Local On-Off Control of a Graphene p-n Photodetector

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Graphene is a promising photonic material whose gapless band structure allows electron-hole pairs to be generated over a broad range of wavelengths, from UV, visible, and telecommunication bands, to IR and THz frequencies [1]. Previous studies of photocurrents in graphene have demonstrated photoresponse near metallic contacts [2] or at the interface between single-layer and bilayer regions. Photocurrents generated near metal contacts were attributed to electric fields in the graphene that arise from band bending near the contacts and could be modulated by sweeping a global back-gate voltage with the potential of the contacts fixed.

Here, we will discuss the photoresponse of graphene devices with top gates, separated from otherwise homogeneous graphene by an insulator. When the top gate inverts the carrier type under the gate, and a p-n junction is formed at the gate edges, a highly localized photocurrent is observed using a focussed scanning laser [3]. Interestingly, a density difference induced by the top gate that does not create a p-n junction does not create local photosensitivity. In this way, by switching from the bipolar to ambipolar regime, our devices allow for on-off control of photodetection (see Figure).

Comparing experimental results to theory suggests that the photocurrent generated at the p-n interface results from a combination of direct photogeneration of electron-hole pairs in a potential gradient, and a photothermoelectric effect in which electric fields result from optically induced temperature gradients.

We envision that this type of local on-off control of photodetection allows for the implementation of broadband bolometers with submicron pixelation.

References

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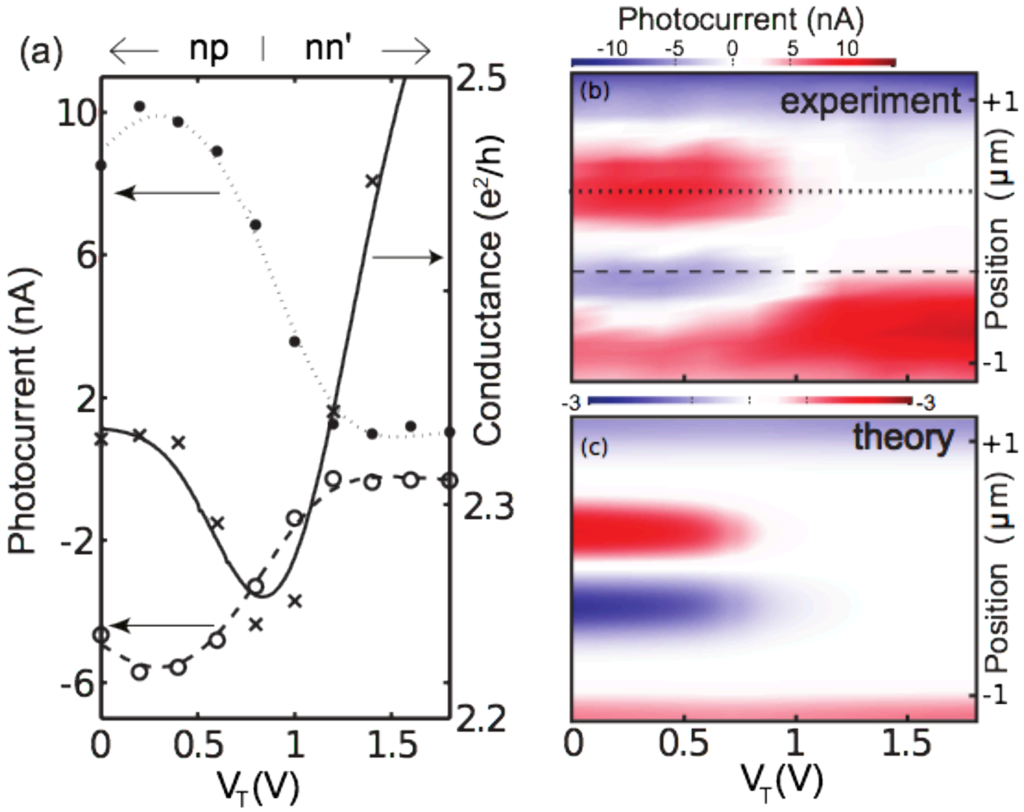
Figures



Caption: a) Photocurrent (left axis, circle markers) as a function of top gate voltage with the laser positioned on either side of the top gate. Photocurrents turn on at the charge neutrality point under the top gate, as the device is switched from n-n'-n to n-p-n configuration. Source-drain conductance (right axis, cross markers) of the photodetector measured in FET configuration as a function of top gate voltage with charge neutrality point at V_T = 0.9 V (drain voltage V_D = 0.6 mV). Due to hysteresis when sweeping the top gate voltage, this curve is shifted compared to the data in Fig 1c. b) Photocurrent as a function of top gate voltage taken across the center of the photodetector in Fig 1. The laser wavelength was λ = 600 nm and the power was P = 40 µW. c) Theoretical model of the photocurrent (Eq. 1), plotted as a function of top gate voltage and position along the center of the photodetector. P_0 = 40 µW and we assume 4.6% absorption of the laser light because it passes through the graphene sheet twice due to mirroring at the SiO_2/Si interface.