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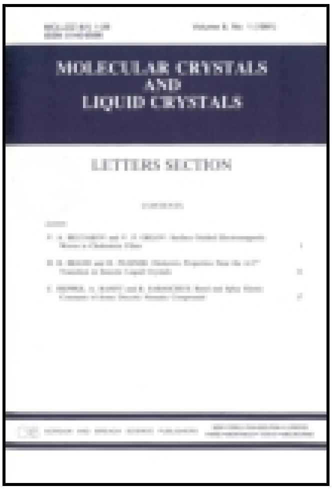

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Response Speed of Polymer-Stabilized Liquid Crystals

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Response Speed of Polymer-Stabilized Liquid Crystals

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Polymer stabilization is an attractive technique because the physical property of liquid crystals can be improved and furthermore the new characteristics may occur. In this study, we try to obtain a high-speed response of nematic liquid crystals by using polymer stabilization technique for realization of the field sequential color. We have researched the dependence of the electrooptical characteristics such as response time and threshold voltage on UV irradiation energy, polymer and liquid crystal materials, and polymer concentration. As a result, it is found that the electrooptical characteristics strongly depend on their conditions.

Keywords liquid crystal; polymer stabilization; response time; threshold voltage; field sequential color

1. Introduction

Currently, color filter (CF) system is used for the color expression of liquid crystal displays (LCDs) which are available in the market. In the CF system, a pixel consists of three sub-pixels with red, green and blue color (RGB). Therefore, the energy efficiency to the incident white light does not exceed 1/3, and the black matrix reduces further the efficiency. Furthermore, in the CF system, the micro-fabrication technique is necessary to divide a pixel into three sub-pixels. On the other hand, the field sequential color (FSC) system is expected for a next generation LCD. The FSC system is based on the temporal color method in which RGB color backlights are turned on sequentially and LC device is used as an optical shutter [1–5]. In comparison to conventional LCDs which use CF, the FSC-LCDs have the following potential advantages since no CF is used: high luminance, low power consumption, high resolution, simplicity of fabrication, and simplicity of the driving circuit. In order to realize the FSC system, the response time of liquid crystal must be less than 1/180 seconds for 1/60 seconds of 1 picture frame. Moreover, for suppressing color brake, the response time should be decreased to sub-millisecond. However, the response time of conventional nematic LCDs is about 10 ms.

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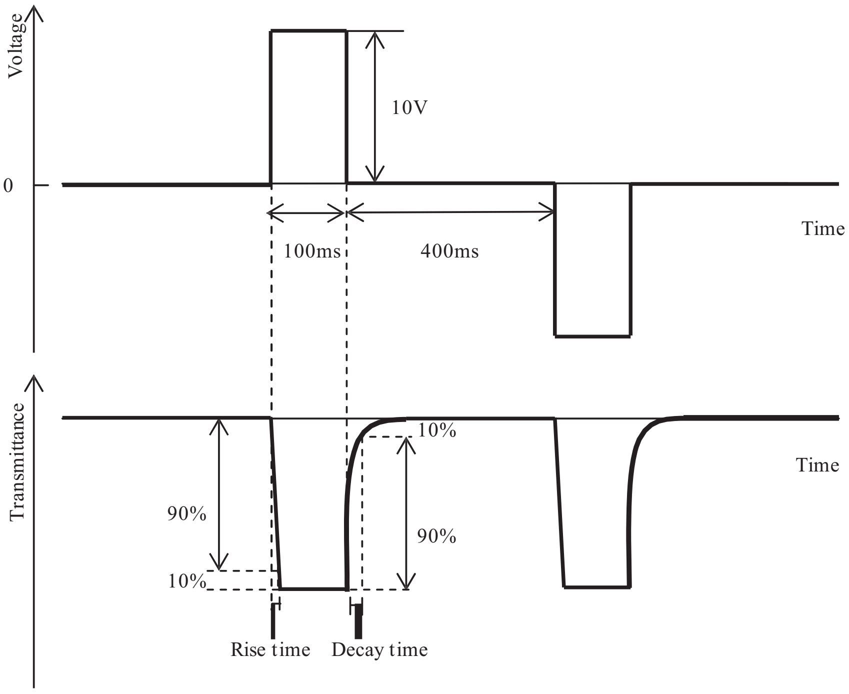

Figure 1. Definition of response time.

