Nanostructures for Photonics

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The physics and technology of nanostructured materials for photonic applications have become a new research paradigm poised to transform current technologies. Synthesis, modeling and characterization of such nanostructures are crucial to enhance the performance of existing optoelectronic devices but also to develop entirely new schemes and unforeseen applications. In this work, we aim at reviewing a plethora of nanostructures for optical metamaterials[1-4] and plasmonic[5-7] applications. In particular, optical metamaterials are required for a number of applications in polarimetric imaging, emission, and sensing using circularly polarized light at the chip-scale, as well as the study of innovative optically active drugs, would potentially benefit from such a technology. However, for this purpose nanoscaling must be applied to complex-shape structures, resulting a particularly challenging fabrication issue. We have recently demonstrated how the focused ion beam induced deposition (FIBID) of metallic deposits, upgraded with the dose compensation[1] and the tomographic rotatory growth[3] concepts, is an effective tool to artificially craft helix-shaped and even multibundled nanostructures. Here, we show the achievement in helix-based metamaterials of extremely high circular dichroism and optical rotation in the VIS, obtained by matching the structural features of the meta-atom with inspecting light. Most relevantly, the technology can be applied not only to different metals but also to various dielectric materials such as carbon[4] or silicon dioxide, thus allowing the management of optical losses and the development of nanoscale 3D dielectric chiral metamaterials. Furhtermore, plasmonic nanostructures like metallic nanoantennas have been widely recognized as functional elements in a wide range of applications. The accompanying tight spatial localization of the near-field is routinely used in single molecule spectroscopy, near-field or nanoscale imaging, and photovoltaic applications. Firstly, we present our findings on the stability of Ag[7] and Al nanostructures, able to operate in the visible range, after being exposure to indoor air at ambient conditions. After, we report simple and robust processes to produce Ag and Al bowtie dimer antennas, operating in the VIS, based on electron beam lithography and the innovative milling-based He^{+}-ion lithography able to provide sub-5 nm gaps. The latter promote a tremendous enhancement of the local electric field in the gap, thanks to the growth of near-field-mediated optical interactions.

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