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THE STUDY OF BATIO3 NANOPARTCLES EFFECT ON THRESHOLD PROPERTIES OF LIQUID CRYSTAL 5CB

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Abstract: *By using the volt-farad characteristics the influence of BaTiO3 nanoparticles on the threshold voltage of the planar-hometrop transition in nematic liquid crystal 4-pentil 4-sianobifenil (5CB) has been studied. It was belived that when the BaTiO3 nanoparticles are added to 5CB the planar-hometrop transition appears in two stages: at* $U_{th1} = 0{,}4V$ *the weak transition and at* $U_{th2} = 2V$ *the strong transition takes place. Besides the decreasing of capacitance of the cell with liquid crystal dopped by BaTiO3 nanoparticles is observed at voltages exceeding 6 V.*

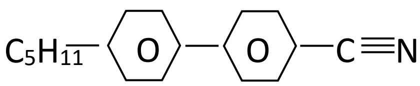
KEYWORDS: Batio3 Nanopartcles, Threshold, Liquid Crystal 5cb, Cell

INTRODUCTİON

Liquid crystals due to their uncial features and properties have wide application in various fields, namely, device manufacturing areas[1-4]. It should be emphasized their main application is in the field of liquid crystal displays. Contemporary devices using these kinds of displayers including computers, notebooks, mobile telephones have lowest dimension and weight. Based on this technology we now have low-weight light modulator due to fast electro optic effect occurring in liquid crystals. Non-stop progresses in technologies also require continuous improvement in characteristics of such devices. One way to achieve such improvement is the synthesis of liquid crystals materials with enhanced parameters. The other way is to combine the properties of liquid crystals with other functional materials in a constructive way. To do this one either should disperse liquid crystals in another medium (for example polymers dispersed liquid crystals) or disperse it with different types of particles (ferromagnetic particles, polymer particles etc)[5]. In the case of submicron dimensions (ferromagnetic or ferroelectric nanoparticles, carbon nanotubes etc.) it is possible to observe more interesting effects because of the fact that these sizes could be compared with size of singularity of director field[3,6]. In the present work, the effects of BaTiO3 nanoparticles on electro-optic features of of 4-penthyl 4-cyanobiphenyl (5CB) nematic liquid crystals threshold properties has been studied.

Eksperiment

In this experiment the widely used nematic liquid crystal 4-pentil 4-cyanobiphenyl (5CB)

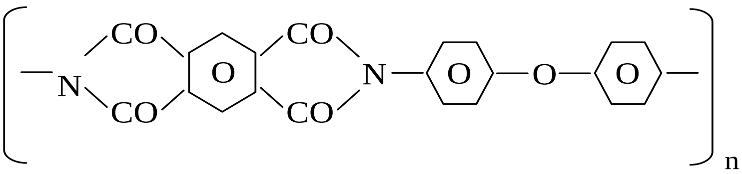


has is been used. This material has nematic phase in 22 ^oC - 36 ^oC temperatur interval and has high positive dielectric anisotropy: $\varepsilon_{u} = 19{,}5,\ \varepsilon_{\perp} = 6{,}7,\ \Delta\varepsilon = \varepsilon_{u} - \varepsilon_{\perp} = +12{,}8$. The material parameters for this crystal could be found from lots of monographs[7].

Barium titanat is a ferroelectric material with high spontaneous polarization ($P_S = 0{,}26\ Kl/m^2$ at room temperature) and its Curie temperature is 120 ^oC[8,9]. BaTiO3 nanoparticles lose their ferroelectric properties in scales smaller than 100 *nm*.

In our experiment the $BaTiO_3$ nanoparticles with average size of 600 nm has been used. Dispersion of these nanoparticles in liquid crystal is carried out under the known technology[10]. BaTiO3 nanoparticles, oleic acid and heptane are solved in weight ratio of 1:2:10. For 10 minutes and under the effect of ultrasound shaker, the nanoparticles uniformly distributed in the system and then stabilized. The resulting colloid system was mixed with nematic liquid crystal by this means that the ratio of BaTiO3 nanoparticles and 5CB is 1: 99. The obtained solution is kept at temperature 60 ^oC for a day to achieve the full evaporation of heptane.

