Plasmonic Metasurfaces - Paper Review

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Material platforms for optical metasurfaces by S.M. Choudhury, D. Wang, K. Chaudhuri, C. DeVault, A. V. Kildishev, A. Boltasseva, and V.M. Shalaev (2018) (1)

The development of optical metasurfaces require the overcoming of large losses. The large losses are often associated with the resonant structures, nanofabrication techniques and the incorporation of active control elements, which frequently requires to be compatible with complementary metal-oxide-semiconductor (C-MOS) composites. The tunable metasurface designs are enabling new ways to better these challenges as optical metasurfaces remain in their unevolved material platforms that are often resilient, and low loss.

Plasmonic metasurfaces reveal colorful properties. The coloration is explained by the interaction of light and nanoparticles by coupling the electromagnetic field and the electronic oscillations of a material. The surface plasmons can be used to control light at the subdiffraction scale with the appropriate design of metallic nanostructures . Plasmonic surfaces, besides the light driving at the nanoscale, can also increase the intensity of a local electromagnetic field, which enable imaging and sensing applications at the nanoscale. One counter back of plasmonic metasurfaces are the optical losses, which limit their use in replacing typical optical elements. The nanostructuring process of metals cause the magnetic field of an incoming electromagnetic wave to be truncated as the wave interacts with the free electrons of the structure, causing optical losses as the conversion of stored magnetic energy into kinetic energy takes place.

Compared to plasmonic metasurfaces, which suffer from intrinsic losses because of strong electron to electron and electron to photon scattering in materials, optical loss can be minimized in dielectric metasurfaces, as the large bandgap energies limit optically induced interband transitions. Due to the low loss, all-dielectric metasurfaces surpass plasmonic metasurfaces in efficiency and resonance quality. Since electric and magnetic resonances can by engineered within dielectric nanoparticles, all-dielectric metasurfaces can: a) be design for unidirectional light scattering purposes, b) to enhance nonlinear effects by near-field enhancement, and c) redirect light with more control than plasmonic metasurfaces (focusing, diffraction, beam steering, holography). The reviewed paper presents a collection of several materials to build metasurfaces with their advantages and limitations, see Table 1 for more details.

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As concluded in the revised paper, the discovery of new promising materials for metal-based dielectric surfaces has a growing interest to implement spatial and time varying elements to pursue spatiotemporal metasurfaces. Graphene exhibits fast nonlinear properties that can possibly enable a temporal phase by switching the optical properties of individual resonators in a sequential order.

Bio-inspired plasmonic leaf for enhanced light-matter interactions by C. Liu, P. Mao, Q. Guo, M. Han, S. Zhang (2019) (2)

Liu et al. showed that the absorption of flat gold films decreases significantly from visible to infrared radiation, making gold a good reflector in the IR region. The authors utilized a fractal geometric shape to mimic the properties of wavegrave pink leaves. The fractal structures enlarged the active region and intensified the light to matter interaction through the increase of Au reflectance and absorption of visible radiation. Besides the improved optical properties, it was observed a photothermal conversion for energy harvesting by the temperature increment of ultra thin gold films. The fractal geometry approach enables a technique to improve the absorption in a broadband way besides the use of multiple resonances or geometric singularities in optic transformations. As stated by the authors, the complexity caused by the self-similarity intensifies the light to matter interactions at different levels and therefore the absorption is enhanced in a wide spectrum, which enables the localisation of multiple wavelengths in the same region (thing that is not possible with multi-resonan systems).

References

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