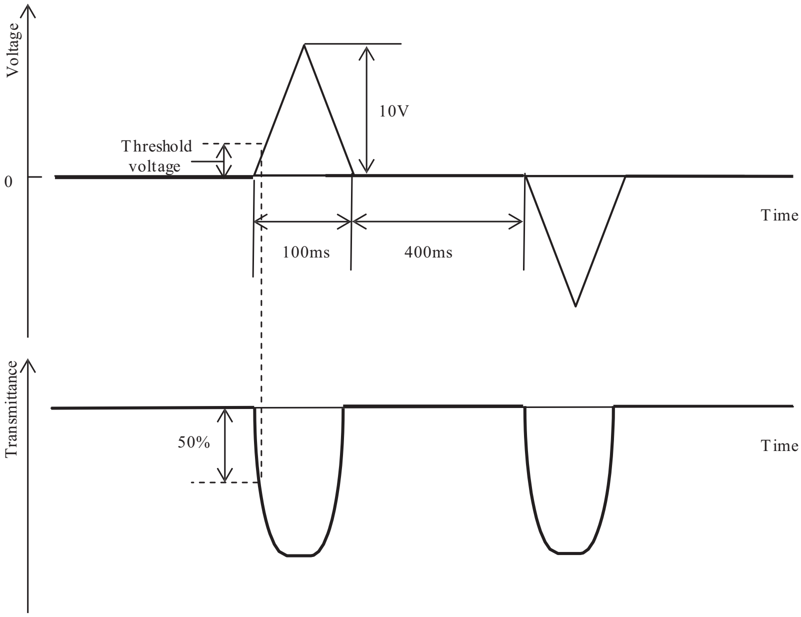

Figure 2. Definition of threshold voltage.

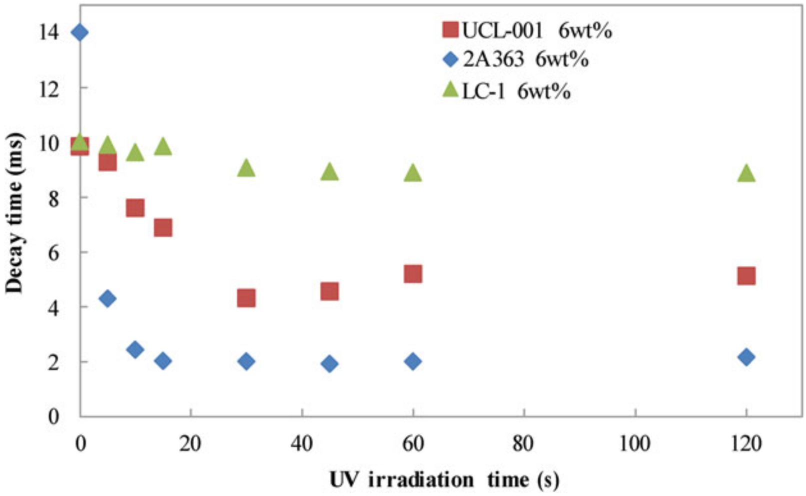

Figure 3. UV irradiation time dependence of t_{decay} (MLC-2062).