The electro-optic and dielectric properties of the liquid crystal are measured in electro-optic cell. The electro-optic cell has layered sandwiched structure and consist of two parallel glass plates separated by teflon film. The internal surfaces of glasses are covered by transparent and conductive layer of ITO. To get a planar orientation (liquid crystal molecules are parallel to surfaces) a thin layer of aligning material is surfaced over the conductor layer. In this experiment the well-known polyimide[11]



has been used because of coating technology of polyimide is well established. The polyimide firstly is solved in dimethylacetamide (5% solution) and then screened through a glass filter with 16 μm pore size. A drop of resulting solution then is laid out on a glass plate with transparent ITO layer and the plate is rotated in a centrifuge machine with frequency 50 sec^{-1} in order to get uniform thickness. Then the glass plate is placed into drying camera with 300^{o}C for a 30 minutes (for full evaporation of heptane). After this thermic treatment (polymerization) step, the uniform polyimide layer is achieved. Finally, the surface of the substrate is rubbed with a soft piece of cloth in one direction. The resulting microgrooves remove the degeneracy in the surface and the homogenous planar orientation of liquid crystal (Chatelain method) is attained.

The thickness of the liquid crystal layer in the electro-optic cell was assigned by a teflon insulator and is calculated exactly from the electric capacity of empty cell:

$$d = \frac{\varepsilon_0 S}{C_0}$$

Here, $\varepsilon_0 = 8{,}85\ pF/m$ is the electric constant, S is the area of electro-optical cell and C_o is the electric capacitance of empty cell. The accuracy of measurement for thickness is about

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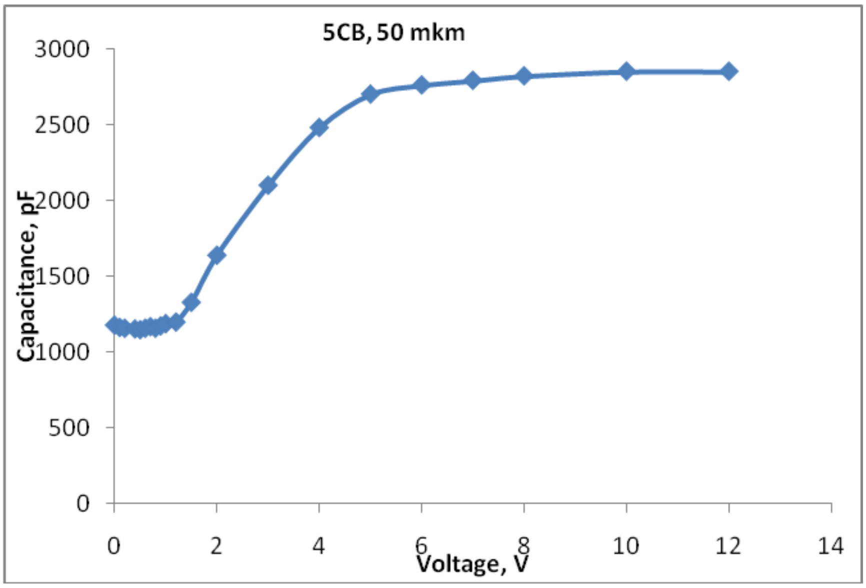
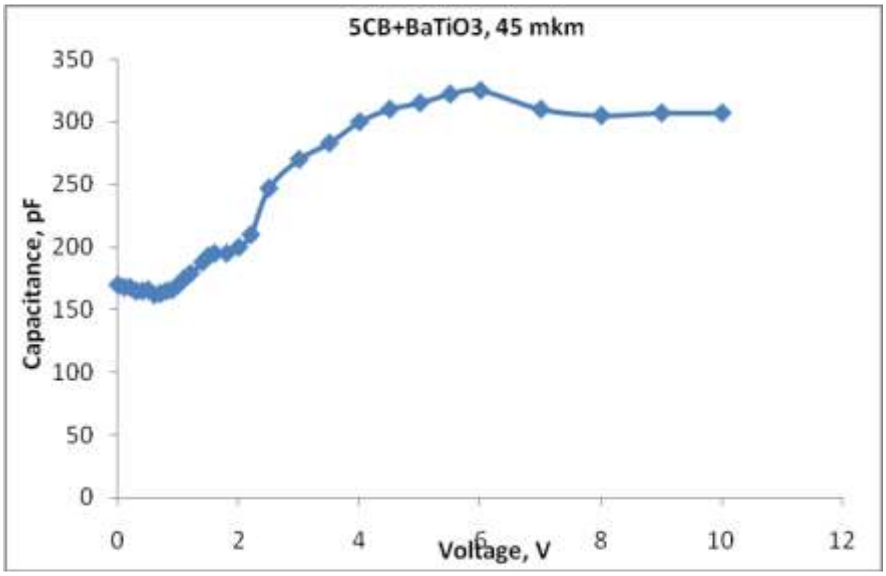
0.5 μm. The homogeneity of thickness is achieved by pinning of glass plates in 4 points via removing of interference pattern. The process of filling of electro-optic cell is carried out in an isotropic phase of liquid crystal by capillary method.

