Vividly colored silicon metasurface, with applications in sensing and lighting

Silicon has many favorable attributes from both the device physics and manufacturing standpoints, and is therefore the pre-eminent material for micro- and nanoelectronics. Furthermore, due to its transparency at infrared wavelengths, silicon-based integrated photonics play a key role in modern optical communications devices. Silicon-based nano-optical antennas have also attracted much interest recently, due to the high refractive index and moderate losses available with silicon. Metamaterials and metasurfaces based on silicon and other dielectric materials have also gained much attention, due to the fact that they offer much lower levels of loss, compared to metals. In this work, we experimentally demonstrate a silicon metasurface in the visible frequency range, with several potential applications. (1) We demonstrate the magnetic mirror behavior of a silicon metasurface with high efficiency in the visible spectral range through direct phase measurement. The phase discontinuity between the reflected and incident light is wavelength dependent and can be engineered by appropriate design. The metasurface also reveals vivid colors across the entire red-green-blue range. (2) Using our silicon metasurface, we demonstrate a colorimetric refractometer from which a liquid's refractive index can be directly monitored with a color camera. (3) We experimentally demonstrate highly directional fluorescent emission using our silicon metasurface at visible wavelengths. Our device offers not only high efficiency, but also a high degree of tolerance in terms of the position, orientation and wavelength of the dipole emitter. We perform a multipole expansion of the fields from each element of the metasurface (a silicon nanorod). This reveals that the metasurface largely behaves as if it comprises an array of electric and magnetic dipoles.

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