In this research, we try to realize a high-speed response of nematic LCs by using a polymer stabilization technique. The polymer stabilization, in which a photocurable mesogenic monomer is doped into a LC medium and a UV photocure is carried out, is an attractive technique because the physical property of LC can be improved and furthermore the new characteristics may occur in terms of the coupling effect between LC molecules and polymer [6–14]. Furthermore, the polymer-stabilized (PS) LC devices have a great potential for flexible large-size LCDs because of the stabilization of the cell gap and the LC molecular alignment structure. In this paper, we mainly focus on the decay response time (t_{decay}) from on-state to off-state of electric field because t_{decay} cannot be controlled by

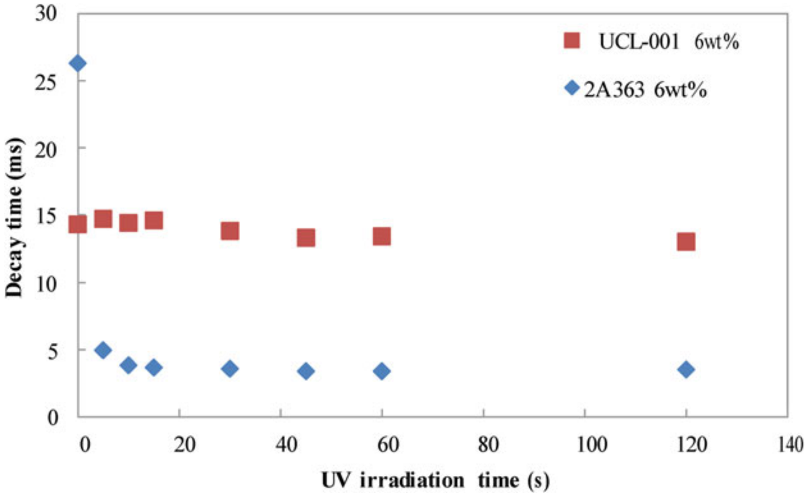

Figure 4. UV irradiation time dependence of t_{decay} (MLC-2058).

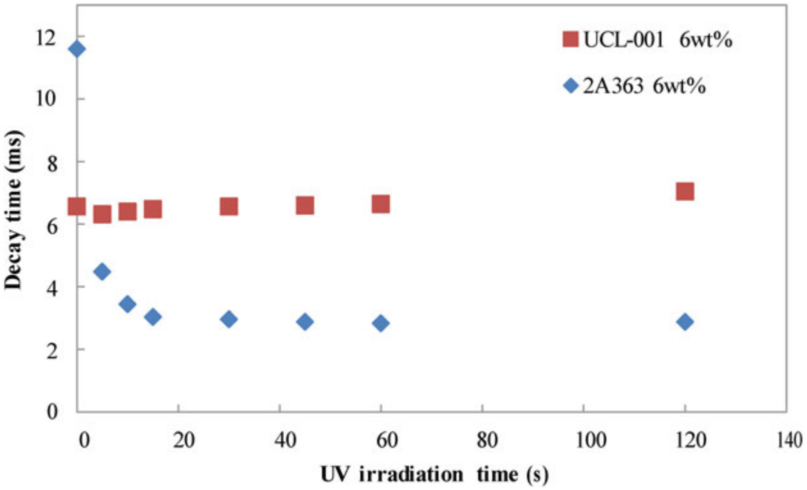

Figure 5. UV irradiation time dependence of t_{decay} (MLC-2141).

electric field though the rise time (t_{rise}) can be. We expect that a high-speed decay response can be obtained by the polymer stabilization of the initial off-state.

2. Experimentals

The materials used in this research were as follows: the nematic LCs were MLC-2062, MLC-2058, and MLC-2141 (Merck); the photocurable mesogenic acrylate monomers were UCL-001, 2A363 (DIC), and LC-1 (Nissan Chemical Industries) which was doped with 1 wt% photoinitiator; and the LC alignment film was polyimide SE-7492 (Nissan Chemical Industries).

