Integration of metal nanoparticles in polymer waveguides: enhancement and redirection of light in photonic structures

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Abstract

Metal nanoparticles (MNPs) are potential candidates to provide novel functionalities in photonic devices [1]. Their exotic optical properties, derived from the highly localized surface plasmon polariton (LR-SPP), can be applied in unusual optical applications, such as the redirection photons or the confinement of the electromagnetic energy in the nanoscale. In this way, these nanostructures have been successfully exploited in several optoelectronic devices, like solar cells [2], optical sensors [3] or subwavelength waveguides [4]. Here we propose suitable technologies to incorporate MNPs in optical architectures compatible with planar organic polymer photonics. Then, their interesting optical properties were used to construct integrated light coupler, or to demonstrate the enhancement of light by a photon-plasmon coupling effect.

In a first approach we propose a novel technology able to grow in situ Au MNPs embedded in the commercially available resist Novolak (NV) [5]. As a consequence, the intensity and position of the plasmonic resonance can be easily tuned in a controllable way by the size of the nanostructures and their concentration into the host matrix. In addition, since NV is a commercially available resist suitable for e-beam or UV lithography, the nanocomposite can be easily patterned facilitating its incorporation in photonic structures. A second approximation consisted of depositing pre-prepared MNPs (ex-site growth) into the polymer waveguide by a simple drop casting technique. Fabrication parameters were carefully controlled to obtain a good homogeneity and to control the concentration of nanostructures on the surface.

Once these technologies were optimized, layers (or patterns) of MNPs were integrated in optical waveguides by depositing the nanostructures on a SiO_2/Si substrate, and then capping with a PMMA layer [5]. Then, optical properties of the MNPs were successfully applied for different purposes. For example, high scattering cross section of MNPs was exploited to demonstrate coupling of normally incident light into the PMMA waveguide. The couplers exhibited a broad wavelength range (400-780 nm) and efficiencies larger than 1 % measured at the output edge of the waveguide structure [5].

In addition, the interaction of MNPs with organic dyes embedded in the PMMA waveguide was studied in order to enhance their emission of photoluminescence (PL) by a photon-plasmon coupling effect [6]. When the gap between the optical emitters and the MNPs was carefully optimized, the high intensity near electromagnetic field of the MNP induced a tenfold enhancement of the light emitted by the dye.

References

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