VSRR for isotropic absorption and nanophotonic sensor

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1. Introduction

Metamaterials have been realized for exotic optical phenomena which can not be found in nature, such as negative refractive index and cloaking. Nowadays, people intend to be more precisely from fundamental physical response to specific functionalities in metamaterials on demand for the development on practical applications, such as optical switches, phase gradient surfaces[1,2], optical modulators, polarizer and wave plate. One of the potential applications is the metamaterial based perfect absorber (MPA)[3]. Due to the strong electromagnetic field confinement arising from surface plasmon resonance, MPA provides a benefitting way for enhancing the efficiency in solar energy capture, nanoplasmonic sensor and bolometer. The commonly utilized structural configuration for MPAs is incorporating a metamaterial array with a perfect reflective mirror separated by a dielectric spacer. Because of the near-field interaction between metamaterials and its mirror images, a strong plasmon field confinement is involved and therefore dramatically enhances the absorption intensity. However, both the electric and magnetic responses play an important role to those of electromagnetic media, especially for the nonlinearity responses. Vertical split-ring resonator (VSRR) attracts a wide interest because it found out that the magnetic reciprocal coupling of incident light [4,5].

2. Results and Discussion

In this work, we merge four-VSRRs into a unit cell, as shown in Fig. 1(a). From the simulated absorption mapping of this structure (Fig. 1(b)), it can be observed that the absorption keeps at a very high value when θ is changed from 0˚ (x polarization) to 90˚ (y polarization) at a resonance wavelength of 1050 nm. The VSRR based perfect absorber can be applied as a refractive index sensor with ultra-high sensing performance[6]. In order to evaluate the sensing performance, both the spectral shift per refractive index unit (RIU) and figure of merit (FOM*) are calculated, as shown in Figs. 1(c) and 1(d). The sensitivity from numerical calculation and experimental measurement is 509.2 nm/RIU and 214.7 nm/RIU, respectively. Although the VSRR benefits the field concentration and helps the induced fields away from the dielectric, the near-field coupling here plays a negative role reducing the sensitivity. Even so, the sensitivity still shows a high value comparing with the other planar metamaterial based sensor. On the other hand, the near-field supports the improvement of FOM* since the perfect absorption response in four-VSRRs based perfect absorber. The numerical result shows an ultra-high FOM* value, which can be achieved to about 250.

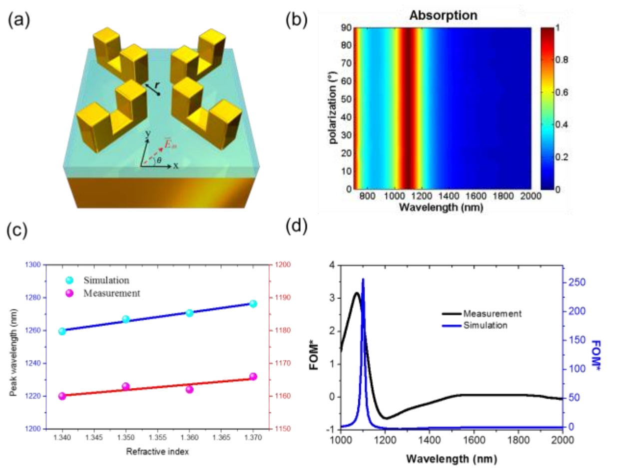

Fig. 1. (a) Schematic diagram of the four-VSRRs based isotropic perfect absorber. (b) The absorption variation with different polarization angles under normal illumination. (c) Resonant wavelength as a function of refractive indexes and (d) FOM* comparison.

3. Conclusions

A single vertical split-ring resonator can be a perfect absorber in the near-infrared region. We use four vertical split-ring resonator to combine a unit cell, it becomes an isotropic perfect absorber which is independent to the polarization angles. Moreover, it could achieve about 80% absorption when the incident angle is up to 60˚ for both TE- and TM-polarized illuminations. This structure can also be utilized as a sensor with sensitivity up to 509.6 nm/RIU and an ultra-high FOM* about 250 could be achieved according to the numerical results. This work provides a feasible way for realizing biosensor and optoelectronics applications.

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