Magnetic graphene metamaterial

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Abstract: We predict strong magnetic response by graphene split nanorings at THz frequencies allowing to achieve tunable metamaterials with very high (>100) wavelength to unit-cell ratios, not attainable by conventional noble metals.

Graphene has emerged as a novel plasmonic material with advantageous properties for metamaterial design, such as highly confined plasmons and electrical tuning by carrier injection.

Here, we follow an apporach based on finite element simulations and analytical calculations to show that graphene split-ring resonators (GSRRs) of nanoscale dimensions can be used to produce strong magnetic response in the THz regime. Arrays of GSRRs under far-IR excitation with incident polarization across the ring gap support resonant excitations that lead to a transmission stop band accompanied by increased absorption (see Fig. 1b). Such metamaterial excitations include a strong magnetic dipole component arising from the current flowing along the circumference of the GSRR (see inset to Fig. 1b). For the orthogonal polarization (parallel to the x-axis) the metamaterial presents no spectral features within the wavelength range of interest. The magnetic resonance of the GSRR metamaterial leads to a strong field confinement with a ratio of resonance wavelength to unit-cell size of the order of 100. Such confinement is not achievable by thin layers of noble metals. For example, in this spectral region, a 50 nm thick (or thinner) layer of gold would lead to a unit cell comparable (or larger) to (than) the excitation wavelength (see Fig. 1c). Moreover, depending on the levels of doping, graphene can be used to produce metamaterials with significantly high quality factors compared to thin noble metal layers (see Fig. 1c), which also provides a tuning mechanism of the metamaterial magnetic response.

In conclusion, we introduce a graphene metamaterial that displays tunable magnetic dipole resonances at the far-IR, and we identify a frequency region in which graphene presents advantages with respect to thin layers of noble metals in terms of field confinement and quality factor.

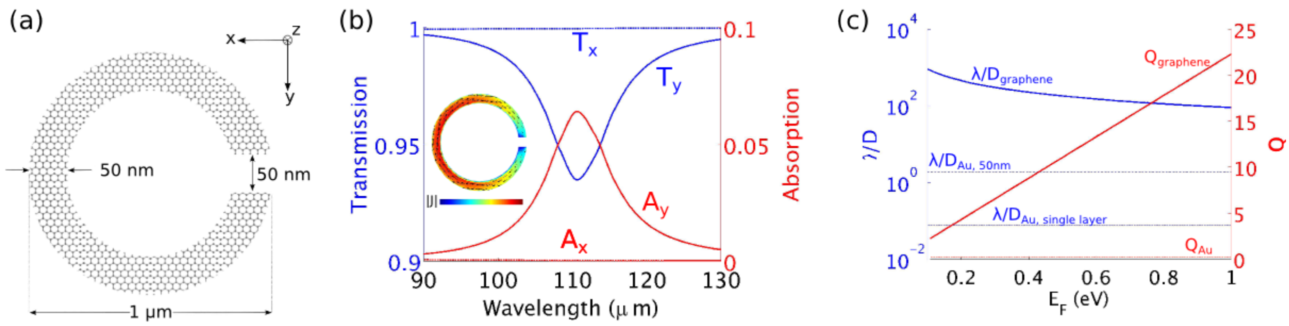

Figure 1. (a) Unit cell of graphene split ring metamaterial. (b) Transmission (blue) and absorption (red) of an array of doped graphene (E_F=0.5 eV) split-ring resonators for polarization parallel (solid curves) and perpendicular (dashed curves) to the gap. Inset: current distribution along the GSRR circumference (c) Confinement factor (defined as the resonant wavelength (110 μm) over the GSRR diameter) as a function of graphene doping for single-layer graphene (solid blue curve), single-layer gold (dashed blue curve) and 50 nm thick gold (dashed-dotted blue curve). The corresponding quality factors are also presented for single-layer graphene (solid red curve) and thin gold (dashed red curve), since for thin layers of gold the quality factor is independent of the thickness. The mobility of the graphene is taken to be 13,000 cm^2/Vs.