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Novel Nanocomposite Materials Based on Mesomorphic Glasses of Metal Alkanoates: Structure and Nonlinear Optical Properties

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Abstract—Novel nanocomposite materials based on an ordered mesomorphic glass of metal alkanoates have been proposed for fast transfer and processing of optical information. Metal alkanoate salts when heated form a smectic mesophase which can be easily supercooled forming an ordered mesomorphic glass at room temperature. The glass has the structure of the smectic-A phase: electrostatic cation–anion layers alternate with bilayers of alkane chains. The mesomorphic glass is a universal matrix for organic and inorganic nanoinclusions and nanosized crystals. In this paper, the structure of the cells of the mesomorphic glasses with various inclusions and their nonlinear optical properties, which become evident upon the impact of pulsed laser radiation with an intensity of up to 5.5 MW/cm^2, have been investigated.

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Liquid crystals (LCs) are widely used for the development of novel nanocomposite materials [1]. Ionic liquid crystals (ILCs) based on metal alkanoates that can form lyotropic LCs, thermotropic LCs, and mesomorphic glasses are a nontraditional class of LCs. Mesomorphic glasses have a layered, nanoporous structure that makes it possible to obtain new solid materials containing nanoparticles and nanoclusters. We have developed a technology for the preparation of cells based on mesomorphic glasses of metal alkanoates doped with dyes (i), lyotropic ILCs with electrochromic additives [2], mesomorphic glasses colored with cobalt alkanoates (ii). It was found by the small-angle X-ray scattering technique that cells with mesomorphic glasses have the structure of the layered smectic A. It was found by the conoscopic method [3] that a homeotropic packing of molecules is observed in the vitrified phase, i.e., molecules are oriented perpendicular to the cell substrates. The nonlinear optical properties and basic holographic characteristics of the composite cells were studied using the method of measuring the nonlinear transmittance and the method of dynamic holography.

EXPERIMENTAL

X-ray measurements of the prepared samples were carried out on a small-angle diffractometer with a slit collimation system. Monochromatic CuK_α radiation with a voltage of 1.2 kV with a focused spot size of 0.4×8 mm was used. The ordering of molecules in the mesomorphic glass was studied by the conoscopic method, as well as by the cell rotation method. It was found from the dependence of the transmission of laser radiation on the angle of the cell rotation that the tilt angle is only 0.1–0.2°. The second harmonic (539.8 nm) of a Nd : YAP pulsed laser opertating in the Q-switched mode (TEM_{00} mode, pulse duration 20 ns) was used as a source for recording dynamic gratings in the cells. The investigation of the relaxation of the recorded gratings was carried out using a continuous He–Ne laser. The spectroscopy of absorption and luminescence in the visible optical range was used as an auxiliary method.

RESULTS AND DISCUSSION

The structure and nonlinear optical properties were investigated in cells (i) with a smectic glass based on $La^{3+}(C_5H_{11}COO^-)_3$ containing dyes of different molecular structures (polymethine dyes of anionic and cationic types, as well as neutral ones, merocyanine and fluorescein). The introduction of the additives does not violate the structure of the mesomorphic glass, the molecules of the additives are well embedded in the matrix. The mesomorphic glasses of lanthanum (III) capronate are transparent in the visible optical range and turn colored by dissolving of the dye in them (concentration of 0.5 wt %). Figure 1 shows the absorption spectra of the studied samples, and the arrow shows the wavelength of the laser excitation. In all the samples the self-diffraction effect is observed under the action of a single