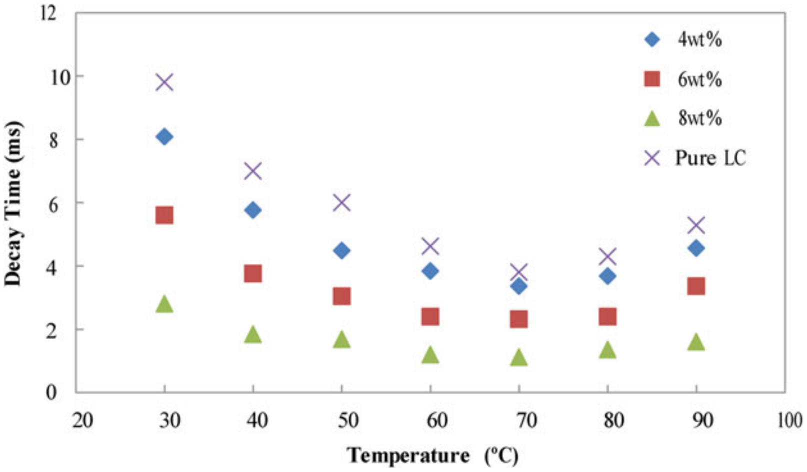

Figure 6. Temperature dependence of t_{decay} (MLC-2062 doped with UCL-001).

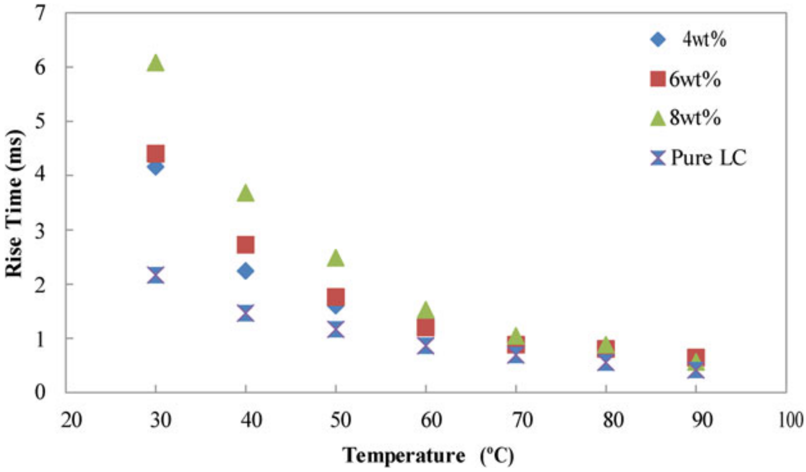

Figure 7. Temperature dependence of t_{rise} (MLC-2062 doped with UCL-001).

We fabricated twisted nematic (TN) LC cells as follows. A solution of polyimide was spun on glass substrates coated with indium-tin oxide (ITO) and then baked. After the thermal treatment, the substrates were rubbed. Then, the nematic LC, which was doped with the photocurable mesogenic monomer, was injected in the isotropic phase via capillary action into an empty cell, in which the rubbing directions and cell gap were set perpendicular and 3 μm, respectively. Next, the cell was cooled gradually to the room temperature. After that, the LC medium was photocured with a UV light source (365 nm, 10 mW/cm^2).

The electrooptical characteristics of PS-TN-LC cells fabricated by above method were measured with a conventional measuring system based on a polarizing microscope. We defined the response time as follows: t_{rise} and t_{decay} are time for 90% transmittance variation at the on and off states, respectively, as shown in Fig. 1. And we also defined the threshold voltage as the voltage for 50% transmittance variation, as shown in Fig. 2. We investigated

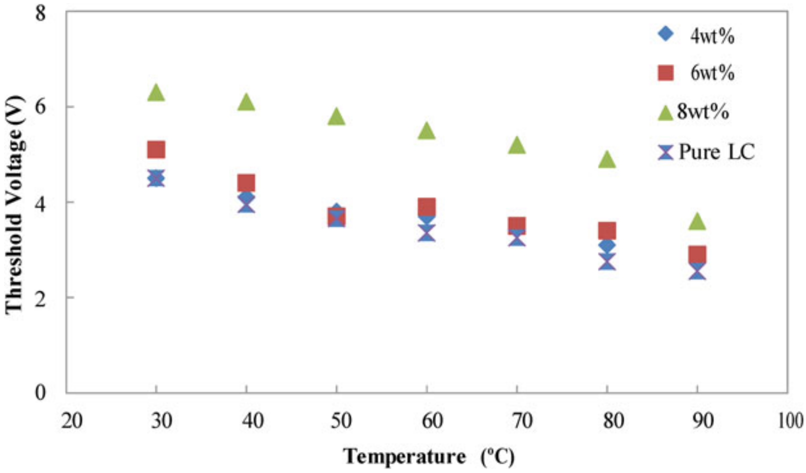

Figure 8. Temperature dependence of threshold voltage (MLC-2062 doped with UCL-001).

