SCIENCE CHINA
Information Sciences

xxxxxxx 2019, Vol. 62 xxxxxx:1–xxxxxx:4
https://doi.org/xxxxxxxxxxxxx

• Supplementary File •

Near-infrared six-band polarization-independent wide-angle absorber based on metal cavity arrays filled with GaAs

Dan HU[1*], Hongyan WANG[2], Xiwei ZHANG[1], Kexin WANG[1] & Qiaofen ZHU[3]

[1]*School of Physics and Electrical Engineering, Anyang Normal University, Anyang 455000, China;*
[2]*School of Education Information Technology and Communication, Anyang Normal University, Anyang 455000, China;*
[3]*School of Science, Hebei University of Engineering, Handan 056038, China*

Appendix A The effective impedance

The effective impedance of the proposed six-band near-infrared absorber can be obtained by the following equation [1]:

$$\tilde{Z}(\lambda) = \sqrt{\frac{(1+S_{11})^2 - S_{21}^2}{(1-S_{11})^2 - S_{21}^2}}, \tag{A1}$$

where the S_{11} and S_{21} are the reflection and transmission coefficients, respectively. The real and imaginary parts of the effective impedances at the six modes are close to 1 and 0, respectively (see Figure A1). It means that the effective impedances are nearly matched to free space, so the proposed six-band near-infrared absorber has extremely low reflectivities, nearly perfect absorptions at these six wavelength positions can be achieved.

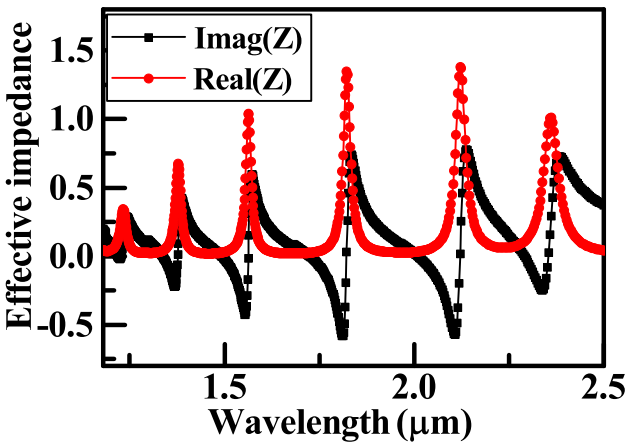

Figure A1 The effective impedance spectra of the proposed six-band near-infrared absorber.

* Corresponding author (email: tylzhd@163.com)

© Science China Press and Springer-Verlag GmbH Germany, part of Springer Nature 2019

Appendix B Electric field intensity distributions of the six-band light absorption

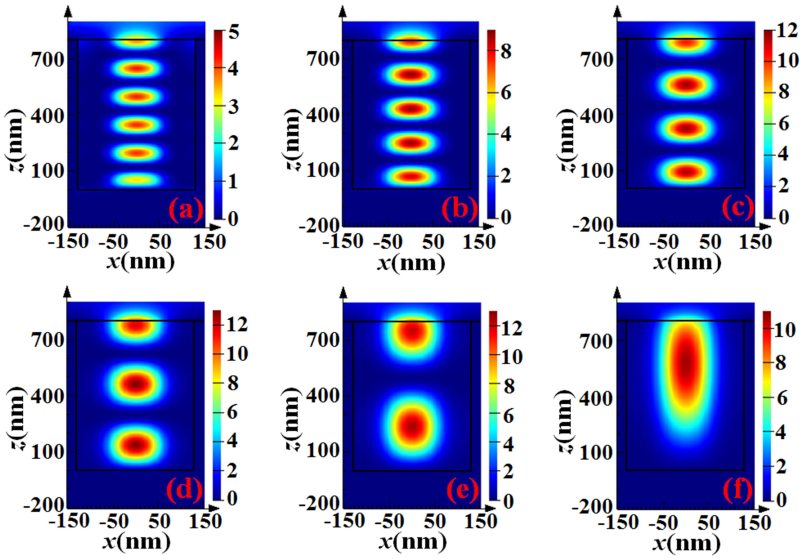

Figure B1 Electric field intensity distributions of ($|E_x/E_0|^2$) at (a) λ_1, (b) λ_2, (c) λ_3, (d) λ_4, (e) λ_5, and (f) λ_6 for the proposed six-band near-infrared absorber.

