DTU Library

Graphene plasmonic photodetector with the bandwidth beyond 110 GHz

Ding, Yunhong; Cheng, Zhao ; Zhu, Xiaolong; Yvind, Kresten; Dong, Jianji; Galili, Michael; Hu, Hao; Mortensen, N. Asger; Xiao, Sanshui ; Oxenløwe, Leif Katsuo

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

Graphene plasmonic photodetector with the bandwidth beyond 110 GHz

Yunhong Ding[1,2], Zhao Cheng[1,6], Xiaolong Zhu[5], Kresten Yvind[1,2], Jianji Dong[6], Michael Galili[1,2], Hao Hu[1,2], N. Asger Mortensen[3,4], Sanshui Xiao[1,4], Leif Katsuo Oxenløwe[1,2]

1. *Department of Photonics Engineering, Technical University of Denmark, 2800 Kgs. Lyngby Denmark*
2. *Center for Silicon Photonics for Optical Communication (SPOC), Technical University of Denmark,2800, Kgs. Lyngby, Denmark*
3. *Center for Nano Optics and Danish Institute for Advanced Study, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark*
4. *Center for Nanostructured Graphene (CNG), Technical University of Denmark, 2800 Kgs. Lyngby Denmark*
5. *Department of Health technology, Technical University of Denmark, 2800 Kgs. Lyngby Denmark*
6. *Wuhan National Lab, for Optoelectronics, Huazhong University of Science and Technology, 430074, Wuhan, China*

Abstract: We demonstrate a waveguide-coupled integrated graphene plasmonic photodetector on a silicon-on-insulator platform and achieve an integrated small-footprint photodetector working at the telecommunication window, with the bandwidth beyond 110 GHz and intrinsic responsivity of 360 mA/W.

Graphene, a unique two-dimensional material, provides great potential in the realization of high-performance optoelectronic devices. In particular, significant efforts have been devoted to graphene photodetectors [1]. The distinct properties of graphene in terms of ultrahigh carrier mobility, zero bandgap property that enables wavelength-independent light absorption over a very wide spectral range, and tunable optoelectronic properties give rise to realize graphene photodetectors with large spectral bandwidth and high speed. However, their performance is still limited by weak light-graphene interaction and large resistance-capacitance product. Due to the weak light-matter interaction, the size of devices has to be at least tens to hundreds of microns to achieve a reasonable responsivity, thus limiting high-speed operation. A small device however gives weak absorption of light, and thus eventually low responsivity. So far, the state-of-the-art bandwidth of the graphene photodetector is ~76 GHz, however with a modest responsivity of 1 mA/W [2]. Here, we report an ultra-compact, on-chip, and high-speed graphene photodetector based on a plasmonic slot waveguide. The subwavelength confinement of the plasmonic mode gives rise to the enhanced light-graphene interactions [3,4,5], and the narrow plasmonic slot of 120 nm enables short drift paths for photogenerated carriers. The schematic of the proposed graphene plasmonic hybrid photodetector is shown in Fig. 1(A), where the light from a fiber is first coupled to a silicon waveguide through a grating coupler and further to the plasmonic slot waveguide by a short taper structure. Fig. 1(B) shows a fabricated graphene-plasmonic photodetector, where the dashed lines represent the graphene coverage boundary, and the corresponding optical bandwidth measured by VNA, impulse response, and frequency beating with ESA is presented at the bias voltage of 1.6 V, showing that the bandwidth is over 110GHz. The performance is comparable with a state-of-the-art commercial 100 GHz semiconductor photodetector [6], and can further be improved significantly. Moreover, the use of chemical-vapourdeposition(CVD)-growth graphene here allows for the scalable fabrication and we believe that our work greatly pushes the 2D material towards practical applications, e.g. in optical interconnects, high-speed optical communications, and so on.

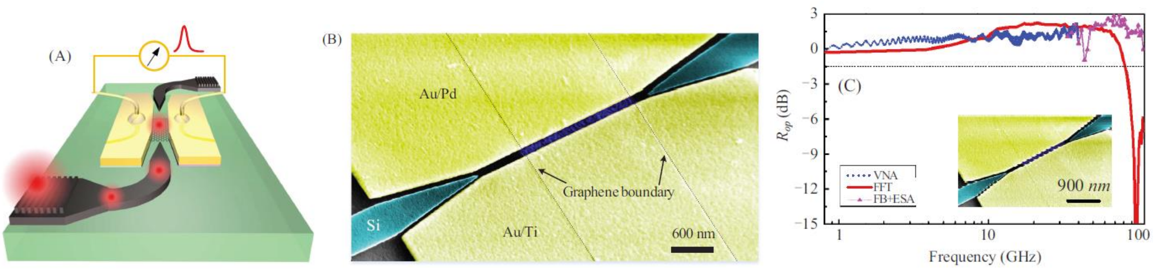

Fig. 1 (a) Schematic of the proposed graphene-plasmonic hybrid photodetector (b) An example of fabricated graphene plasmonic photodetector with the graphene coverage length of 2.7 um (c) Its corresponding optical bandwidth measured by VNA, impulse response, and frequency beating with ESA at the bias voltage of 1.6V.

References

[1] F. Xia, T. Mueller, Y. Lin, A. Valdes-Garcia, and P. Avouris."Ultrafast graphene photodetector," Nature Nanotechnol 4, 839–843 (2009).
[2] D. Schall, C. Porschatis, M. Otto, and D. Neumaier. "Graphene photodetectors with a bandwidth >76 GHz fabricated in a 600 wafer process line," J. Phys. D: Appl. Phys. 50, 124004 (2017).
[3] M. Ayata et al., "High-speed plasmonic modulator in a single metal layer," Science 358, 630–632 (2017).
[4] Y. Salamin et al. "100 GHz Plasmonic Photodetector," ACS Photon. 5, 3291-3297 (2018).
[5] Y. Ding, Z. Chen, X. Zhu, K. Yvind, J. Dong, M. Galili, H. Hu, N. A. Mortensen, S. Xiao, and L. K. Oxenløwe, "Ultra-compact integrated graphene plasmonic photodetector with bandwidth over 110 GHz", submitted (2018). arXiv:1808.04815
[6] FINISAR 100 GHz Single High-speed Photodetector, https://www.finisar.com/communication-components/xpdv412xr