Ferroelectric Cholesteric Suspension

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Abstract

We developed a new cholesteric material for bistable LCDs. The material consists of dispersion of sub-micron ferroelectric particles in cholesteric host. We found that the doping of the cholesteric with ferroelectric particles in small concentration (< 1% by weight) strongly improved basic characteristics of the transition between poly-domain planar texture and focal conic texture. Decrease of the driving voltage, increase of the reflection contrast and the steepness of the transition is associated with giant steady dipole and dielectric constant of the ferroelectric particles.

1. Introduction

Liquid crystal suspensions possess many properties that make them interesting for research and attractive for a variety of applications. Long-range forces between ultra-fine particles imbedded in liquid crystal (LC) matrices result in intriguing colloids [1-5]. Large (≥ μm) colloidal particles form defects in LC matrices due to strong director deformations. Ensembles of these particles and defects can form complex structures. Small (≤ μm) particles do not significantly perturb the director field and defects do not form. However, if the concentration of small particles is large enough (> 2-3% by weight), even the weak deformations in the director create an almost rigid suspension. We have recently shown that at lower concentrations the diluted suspensions of sub-micron particles in nematic matrix behave as pure LCs possessing unique properties [6]. The sub-micron particles are large enough to maintain their intrinsic properties but small enough to "share" these properties with the LC matrix, like a molecular dopant. The resulting suspension macroscopically appeared similar to a pure nematic with no readily apparent evidence of dissolved particles. However, it possessed enhanced dielectric anisotropy and revealed ferroelectric and paraelectric properties intrinsic to the imbedded nanoparticles. Namely, we found that ferroelectric nematic suspension possessed enhanced dielectric anisotropy and revealed ferroelectric and paraelectric properties intrinsic to the imbedded ferroparticles. These results pointed to astonishing possibility to develop a new kind of advanced liquid crystal materials possessing unique and controllable electro-optical properties.

In this paper, we report on the development of suspension of sub-micron ferroelectric particles in cholesteric matrix (*ferroelectric cholesteric suspension*) and present the main characteristics of planar- focal conic transition in this system.

2. Experimental

We used the ferroelectric thiohypodiphosphate ($Sn_2P_2S_6$). At room temperature $Sn_2P_2S_6$ has a spontaneous polarization of 14 μCcm^{-2} parallel to the [101] direction of monoclinic cell and a dielectric constant of $\varepsilon^{ferro} = 350$ [7,8].

We get small ferroelectric particles by milling large particles as opposed to chemical fabrication because we can maintain ferroelectricity even down to 10 nanometer sized particles.[6, 9] Ferroelectric particles of $Sn_2P_2S_6$ (≅1 μm size) was mixed with a solution of oleic acid (surfactant) in heptane in a weight ratio of 1:2:10 respectively. The mixture was ultrasonically dispersed and ground in a vibration mill for 120h. The resulting ferroelectric particle suspension was mixed with the cholesteric matrix BL

119 (Merk). After that heptane was evaporated and the mixture was ultrasonically dispersed for 5 min. The resulting suspension contained ferroparticles (concentration (0.5-1)% by weight) in cholesteric matrix. We estimated the upper limit of the particle size as 0.2 μm using scanning electron microscopy.

The cells with the suspension was filled at elevated temperature $T > T_c$ and cooled down to a room temperature. The cells consisted of two ITO coated glass substrates and calibrated rod-like polymer spacers, 5 μm, controlled cell spacing. Besides the cells with ferroelectric suspension we also prepared the identical cells filled with pure BL 118, with the suspension of aerosil R-812 from Degussa (concentration (0.5-1)% by weight) in BL-118 and with the suspension of polystrene particles from Sekisui (concentration (0.5-1)% by weight) in BL-118.

The produced suspensions were stable during several months. Being in the isotropic phase they scattered a light not strongly as the isotropic phase of pure LC.

