Poster IV.p.38

Excitation of surface plasmon-polaritons in metal-dielectric structures based on opals

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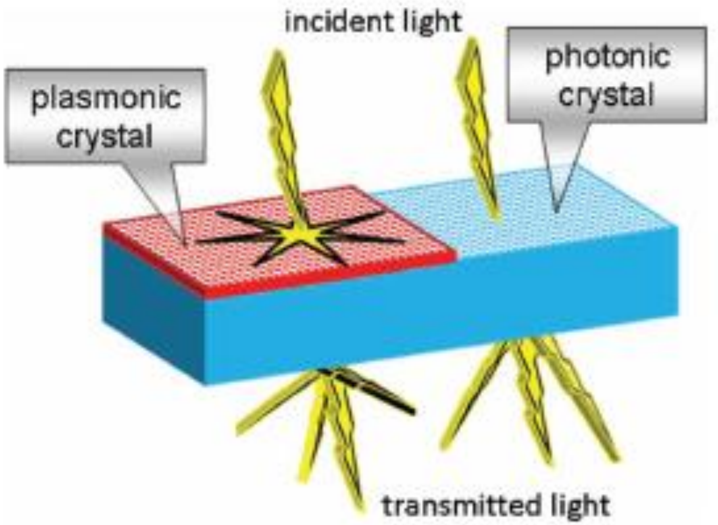
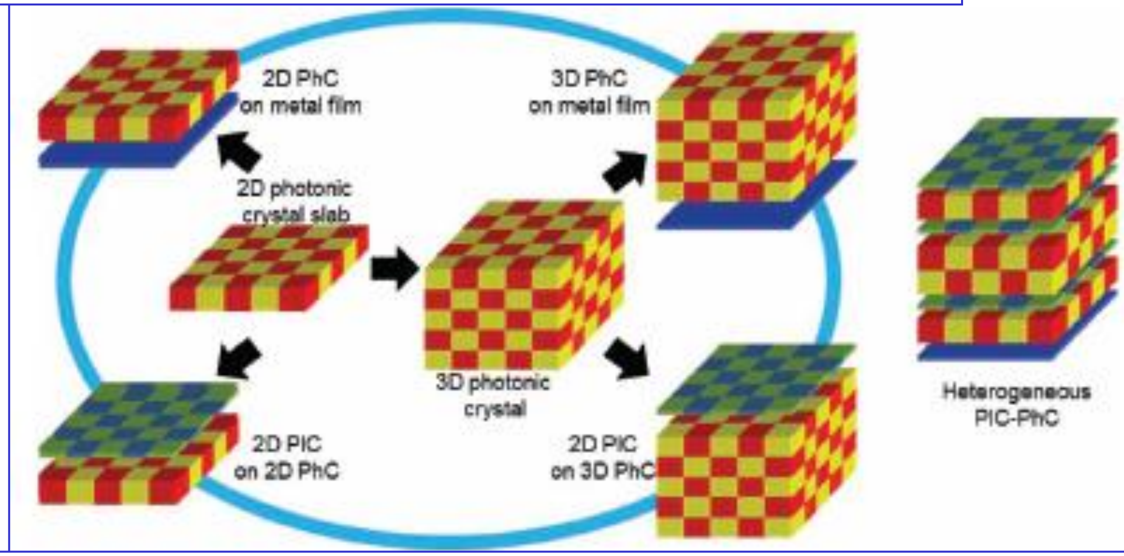
Abstract

Structure and optical properties of metal-dielectric nanocomposite materials based on opal matrices have been investigated.

An anomalous transmission and absorption of light by hybrid plasmon-photonic layered heterostructures, which is apparently associated with excitation of surface plasmon-polaritons (SPP), propagating along metal-dielectric interfaces, was revealed.

