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Metamaterials: From 3D Plasmonic Nanostructure to Reflective Metasurface

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1. Introduction

Manipulating light is highly desired in photonics research. Restricted by the variable range of permittivity for natural materials, conventional photonic elements are often optically thick and their light-manipulation abilities are quite limited by chemical composition. Plasmonic metamaterials are artificial composite by sub-wavelength local resonance structures of electric and/or magnetic type with novel electromagnetic property such as negative refraction and perfect lens, etc. [1, 2]. Recently, ultra-thin metasurfaces with abrupt-varying material properties provided by the geometries of metallic nanostructures on the interface were found to exhibit boardband light-manipulation abilities [3- 5].

2. Result and Discussion

We present a novel plasmonic nanostructure, three-dimensional erected split-ring resonator (SRR), fabricated by the double exposure electron beam lithography (Fig.1(a)) [6]. In comparison with planar SRR, the erected U-shape gold nanostructure can directly interact with the magnetic field of the incident light, and thus enhance magnetic-dipole coupling in the near-field region. In Fig. 1(b), three SRRs are integrated into a unit cell showing magnetic dipole-quadrupole coupling induced Fano resonance. Through fine tuning the coupling between 4 erected SRRs, the toroidal dipole response, a fundamental resonance mode supported by toroidal structures, can be generated at optical region (Fig.1(c)) [7]. The gain-assistant optical spectra for toroidal resonance are also studied [8]. Subsequently, we demonstrate a new type of gradient metasurface with 130-nm-thick Au ground plane, which couples with the Au rod optical antennas on the upper layer via a 50-nm-thick MgF_2 (ε = 1.892) spacer (Fig.1(d)). The proposed metasurface can cancel the transmitted signals and support a single anomalous reflection beam, and thus significantly improve the light-manipulation efficiency (~80%) around wavelength 850 nm [5]. In Fig. 1(d), based on the proposed reflective meta-surface, a polarization-controllable and high-efficiency (~18%) meta-hologram working in visible range are further achieved [9].

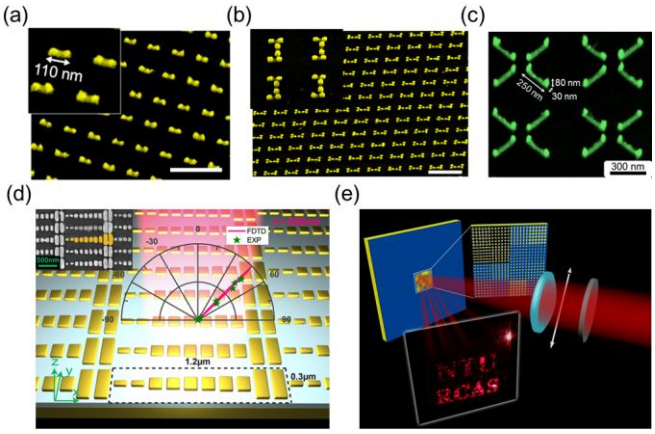

Fig. 1. SEM images of (a) erected SRRs, (b) magnetic metamolecules consisted by three SRRs and (c) toroidal metamolecules. Schematic diagrams (d) high-efficiency metasurface and (e) meta-hologram.

3. Conclusion

In conclusions, we have demonstrated the three-dimentional plasmonic SRR metamolecule with rich reponses to the magnetic field on incident wave. By integrating SRRs into a unit cell, the Fano resonance as well as toroidal resonance can be excited through the incident wave in optical region. A reflective and high-efficiency meta-surface using quasistatic phase elements is proposed for light manipulation, it provides the possibilities to achieve electromagnetic devices in arbitrary frequency regions.

References

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