3. Results and discussion

We analyzed the LC textures and their changes in an electric field in the polarizing microscope and carried out the measurements of the reflection spectra of the samples.

The photos of the poly-domain planar textures of the ferroelectric suspension and pure cholesteric are shown in Figure 1. The texture of the pure cholesteric looks rather smooth and does not contain evident defects. The planar texture of ferroelectric suspension looks similar to the texture of polymer doped cholesteric [10] and has a micro-grain structure which is caused by poly-domain imperfect planar alignment of the cholesteric spiral. The planar structures of the suspensions of aerosil and polymer particles do not notably differ from the textures of pure cholesteric.

The reflection spectra from the planar textures and focal-conic structures of the suspensions and pure cholesteric are shown in Figure 2. The reflection of the tested light (35°-incidence) from the focal conic domains is much less for the suspension then for the pure cholesteric. In opposite, the poly-domain texture of the suspension reflects more light. As the result, the contrast of the ferroelectric suspension is much better than of the pure cholesteric; the ratio, R, of the reflectance between the textures measured at the maximum of the reflection of the planar texture is 20 for the suspension and $R = 6$ for pure cholesteric. The adding of aerosil and polymer spacers does not lead to improvement of the contrast but make is worse. The reflectance from the planar texture changes a little and the reflectance from the focal conic texture even increases; the ratio $R = 5$ for the aerosil suspension and $R = 4$ for the polymer spacer suspension.

