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COHERENT RADIATION FROM MICRODISKS OBTAINED BY INKJET PRINTING

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Abstract This work describes the production of photonic chip based on microlasers with whisper-gallery effect mode (WGM) by inkjet printing. A series of polymers were investigated as a candidates for polymer matrix for encapsulation of perovskite quantum dots. The best results for obtained with polystyrene and corresponding inks were made. The optimization of printing parameters and drying conditions led to forming microdisks which were characterized by atomic force microscopy. The obtained results could be applied in direct writing of fully integrated coherent light sources for advanced photonic and optoelectronic.

Introduction. The method of inkjet printing allows for a high-precision location of individual drops (drop-on-demand method) on the surface of the substrate, as well as to control the volume of the drop, and thus to dose equal concentrations of nanoparticles on the substrate. When controlling the location of nanoparticles during the drying of the droplet, it becomes possible to study their interaction in detail, which gives a high degree of control over the distribution of particles and the creation of new functional materials. The study of the photonic properties of halide perovskites has become one of the main reasons for finding an effective technological solution for creating microdiscs of coherent radiation. At the moment, the main method of forming such structures is lithography. Recently, a laser ablation method has been proposed, which significantly reduces the cost of production of required objects by PeroLab ITMO University, while we suggest to use more simple, fast and scalable techniques as inkjet printing. A promising direction will be the formation of microlaser discs based on perovskite nanoparticles by inkjet printing. Despite the versatility of this method, the disadvantage of inkjet printing is the need to select and optimize the printing parameters for each ink composition. At the same time, the ink application parameters (the size and shape of the supplied pulse, the speed of extrusion of drops and the geometry of their location, the drying parameters) are the determining factors for the creation of optical devices with high resolution and controlled structure. A polymer matrix will be introduced in this study to stabilize inks containing perovskite nanoparticles/quantum dots (QDs).Thus, this study will try to answer the fundamental question of the relationship between the type of polymer matrix and the optical properties of perovskite nanoparticles. Based on the obtained data, the production of optical circuits/displays based on microlaser disks by inkjet printing could also be significant for applications.

Main part Series of different polymers were investigated for obtaining composites with perovskite quantum dots ($CsPbI_3$). Parameters of choice of polymers were their hydrophobicity, strong mechanical characteristics, thermal stability and good optical properties such refractive index and transmittance. It was shown that polymers containing in their structure amino groups, namely polyurethanes, poly(dimethyldiallylammonium) bis(trifluoromethylsulfonyl)amide, polyethyleneimine , react with quantum dots and fluorescence was not observed. Some polymers, for example, poly(vinylidene fluoride) could not be used for printing due to their pure solubility or solubility in the solvents which led to decomposition of QDs (DMSO, DMF). For other polymers, namely, poly(methyl methacrylate), polystyrene, PDMS, quantum yield of fluorescence of incorporated QDs was 14%, 5%, 8%, respectively. Because of the necessity of achievement specific rheological parameters for inkjet printing, polystyrene was chosen as a matrix, 1,2-dichloroethane as a solvent, concentration of QDs was 0,4 mg/ml. Obtained inks has viscosity 2,5 mPa•s, dzeta potential 0,55 mV and surface tension 29,5 mN/m. The optimization of such parameters of inkjet printing as waveform led to obtaining microdisks with QDs, which exhibit

whispering gallery mode structure.

Conclusions Polymers such as polystyrene and some of its copolymers, polymethylmethacrylate, polydimethylsiloxane, polyvinyl chloride, polycarbonate XXX were tested as matrix for incorporation of perovskite nanoparticles. Inks based on polystyrene were created and the required print parameters were selected for them, glass was used as a substrate. The shape and dimensions of the printed microdisk were characterized using an atomic force microscope. The diameter of the microdisc was 67 μm. The solution to this problem will achieve new and practically significant results in the creation of optical circuits and displays based on microlaser disks.

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