Introduction

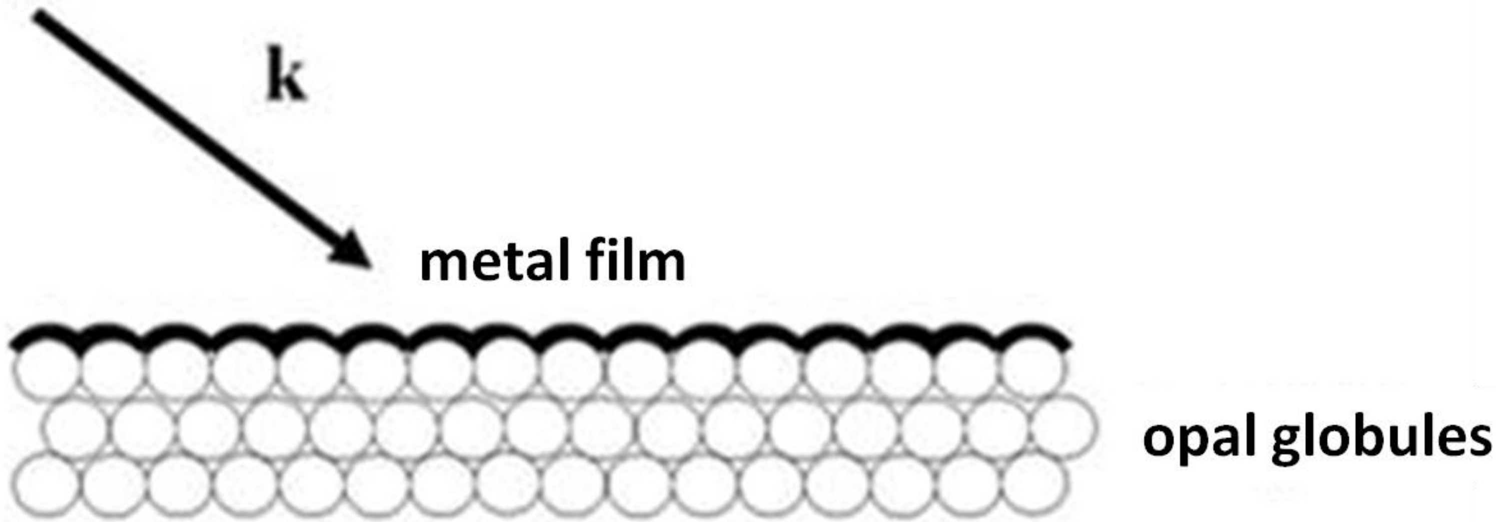




Surface plasmon polaritons (SPP) propagating at tangential directions along metal-dielectric interfaces [1] allow expanding functionality of photonic crystals (PhC) [2] that control the flows of electromagnetic (EM) radiation [3].

1. S.A. Maier, Plasmonics: Fundamentals and Applications (Springer, New York, 2007).
2. S.G. Romanov, A. Korovin, A. Regensburger, and U. Peschel. Adv. Mater. **23** (2011) 2515.
3. J.D. Joannopoulos, R.D. Meade, and J.N. Winn, Photonic Crystals: Molding the Flow of Light (Princeton Univ. Press, Princeton, 2008).

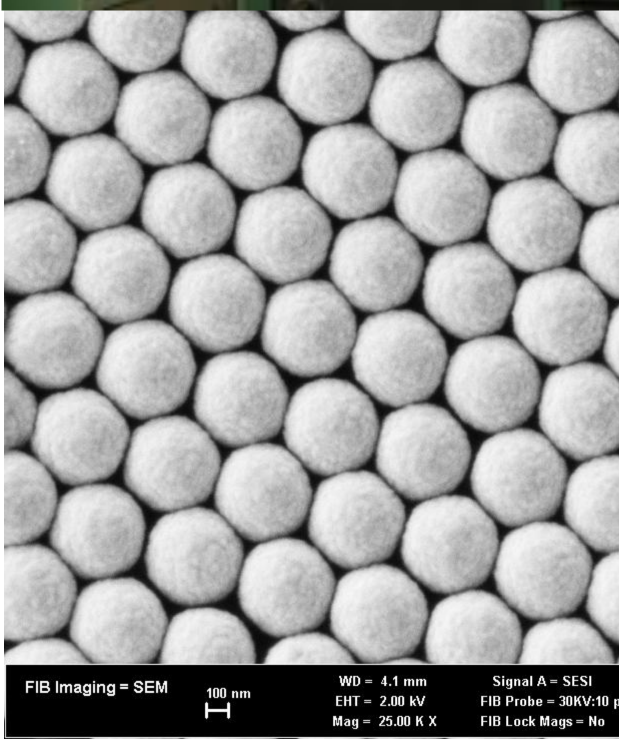
Phase-matching to SPP by grating coupling

