

Photonic and Optoelectronic Device Applications Based on 2D Materials

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Abstract

Our research interests are mainly focused on the light-matter interactions in 2D materials in terms of nonlinear light absorption, light modulation (amplitude, phase and polarisation), wave-guiding and photo-detection. This talk will give an overview of photonic and optoelectronic device applications based on these optical phenomena in 2D materials [1]. Firstly, to overcome the limit light absorption in graphene and obtain large nonlinear optical modulation depth, we developed a series of new saturable absorbers based on graphene heterostructures and other 2D materials, including graphene/Bi₂Te₃[2], black phosphorus[3] and self-doped plasmonic 2D Cu_{3-x}P nanosheets[4] as well as 2D halide perovskite [5]. Depending on their nonlinear optical properties, either high energy Q-switched laser or ultrafast mode-locked pulse generation were demonstrated. Secondly, in order to fabricate improved graphene photodetectors working in different spectral ranges, we integrated graphene with other 2D materials with variant electronic structures, *for example*, graphene/perovskite for visible light detection [6], graphene/MoTe₂ and graphene/Cu_{3-x}P for near infrared light detection [7], and graphene-Bi₂Te₃ for broadband infrared light detection [8]. We show how photo-gating effect plays a significant role to amplify the photocurrent in the photodetectors as well solar cell device [9]. By fine tuning or aligning the electronic structure, we are able to engineer the depletion width in 2D material heterostructures, such as graphene/WS₂, MoS₂/WS₂ and WSe₂/WS₂ heterojunction [10], monolayer-bilayer WSe₂ heterojunction[11] and 2D perovskite *p-n* junction [12], so as to achieve higher photo-responsivity and large photo-active area. Lastly, the THz light modulation associated with plasmonic excitation in graphene/Bi₂Te₃, topological insulator Bi₂Te₃, graphene nanoribbon and 3D graphene was also investigated using either spectroscopic or real space imaging techniques.[13] We show how the plasmonic coupling happens in two Dirac materials, how high-order plasmonic modes are observed in 3D graphene structure, how multiple plasmonic modes at sub-wavelength are achieved in graphene nanoribbon and how edge chirality controls the plasmonic shift. [13] Furthermore, we update our recent progress on the synthesis of 2D non-layered perovskite nanosheets [5] and other form of low-dimensional perovskites [14] as well as their optoelectronic applications in waveguide [15], LED and solar cells [16]. In summary, the advances of 2D materials may pave the way for the next generation photonic and optoelectronic device applications.

Keywords: graphene; photonics; optoelectronics, 2D materials.

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Short biography: Dr. Qiaoliang Bao received his Bachelor (2000) and Master (2003) degree from School of Materials Science and Engineering, Wuhan University of Technology, and Ph. D degree from Department of Physics, Wuhan University (2007). From 2006 to 2008, he studied at Nanyang Technological University as a visiting student and research associate. From 2008 to 2012, he worked as a postdoctoral fellow in Graphene Research Centre, National University of Singapore (NUS). He was enrolled into China Thousand Youth Talent Program in 2012. He obtained ARC Future Fellowship in 2016 and is now an Associate Professor at Department of Materials Science and Engineering, Monash University, Australia. He has authored or co-authored more than 160 refereed journal articles with more than 18,000 total citations and an H-index of 56 (Google Scholar). His research interests include synthesis and optical characterization of two-dimensional materials as well as their incorporation into photonic and optoelectronic devices.