Superlattices and Microstructures 97 (2016) 277–286

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

A novel Tunneling Graphene Nano Ribbon Field Effect Transistor with dual material gate: Numerical studies

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A R T I C L E I N F O

Article history:
Received 25 March 2016
Received in revised form 5 June 2016
Accepted 22 June 2016
Available online 23 June 2016

Keywords:
Tunneling Graphene Nano Ribbon Field Effect Transistor (T-GNRFET)
Non-Equilibrium Green's function (NEGF)
Drain Induced Barrier Shortening (DIBS)
Am-bipolar

A B S T R A C T

In this work, we present Dual Material Gate Tunneling Graphene Nano-Ribbon Field Effect Transistors (DMG-T-GNRFET) mainly to suppress the am-bipolar current with assumption that sub-threshold swing which is one of the important characteristics of tunneling transistors must not be degraded. In the proposed structure, dual material gates with different work functions are used. Our investigations are based on numerical simulations which self-consistently solves the 2D Poisson based on an atomistic mode-space approach and Schrodinger equations, within the Non-Equilibrium Green's (NEGF). The proposed device shows lower off-current and on-off ratio becomes 5order of magnitude greater than the conventional device. Also two different short channel effects: Drain Induced Barrier Shortening (DIBS) and hot-electron effect are improved in the proposed device compare to the main structure.

1. Introduction

In order to overcome limits of miniaturization or scaling down of silicon based field-effect transistors, it seems necessary to introduce new materials instead of silicon. During the last decade, Graphene, a 2 dimensional atomically thin film of carbon, is highly regarded due to its special electronic, mechanical, optical and thermal properties [1–3]. Also it's ultra-thin body structure makes it suitable for overcoming short channel effects in scaled-down device [4,5]. Because of its zero band gap, graphene is used in the form of nanotubes (CNT) [6] and nanoribbons (GNRs) [7].

GNRFETs like CNTFETs can be categorized into three groups: Schottky barrier GNRFETs (SB-GNRFETs) [8], MOSFET-Like GNRFETs (MOS-GNRFETs) [9–11] and Tunneling GNRFETs (T-GNRFETs) [12–15].

Schottky barrier GNRFETs are well-known GNRFETs that have been given much attention. However, a large sub-threshold swing, a low *I*on/*I*off ratio, and a strong am-bipolar behavior are characteristics that can limit the use of SB-GNRFETs. MOSFET-like GNRFETs are alternative nanoribbon transistor structures with improved performance and are fabricated by doped GNRs as source/drain regions. They have a higher *I*on/*I*off ratio, a lower leakage current and a smaller sub-threshold swing but with classical limit of 60 mV/decade. The other type is T-GNRFETs. Since the on-current are generated by the tunneling mechanism,

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http://dx.doi.org/10.1016/j.spmi.2016.06.034
0749-6036/

TFETs are promising candidate to achieve a sub-60 mV/dec sub-threshold slope (ss) and a low off-state current for high speed circuits with low static power consumption.

In order to reduce off-current and am-bipolar behavior of the MOS-GNR(CNT)FETs, researchers have proposed various approaches such as use of linearly doped S/D regions [16], use of lightly doped S/D regions [17], electrically activated source and drain extension [18] and use of dual-gate structure with different work functions [19,20]. Taking advantage of the less troublesome approach of [19,20], we have proposed to introduce a new T-GNRFET in which with the use of dual material gate structure and work function engineering of the gate, off current (I_{OFF}) and DIBS (Drain Induced Barrier Shortening) are significantly reduced, meanwhile persevering ON state characteristics specially sub-threshold swing. This new structure is named Dual Material Gate T-GNRFET (DMG-T-GNRFET).

The rest of the paper is organized as follows. In Section 2 and 3 we describe the proposed device structure and the approach of simulation, respectively. Section 4 presents the numerical results and related discussions. Finally, the paper is concluded in Section 5.

2. Device structure

Fig. 1(a) and (b) illustrates 2 dimensional cross-sectional view of the conventional GNR-TFET and the proposed device respectively. The GNR used for simulation is armchair edge with n = 12 which N represents the number of dimmer carbon atoms. The Graphene is sandwiched between two 1.5 nm dielectric layers of HfO_2 with K = 16.

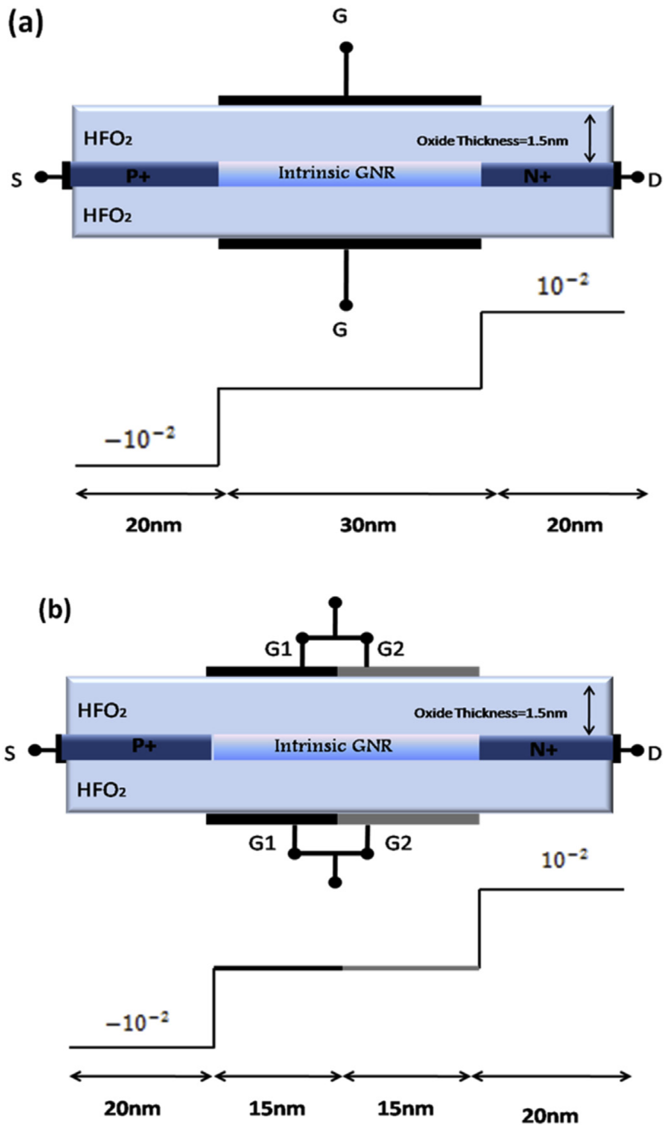

Fig. 1. The cross sectional and doping profile of (a) T-GNRFET and (b) DMG-T-GNRFET. A HfO_2 dielectric layer with $\varepsilon_{ox} = 16$ and $t_{ox} = 1.5$ nm is used. The source (drain) region is doped with 10^{-2} (dopant/atom) P (n) type impurities.