Theory and Applications of Metafilms: The 2-D Equivalent of Metamaterials

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Metamaterials are commonly engineered by arranging a large number of small scatterers in a regular array throughout a region of space so as to obtain some desirable bulk electromagnetic behavior. Double-Negative (DNG) materials exhibiting negative refractive index have been achieved by using small scatterers composed of metallic or magneto-dielectric materials (e.g., metallic rings and rods or spherical magneto-dielectric particles). This concept can be extended by arranging electrically small scatterers into a two-dimensional pattern at a surface or interface. This surface version of a metamaterial has been given the name metafilm. Like that of a metamaterial, the behavior of a metafilm can be characterized by the electric and magnetic polarizabilities of its constituent scatterers.

The most convenient method to analyze metamaterials is with effective medium theory. On the other hand it is inappropriate and a misinterpretation to characterize metafilms as an effective-medium, contrary to what has been presented in some of the literature [Padilla et al., *Phys Rev B*, **75**, 2007]. The problem is that the effective material properties are not uniquely defined for a metafilm. A metafilm is more appropriately characterized by generalized sheet transition conditions (GSTCs), as opposed to the effective-medium description used for a metamaterial. The GSTCs were given in [Kuester *et al.*, *IEEE Trans. AP*, **51**, 2641, 2003], and can also be expressed in the form:

$$\bar{a}_z \times \bar{H}\,|_{z=0^-}^{o^+} = j\omega\varepsilon\vec{\chi}_{ES} \bullet \bar{E}_{t,av}\,|_{z=o} + \bar{a}_z \times \nabla_t \left[\chi_{MS}^{zz} H_{z,av}\right]_{z=0}$$
$$\bar{E}\,|_{z=0^-}^{o^+} \times \bar{a}_z = -j\omega\mu\vec{\chi}_{MS} \bullet \bar{H}_{t,av}\,|_{z=o} + \nabla_t \left[\chi_{ES}^{zz} E_{z,av}\right]_{z=0} \times \bar{a}_z$$

where $\vec{\chi}_{ES}$ and $\vec{\chi}_{MS}$ are the dyadic surface electric and magnetic susceptibilities, which are related to the densities of polarizability of the scatterers.

For many applications, metafilms can be used in place of metamaterials. Metafilms have the advantage of taking less physical space than do full 3-D metamaterial structures, and as such, metafilms offer the possibility of less lossy structures. In this presentation, we will discuss the theory of metafilms and present some potential applications. Such applications include; (1) controllable "smart" surfaces, (2) miniaturizing cavities, (3) new waveguiding structures, (4) switches, and (5) bio-medical devices, to name only a few.