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Periodic silver based structures assembled in gel

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Non-linear processes at the interface of inorganic nanoparticles, here silver (Ag), and polymer matrix, here agar, mimic a large variety of natural processes—such as formation of dissipative structures [1], self-healing [2], actuation [3], and delivery [4]—but they are still not well understood [5]. We suggest investigating spatiotemporally triggered local changes in the gel during diffusion of silver nitrate solution for non-linear optical materials with controllable interference and polarization, "record" of nanostructured patterns with UV-visible exposure and regulation of nonlinearity in materials, etc.

The main aims of the research are: 1) Formation of periodic silver-based structures in gel due to non-linear spatiotemporal self-organization; 2) Investigation of optical properties of the silver based structures in agar gel; 3) Mathematical prediction of self-organization of silver based structures; 4) Investigation of combined structured precipitation and nanoparticles for Surface Plasmon Resonance (SPR) formation.

Periodic precipitation, a relatively well known and described process of quasi-periodic structure appearing due to supersaturation processes, was used to create structured material.

Gradient films and films for comparison were created for the experiment by using 1% agar and AgNO3 solution of varying concentration. The Agilent Cary 60 spectrophotometer was used to investigate the transmission of the films. We prove formation of silver nanoparticles by UV-Vis spectra, where characteristic SPR peak at 325 nm is observed [8]. The highest figures in gradient structures are observed at the center, and a constant decreasing of the intensity when going to the side is observed in Figure 1, B. However, our system behaves this manner by itself, i.e. without any periodic execution made by a human. In other words, the system demonstrates self-organization.

The following reactions summarize the formation of the silver based structure. When diffusion of silver salt into agar gel occurs, Ag^+ ions react with galacturonic acid monomers in pectin to form white precipitation [6]. Then upon light irradiation [7] salt decompose to form metal silver nanosized aggregations. The system could be described by the classical nucleation and growth model. As a result, these reactions during diffusion were described by a set of differential equations for compiling a mathematical model of the reaction.

For a given concentration $AgNO_3$, the bands of the periodic structures follow the spacing law of consecutive band distance, which is related to the spacing coefficient [8]: $r_{(n+1)} / r_n = p$, where r is the position of precipitation zone and p is the geometric ratio. The value of p decreases with increasing concentration of silver nitrate. This dependence correlates with the Matalon-Packter law for Liesegang patterns.

Accordingly, in this research work instructions for the creation of optically active thin, flexible and free-standing films and periodic structures have been presented. The patterning of the material occurs due to non-linear chemical phenomena of periodic assembly. Moreover, a good correlation of the suggested model with the experiment was obtained using the classical “nucleation and growth” model. Parameters for system description were established. The gradient of SPR was obtained due to the creation of silver nitrate gradient.

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