THz Devices using Graphene, Topological Insulator, and Magnetic Heterostructures

National Univ. of Singapore, °Hyunsoo Yang

E-mail: eleyang@nus.edu.sg

We use graphene films as transparent electrodes for THz applications such as phase shifters, reflector, and intensity modulators, leading to a low voltage operation and very small insertion loss. We first demonstrate the excellent performance of THz modulators based on graphene/ionic liquid/graphene sandwich structures [1,2]. The modulation covers a broadband frequency range from 0.1 to 2.5 THz with the modulation depth of up to 99% by applying a small gate voltage of 3 V. We also report a highly efficient tunable THz reflector in graphene [3]. By applying a small gate voltage (up to ± 3 V), the reflectance of graphene is modulated from a minimum of 0.79% to a maximum of 33.4% using graphene/ionic liquid structures at room temperature, and the reflection tuning is uniform within a wide spectral range (0.1 – 1.5 THz). In addition, we design and fabricate THz phase shifters based on thin liquid crystal cells sandwiched by two graphene layers [4]. A maximum 10.8 degree phase shift is obtained with 5 V voltage. The proposed phase shifters are fully electrical controllable, continuous tunable, and require very low DC voltages for operation. Topological insulator based THz modulators will be also introduced [5].

Finally, we show a high performance THz emitter based on ferromagnetic/nonmagnetic heterostructures [6,7]. Our THz emitter based on magnetic heterostructures has a peak intensity exceeding 500 μm thick ZnTe crystals (standard THz emitters). We have also fabricated the devices on flexible substrates with a great performance, and demonstrated that the devices can be driven by low power fiber lasers. By integrating our spin based THz emitter with a semiconductor based photoconductive antenna, 2–3 order enhancement of the THz signals in a lower THz frequency range (0.1–0.5 THz) is achieved, which is highly desired for spectroscopy applications [8].

[1] Y. Wu et al., Adv. Mat. 27, 1874 (2015)
[2] J. Liu et al., Opt. Lett. 41, 816 (2016)
[3] Y. Wu et al., Nanotechnology 28, 095201 (2017)
[4] Y. Wu et al., Opt. Express 21, 21395 (2013)
[5] X. B. Wang et al., Sci. Rep. 7, 13486 (2017)
[6] Y. Wu et al., Adv. Mat. 29, 1603031 (2017)
[7] M. Chen et al., Adv. Opt. Mat. 6, 1800430 (2018)
[8] M. Chen et al., Adv. Opt. Mat. 7, 1801608 (2019)