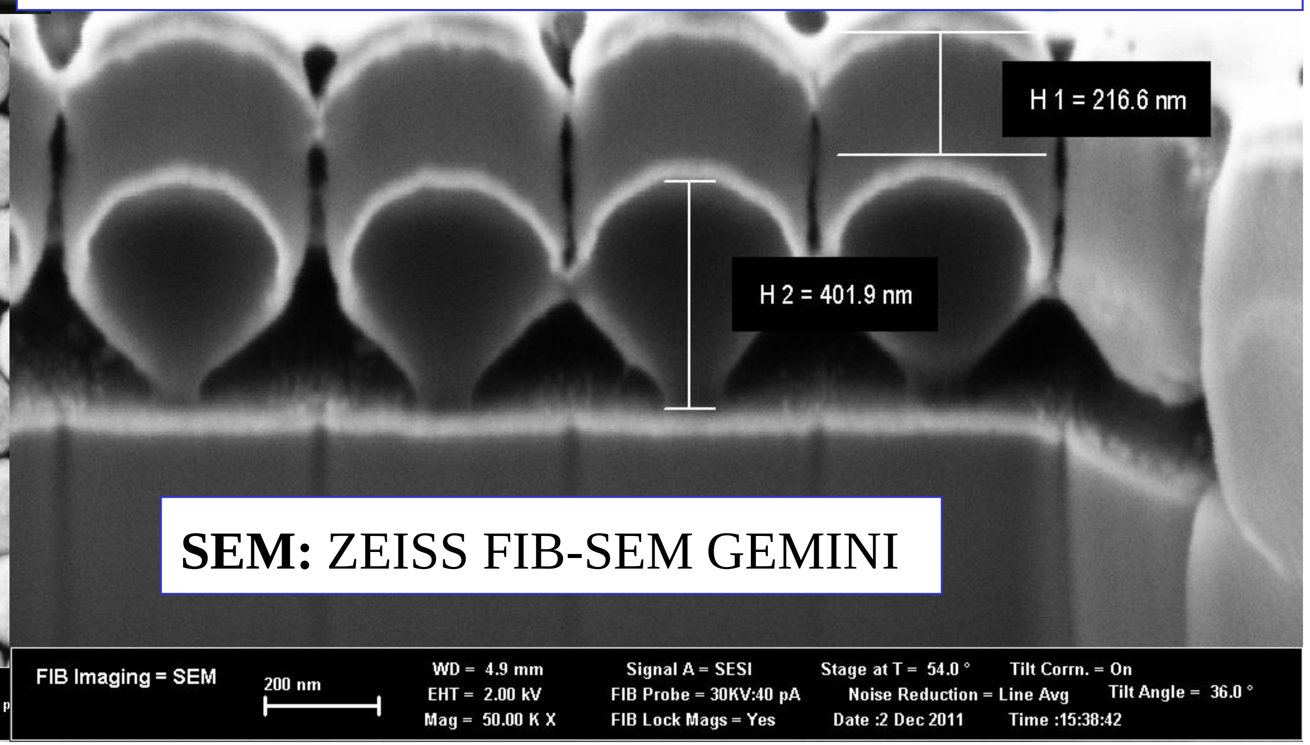


$\beta = k_x + 2\pi l / a$, β and k_x – tangential projections of wave vectors of SPP and incident photon, respectively,
a – period of grating, l – an integer.

Experimental

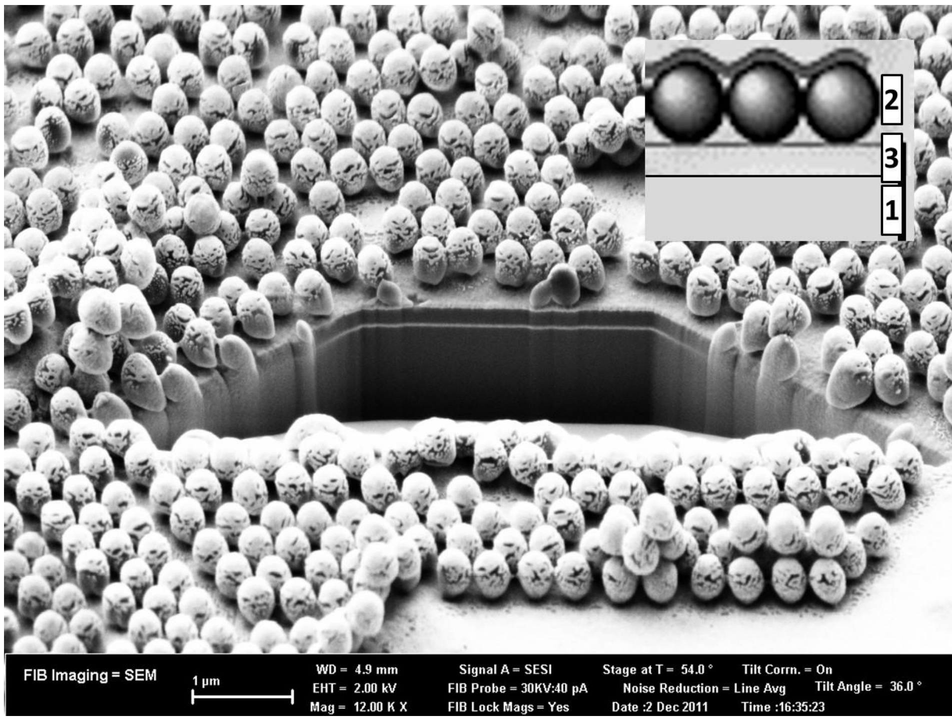
Fabrication of hybrid plasmon-photonic crystals by deposition of Ag and SiO_2 films on monolayer (ML) of opal globules by magnetron sputtering on an ATC ORION SERIES SPUTTERING SYSTEM





