Broadband Polarization-Independent and Wide-Angle Metasurface for Radar Cross Section Reduction

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Abstract

In the past few years, metamaterial perfect absorbers (MPA) have been extensively studied due to their incredible ability to manipulate electromagnetic waves and provide a broadband, polarization-independent, and wide-angle response for a host of applications. The need for high-performance terahertz regime MPA is increasing for both the commercial and the military applications to provide concealment and shield objects. We report periodic arrays of tapered cylindrical heavily-doped silicon structures to realize an ultra-broadband and polarization independent THz perfect absorber for a wide-angle response. In this proposed structure, we deployed heavily-doped silicon to improve the THz absorption efficiency and bandwidth of the response, and secondly, the conventional microfabrication technology can be easily integrated to support the fabrication of this silicon-based MPA.

In this work, we used COMSOL Multiphysics® to model the electromagnetic wave response of the proposed structure using the RF Module. The unit cell of the proposed structure was modeled with the Floquet boundary conditions for the side faces, excitation port with diffraction orders for the top face to eliminate the influence of the scattered light, and an output port for the bottom face. The obtained frequency dependent transmittance, reflectance, and absorbance were calculated using the S11 and S21 parameters. The structure was simulated at normal and oblique incidence for transverse electric and transverse magnetic incident waves in the frequency range from 0.1 to 5.0 THz for an incidence angle of 0 to 75 degrees. The proposed structure was found to support a near-unity absorbance for a frequency spectrum of 1.6 to 3.8 THz along with polarization independent and wide-angle response up to 60 degrees of incident angle. The analysis of field patterns and power loss density revealed the underlying mechanisms to be a combination of an air-cavity mode and mode-matching resonance for frequency lower than 2.0 THz and Fabry-Perot resonances for frequencies higher than 2.0 THz. Secondly, the tapered cylindrical periodic structures provide impedance matched surface to the air for both polarizations allowing efficient coupling with the metasurface and the lossy doped silicon also aids in efficient absorption along the propagation. Our proposed MPA structure can be easily fabricated and scaled with current microfabrication technology, and it can be readily integrated with applications in THz imaging systems, sensors, anti-radar cloaking and so on. This proposed structure can significantly reduce the radar cross section over a wide spectral range in the terahertz region by efficiently absorbing the incident radar waves of any polarization and incident angle.

Figures used in the abstract

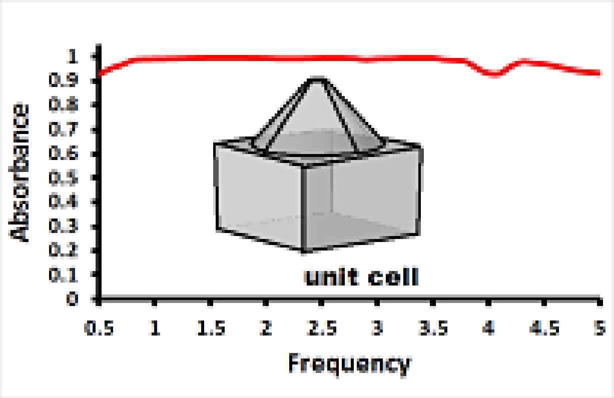

Figure 1: Absorbance in the periodic arrays of tapered-cylindrical heavily-doped silicon structures for a frequency range of 0.5 to 5.0 THz at normal incidence.