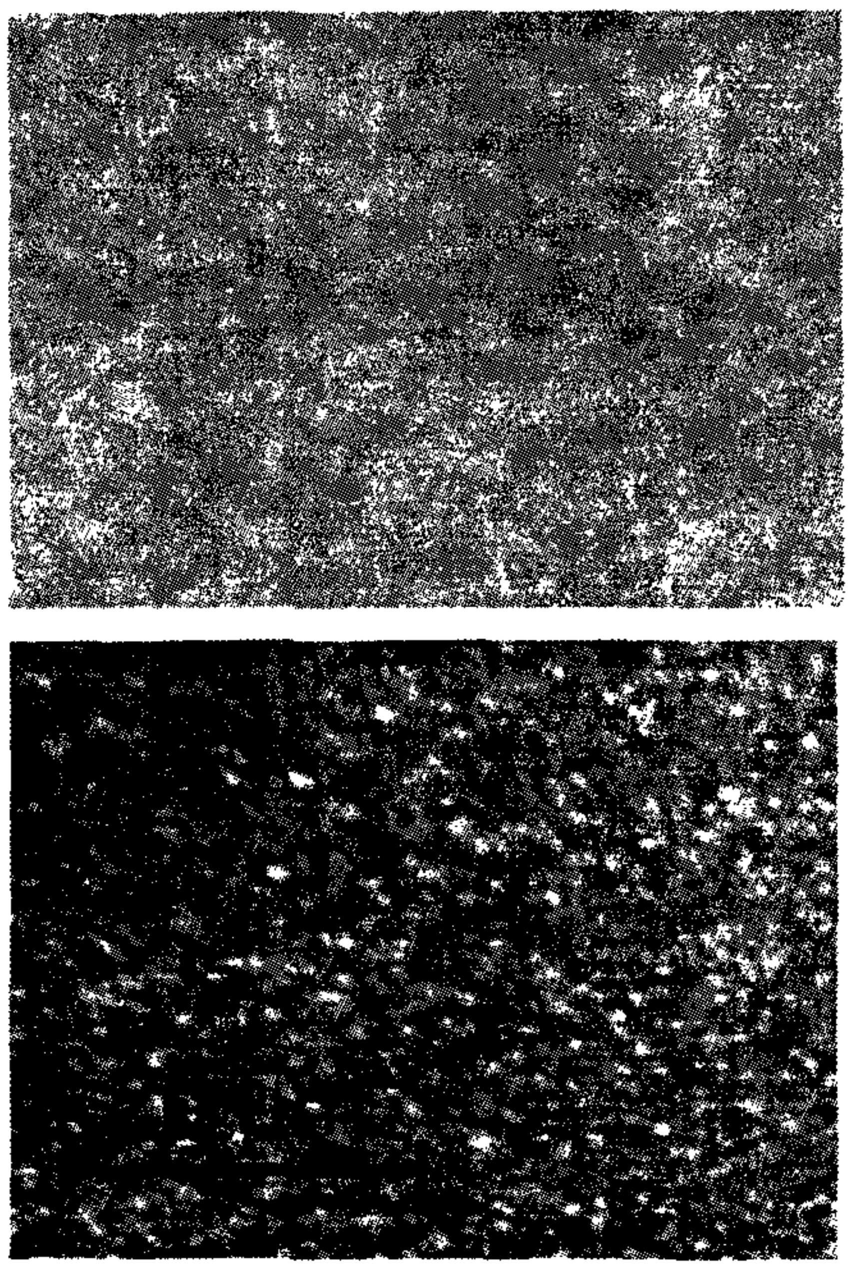

Figure 1. The planar textures of the pure cholesteric (above) and ferroelectric suspension.

We discovered that the ferroparticles, aerosil and polymer spacers all change the bistable electro-optical response of the cholesteric. The measurement setup corresponds to the conventional driving scheme [10]. First, a resetting voltage V_{reset} (1 kHz, 60 = V) during 100 ms was applied to switch the material to the homeotropic stage and reset to the planar texture afterward. After 1 s delay the addressing pulse during 100 ms was applied, and the reflectance of the cell at the 35°-incidence was measured.

The dependence of the cell reflectance on the addressing pulse voltage for pure cholesteric and 1%-suspensions is shown in Figure 3. One can see that ferroelectric particles resulted not only in increase of the reflectivity in a planar state but in increase of the steepness of the planar-focal conic and the reverse transitions. Moreover, adding of the ferroelectric particles leads to the decrease of the voltage of these transitions. The dependence of the reflectance spectra on the concentration of the ferroelectric particles is depicted in Figure 4.