Appendix C More information

Appendix C.1 Influence of different polarization angles and oblique incidence angles on the absorption spectra

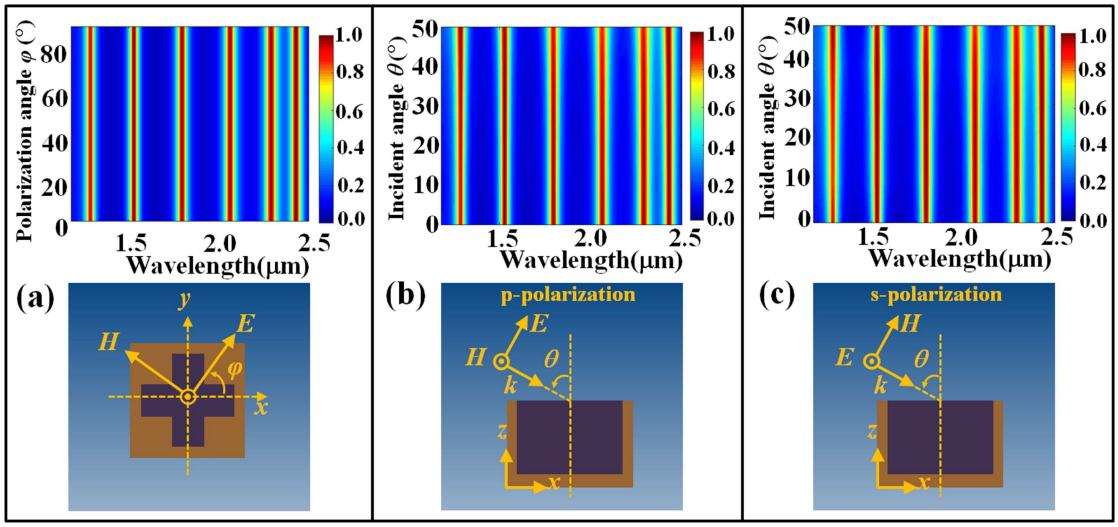

Figure C1 (a) Calculated absorption spectra with different polarization angles. Calculated absorption spectra with different incident angles for p-polarization (b) and s-polarization waves (c).

Appendix C.2 Influence of basic structure parameters on the absorption spectra

In order to study the influence of basic structure parameters on the absorption spectra, various simulations are performed by only changing one structure parameter while all other structure parameters are kept fixed. Figure C2(a) shows the absorption spectra with different cavity widths. The FP cavity mode wavelengths decrease when the width w increases. This is because the effective refractive index decreases as width increases [2], leading to shifts of resonance wavelengths to shorter wavelengths. The effective refractive index can also be affected by the cavity length and period of the cavity. Figure C2(b) and C2(c) show the relation between the absorption spectra and the cavity length l and the period p. When increasing the cavity length l and the period p, the resonance wavelengths also increase [3]. Figure C2(d) shows the effect

of the cavity depth h on the absorption spectra. The resonance wavelengths shift to longer wavelengths when increasing the cavity depth h, which is consistent with the equation (1) in this letter.

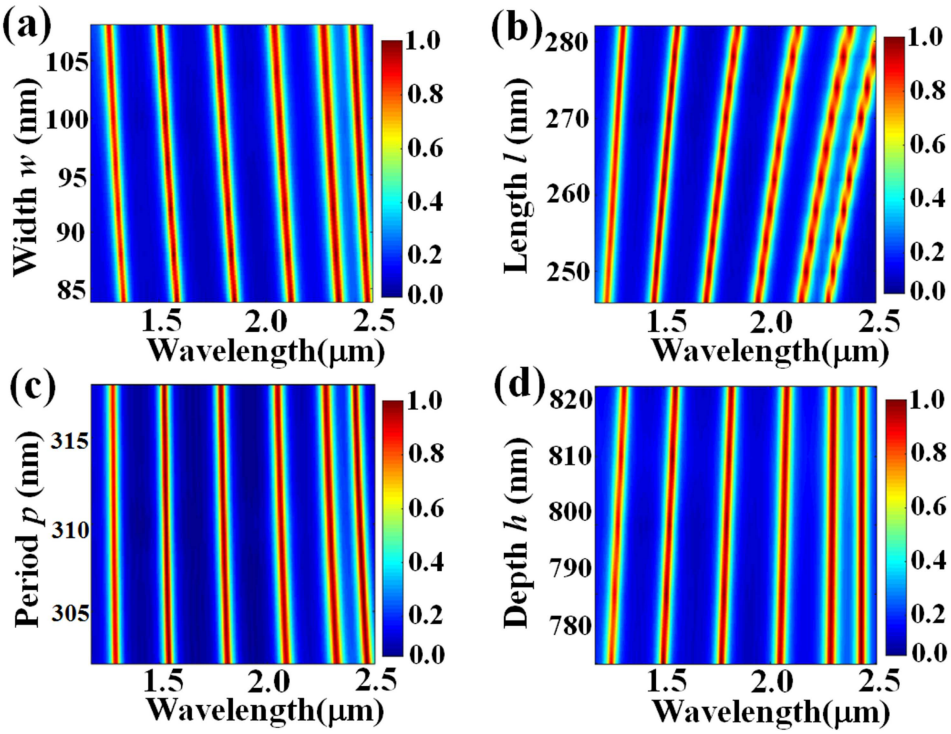

Figure C2 Calculated absorption spectra with different cavity widths w (a); lengths l (b); the periods p (c); and depths h (d).

