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Special Topic: Metamaterials

Metamaterials: artificial materials beyond nature

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Research in advanced materials is continuously driving modern technologies forward. For example, semiconductors have laid the foundation for today's electronics industry. While constantly searching for new materials in nature, another approach is to craft novel composite materials beyond the naturally available properties. This is accomplished by directly designing the arrangement of the 'atoms' into a desired architecture or geometry, instead of chemical compositions in natural materials. This new type of artificial material is called metamaterial—a new frontier of science, which first emerged in the field of optics and photonics. In the past two decades, we have witnessed an explosion of the meta-concept, bending the fundamental rules of light. This consequently realized the full exploitation of dielectric and metallic properties in the permittivity–permeability plane, leading to unique optical effects, such as negative optical refractive index and superlenses. These intriguing light–matter interaction behaviors, enabled by metamaterials, provide the further prospect of new functional photonic technology. This technology has a strong impact on our life, ranging from highly integrated photonics circuits, energy-efficient light sources, sub-diffraction-limited optical imaging, environmental and healthcare sensing, etc.

In this special topic, Professor Sir John Pendry shares his views and the history of metamaterials in our interview. In metamaterials, the intrinsic material losses associated with metals can significantly deteriorate the artificially designed optical property and functionality. The solutions to this challenge are discussed by Yuri Kivshar. He offers a general overview on newly emerging all-dielectric metamaterials that still exhibit exotic optical properties, yet avoid the use of metals. Han Zhao and Liang Feng further extend the design of metamaterials to the entire complex-index domain, where losses are strategically utilized to play many positive roles. Remarkably, the evolved meta-principle is generally applicable to different wave systems, such as acoustics, breaking a number of conventional barriers in acoustic materials and devices, as reviewed by Yan-Feng Chen, Nicholas Fang and Ping Sheng *et al.* Beyond scientific curiosity, the progress of metamaterials has delivered various significant technological impacts. In a perspective article, Tie Jun Cui discusses how microwave technology is being reshaped by metamaterials. Xiangang Luo reports on his work on subwavelength plasmonic lithography, a workhorse in the electronics industry. In another perspective, Qian Ma and Zhaowei Liu demonstrate beating the diffraction limit to obtain a clearer picture of the nanoworld using metamaterials for illumination nanoscopy. Additionally, metamaterials tremendously enrich the toolbox for effective thermal engineering, guiding and routing the flow of heat at will, as discussed by Sophia R. Sklan and Baowen Li. They also offer an energy application of radiative sky cooling, reviewed by Shanhui Fan and Aaswath Raman.

While we cannot cover, due to length limitations, every important aspect of metamaterials, we hope that this special topic will provide a glimpse of the exciting developments in the field, further promoting research in metamaterials. We would like to thank all the authors, reviewers and editorial staff for their substantial support in preparing this special topic.

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