Terahertz metamaterial biosensor based on plasmon-induced transparency

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Metamaterials[1] are periodic artificial electro-magnetic media structured with a size scale smaller than the wavelength of external stimuli. Metamaterials are suitable for THz biosensing applications as metamaterials with special specifications such as size and shape, they provide spoof surface plasmons, and localized resonances excited in metamaterials show a dramatically enhanced electromagnetic field near the structures, large values of quality factor which show high sensitivity to minor environment changes.

Plasmon-induced transparency (PIT)[2] mimics the electromagnetic-induced transparency effect, which is caused by destructive interference between two paths in a three-level atomic system. The destructive interference induces a sharp and narrow spectral peak in transmission. PIT metamaterials are the best choice for development due to their flexible design and easy implementation.

Many metamaterial structures have been proposed to introduce the PIT effect, such as plasmonic nanostructures, split ring resonators. Recently, the emergency and development of graphene technology provides us with new ideas and means in optics and optoelectronics. It is well known that graphene has many outstanding properties such as high electron mobility, excellent ability to support surface-plasmon polaritons and tunable surface conductivity. These properties enable graphene to be a highly promising plasmonic material and an excellent platform for the generation and active control of the PIT effect, especially at the THz regime.

Initially, the monolayer graphene was deposited on SiO_2 (100 nm) / Si substrate by CVD method. Then a layer of ZEP-520A (about 200 nm) was coated on the top of graphene. The exposure dose is 105 μC / cm^2 of e-beam lithography system. After exposure, the sample was developed in ZED-N50 for 60 s and MIBK for 60 s, and then was dried naturally. Finally, short time (around 15 s) based on oxygen etching (O_2 flow: 100 sccm; Pressure: 13 Pa; Power: 100 W) didn't influence the overall quality. Regarding the removal of photoresist: The solution is DMAC (NND), soak it at 90 degrees for one minute. Use TAS7500TS to measure terahertz transmission spectrum.

We present a design of PIT metamaterial based on a graphene metamaterial structure operating in the THz regime. Fig. 1 presents the experimental transmission spectra of metamaterial comprised of graphene cut wire resonator (GCWR) and graphene closed ring resonators (GCRR) acting as two bright modes, which can achieve PIT effect. When excited with a normal incidence, as illustrated by the curve, showing a transparency window of 0.27 THz.

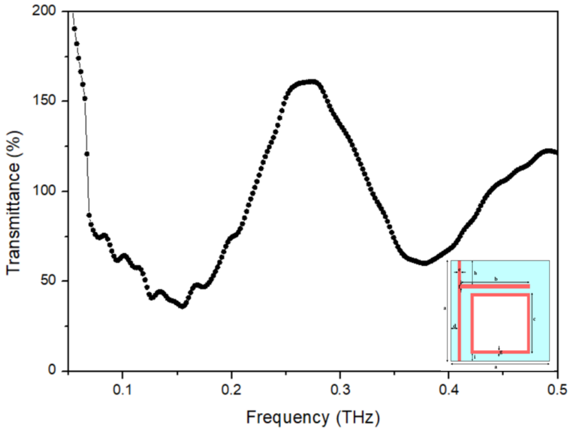

Figure 1. Transmission spectrum of metamaterials. The inset in (1) shows close-up view of unit cell.

In this article, Its transmission characteristics and refractive index sensing performance are experimentally investigated. Results reveal that the PIT resonance frequency depends substantially on the change in the surrounding medium's refractive index, indicating the PIT metamaterial can be employed as a biosensor with high sensitivity. Furthermore, the dramatic tunability of the PIT transmission window is also investigated.

Reference:

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[2] S. Zhang, D. A. Genov, Y. Wang, M. Liu, and X. Zhang, "Plasmon-induced transparency in metamaterials," Phys. Rev. Lett. 101(4), 047401 (2008).