Graphene-based tunnel field-effect transistors for terahertz detection

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Abstract

It was recently shown that graphene represents a promising platform for detectors of terahertz radiation due to its high electron mobility. In previous works, terahertz photoresponse of graphene-based FET detectors was shown to arise from thermoelectric effect and resistive self-mixing (also known as Dyakonov-Shur mechanism) [1]. Here, we propose a different THz detection principle exploiting rectification of high-frequency signal by nonlinearities of lateral tunnel junctions [2]. These junctions are realized in bilayer graphene (BLG) with global back and local top gates. By adjusting the gate voltage polarities, we are able to switch our detector between “tunnelling” and “thermionic” regimes. We find that both voltage and current responsivity of BLG detector in the tunnelling regime exceed that in thermionic regime by up to an order of magnitude. As a result, we are able to achieve noise equivalent power as low as 0.2 pW/Hz$^{1/2}$ at cryogenic temperatures (Fig. 1b).
Strong nonlinearity of our tunnel junction is due to (1) exponential dependence of electron tunnelling probability on junction field (2) abrupt dependence of joint density of states on band alignment [3]. The same effects govern superior sub-threshold slope of tunnel field-effect transistors [4]. Our modelling reproduces strong asymmetry of photoresponse between thermionic and tunnelling regimes, and shows optimization routes toward higher responsivity.

References

[1] Bandurin, D. A., et al. Applied Physics Letters (2018) **112**.14:141101
[2] Bandurin, D. A., et al. Nature Communications (2018) **9**.1:1-8.
[3] G. Alymov et.al., Scientific Reports (2016) **6**:24654
[4] H. Lu, A. Seabaugh *IEEE Journal of the Electron Devices Society* (2014) **2**.4:44-49

Figures

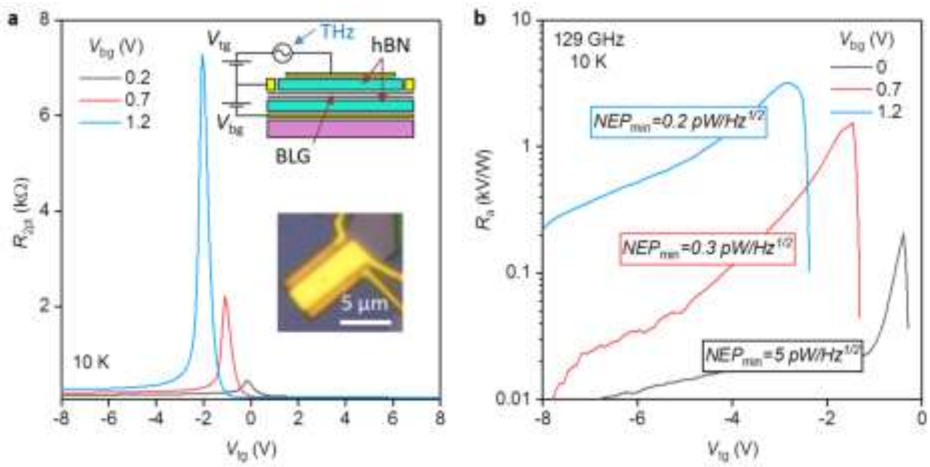

Figure 1: a) Response voltage dependence on voltage applied to the top gate with fixed values of bottom gate voltage; inset schematically shows the structure of the detector; b) Responsivity dependence on top gate voltage with estimated minimum values for noise equivalent power.