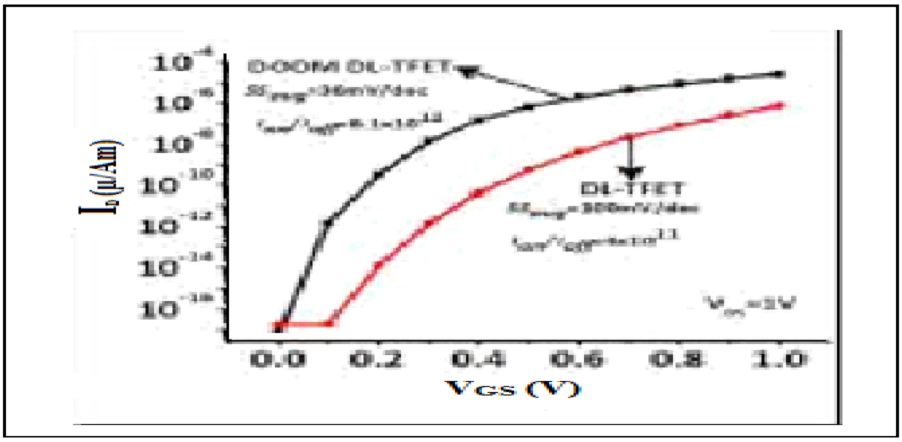

Fig. 9: The properties of DL-TFET and HG-DL-TFET devices in terms of transfer.

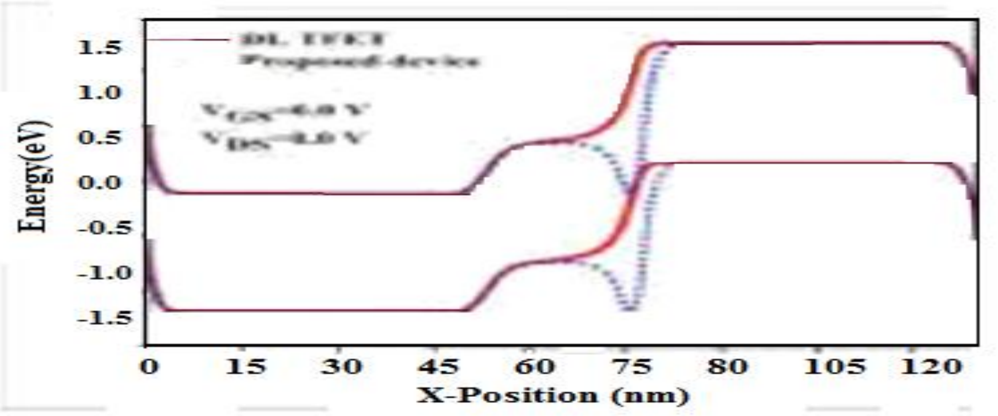

Fig. 10: Variation of the ML-TFE energy band across the channel orientation in thermal equilibrium.

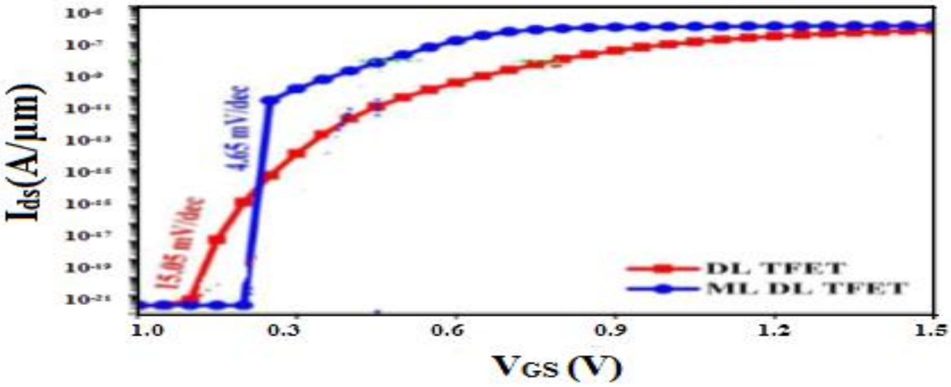

Fig. 11: The characteristics of ML-TFET and DL-TFET devices with respect of transfer.

4. Parametres Wise

4.1 Sub threshold swing

MOSFETs are restricted to an SS of 60mv/decade. When it comes to TFETs, their SS is less than 60mV/decade, or around 52.8 mV/decade at ambient temperature [19], whereas a conventional DLTFET's SS is 100mV/decade [11]. This is a drawback of the introduction device, although high temperatures are not necessary in its construction. In a DODLTFET, SS improves by 30% [20] whereas an HGDO DLTFET improves by 3.8%, or 37mV/decade, and an ML DLTFET improves by as little as possible, or 5mV/decade, when compared to all of the aforementioned devices..

4.2. ON CURRENT

TEFT has an ON current of around 1A per m. The on current can be increased further by using a smaller band gap material, a thinner oxide layer, and a more abrupt source doping profile. The ON current of the DLTFET is -1.1 10-5 A/m, which is essentially identical to that of the traditional TFET. The ON current of a DODLTFET is almost 6.14 times higher than that of a DLTFET. The combination of low work function metal and high K dielectric in an HGDODLTFET [21] improves ON state performance and increases ON current by 65 times over the DLTFET. The switching speed of an MLTFET rises due to the band steepness [22].

4.3 Ion/Ioff RATIO

At a Vgs of 1v, the ON and OFF currents of a TFET are 12.1a and 5.4a per micrometer. Despite having a lower SS value, TFETs have a lower Ion/Ioff ratio than traditional MOSFETs. The Ion/Ioff ratio of a DL-TFET is comparable to that of a TFET, with the added benefit of not requiring high temperatures during manufacturing. When compared to a DLTFET, the Ion/Ioff ratio in a DODLTFET and HG-DLTFET is increased by 6.14 and 74 times, respectively.

5. Applications

Because of the TFET's ambiolar nature, it may be employed in BIOSENSING applications [23]. TFETs can also be employed as an energy-saving electronic switch [24] and as a memory device [25]. DLTFETs are useful in low-power applications.

6. Conclusion

This paper provides a comparison of traditional TFETs and several types of Doping less TFETs. According to the results of the study, all of the DLTFETs considered had increased performance in terms of Ion, Ion/Ioff ratio, threshold voltage, and frequency of operation when compared to a regular TFET. Furthermore, as compared to others, an MLTFET exhibits good performance with a rapid switching speed. The issues presented by TFETs can be readily solved by DLTFETs, according to this article.

7. Futurescope

Researchers and the VLSI industry are interested in DLTFETs because of their enhanced properties. With its strong ON CURRENT, better control over channel width, enhanced threshold voltage, and reduced thermal budget, they pave the way for the future of low power applications. With all of these benefits, DLTFETs have the potential to dominate the VLSI market in the future.

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