A Physical Explanation of Angle-Independent Behavior of Metafilms/Metasurfaces

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Highly reflecting and transmitting coatings used as filters and mirrors are typically constructed from multilayered structures consisting of dielectric materials. Because the transmittance and reflectance properties of the structures result from multiple-beam interference effects, they show strong dependence on the angle of the incident beam. It would therefore be desirable to achieve tailored reflectance and transmittance properties at an interface that are angle-independent. In this paper, we explore the use of a resonant surface, inspired by metamaterials research for making highly reflecting and transmitting surfaces that are angle-independent. Although angle-independence of surfaces and structures has been suggested in the literature, we show theoretically, and give a physical explanation as to why this behavior occurs in certain metafilms. We illustrate that a metafilm (the two-dimensional equivalent of a metamaterial, also referred to as a metasurface) can be designed to have transmission and reflection properties that are independent of the angle of the incident wave. We discuss the physical reason why these properties occur, and we have show that if the transverse surface susceptibilities (of the metafilm/metasurface) are sufficiently large, as compared to the normal component of the surface susceptibility, then the metafilm will exhibit this angle- independent property.

We show that, by choosing an inclusion with sufficiently strong resonances, the angle dependence of the metafilm becomes negligible. Metafilms operating at microwave frequencies and composed of both lossless and lossy resonant spherical inclusions as well as electrical resonators are investigated. Numerical and spherical-harmonic mode-matching approaches are used to investigate the angular dependence of the reflection properties of these metafilms. Such angular-independent properties can have applications in extending the modes supported in a metafilm waveguide and have direct applications to photonics where, due to fabrication obstacles, the application of optical metamaterials have been limited to single, and multiple-stacked, two-dimensional arrays of plasmonic structures.