Tailoring active far-infrared application with graphene metasurface

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Abstract-In this work, we demonstrate strong electric resonance response in perforated graphene sheet at far-infrared part of electromagnetic spectrum. Unlike the metallic meta-materials relying on the geometrical inductance for magnetic response, the electric resonance in graphene is mainly caused by localized plasmons and thus enabling sub-wavelength confinement of electromagnetic field. The active tunable electric resonance by electrostatic doping on the graphene sheet provides efficient route for compact biosensing, far-infrared imaging and detection.

The human history of humankind is linked to the use and exploration of the electromagnetic spectrum from ultraviolet, visible to infrared in various applications. While the far-infrared part of electromagnetic spectrum roughly corresponds to frequencies from 0.3THz to 30THz still present a challenge for both electronics and photonic technologies. Since the molecules of many chemical compounds have rotational and vibrational modes lying in the same energy range as far-infrared radiation, utilization of this particular part of spectrum is greatly desired in many fields including defense, biomedical, pharmaceutical and food industries1. Especially, far-infrared radiation with the frequency in the range from 0.3-10THz (which nowadays is renamed as “terahertz band”) is viewed as the foundation to next generation of noninvasive imaging, wireless communication and astronomy2. However, far-infrared technology is still immature due to lack of efficient sources and detectors working in this region. Over the past decades, we has seen significant progress of photodetector and emitter design leading to the initially promising achievements, such as metamaterial-based hot electron bolometer3, quantum cascade laser4, active terahertz modulator5,6, etc. Among them active device is critical for real-time manipulation of far-infrared or terahertz waves. In many studies, split rings have become a central element from far-infrared to near-infrared because of its large magnetic response driven by the circular current and produce fascinating optical properties, such as superresolution imaging, cloaking and sensing7-10. Graphene, a monolayer carbon atom arranged in honeycomb structures, is a promising candidate for this application because of its electrically tunable properties and low-loss in comparison with metals working at near-infrared frequencies11-14. Therefore, desirable applications can be achieved by taking advantage of graphene in the scope of metamaterials. At present, most studies are focus on the hybrid structure between artificial-metamaterials and graphene with dynamically controlling its optical response from terahertz to mid-infrared, which is relying on the strong interaction...
between local electric field and Dirac fermions of graphene\textsuperscript{15-17}. Despite the broadly tunable carrier density, the modulation depth is still limited by its one-atom-layer thickness and the nonresonant nature of the finite intraband-absorption. On the other hand, the potential of graphene as novel plasmonic material has been considered due to deep subwavelength confinement and electrical tunability at mid-infrared frequency\textsuperscript{18}. However, the nature of graphene-based metamaterials in response to far-infrared radiation still lack of sufficient awareness. In this work, we investigated the intrinsic response of graphene-based metamaterial to the incident far-infrared radiation. The results indicate dominant electric-resonance in graphene metamaterial rather than the usually magnetic-response, furthermore, we demonstrate the realization of active tunable graphene metamaterial following the Babinet’s principle\textsuperscript{19} for applications in bio-sensing, photo-detection and imaging.

![Graphene-based metamaterial](image)

**Fig. 1.** a. graphene-based metamaterial investigated in this work, b. field profile for graphene SRR and rings, and composite metamaterial, c is the spectral characteristic of graphene ring structures, d is the spectral characteristics of graphene-based composite metamaterial under difference polarizations.

**REFERENCES**