One of the important parameters for liquid crystal displays and light modulators from application point of view is the threshold voltage U_{th}. This parameter could be derived from the voltage dependence of cell capacity (volt-farad characteristics). The electro-optic effect changes the effective dielectric permittivity of liquid crystal and this reflects in the change of electrical capacity of electro-optic cell. The electro-optic effect in liquid crystal 5CB is the planar-homeotropic transition due to positive dielectric anisotropy of 5CB. In this transition As a result of increase of effective dielectric permittivity of liquid crystal the electric capacity of the electro-optic cell. As the threshold voltage is taken the voltage from which the capacitance starts grow up.

As seen from volt-farad characteristic as a result of planar-homeotrop transition the electric capacity increases $\frac{C_{\max}}{C_{\min}} = \frac{2850}{1150} \approx 2{,}5$ time for electro-optic cell with pure 5CB and $\frac{C_{\max}}{C_{\min}} = \frac{325}{165} \approx 2$ time for for electro-optic cell with 5CB+$BaTiO_3$ that are sufficiantly lower than the expected value $\frac{\varepsilon_{II}}{\varepsilon_{\perp}} = \frac{19{,}5}{6{,}7} \approx 2{,}9$.



(Fig 1, volt-farad characteristics of electrooptic cell containg 5CB).



(Fig 2, volt-farad characteristics of electrooptic cell containg 5CB+$BaTiO_3$).

Experimental Results

In figures 1 and 2 the volt-farad characteristic of electro-optic cells with pure 5CB and composite 5CB + BaTiO3 nanopartciles, respectively, are presented.

As we see the elctric capacity increasing of the cell with pure liquid crsytal starts at U_{th}=1.2 V. As mentioned above this is related to the increase of effective dielectric permittivity as the result of transition of liquid crystal from planar to homeotropic orientation. Adding of BaTiO3 nanoparticles to liquid crystal cause the important changes of volt-farady chracteristics. Starting from U_{th1}=0.4 V, the capacity increase weakly and from U_{th2}=2 V it starts to increase strongly. In addition, for composite of liquid crystals and BaTiO3 nanoparticles, the capacity slightly decreases starting from 6 V.

Discussions

The threshold voltage of planar-homeotropic transition for liquid crystal with positive dielectric anisotropy for the case of strong anchoring of liquid crystal molecules to the surface could be defined by the formula:

$$U_{th} = \pi \sqrt{\frac{K_{11}}{\Delta\varepsilon\varepsilon_0}}$$

K_{11} is the splay elastic constant of liquid crystal, $\varepsilon_0 = 8{,}85\, pF / m$ is the electric constant and $\Delta\varepsilon = \varepsilon_{II} - \varepsilon_{\perp}$ is the anisotropy dielectric permittivity. The planar-homeotropic transition initially occurs in the volume (in the middle of the cell) and then spreads towards the surfaces as the electric field increase. In the case of strong anchoring the liquid crystal molecules turns at the surface less than bulk molecules and the obtained final homeotropic orientation is not perfect even at voltages much higher than threshold voltage, so the value of dielectric permittivity $\varepsilon_{II} = 19{,}5$ is found unachievable.

The existence of two threshold voltage for the case of addition of $BaTiO_3$ nanoparticles could be explained as follow. The simplest calculations show that for 1% weight value of $BaTiO_3$ nanoparticles the average distance between $BaTiO_3$ nanoparticles are of order of 10 µm. In the absence of electric field the $BaTiO_3$ particles have polydomain structure (the total spontaneous polarization is zero) and does not disturb the director field of liquid crystal. The application of electric field leads to partial polarization of particles that create their own (local) field. When the voltage applied to electro-optic cell exceeds first threshold voltage U_{th1} the local field changes the orientation of liquid crystal molecules around these particles that sensibly changes the dielectric permittivity of liquid crystal. As the voltage increase the polarized particles changes orientation of the liquid crystal molecules at higher distances and when the applied voltage becomes higher than second threshold voltage U_{th2} the action distance of polarized particles have the same order as distance between them and this causes all the molecules to be aligned perpendicular to the surface in the bulk (homeotropic orientation). This whereas causes the secondary sharp increasing of dielectric permittivity. Two step character of planar- homeotropic transition in the case of $BaTiO_3$ added liquid crystal cell is confirmed by other electro-optic measurements[13]. The reason of slight decrease in capacity at higher voltages could be explained by electro occurrence of hydrodynamic instability. This is proved true by visual observations under polarization microscope (fig 3c).

a) b) c)

200 mkm

Fig 3. The appearance of electro optic effects of liquid crystal with additional BaTiO3 under polarization microscope: a)U=0 initial planar state; b)U=4V homeotrop state;

c)U=8 V electrohydrodynamic instability.

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