Graphene based Photonics: From Visible to Microwave

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Abstract: In this talk, I will summarize our recent work on graphene based adaptive surfaces operating in a very broad spectrum covering from the visible to microwave. Our method relies on electro-modulation of interband and intraband electronic transition of large area single and multilayer graphene in various device architectures. Based on this principle, we developed new class of adaptive surfaces capable of real time electrical-control of its appearance. I will also talk about integration of possible feedback systems which allow us to realize adaptive camouflage systems that can sense the time-varying background and change the appearance to bend itself in the background.

Keywords: Graphene, optoelectronics, smart surfaces

INTRODUCTION

In nature, adaptive coloration has been used for concealment and signaling. Various biological mechanisms have evolved to tune the reflectivity of visible and ultraviolet light. In modern technology, however, there are limited number of active materials that can be used to develop surfaces with reconfigurable reflectance and transmittance in a very broad spectral window. Graphene provides new perspective for "smart" surfaces which can enable new technologies such as active radar shields to conceal objects from radar detection or flexible display devices for optical camouflage. The ability to control interaction of electromagnetic waves with matter forms the heart of these emerging applications.

Gate-tunable optical properties of graphene have been the subject of an active research in optoelectronics [1-4]. The interband electronic transition of single and bilayer graphene can be blocked by electrostatic doping. Recently, we discovered a new type of optical modulation scheme using graphene supercapacitors. We showed that optical transmittance of single layer graphene electrode can be modulated by 2% via electrostatic doping. However, controlling interband transition of thick multilayer graphene is not possible by electrostatic doping due to screening of the top layers. Here, we show that fast and reversible intercalation process can control optical absorption of multilayer graphene which yields a tunable optical transmittance with high-contrast.

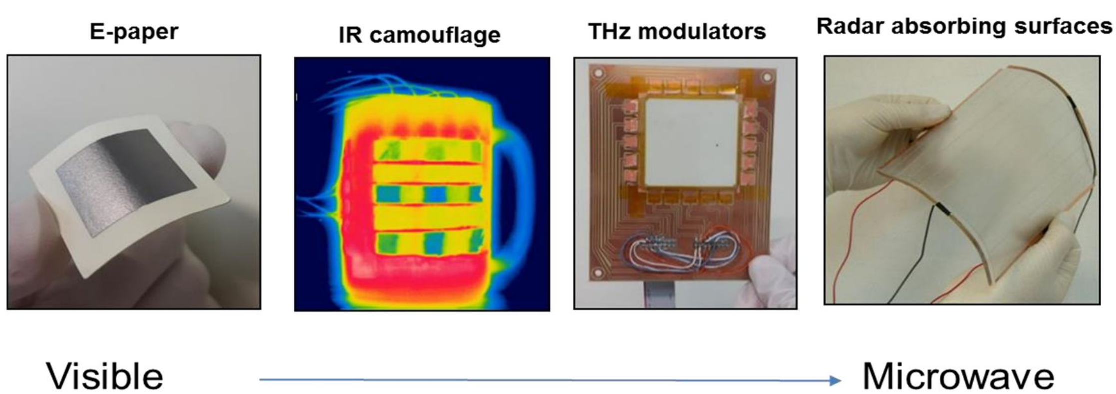

Fig. 1. Examples of graphene based adaptive surfaces operating in a very broad spectrum (1-3)

RESULTS

Graphene provides new perspectives to control electromagnetic radiation in a very broad spectral range, from visible to microwave frequencies. Optical absorption of graphene can be tuned by electrostatic gating owing to the Pauli blocking. Although, optical response of graphene has been studied extensively, the use of graphene for dynamic control of thermal radiation has remained unexplored because of the small optical absorption (< 2%) in mid-IR region. We developed a new class of active thermal surfaces using multilayer graphene, which yields significant tunable optical absorption in IR region. Since thermal radiation originates from the very top surface, top-gating or electrolyte gating schemes are not suitable for the control of thermal radiation. These gating methods generate either buried graphene surfaces or low electrostatic doping which yields negligible IR modulation. None of the previously reported graphene devices by our group and others are suitable for dynamic control of thermal radiation. Therefore, we introduce a new gating scheme using an inverse device structure, which leads intercalation of a nonvolatile ionic liquid into graphene layers from the porous substrate. The inverse device configuration yields an uncovered graphene surface with tunable charge density and Fermi energy. Figure 1a shows the schematic of the active thermal surface consisting of a multilayer-graphene electrode on a porous polyethylene (PE) membrane and a back gold-electrode. We synthesized multilayer-graphene on nickel foils using a chemical vapor deposition method and then transferred them on PE membrane, which is IR transparent and can hold the electrolyte (room-temperature ionic liquid, RTIL).

CONCLUSIONS

As a conclusion, we demonstrated a new class of flexible optoelectronic devices using single and multilayer graphene electrodes. We show that the optical transmittance of graphene can be controlled by electrostatic doping via reversible intercalation of charge into the graphene layers. Simultaneous electrical and optical characterization of the graphene electrochromic devices reveals the mechanism behind electrochromic operation. The demonstrated reflective/transmissive multipixel electrochromic display device and reflection type device highlights the promises of the method. The key attributes of our flexible devices are the simplicity of device architecture, high optical contrast and broad band operation. Compatibility with roll-to-roll fabrication processes enables scalable approaches for large area applications. We believe that this work provides a significant step in realization of flexible optoelectronic devices operating over a very broad spectrum.

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