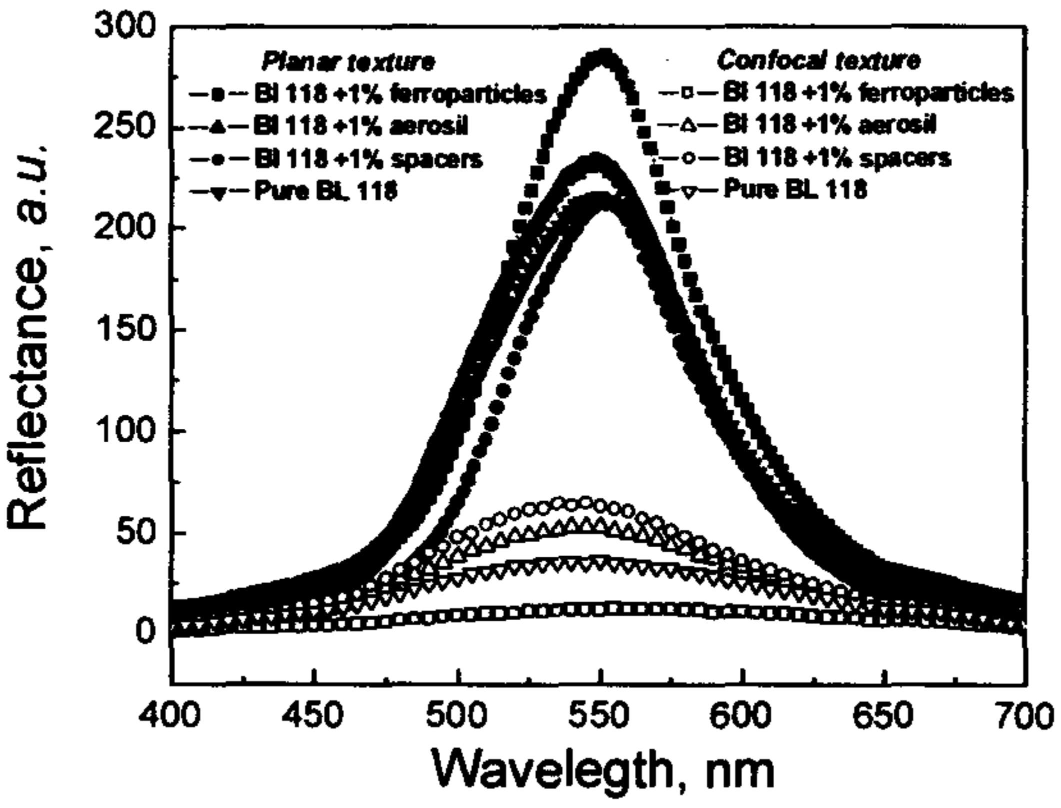

Figure 2. The reflection spectra of the BL-119 and the suspensions.

The aerosil and polymer particles also change the response of the cholesteric to voltage pulses but they do this in opposite way: these inclusions increase the driving voltage and decrease the steepness of the structural transitions (Figures 3,5).

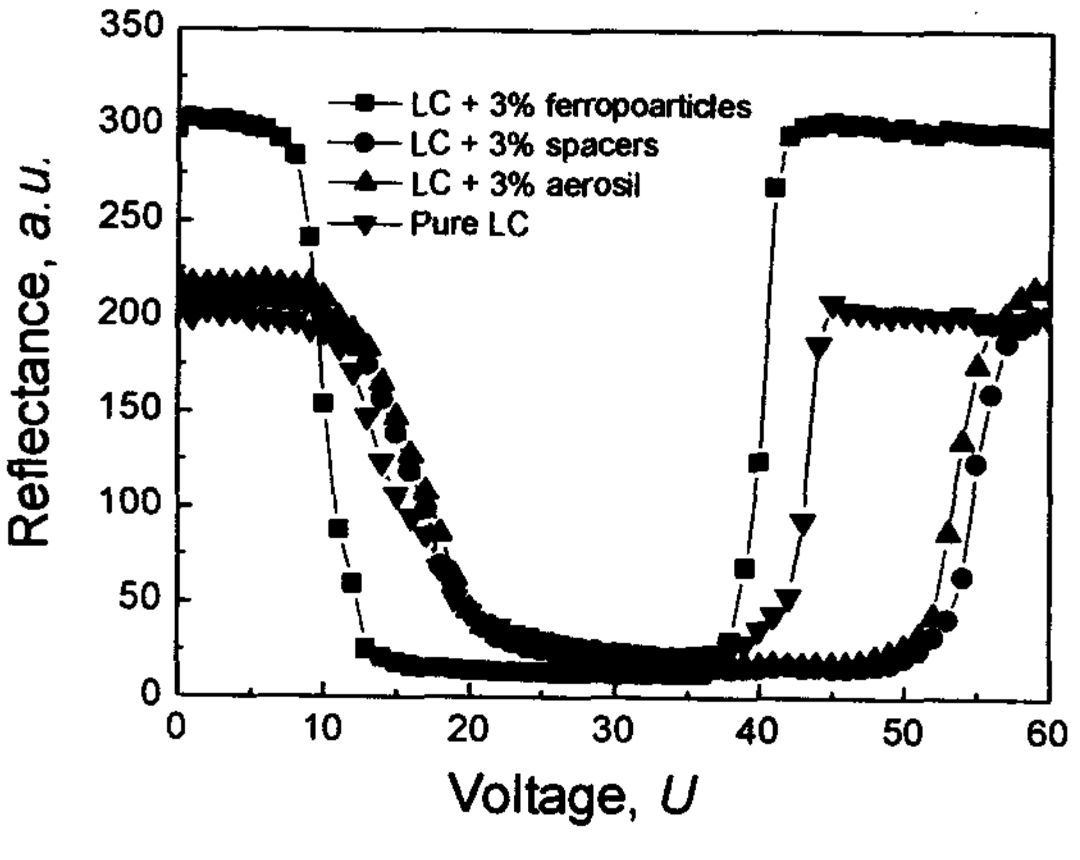

Figure 3. The reflection spectra of the suspensions and pure cholesteric *vs* voltage.

