Optical properties of high-performance liquid crystal-xerogel microcomposite electro-optical films

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Sol-gel method in combination with phase separation enables to fabricate hierarchically porous metal and silicon oxides [1]. When highly polar solvent is used in sol-gel process instead of or in combination with classical alcohol solvents, polycondensation leads to phase separation in form of spinodal decomposition or nucleation growth. In such materials, in addition to micro- and in some occasion mesopores that are characteristic to xerogels prepared by sol-gel method, macropores can be obtained. First systematic study of the macroporous monolithic silica prepared using sol-gel method together with phase separation was published in 1991 [2]. The same year, Levy et. al. used 4-cyano-4'-pentylbiphenyl liquid crystal as polar solvent to achieve phase separation [3]. Obtained material is called gel-glass dispersed liquid crystal (GDLC). GDLC is a hybrid electro-optical film material composing of LC microdroplets encapsulated in inorganic or organically modified silica or mixed oxide matrix. Due to the dielectrical and optical anisotropy of liquid crystal phase inside amorphous oxide matrix the material can be switched from opaque to transparent state by applying an electric field in a similar manner to parallel plate capacitor whereas dielectric layer between electrodes is replaced by microcomposite GDLC film and transparent conductive films (usually indium-tin oxide) on transparent substrates are used as electrodes.
The electro-optical quality (difference between transmittance with applied electric field and without the applied field) is mainly determined by the film thickness and the magnitude of mismatch between refractive index of the matrix and the ordinary refractive index of liquid crystal. In this work we report the significant improvement compared to our previously reported results [4]. GDLC film preparation process was elaborated to incorporate titanium alkoxides in synthesis process. This enabled the adjustment of the refractive index of silica glass matrix without having destructive influence on macroscopic liquid crystal phase separation at the same time. That is a fundamental problem with the use of titanium alkoxides since the orders of magnitude greater hydrolysis and polycondensation rates of titanium alkoxides lead to too rapid gelation. High performance films that exhibit remarkable 78% change in transmittance as an electric field is applied were prepared. An original setup was developed that enables measurement of transmittance dependence on applied voltage at different temperatures in full visible and near-IR spectral range. For the first time, function of change of transmittance vs. wavelength of light was measured for GDLC film, showing the distinct maxima in the mid-visible range. Transmittance vs. applied voltage measurements at different temperatures demonstrate electro-optical effects at least down to -13 °C which means that liquid crystal must be in molten (liquid crystal) state at these temperatures in the microscopic volume confined in xerogel matrix. That is remarkable since it is known that liquid crystal 4-cyano-4'-pentylbiphenyl crystallizes in macroscopic volume at 24.5 °C [5].

References
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Figures

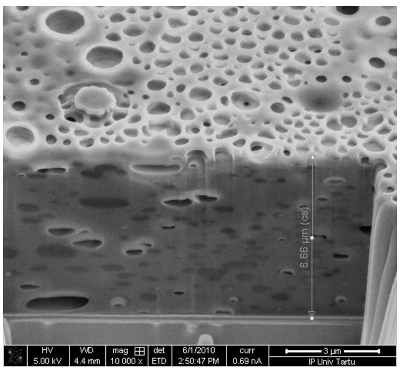

Fig. 1. SEM image of a cross section of GDLC film