Wide-band metamaterial perfect absorber in the long wave infra-red (LWIR) region

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Abstract

Uncooled bolometers are resistive IR detectors which detect change in resistivity due to heat generation by IR radiation. Highly efficient thin film IR absorbing coating is required for such absorbers. Metamaterial absorbers with thin layers of metal-dielectric-metal structure have been reported to produce perfect absorption with sharp band and absorption over wide angle. However, obtaining broadband absorption for applications with such absorber has been a challenge so far. We demonstrate a CMOS compatible thin metamaterial broadband absorber in the range from 8–14 microns with ~98% absorption. The absorber has a 3 layer metal-dielectric-metal structure which is fabricated using vacuum deposition methods and standard photo-lithography. A dispersive dielectric (SiO₂) is used to achieve multiple absorption bands. MDM cavity theory and FDTD simulations are used to design the absorber. Angle dependent reflectivity measurements confirm wide-angle absorption bands which are also polarization independent.

Image of simulated absorbance as a function of wavelength and period of the squares. The size of the squares and thickness of the dielectric are $l = 3$ microns and $t = 1.4$ microns, respectively. $l$ and $t$ remain constant as period varies from 6–10 microns. Absorption band remain little effected by the change in period.

Colormap of absorbance as a function of wavelength and (a) dielectric thickness or (b) size of squares. Analytically (dashed line) and numerically (solid line) calculated resonance wavelengths as a function of (c) dielectric thickness, (d) size of squares.

MDM cavity metamaterial perfect absorber

The path difference between the points A, B and C is

\[ \Delta = (b + l)\pi / (2l + t) \]

The phase difference including -p for reflection from metal is

\[ \phi = 2\pi / (2l + t) \]

Using the condition that \( \cos \phi = 1 \) for standing waves formation

As $l_0 = 2b + l + (b + l)\sqrt{l^2 + t^2 / (b + t)}$
For $m=0, 1, 2, ...
\]

The squares can be considered as isolated and non-interacting.

Theoretical calculation of resonance wavelengths

A dispersive dielectric gives multiple solutions for resonance wavelength for the same order of resonance. Blue line in the figure represent refractive index, $n$ of SiO₂, green and red lines represent first order and second resonance conditions. Intersection of these lines with SiO₂ refractive index gives the solutions. Multiple resonances are predicted by theory.

Experimental reflectance spectrum of a absorber shows strong broad band absorption

Experimental reflectance spectra of a fabricated mid-IR absorber using a BOMEM DA8 FTIR spectrometer. The measurement was done at near normal (~8 deg) incidence. More than 80% absorption is obtained from 8–14 microns.

Simulation results for broadband LWIR absorber

Colormap of absorbance as a function of wavelength and (left) dielectric thickness or (right) size of squares.

Summary

We experimentally demonstrated of a metamaterial perfect absorbers LWIR regions. The absorber has a simple 3 layer structure with thickness of only 1.5 microns. Strong broadband absorption is obtained from 8–14 microns which is useful for IR bolometers working in this range. Absorption remains more than 80% from 8–14 microns. Such thin, CMOS compatible absorber has potential use in thermal imaging.