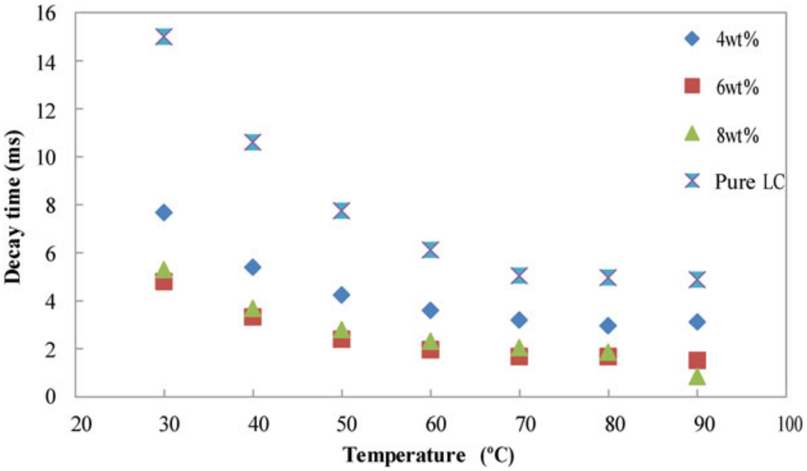

Figure 9. Temperature dependence of t_{decay} (MLC-2058 doped with 2A363).

the dependence of the electrooptical characteristics on the fabricating conditions of PS-LCs such as UV energy, polymer and LC materials, and polymer concentration.

3. Results and Discussion

Figure 3 shows the UV irradiation time dependence of t_{decay} (MLC-2062) measured with a bipolar pulsed AC voltage shown in Fig. 1 at 30°C. The PS-TN-LC cell used was fabricated with 6 wt% monomer concentration and photocure at 30°C. It is found that t_{decay} is almost constant after 30 s UV irradiation, and strongly depends on monomer materials. The t_{decay} of PS-TN-LC cell fabricated using 2A363 is shortest of monomer materials used. This is because 2A363 is diacrylate and thus, forms relatively rigid polymer networks. On the other hand, in the case of LC-1, t_{decay} is not almost varied. This is because LC-1 is monoacrylate

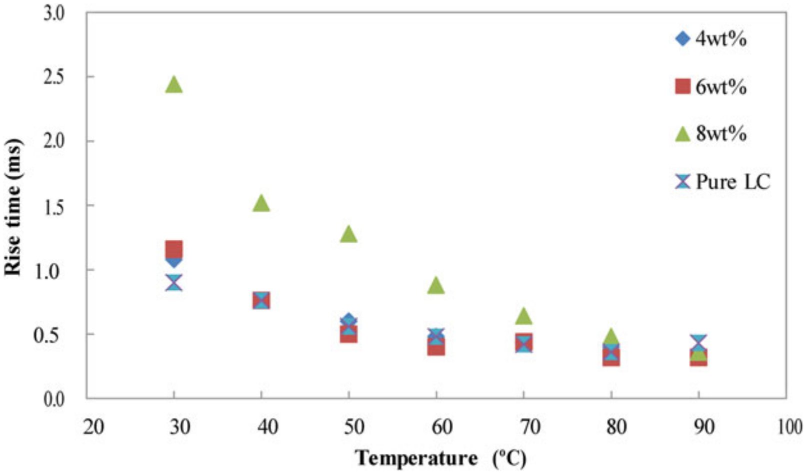

Figure 10. Temperature dependence of t_{rise} (MLC-2058 doped with 2A363).