Appendix C.3 Influence of different fill materials and metals on the absorption spectra

We investigate the effect of metal cavity with different filling dielectric materials on absorption spectra, as shown in Figure C3(a). It is seen that the absorption spectra from indium phosphide (InP) [4], gallium phosphide (GaP) [4], and silicon (Si) [5] also achieve six absorption bands and near perfect absorption rates simultaneously. The results demonstrate that the positions of the absorption peaks can also be tuned by filling different dielectric materials. Figure C3(b) shows the simulated absorption spectra for absorbers made of different kinds of metals, including Au [6], Ag [7], Cu [7], and Al [7], where the absorption spectra from Ag, Cu, and Al are nowhere near as good as from Au in absorption performance.

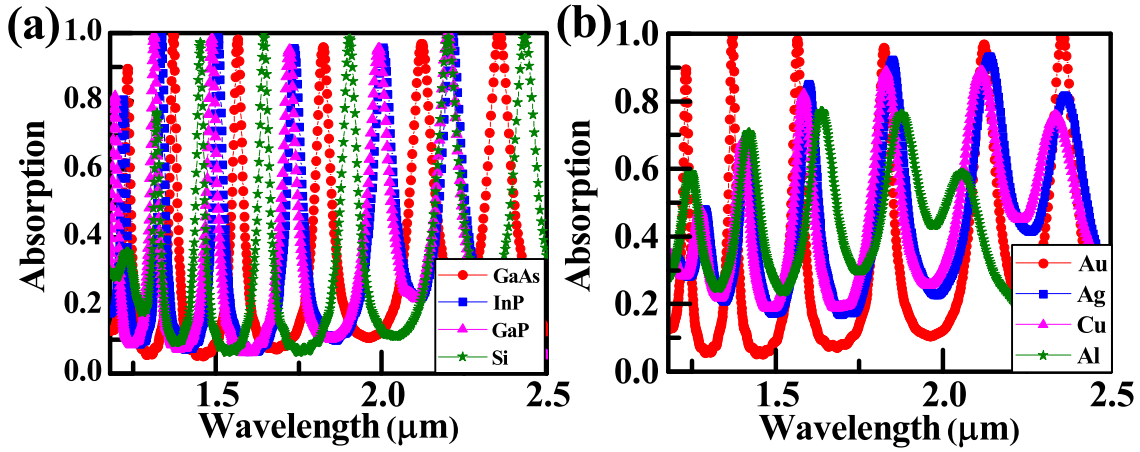

Figure C3 (a) Calculated absorption spectra for metal cavity with different filling dielectric materials (GaAs, InP, GaP, and Si). (b) Calculated absorption spectra with different kinds of metals (Au, Ag, Cu, and Al).

References

1 Smith D R, Vier D C, Koschny T, et al. Electromagnetic parameter retrieval from inhomogeneous metamaterials. Phys. Rev. E, 2005, 71: 036617.

2 Shi H F, Wang C T, Du C L, et al. Beam manipulating by metallic nano-slits with variant widths. Opt. Express, 2005, 13:6815-6820.

3 Fan X B, Wang G P, Lee Wai J C, et al. All-Angle Broadband Negative Refraction of Metal Waveguide Arrays in the Visible Range: Theoretical Analysis and Numerical Demonstration. Phys. Rev. Lett. 2006, 97: 073901.

4 Aspnes D E, Studna A A. Dielectric functions and optical parameters of Si, Ge, GaP, GaAs, GaSb, InP, InAs, and InSb from 1.5 to 6.0 eV, Phys. Rev. B, 1983, 27: 985-1009.

5 Palik E D, Handbook of Optical Constants of Solids (New York: Academic), 1997.

6 Lide D R, (ed) CRC, Handbook of Chemistry and Physics 86th edn (Boca Raton, FL: CRC Press), 2005.

7 Rakić A D, Djurišic A B, Elazar J M, et al. Optical properties of metallic films for vertical-cavity optoelectronic devices, Appl. Opt., 1998, 37: 5271-5283.