Terahertz Metasurfaces for Antireflection Coatings

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***Abstract*—We demonstrate a new strategy of ultrathin terahertz antireflection coatings employing metasurfaces. The antireflection performance is determined by the metasurface structure design rather than the properties of materials being used, and it is scalable to operate at any relevant wavelengths and substrates of arbitrary refractive index.**

I. INTRODUCTION AND BACKGROUND

LIGHT reflection at the boundary of two different media causes considerable losses. It is particularly severe in the terahertz (THz) frequency range where the available power is typically low using table-top sources. Additionally, many optical components have optical thickness comparable with the wavelength, which result in undesirable interference fringes and affect spectral analysis. Traditionally, optical antireflection is realized using single- or multiple-layer dielectric films, or graded index surface relief structures, in various wavelength ranges. However, these approaches either impose strict requirements on the refractive index matching and film thickness, or involve complicated fabrication processes and non-planar surfaces that are extremely challenging for device integration.

Recently, a metamaterial antireflection coating [(Figs. 1(a) and (e)] was demonstrated in the THz regime using a structure consisting of a subwavelength metal mesh and an array of subwavelength resonators, which are separated by a thin dielectric spacer [1], [2]. Essentially, this metamaterial antireflection coating is a reduced size Fabry-Pérot cavity where the multireflection experiences a destructive interference in the overall reflection, and the transmission is greatly enhanced [1], [3]. In this work, we present our new results in the development of novel metasurface antireflection structures in which the fabrication can be greatly simplified while the performance can be superior.

II. RESULTS

Figures 1(b-d) illustrate the schematic of new metasurface structures for antireflection coatings. In Fig. 1(b), we remove the metal mesh but the structure is otherwise the same as in Fig. 1(a). Our numerical simulations show that, when the refractive index of the spacer layer is relative small as compared to the substrate, excellent antireflection can be accomplished. This concept was recently demonstrated also at mid-infrared wavelengths [4]. Similarly, we can remove the top resonator array but keep the mesh, as shown in Fig. 1(c). In this case, the dielectric layer should have a relatively high refractive index in order to achieve good antireflection performance. The last metasurface antireflection structure is shown in Fig. 1(d). It can be fabricated by photolithographic methods and reactive ion etching to first form an array of silicon cylinders on the silicon substrate, and gold films can then be deposited using highly directional ebeam metal deposition. This structure is essentially the same as the one shown in Fig. 1(a). Our numerical simulations and experimental results show that all of these metasurface structures have excellent antireflection performance that is comparable or superior to Fig. 1(e).

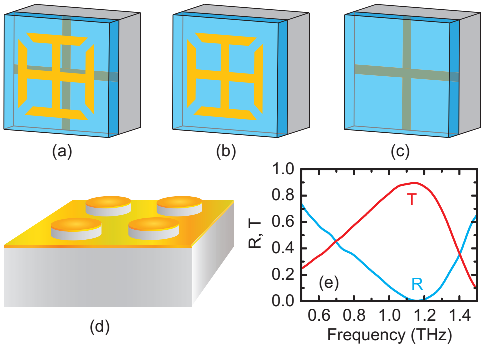

Fig. 1. (a-d) Schematic of metasurface antireflection coatings, where the gray areas indicate substrate, cyan areas indicate dielectric coating, and orange areas indicate metal. (e) Experimentally measured reflectance (R) and transmittance (T) for a structure shown in (a) on silicon substrate.

III. CONCLUSION

The design flexibility of the metasurface facilitates excellent antireflection at specific wavelengths. This antireflection strategy does not rely on the refractive index of the low-loss coating materials being used, is applicable to virtually any substrate with arbitrary high refractive index, and is suitable for standard clean room fabrication techniques.

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