**Topological micro- nanophotonics:**

**new physical principles to create hybrid elements by 4D-laser technologies (optics+electrophysics)**

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1. To obtain nanostructures and thin films on a solid surface with controlled topology, we used several techniques. Namely, in addition to direct laser modification of solid target surfaces, the schemes with laser ablation of various targets (noble metals and their complexes with graphite and silicon, bimetals, refractory metals, semiconductors, graphite, etc.) in various liquids (from water to ethanol and glycerin, liquid nitrogen) with widely ranging viscosity were also implemented. In this case, first, a colloidal system was obtained; then nanoparticles were deposited from the colloid on a solid surface to form the nanostructures of required topology in two ways: by laser radiation and by a drop method from the colloid through an appropriate nozzle. These processes in colloid systems with metal nanoparticles during laser ablation are associated with variations in local heating, an increase in the exposure time of each specific local volume, and control of laser-induced thermal diffusion of nanoparticles in the liquid. In general, for the case both non-steady states random and non-ergodic processes in cluster dynamic systems under conditions of size quantization take place, and result in new phase transitions. Moreover, laser-induced nanostructures and thin films with controllable topology vs time may be presented as 4D-laser technology fabrication of new structures and materials. This is due to the reason that, e.g. thermodiffusion, gas-dynamic evaporation in pore-like structures with bubbles, ablation products, ballistic movement of the particles in liquid depend on the laser pulses duration. Thus, the interaction effects of solid targets with laser pulses of different duration for obtaining of various nanocluster structures can be viewed as the possibility of synthesizing the 4D-objects, when the result depends not only on the stationary topological/geometric parameters of the system, but also on the dynamic interactions in the system leading to different final stable structures.

2. Using numerical methods, we have demonstrated the procedures for obtaining thin granular metal films with an arbitrary topology upon variation in the control parameters of the problem, as well as the possibility of predicting both their optical properties and electrical conductivity by computer simulation. The electrical conductivity and reflection, transmission, and absorption coefficients in the visible spectral range were calculated for various cases. For this, modern computer technologies were used in combination with original computer simulation algorithms. As a result, good agreement with experimental data was obtained.

3. In experiment with nanostructures in thin films on the surface of a substrate, we observed competition between two processes: first, an increase in electrical conductivity as a result of the opening of new channels in a spatially inhomogeneous conducting system and, second, an increase in resistivity due to an increase in the distance between conducting islands. Such electrical transport properties are determined by quantum correlated states leading to tunnel and hopping electrical conductivities. They can be represented as a special type of topological electrophysical surface structures (both localized and delocalized) for the bound states of charge carriers. A sharp increase in electrical conductivity (by several orders of magnitude) was detected in our experiments due to a change in the topological features of the thin-film nanocluster system. We consider some physical principles for such processes in partially non-uniform complexes with different elemental compositions of thin multilayer cluster films on a solid surface, when free charged particles propagate along the boundaries of conducting surfaces. A fundamentally new point of our study is the finding of trends to superconductivity based on fundamental effects in nanocluster structures with a specific selected topology.

4. Granular thin films formed from spherical metal nanoparticles (e.g., of noble metals) deposited on both the dielectric substrate and the surface of individual other nanoobjects of significantly larger size, e.g., in the Au + Si combination, are of special significance for the optical characteristics. These structures with a controlled optical response can be used in the development of various sensors, electrochromic devices, supercapacitors, photoelectrochemical converters of solar energy, etc.

5. The results of this work make it possible to consider new physical principles for creating topological optoelectronic and photonic functional elements in a hybrid (optics + electrophysics) circuit using various spatial structures of an ensemble of nanoclusters in thin films on a solid substrate at room temperature, which, in fact, are incommensurable structures with laser-controlled symmetry. The aforementioned features of the fundamental effects in nanostructured thin-film solid-state systems make it possible to speak about the formation of a new line of research, i.e. topological photonics, which has undoubted applied promise, in particular, for femtosecond nanoelectronics.