The peculiarities of the electro-optics characteristics of the studied suspensions deserve additional detailed studies. At the present stage we can suggest that the embedding of micron- and submicron particles of different nature (ferroelectrics particles of $Sn_2P_2S_6$, dielectric inorganic silica particles of aerosil and dielectric organic spacer particles) to the cholesteric host changes the electro-controlled balance between planar and focal conic textures of cholesteric LC. These changes can be the result of both anchoring and bulk interaction of the particles with the molecules of cholesteric.

The ferroelectric particles that posses a giant dielectric constant and huge permanent dipole moment, change the balance between textures essentially. The data depicted in Figures 2;4 shows that the ferroelectric particles encourage the formation pure textures – either planar or focal-conic ones. These result in the increase of the reflectivity of the samples in the reflective planar states, decrease of the reflectivity/scattering of the focal conic state, and in the sharpness of the texture transitions. The decrease of the transitions voltage is caused by the enhanced effective dielectric anisotropy of the ferroelectric suspension [6].

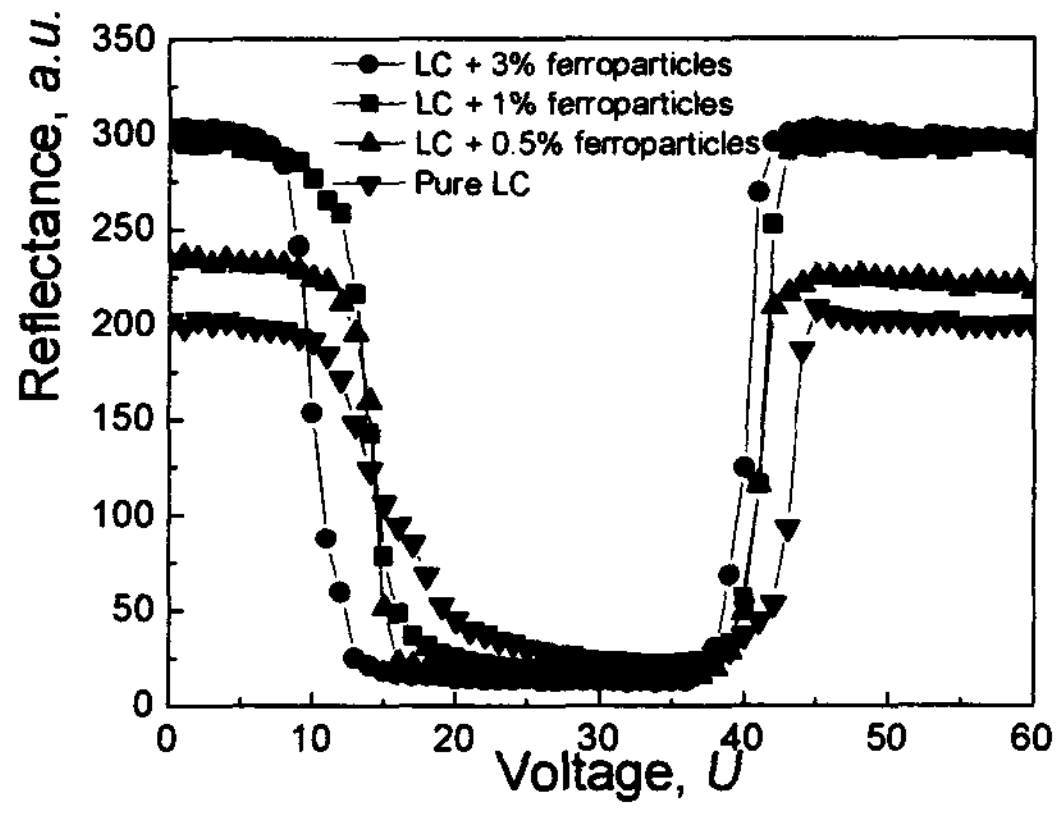

Figure 4. The reflection spectra of the ferroelectric suspension and pure cholesteric *vs* voltage at different concentration of ferroelectric particles.

Dielectric inclusions of the aerosil and polymer spacers work in opposite way; they stabilize both planar and focal conic domains. It leads to less reflectivity of the planar texture and in increase of the reflectivity of the focal conic state where the presence of the weak Bragg reflection from the residual planar domain is evident (see Figure 2). The presence the focal conic texture in the planar texture and vice versa results in decrease of the contrast and increase of the driving voltage (Figures 5,6). At the same time, the stabilization of the complimentary textures leads to the graduate transitions between the bistable states, which we found for 1% suspension of spacer (Figure 5). It makes these systems promising for obtaining gray scale reflection.

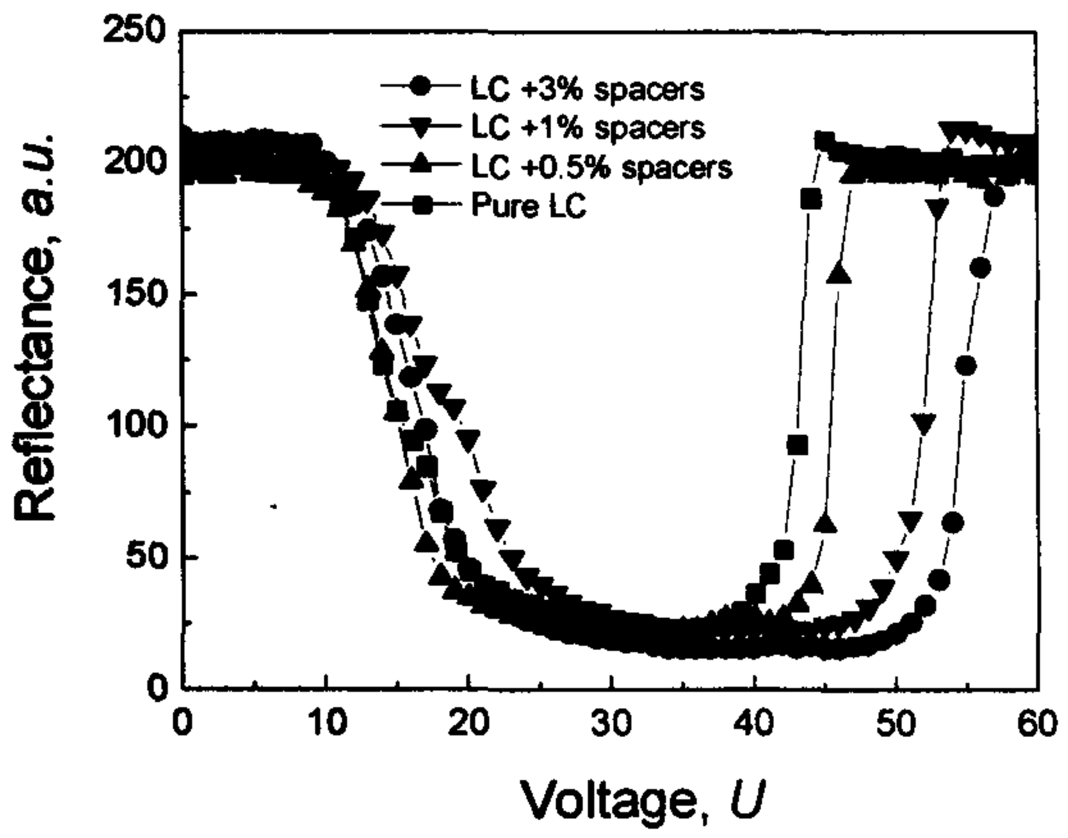

Figure 5. The reflection spectra of the polymer spacers suspension and pure cholesteric *vs* voltage at different concentration of polymer spacer.

