MODELLING OF FANO RESONANCE IN NANOSTRUCTURED MATERIAL
МОДЕЛИРОВАНИЕ РЕЗОНАНСА ФАНО В НАНОСТРУКТУРИРОВАННОМ МАТЕРИАЛЕ

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Abstract: *Optical properties of novel nanostructured material Ag / opal have been modelled on the basis of the Bragg diffraction and the Fano resonance between diffracted in Ag / opal composite photonic crystal electromagnetic waves and those resonantly scattered by silver dendrites.*

Keywords: *Fano resonance, nanostructured silver, opal photonic crystals*

Optical properties of novel photonic crystal Ag / opal prepared by electro-thermo-diffusion of silver in opal template have been studied by angle-resolved reflectance spectroscopy in [1]. Normalized to the maximum value Bragg reflectance spectra of opal template and those of nanocomposite Ag / opal at two different angles of light incidence are shown in Fig. 1. Curves 2 and 4 clearly demonstrate asymmetry of reflectance band and characteristic transition from maximal to minimal reflectance which is typical for the Fano resonance [2, 3].

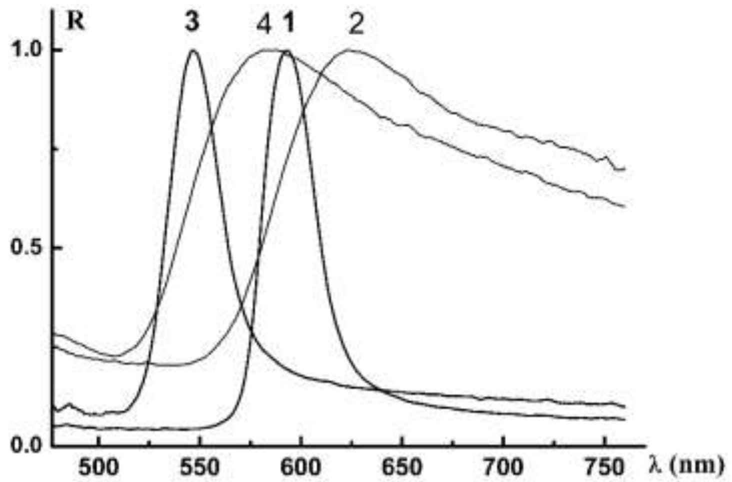

Fig. 1. **Normalized reflectance spectra of opal template (1, 3) and those of nanocomposite material Ag / opal (2, 4) at the angles of incidence 15° (1, 2) and 35° (3, 4) [1]**

When the Fano resonance occurs, one can describe reflectance spectrum by the well-known formula [3]:

$$R(\varepsilon) = 1 - \frac{(\varepsilon - q)^2}{\varepsilon^2 + 1} \cdot \frac{1}{1 + q^2}, \qquad (1)$$

where q represents the phenomenological Fano parameter, $\varepsilon = \frac{E - E_R}{\Gamma}$, E is the energy, E_R and Γ correspond to the position and the width of the Fano resonance, respectively.

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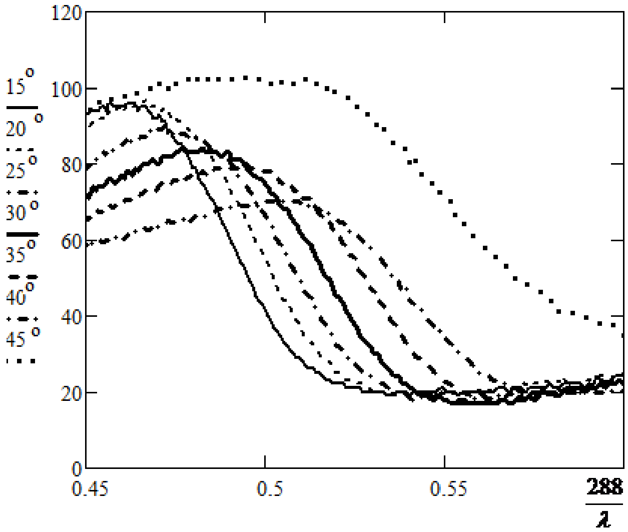

Fig. 2. **Reflectance spectra of nanocomposite material Ag / opal at different angles of light incidence (from 15° to 45°)**

Figure 2 demonstrates experimental reflectance spectra of nanocomposite Ag / opal at different angles of light incidence (mean sphere diameter of opal template $D \approx 288\,\mathrm{nm}$). Comparison of experimental results (Fig. 2) with theoretical predictions (formula (1)) reveals rather weak dependence of reflectance spectra of the Fano parameter *q* (all the curves in the Fig. 2 have similar shapes and slopes, but the resonance position E_R dramatically changes). One can use the experimental data (Fig. 2) to estimate parameters E_R (defining the resonance position) and Γ (affecting the curve slope during the maximum minimum transition) in formula (1). Two examples of this estimation are depicted in Fig. 3. It should be noted that the shape and width of maxima in experimental reflectance spectra are under the influence of many uncontrollable factors, so we did not consider these values as basic parameters in this approach.

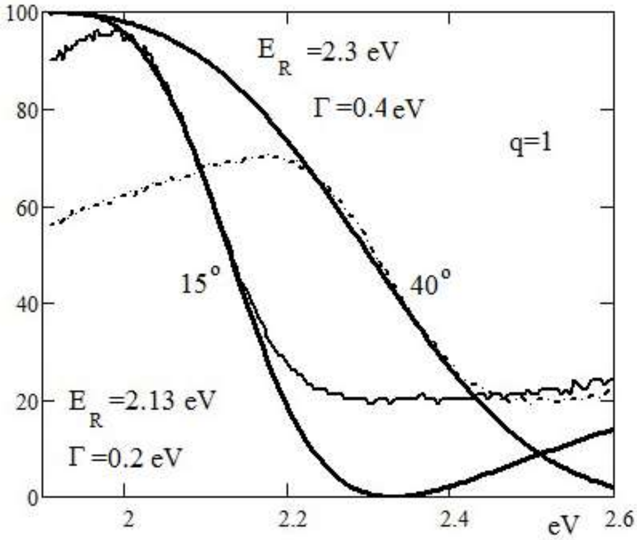

Fig. 3. **Reflectance spectra of Ag / opal photonic crystal at 2 angles of light incidence (15° and 40°) and their approximation with Fano formula (1)**

Analysis of nanocomposite Ag / opal preparation process (especially the saturation of electric current) arrives at a conclusion that metal dendrites are probably formed during the electro-thermo-diffusion of silver in opal matrix [1]. Thus, one can assume that light scattering at silver dendrites takes place, so we use the simplified model (like that is used in quantum theory when potential barrier is considered) in which the transmission amplitude is written in the following form [3]:

$$t \propto \frac{E - E_{zero}}{E - E_R + i\Gamma},$$

where E_{zero} is the zero-energy of the resonance (the amplitude becomes zero during transmission through the barrier, i.e., dendrite).

More accurate and complicated model taking into account simultaneous Bragg reflection from opal matrix and scattering at silver dendrites will probably improve the agreement between theory and experimental results. In this case one can also obtain the value of the Fano parameter

$$q \propto \frac{E_R - E_{zero}}{\Gamma}.$$

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