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Ellipsometric study of the optical resonances of colloidal assemblies

Virginie Ponsinet
Centre de Recherche Paul Pascal, University of Bordeaux, CNRS, France
virginie.ponsinet@crpp.cnrs.fr

Abstract

Nanotechnology was seeded by the idea of versatile material synthesis by direct manipulation and assembly of atoms or elementary entities. It has unraveled nanosize-related enhanced or even unique mechanical, catalytic, electrical, and optical properties; and has led to an exponential growth of new engineered nanomaterials and their applications in microelectronics, medicine, energy, etc. It has developed in the capacities to achieve a wide range of functions and structures, which are in the process of revolutionizing many aspects of our lives. In the field of optics and imaging, the pace of evolution is specifically high, with nanophotonics exploring the possibility of modulating light propagation with very small amount of matter using nanoscale phenomena. Diffractive effects are involved when characteristic sizes are of the order of the wavelength of light, while optical resonances are used in metamaterials structured at subwavelength dimensions.

Metamaterials and metasurfaces are artificial composite media engineered to exhibit extraordinary properties of wave propagation. In bulk (3D) metamaterials, such extreme properties may result from nonconventional values of effective homogeneous optical parameters such as the electric permittivity and the magnetic permeability. These features generally originate in the collective response of the constitutive structural elements, which have to be of sub-wavelength dimensions to satisfy the requirement of optical homogeneity, and which have to be highly polarizable to provide efficient optical functions. For visible light applications, sub-wavelength dimensions imply structuration at the nanoscale whereas high polarizability can be achieved by optical resonators such as plasmonic or Mie resonators. Metasurfaces, on the other hand, are 2D equivalent of metamaterials, designed to control the phase, amplitude and possibly polarization of incident EM waves with subwavelength thickness, using interfacial discontinuities effects. This review shows how the bottom-up approach based on nano-chemistry and the self-assembly methods of colloidal physical chemistry can be used to produce nano-sized tunable resonators which can be assembled in bulk nanostructured metamaterials as well as in optically thin metasurfaces. Focusing mainly on work carried out at the University of Bordeaux over the past decade, we review some of the fabricated systems and the extraction of their effective optical parameters.

Authors : Quentin Flamant, Alexandre Baron, Ashod Aradian, Philippe Barois, Virginie Ponsinet
Affiliation : Centre de Recherche Paul Pascal, University of Bordeaux, CNRS UPR3051, F-33600 Pessac, France