Graphene enhanced free-standing silicon anapole-type metasurface

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In recent times, the concept of anapole has gain significant consideration in the area of photonics due to its ability as a non-radiating state of light which is induced by interference of the electric and toroidal dipole moment [1]. These electric and toroidal dipoles have identical energy but oscillate out of phase and cancel each other. Being able to produce/tune a meta-atom lattice of a metasurfaces for it to have a high-Q resonances will potentially increase the improvement of the interactions between light and matter in both microwave and terahertz regions of the meta-atoms for sensing applications [2,3].
We present metamaterial structure comprises of a periodic array of anapole-type metasurface of free-standing membrane of Si and patterned with a doped layer of graphene as a novel sensing principle in the THz range as shown in Fig.1.

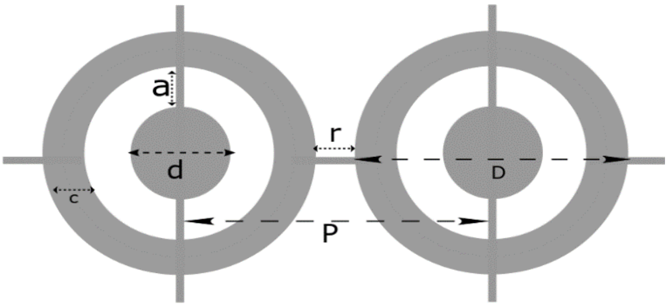

Figure 1: 2D view of metasurface of free-standing Si membrane with dimensions. a is the distance between meta-atom and unit structure, d diameter of the meta-atom, c is the width of big ring, D is diameter of unit cell, p is the period between the unit cell, r is inter-unit cell distance.

The spectral position of anapole modes shaped of a periodic-spherical silicon meta-atom is first investigated without graphene layered and when patterned with highly doped graphene sheet with THz-TDS in both transmission and reflection mode. Our simulations and experimental data reveal that our modeled transmission and reflection spectra of the structure at the normal incident angle up to 1THz structure has very high Q-factor, anapoly-type behavior and resonances of absorption in THz range. Higher resonances were observed at frequencies up to 1 THz range in a normal incidence of THz beam for both with and without graphene. However, there was enhancement when graphene was transferred on the structure.

This shows that our anapole metamaterial spectra do not depend on the angle of the incident reflection measurements and dependence on incidence angle. However, changing the chemical potential of graphene or conductivity of silicon, produces hysteresis of resonant frequency because of hybridization of mode of particles and graphene impedance.

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References

1. E. Takou, A. C. Tasolamprou, O. Tsilipakos, Z. Viskadourakis, M. Kafesaki, G. Kenanakis, and E. N. Economou ‘‘Anapole Tolerance to Dissipation Losses in Thermally Tunable Water-Based Metasurfaces” Physical review applied 15, 014043-17 2021
2. K. Du, P. Li, Q. Miao, K. Gao, H. Wang, L. Sun, W Zhang, and T. Mei ‘‘Optical Characteristics of Metasurfaces at Meta-Atom Anapole’’ IEEE Photonics Journal 13 (3) 2021
3. E. Zanganeh, M. Song, A. Evlyukhin, and P. Kapitanova ‘‘Electromagnetic Anapole States of Nano-disks’’ 5th International Conference on Metamaterials and Nanophotonics METANANO 020138-1–020138-4, 2020