Perspectives of graphene SymFETs for THz applications

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***Abstract*— We explore the potential of graphene symmetric tunneling field effect transistors (SymFETs) for THz applications. The interplay between the negative differential conductance in these devices and electron plasma waves occurring in the graphene layers might lead to very sensitive THz detection (R > 100 kV/W) or amplifiers with power gains ~ 7 dB at RT.**

I. INTRODUCTION AND BACKGROUND

GRAPHENE is an intrinsically two-dimensional semiconductor. Owed to its high carrier-mobility and perfect 2D carrier confinement this atom thick material has been the subject of interest for future electronic devices. One of such proposed devices is the SymFET [1]; which consists of two stacked graphene layers separated by a thin insulator (Fig. 1a). The current in SymFETs flows by vertical tunneling between the two graphene layers. This device exhibits a resonant *I-V* as depicted in Fig. 1b thus there is a V_{DS} voltage bias region where the tunneling current presents negative differential conductance (NDC).

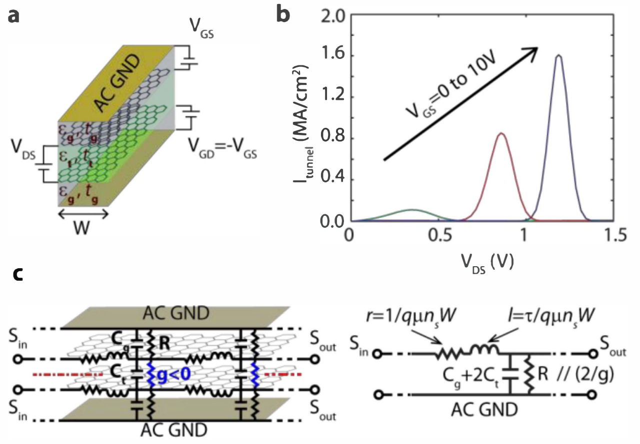

Fig. 1. a) Sketch of a graphene SymFET. b) Simulated *I-V* characteristics, the quality of the resonance thus NDC strength increases with V_{GS}. c) High frequency model, the device can be represented as an active transmission line.

Waves of electron density, the so-called electron plasma waves [2], can be excited in the graphene layers. Early work by Ryzhii *et al* showed that in HEMTs with gate-stacks exhibiting NDC, the detector responsivity could be enhanced [3] and THz emission could be possible [4]. Moreover, by employing a transmission line model, it was demonstrated that stable power gain is achievable in these structures at THz [5]. The high-frequency equivalent circuit model of the SymFET is depicted in Fig. 1c; if the device is biased in the NDC region, the electron plasma wave damping due to electron scattering can be counteracted [5]. In this work we show that excitation of plasma waves in the plane of the graphene, together with the effect of the vertical negative differential conductance (which provides a gain medium for these plasma waves) can lead to interesting THz applications.

II. ANALYSIS

The tunneling current between the graphene layers was modeled employing the theory by Zhao *et al* [1]. A coherence length (size of ordered areas in the graphene films) of 200-nm was assumed. All the calculations were performed assuming room temperature, electron mobility of $\mu = 2\text{x}10^4$ cm^2/V.s, and momentum relaxation time (τ) of 10^{-13} ps. The dielectric constants of the gate and tunneling insulators were taken as $\varepsilon_t = \varepsilon_g = 9\ \varepsilon_0$. The thickness of the tunneling dielectric (t_t) was chosen as 0.5-nm. In order to start counteracting the electron plasma wave damping, it was found that V_{GS} should be > 10 V for a gate dielectric thickness (t_g) of 20-nm. For illustration purposes the amplifier and detector configurations studied in Ref. [5] and [6] were analyzed. Our theoretical analysis showed that graphene SymFETs might allow responsivities > 100 kV/W (Fig. 2a) and power gains ~ 7 dB (Fig. 2b) in the detector and amplifier configurations respectively.

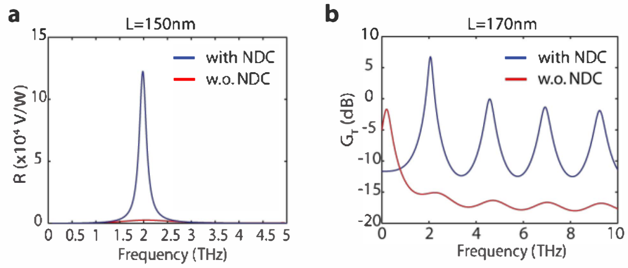

Fig. 2. a) Simulated responsivity versus frequency for a 150-nm graphene SymFET in a THz detector configuration. b) Transducer power gain as a function of frequency in an amplifier configuration; design for maximum gain at 2 THz.

III. CONCLUSION

We have studied the perspectives of graphene SymFETs for THz applications. Theoretical analysis shows that these devices can be employed in detector or amplifier configurations outperforming normal graphene field effect transistors (i.e. without NDC, see Fig. 2).

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