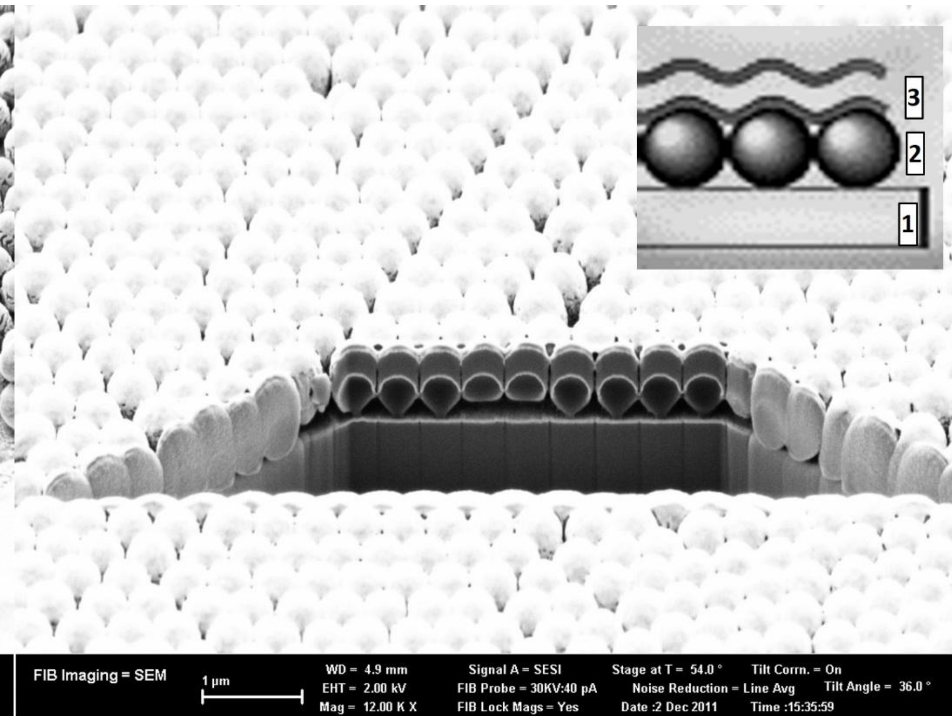
SEM: ZEISS FIB-SEM GEMINI

SEM images of 2 types of opal-based hybrid plasmon-photonic crystals



1

$Ag/ML/Ag/SiO_2/Ag$



2

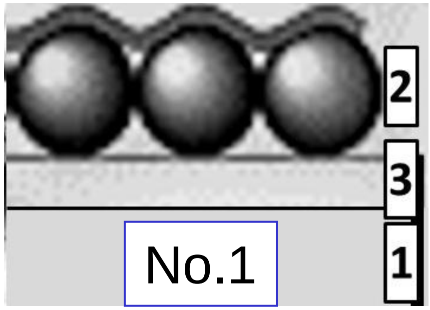
$Ag/SiO_2/Ag/ML/Ag$

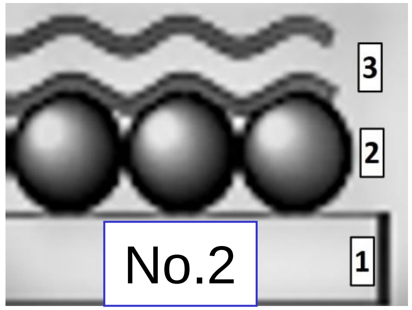
Inserts: 1 – glass substrate, 2 – ML of opal globules, 3 - resonator Ag/SiO_2/Ag.