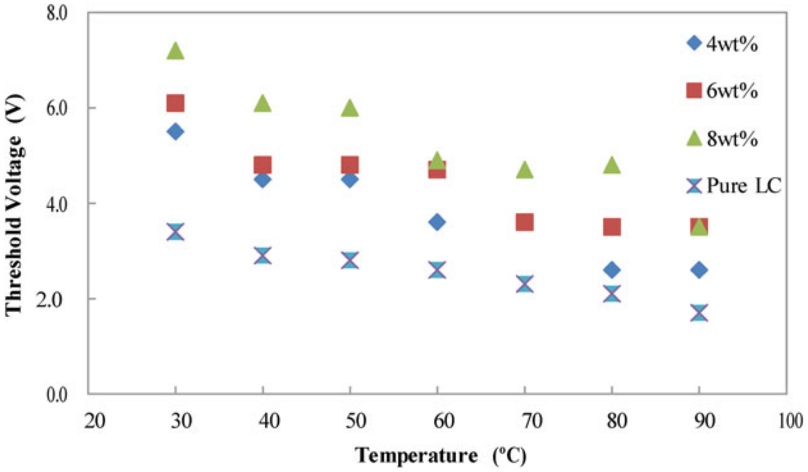

Figure 11. Temperature dependence of threshold voltage (MLC-2058 doped with 2A363).

and has a flexible alkyl spacer between the polymer main chains and mesogenic side chains. Therefore, the kind of polymer materials is a very important factor for realizing the high-speed response of PS-LC. Figures 4 and 5 show the UV irradiation time dependence of t_{decay} in MLC-2058 and MLC-2141, respectively. It is found that t_{decay} is not almost varied even in the case of UCL-001 which is monoacrylate without alkyl spacer. Furthermore, it is found that the shortest t_{decay} can be obtained in MLC-2062 dopd with 2A363 (2 ms, as shown in Fig. 3). Therefore, the combination of LC and polymer materials is also a very important factor.

Figure 6 shows the temperature dependence of t_{decay} in the PS-TN-LC cell (MLC-2062 doped with UCL-001) fabricated by 30 s photocure at 30°C. It is found that the higher the concentration of polymer is, the faster the decay response speed is. It is thought that the polymer networks can strongly stabilize the initial off-state LC molecular alignment

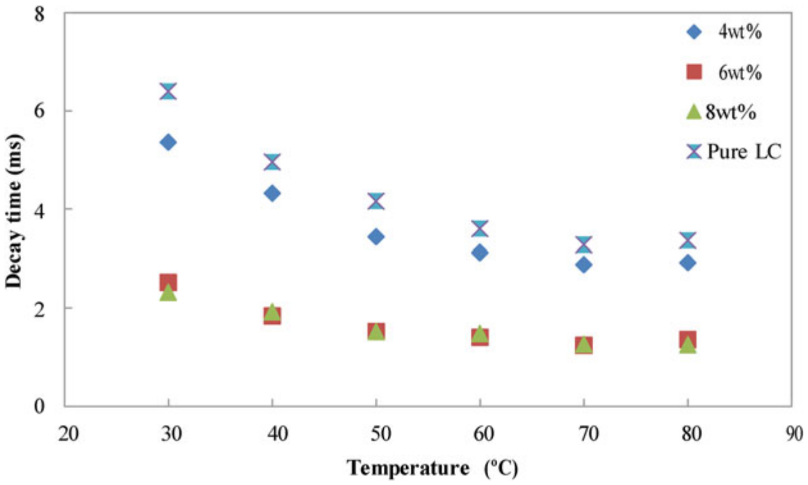

Figure 12. Temperature dependence of t_{decay} (MLC-2141 doped with 2A363).

