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Photonic and Optoelectronic Device Applications Based on 2D Materials

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 [1-5]. Firstly, to overcome the limit light absorption in graphene and obtain large nonlinear optical modulation depth, we developed a serials of new saturable absorbers based on graphene heterostructures and other 2D materials, including graphene/Bi_2Te_3 [6-8], black phosphorus [9-11] and self-doped plasmonic 2D $Cu_{3-x}P$ nanosheets [12] as well as 2D halide perovskite [13-14]. 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 [15-16], graphene/$MoTe_2$ and graphene/$Cu_{3-x}P$ for near infrared light detection [17-18], and graphene-Bi_2Te_3 for broadband infrared light detection [19-20]. We show how photo-gating effect plays a significant role to amplify the photocurrent in the photodetectors as well solar cell device [21]. By fine tuning or aligning the electronic structure, we are able to engineer the depletion width in 2D material heterostructures, such as graphene/WS_2, MoS_2/WS_2 and WSe_2/WS_2 heterojunction [22-26], monolayer-bilayer WSe_2 heterojunction [27] and 2D perovskite *p-n* junction [28], so as to achieve higher photo-responsivity and large photo-active area. Lastly, the THz light modulation associated with plasmonic excitation in graphene/Bi_2Te_3, topological insulator Bi_2Te_3, graphene nanoribbon and 3D graphene was also investigated using either spectroscopic or real space imaging techniques [29-32]. 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 [29-32]. Furthermore, we update our recent progress on the synthesis of 2D non-layered perovskite nanosheets [13-14] and other form of low-dimensional perovskites [33-34] as well as their optoelectronic applications in waveguide [35-36], LED and solar cells [37-39]. 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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