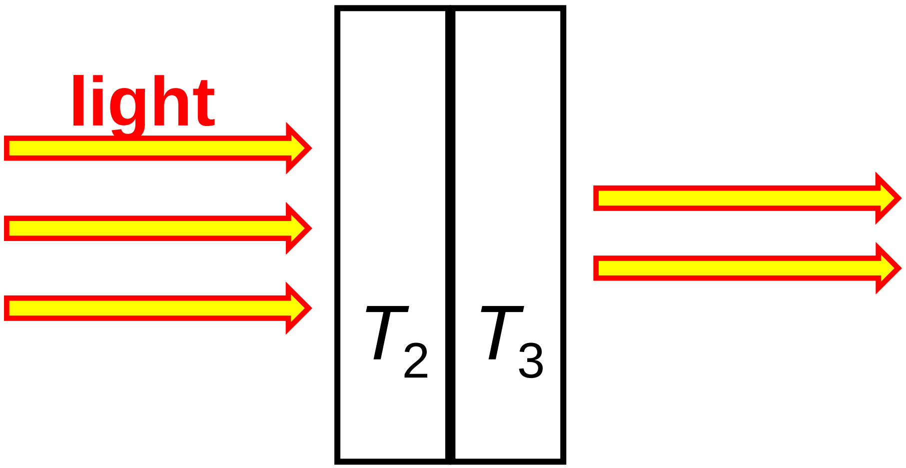
Experimental

The transmission and reflectance spectra of s- and p-polarized light by layered thin-film heterostructures (when the vector of the electric field of the EM wave is perpendicular or parallel to the plane of incidence, respectively) were studied with angular resolution using an experimental setup based on the OceanOptics QE65000 spectrometer. At large angles Bragg reflectance spectroscopy was complemented with spectral ellipsometry due to well-known main ellipsometric equation: $tan\Psi \cdot e^{i\Delta} = R_p/R_s$, where R_p and R_s are the reflectance coefficients for two types of light polarisation, Ψ and Δ being ellipsometric parameters. Ellipsometric measurements were carried out with “Ellipse–1891” spectral ellipsometer.

