Advances in Metasurfaces Based on Metamaterial-Lined Apertures and Discs

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The rapid recent progress in the field of metasurfaces (MTSs) has been enabled by developments in analytical and numerical modeling, fabrication technologies, and intense interest in realizing their applications. These applications include exotic beam generation (OAM beams, Bessel beams, Vector beams), beam steering/splitting, anomalous diffraction, subwavelength imaging, polarization rotation, and many more.

Previously, we have shown that lining a subwavelength circular aperture in a conducting screen with a thin layer of ϵ-negative and near-zero (ENNZ) metamaterial liner can introduce a dramatically reduced resonance frequency of the fundamental mode (E. Baladi, J. G. Pollock, and A. K. Iyer, Opt. Express, vol. 23, no. 16, pp. 20356-20365, 2015). An array of such apertures was used to create a new class of resonant metascreens that showed strong transmission at resonance with a fano-shape profile. We recently demonstrated that a nonuniform array of these apertures can be used to perform subwavelength imaging of conducting obstacles in both the microwave and optical domains (E. Baladi and A. K. Iyer, IEEE Trans. Antennas Propagat., vol. 66, no. 7, pp. 3482-3490, 2018).

In the current work, we present recent results in metamaterial-lined aperture-based MTSs. Thereafter, we present a complementary metafilm unit cell obtained by exchanging the metallic and dielectric regions of the metascreen, which shows dual transmission/reflection behaviour. This metafilm unit cell may be considered to consist of metallic discs lined using μ-negative and near-zero (MNNZ) metamaterial liners, exhibiting a fano-shape reflection profile at the fundamental mode's resonance frequency. These fully-printed metafilm unit cells measure $\lambda/7$ or smaller at 2.45 GHz and exhibit a 5-dB increase in reflection at resonance compared to an unlined disc array. Finally, we describe the unique fabrication challenges that we have overcome using state-of-the-art nanofabrication at the University of Alberta, to create the abovementioned MTSs at optical frequencies. We will show that we have achieved reliable patterning of sub-10-nm features in a polycrystalline gold film over a range of more than $5\,\mu m^2$.

The proposed MTS technologies are ideal for myriad applications as their unit cells may be made extremely subwavelength, are largely insensitive to periodicity and angle of incidence, and exhibit extremely high resonance-antiresonance contrast. These properties can be exploited for the design of inhomogeneous partially transmitting/reflecting surfaces as well as selective filtering applications. They can also be utilized for the design of far-field, high-resolution magnifying devices or, with the addition of a nonlinear or tunable material, a host of other exotic applications.