Scalable and efficient photonic designs using disordered metamaterial nanounits

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Abstract. Subwavelength metamaterial nanounits can efficiently harvest electromagnetic (EM) waves, resulting in near unity light absorption in the narrow or broad frequency range. Thus, in last decades, many applications are interested for these metamaterial-based perfect light absorbers. Although advancements in nanofabrication have allowed for the realization of strong light–matter interaction in a variety of optical nanostructures, the reproducibility and upscaling of these nanounits for large scale applications has remained as a challenge. The most widely employed tool for fabrication of nanounits is electron beam lithography (EBL), a high-cost and large-scale incompatible route. Although nanoimprint lithography (NIL) can be used to pattern nanounits in large areas but this tool is also high-cost, complex and fabrication of packed, high aspect ratio nanodesigns is generally challenging. Bottom-up approaches can be also adopted to obtain these 3D designs, however, these techniques have also material limitation. Due to their ease of manufacture and excellent functionality, the concept of lithography-free planar light perfect absorbers has gotten a lot of interest in recent years in many parts of the EM spectrum. To address this issue, my group has pioneered numerous fabrication techniques over the previous five years.The i) strong interference in planar ultrathin designs[1–3], ii) dewetting induced surface texturing[4], nanohole[5] and nanoparticle formation[6], and iii) oblique angle deposition of nanorods with deep sub-wavelength gaps[7–10], and iv) utilization of densely packed chemical synthesized trapping scaffolds[11–13] are examples of these studies. Later, this disorder tightly packed nanounits have been brought into novel applications.

For this purpuse, first, we explored the material and architecture requirements for the realization of light perfect absorption using these metamaterial designs from ultraviolet (UV) to far-infrared (FIR) wavelength regimes. We show that, by the use of proper material and design configuration, it is possible to realize these lithography-free light perfect absorbers in every portion of the EM spectrum[14]. This, in turn, opens up the opportunity of the practical application of these perfect absorbers in large scale dimensions. In last couple of years, we adopted these lithography-free techniques in many applications including photoelectrochemical water splitting, photodetection, light emission, sensing, filtering and thermal camouflage[2,7–9,11,13,15,16]. This presentation will summarize our recent accomplishments in scaleble photonic and photoelectronic designs for various applications.

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