Results and discussions





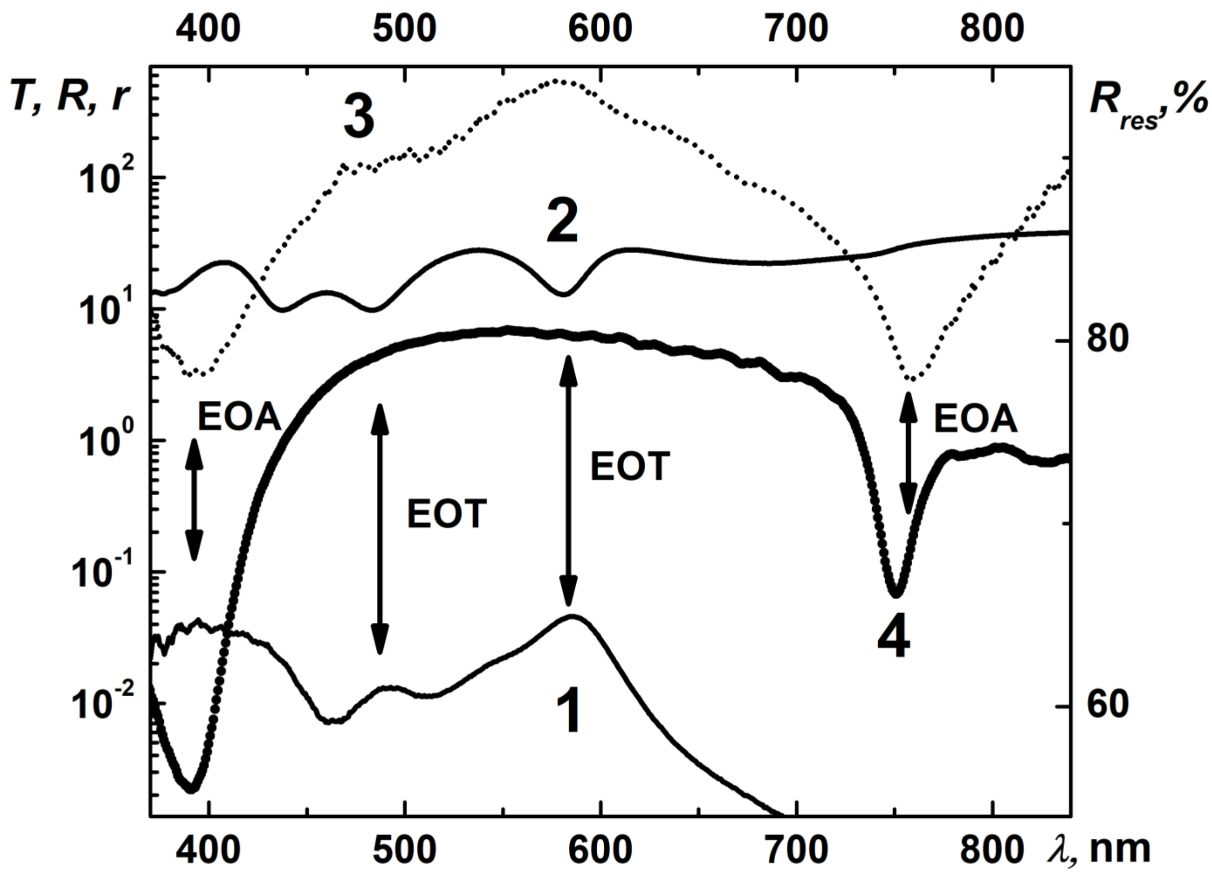


Both types of the samples under study (No. 1 and No. 2) can be considered as systems consisting of two optical elements (monolayer of opal globules and resonator with transmission coefficients T_2 and T_3, respectively) connected in serious and located one after another.

In the absence of interaction between these "passive" optical elements one can calculate the total transmission coefficient T from the relation $T=T_2 \cdot T_3$, hence, the ratio $r = T/(T_2 \cdot T_3) =1$. Experiment confirms this assumption for the sample No. 1 with plane surface resonator.

Results and discussions

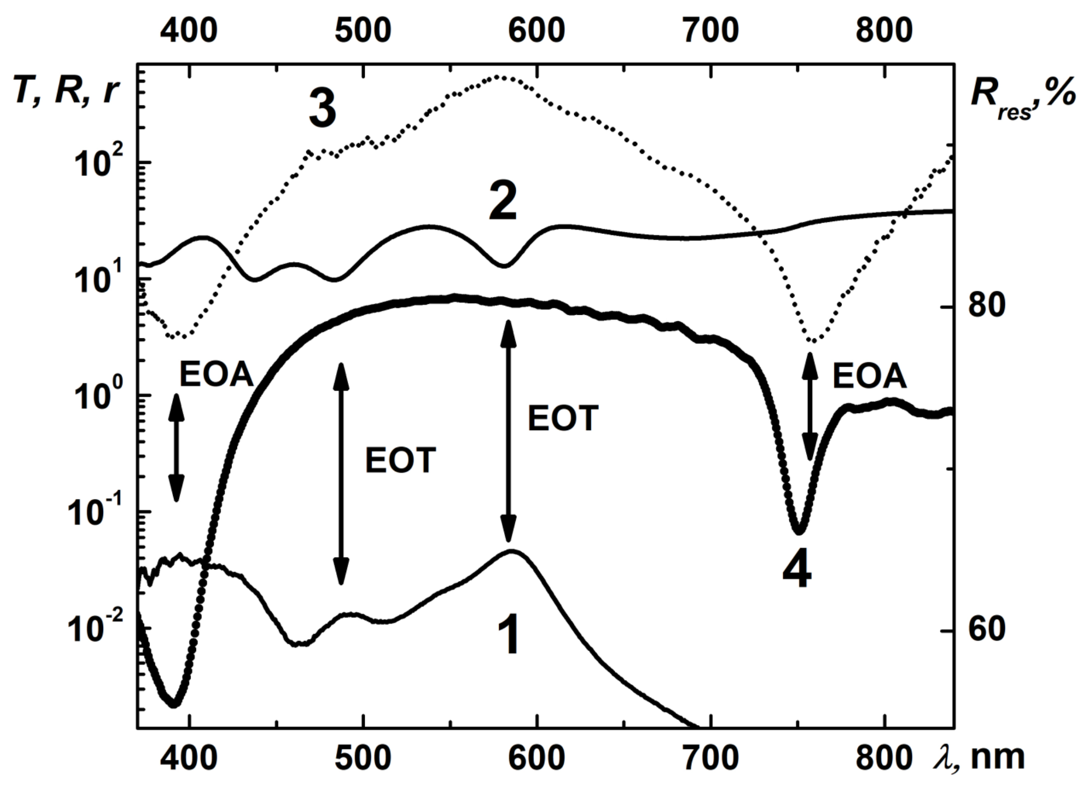
However, for the system *Ag/SiO₂/Ag/ML/Ag* (sample No. 2), where the outer surface of a thin layer covering the opal globules retained the shape and spatial periodicity characteristic of the interface between the opal-like film and this layer, the ratio $r = T/(T_2 \cdot T_3) \neq 1$ and demonstrates pronounced spectral dependence with maxima at about 489 and 584 nm and minima at 392 and 760 nm (curve 3).