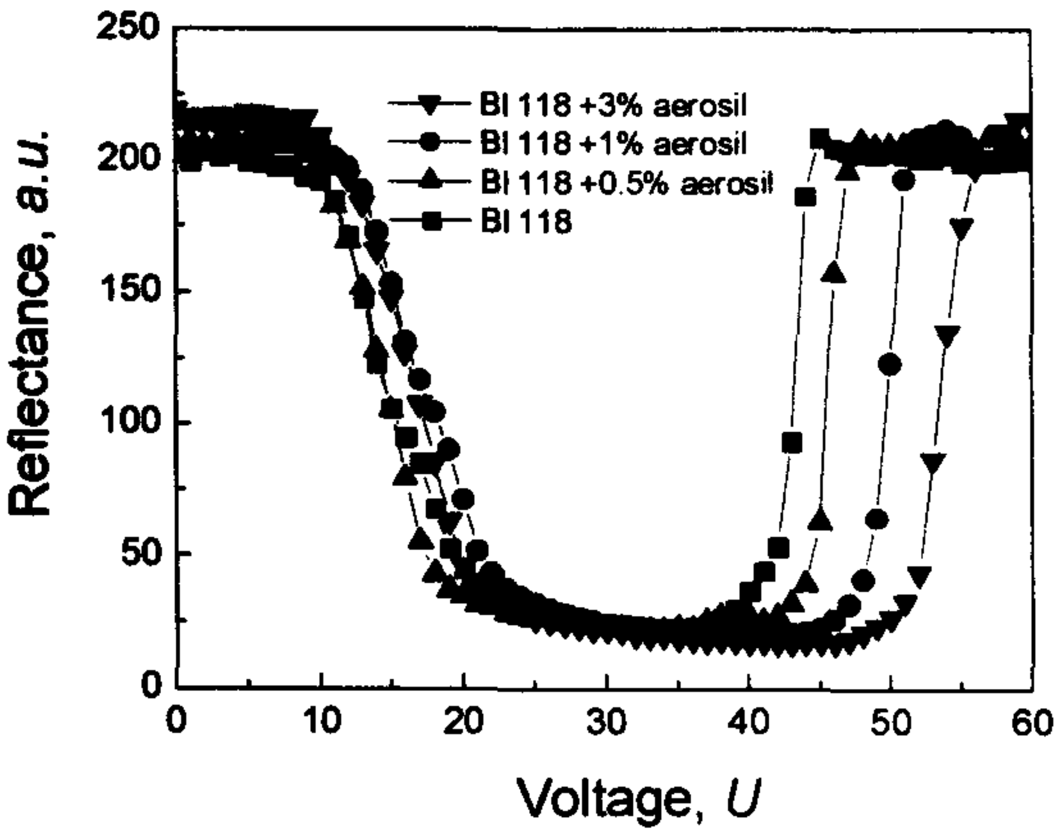

Figure 6. The reflection spectra of the aerosil suspension and pure cholesteric *vs* voltage at different concentration of aerosil.

4. Conclusion

The doping of the cholesteric with ferroelectric particles in small concentration (< 1% by weight) strongly improved basic characteristics of the transition between poly-domain planar texture and focal conic texture. Decrease of the driving voltage, increase of the reflection contrast and the steepness of the transition is associated with giant steady dipole and dielectric constant of the ferroelectric particles.

5. Acknowledgements

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