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Self-consistent surface charges and electric field in p-i-n tunneling transit-time diodes based on single- and multiple-layer graphene structures

V L Semenenko[1], V G Leiman[1], A V Arsenin[1], V Mitin[2], M Ryzhii[3], T Otsuji[4] and V Ryzhii[5]

[1] Laboratory of Nanooptics and Plasmonics, Moscow Institute of Physics and Technology, Dolgoprudny, Russia
[2] Department of Electrical Engineering, University at Buffalo, Buffalo, U.S.A.
[3] Computational Nanoelectronics Laboratory, University of Aizu, Aizu-Wakamatsu, Japan
[4] Computational Nanoelectronics Laboratory, University of Aizu, Aizu-Wakamatsu, Japan
[5] Research Institute for Electrical Communication, Tohoku University, Sendai, Japan

E-mail: sma_rt2002@mail.ru

Abstract. We develop a device model for p-i-n tunneling transit-time diodes based on graphene single- and multiple-layer structures operating at the reverse bias voltages. The model of the graphene tunneling transit-time diode (GTUNNETT) accounts for the features of the interband tunneling generation of electrons and holes and their ballistic transport in the device i-section, as well as the effect of the self-consistent electric field associated with the self-consistent charges of propagating electrons and holes. Using the developed model, we calculate the dc current-voltage characteristics and the ac frequency-dependent admittance as functions of the GTUNNETT structural parameters, in particular, the number of graphene layers.

1. Introduction

Since the pioneering works [1],[2] on the ballistic electron and hole transport (BET/BHT) in a semiconducting structures, this topic have been attracting an interest of the researchers. Graphene is the perfect material for realization of devices based on the BET for its extremely high achievable charge carriers mobility [3],[4]. In this paper, we consider a p-i-n doped multilayer graphene structure with the applied reverse bias voltage (see Fig. 1a). Electron-hole pairs are generated across the i-section, move in the opposite directions with constant velocities $\pm v_W$, as shown in the figure 1b. Such motion of charges in the i-section (unlike the case of electrons in the 2DEG [5]) leads to the negative AC conductivity of the device in a certain frequency range [6].

At this work, in contrast to the previous treatment [6],[7] we account for the self-consistent electric field associated with the variations of the electron and hole lateral charges in the i-section and their effect on the injection and the dc and ac characteristics (see also V.L. Semenenko et al [8]).

2. Results

It is shown that the admittance real part can be negative in a certain frequency range. As revealed, if the i-section somewhat shorter than one micrometer, this range corresponds to the terahertz frequencies. Due to the effect of the self-consistent electric field, the behavior of the GTUNNETT admittance in the range of negativity of its real part is rather sensitive to the relation between the number of graphene layers and dielectric constant. The obtained results demonstrate that GTUNNETTs with optimized structure can be used in efficient terahertz oscillators.

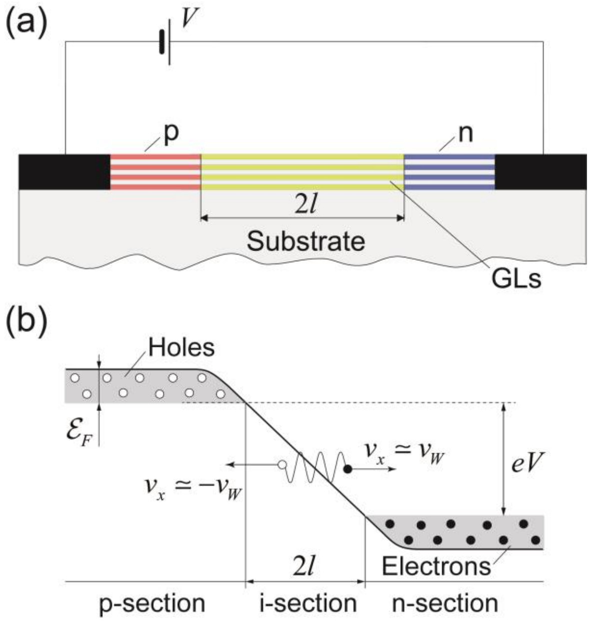

Figure 1. Schematic view (a) of GTUNNETT p-i-n diode with the MGL structure, and (b) its band diagram at reverse bias. Arrows show the propagation directions of electrons and holes generated. due to interband tunneling (mainly in those regions, where the electric field is relatively strong).

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