Nonlinear optical response of smectic structure glasses based on cobalt alkanoates

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Abstract: Nonlinear-optical response of metal-alkanoates anisotropic glasses based on cobalt-alkanoate was studied using method of the dynamic holography. Fundamental optical (refractive index *n* and absorption coefficient *α*) and nonlinear-optical (nonlinear susceptibilities $\chi^{(3)}$ and polarizabilities γ_{NL}) parameters of the mesomorphic glasses based on cobalt-alkanoates can be tuned via varying chain length anion (interlayer distance of homologous lines) and\or by changing of the cation composition (exploiting binary or ternary systems).

I. Introduction

Metal alkanoates ($(C_nH_{2n+1}COO^-)_k Me^{+k}$, where Me^{+k} – metal cation, $C_nH_{2n+1}COO^-$ - alkanoate-anion, k = 1-3) can form almost all states of condensed matter: solid crystalline state (including plastic crystals), liquid state (molten salts and even ionic liquids), liquid crystalline state (both thermotropic and lyotropic liquid crystals), isotropic and anisotropic glasses, and also low-dimensional systems (for instance, Langmuir-Blodgett films) [1-2].

First systematic studies of the nonlinear-optical properties of the mesomorphic glasses based on cobalt-alkanoate were presented. It was found that such rigid glasses with intrinsic layered structure demonstrate enhanced third-order nonlinear-optical response ($\chi^{(3)} \sim 10^{-8}$ esu) of an electronic origin (mechanism of the laser-induced electronic nonlinear polarization) at nanosecond time scale. Also it was shown that thermal optical nonlinearity can be neglected at nanosecond time scale for these materials. Based on this, the main nonlinear-optical parameters ($\chi^{(3)}$, γ_{NL}) were recalculated.

II. Materials

The following chemical compounds were used for spectral and nonlinear-optical studies: 1) homologous series of cobalt alkanoates (cobalt octanoate $(C_7H_{15}COO^-)_2Co^{+2}$), cobalt decanoate $(C_9H_{19}COO^-)_2Co^{+2}$), cobalt laurate $(C_{11}H_{23}COO^-)_2Co^{+2}$); 2) binary systems (cobalt octanoate\lithium octanoate $(C_7H_{15}COO^-)_2Co^{+2}\big|C_7H_{15}COO^-Li^{+1}$, 0.5:0.5 molar ratio), cobalt octanoate\potassium octanoate $(C_7H_{15}COO^-)_2Co^{+2}\big|C_7H_{15}COO^-K^{+1}$, 0.5:0.5 molar ratio); ternary system (cobalt octanoate\lithium octanoate\potassium octanoate $(C_7H_{15}COO^-)_2Co^{+2}\big|C_7H_{15}COO^-Li^{+1}\big|C_7H_{15}COO^-K^{+1}$ 0.5:0.25:0.25 molar ratio).

III. X-ray small angle scattering

Smectic structure of the studied materials was confirmed using X-ray small angle scattering method. Using this powerful technique, smectic bilayer spacing (d_l) and its temperature dependence were measured for all studied materials. Typical temperature dependence of the bilayer spacing is shown at Fig. 1: under heating d_l slightly decreases until phase transition temperature $\boldsymbol{T_{C\text{-}LC}}$; at $\boldsymbol{T_{C\text{-}LC}}$ temperature d_l decreases sharply. After that, liquid crystals are cooled and d_l is still the same as at temperature $\boldsymbol{T > T_{C\text{-}LC}}$. It means that under cooling liquid crystalline smectic structure was “frozen” into vitrified state. Such a behavior of the dependence $d_l(T)$ confirms both smectic structure of the studied materials and mesomorphic glass formation which takes place under cooling from liquid crystalline state until room temperature.

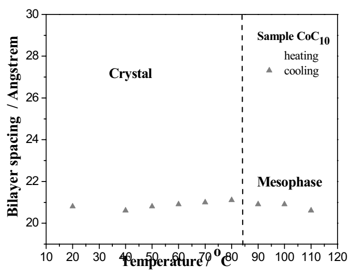

Fig.1. Temperature dependence of the bilayer spacing (studied material – cobalt decanoate $(C_9H_{19}COO^-)_2Co^{+2}$).

IV. Absorption spectra

All studied mesomorphic glasses absorb light in the visible optical diapason (500 – 600 nm, see Fig.2). Positions of the