Thin Nanoporous Films with a Honeycomb Structure: Internal Fields, Spectral and Scattering Properties

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Nanoporous thin films with a honeycomb structure fabricated at aluminum electrochemical anodization are now of a great interest because of their unique ability to light spectral and angular selection [1, 2]. Utilizing a self-organized matrix of porous anodic alumina (PAA) is considered to be very promising for applications in microelectronics, magnetic recording, formation of nanotubes, etc. [3]. An attractive optical application of the PAA is connected with imbedding of the luminescent centers, for example ions or semiconductor nanocrystalls [4]. Strong transformation of luminescence spectra and angular distribution of light passed through the PAA are due to multiple scattering, local field enhancements into pores and density of states effects caused by a 2 D photon-crystal structure of the PAA.

New opportunities for these effects controlling may arise when pores are infiltrated with colloidal solutions of noble metallic nanoparticles (MNP). The related joint photonic–electronic confinement becomes possible to manifest at the spectral range of the MNP surface plasmon resonances. In order to determine the most favorable conditions we have developed a calculation method and made numerical simulations of internal fields, spectral and scattering properties in dependence on the PAA and MNP structural parameters.

The PAA films were considered as a high-ordered array of finite circular cylinders, parallel to each other and oriented perpendicularly to a planar substrate. Previously [1] we have developed a model of light propagation through the correlated cylinders ensemble that based on the statistical theory of multiple wave scattering considering single cylinder scattering with the use of the volume integral equation formalism [5]. Now we propose the modification of this scheme applied to the PAA infiltrated with colloidal solutions of the MNP.

Using this approach we have analyzed the PAA transmission spectra and field distribution into the pores at different pore sizes and materials embedded under condition of incident light directed along a pore axis. We have found a strong shift of the PAA transmission spectra short-wavelength cut-off boundary with a pore size enlarging. Theoretical results have shown a good agreement with experimental data. We have also established a possibility to increase the steepness of the cut-off boundary and to create a band type of the PAA transmission spectra by the MNP embedding. The transmission spectra modification is found to be accompanied by strong changing of the local internal field picture and scattering properties.

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