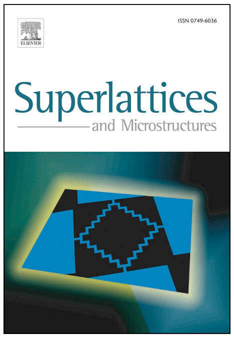

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Influence of Germanium Source on Dopingless Tunnel-FET for Improved Analog/RF Performance

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Abstract

Dopingless (DL) and junctionless devices have attracted attention due to their simplified fabrication process and low thermal budget requirements. Therefore, in this work, we investigated the influence of low band gap Germanium (Ge) instead of Silicon (Si) as a ”Source region” material in dopingless (DL) tunnel field-effect transistor (DLTFET). We observed that the Ge source DLTFET delivers much better performance in comparison to Si DLTFET under various analog/RF figure of merits (FOMs), such as transconductance (g_m), transconductance generation factor (TGF) (g_m/I_d), output conductance (g_d), output resistance (R_O), intrinsic gain ($g_m R_O$), intrinsic gate delay (τ) and RF FOMs, like unity gain frequency (f_T), gain bandwidth product (GBW) along with various gate capacitances. These parameters were extracted using 2D TCAD device simulations through small signal ac analysis. Higher I_{ON}/I_{OFF} ratio (10^{14}) of Ge source DLTFET can reduce the dynamic as well as static power in digital circuits, while higher transconductance generation factor (g_m/I_d) ~2287 V^{-1} can lower the bias power of an amplifier. Similarly, enhanced RF FOMs i.e unity gain frequency (f_T) and gain bandwidth product (GBW) in Gigahertz range projects the proposed device preference for RF circuits.

Keywords: Tunnel field effect transistor (TFETs), band-to-band tunneling (BTBT), charge plasma, band gap engineering, germanium (Ge), analog FOMs, RF FOMs, TCAD.

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1. Introduction

With technology scaling, nano-CMOS devices are experiencing several challenges mainly short channel effects (SCEs) and complex fabrication process, in this pursuit, junctionless and dopingless devices are extensively studied in the recent past. Further, higher energy efficiency and switching performance even at reduced supply voltage level makes tunnel field-effect transistor (TFET) as an alternative to the conventional transistor, MOSFET. Steeper sub-threshold swing (less than 60 mV/dec at room temperature) and low standby power (leakage current~femtoamperes), favors TFET for ultra low power applications [1, 2, 3]. Despite of these merits quantum-mechanical tunneling of carriers significantly limits the ON-current (I_{ON}) of Si-TFETs due to indirect and large energy bandgap. However, for high I_{ON}, transmission probability of carriers through interband tunneling requires source material with small bandgap along with abrupt doping profile at the source-channel junction. These stringent requirements enforce complex fabrication process with high thermal budget requirements due to ion-implantation and thermal annealing techniques [4, 5]. In addition, these abrupt junctions restrain aggressive scaling because of enhanced random dopant fluctuations (RDFs), as a result, these devices are more vulnerable towards process variations related issues [6, 7, 8, 9].

In this paper, we have proposed a Germanium source Dopingless (DL) Tunnel-FET (Ge source DLTFET) device structure that employ combination of two device engineering approaches: (a) low band gap source material i.e. Germanium source, for improving the ON state current (I_{ON}), and (b) dopingless structure throughout from source, channel and drain regions, to relax the fabrication process and variability related problems. Replacing the Si-source in conventional TFET through Germanium source will reduce energy barrier width at source junction, as a result,

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