Results and discussions

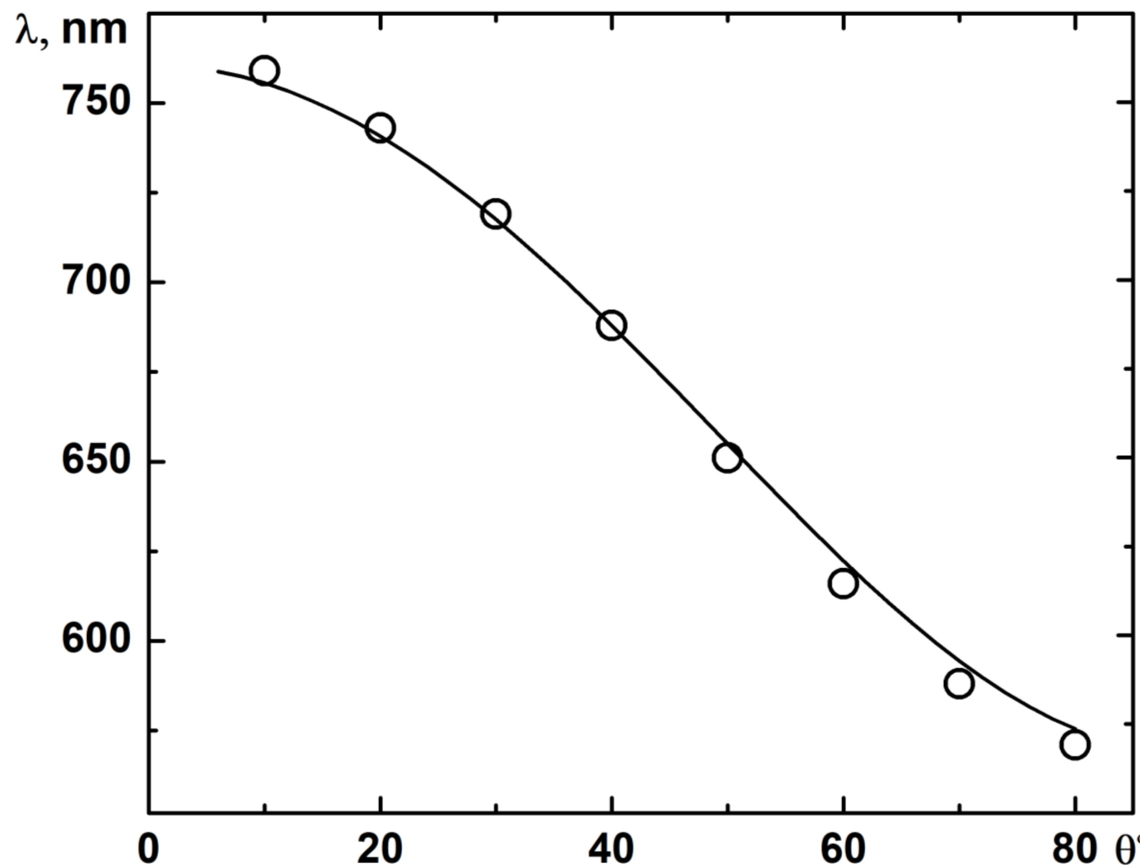
We attributed these maxima to an extraordinary transmission (**EOT**) and minima – to an extraordinary absorption (**EOA**) associated with the excitation of “bright” and “dark” SPPs, respectively. EOT maxima in transmission spectrum of a hybrid plasmon-photonic crystal *Ag/SiO$_2$/Ag/ML/Ag* (curve 1) correspond to minima in its reflectance spectrum (curve 2).

At the same time, the spectral positions of EOA (curve 3) correlate with the minima in the reflectance spectrum of the resonator *Ag/SiO$_2$/Ag* (curve 4).



