Modelling of graphene-based sensing devices

Elefterios Lidorikis, Nojoon Myoung, Spiros Doukas, Sofia Evangelou, Alva Dakgli

Department of Materials Science and Engineering, University of Ioannina, 45110 Ioannina, Greece
elidorik@cc.uoi.gr

Abstract

Graphene's optical response is characterized by a constant absorption in the visible-NIR and a large electrical tunability of its plasmonic excitations in the IR spectrum. The light-graphene interactions become even stronger when graphene is integrated into a resonant photonic cavity. In this case, small changes in the graphene doping can alter the coupling condition and shift the optical response, enabling sensitive photodetection and sensing applications [1,2]. We present a numerical optimization study of graphene-based modulation and sensing in two examples. The first involves a plasmonic perfect absorber metamaterial, designed by placing a plasmonic nanoantenna in close proximity (few nm) to a mirror with a dielectric spacer in between. With graphene placed under the antenna, the resonant frequency is modulated according to graphene's doping, providing a promising route to sensitive chemical and biological sensing. The design rules for the metamaterial absorber are explored and we extract a useful general relation between the resonant wavelength and the geometrical features (Fig. 1a). The sensing capability of the metamaterial to the chemical doping of graphene is then evaluated for different metamaterial designs. Our second example involves a recently proposed spectrometer-free setup utilizing nanostructured graphene plasmons [3]. By scanning the graphene electrostatic doping level, the graphene plasmon spectrum shifts through the molecular modes, with the overall absorption peaks revealing the molecular level spectrum (Fig. 1b). We explore here the use of higher-order graphene nanoribbon plasmons to further enhance the resolution and sensitivity compared to what is achieved by the dipole plasmon.

References

[1] F.H.L. Koppens et al., Nature Nanotechnology **9**, (2014) 780.
[2] A.C. Ferrari et al., Nanoscale **7**, (2015) 4598.
[3] A. Marini et al., ACS Photonics **2**, (2015) 876.

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Figures

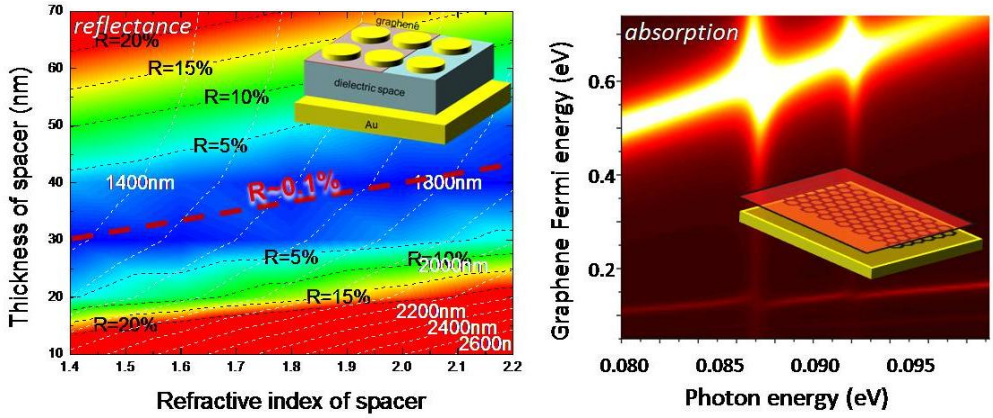

Figure 1. (a) optimization map for a metamaterial perfect absorber, (b) overall absorption of a graphene ribbon decorated with an organic monolayer.