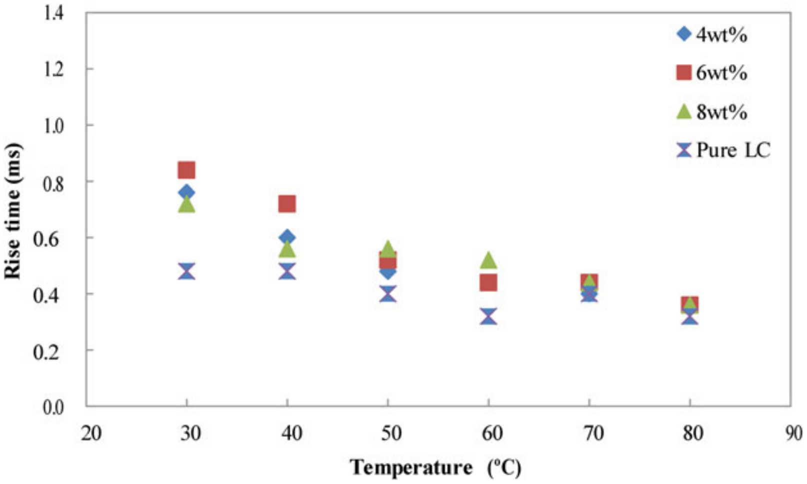

Figure 13. Temperature dependence of threshold voltage (MLC-2141 doped with 2A363).

structure and then the high-speed decay response can be obtained. On the other hand, it is found that the higher the concentration of polymer is, the higher the t_{rise} and the threshold voltage are, as shown in Figs. 7 and 8, respectively. Since the polymer networks stabilize the initial off-state LC alignment, the threshold voltage and t_{rise} may increase due to the polymer stabilization. Therefore, there exists basically the trade-off relation between t_{decay} and them. The measurement results in the case of MLC-2058 and MLC-2141 doped with 2A363 are shown in Figs. 9–11 and Figs. 12–14, respectively. It is confirmed that the higher the polymer concentration is, the lower the t_{decay} is but the higher the t_{rise} and the threshold voltage are. Thus, it is important to select an appropriate polymer concentration for the fabrication of available LC displays.

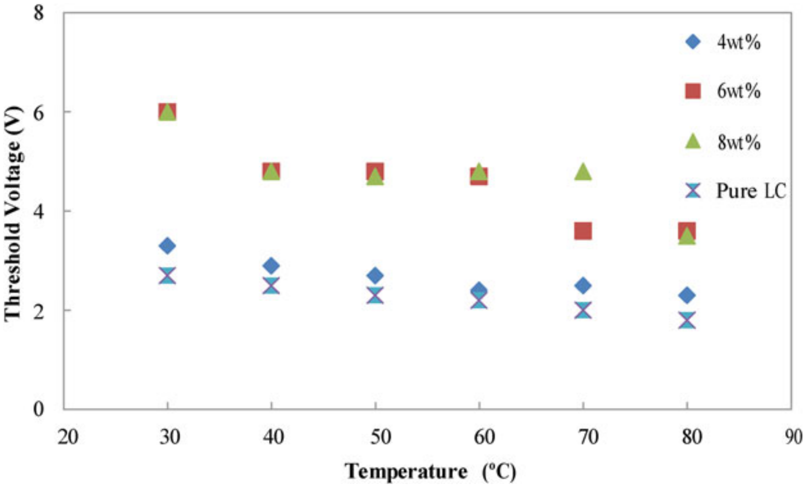

Figure 14. Temperature dependence of threshold voltage (MLC-2141 doped with 2A363).

4. Conclusions

In this research, we tried to obtain a high-speed response of nematic liquid crystals by using polymer stabilization technique for realization of the FSC-LCDs. We researched the dependence of the electrooptical characteristics in PS-TN-LC such as response time and threshold voltage on UV irradiation energy, polymer and LC materials, and polymer concentration. As a result, it was found that the electrooptical characteristics strongly depend on their conditions. The rigid polymer such as 2A363 more strongly effects the characteristics of TN-LC. The t_{decay} decreases as the polymer concentration increases, although the threshold voltage and t_{rise} increases.

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