Results and discussions

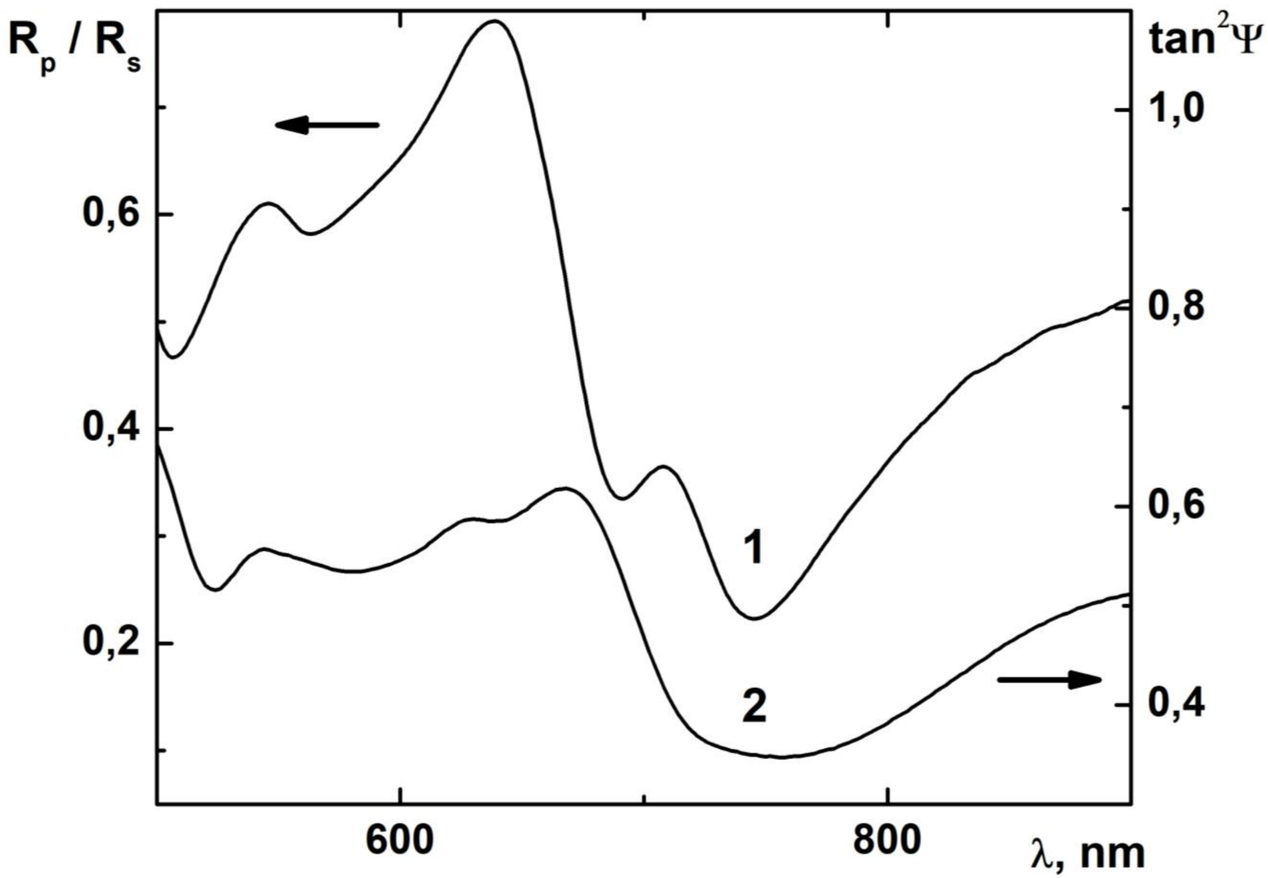
We observed this correlation for all the light incidence angles, as can be seen from the angular dispersion of the long wavelength EOA position and that of the corresponding minimum in the reflectance spectrum of resonator $Ag/SiO_2/Ag$ (circles).



Solid line shows angular dependence of the transmission peak of the interference filter.

Results and discussions

Optical spectra of a hybrid plasmon-photonic crystal *Ag/ML/Ag/*SiO_2*/Ag* obtained from the ratio of its reflectance coefficients R_p/R_s (curve 1) correlate with those calculated from ellipscometric parameter Ψ(curve 2).



Conclusions

1. Experimental results suggest that in opal based hybrid plasmon-photonic crystals with a complex architecture, excitation of surface plasmon-polaritons (SPP) is possible when the phase synchronism condition is met.
2. Two types of surface plasmon-polaritons may be excited in such metal-dielectric structures – “bright” SPP, responsible for extraordinary transmission (EOT), and “dark” SPP causing extraordinary absorption (EOA).

References

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Acknowledgements

The authors are grateful to U. Peschel and D. Ploss for assistance in conducting experiments. This work was partially supported by the German Academic Exchange Service (DAAD) and by the Russian Foundation for Basic Research (RFBR), project No. 20-32- 90003.

Thank you for your attention!