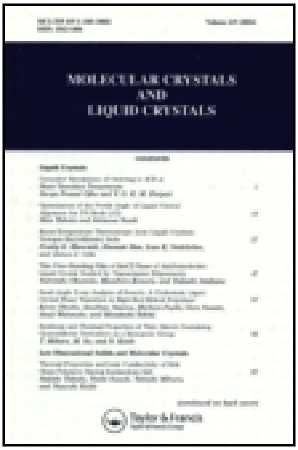

Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Characteristics of Nanoparticle Doped Nematic Liquid Crystals in Low Temperature

K. Miyamoto [a], S. Saito [a], T. Takahashi [a], Y. Toko [b], S. Yokoyama [c], S. Takigawa [c], N. Toshima [d] & S. Kobayashi [e]

[a] Department of Information and Communications Engineering, Kogakuin University, Tokyo, Japan

[b] Stanley Electric Co., Ltd., Kanagawa, Japan

[c] Ube Industries, Ltd., Ube, Yamaguchi, Japan

[d] Advanced Material Institute, Tokyo University of Science, Yamaguchi, Japan

[e] Liquid Crystal Institute, Tokyo University of Science, Yamaguchi, Japan

Version of record first published: 05 Oct 2009

Mol. Cryst. Liq. Cryst., Vol. 507, pp. 108–113, 2009

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400903050285

Characteristics of Nanoparticle Doped Nematic Liquid Crystals in Low Temperature

K. Miyamoto[1], S. Saito[1], T. Takahashi[1], Y. Toko[2], S. Yokoyama[3], S. Takigawa[3], N. Toshima[4], and S. Kobayashi[5]

[1]Department of Information and Communications Engineering, Kogakuin University, Tokyo, Japan
[2]Stanley Electric Co., Ltd., Kanagawa, Japan
[3]Ube Industries, Ltd., Ube, Yamaguchi, Japan
[4]Advanced Material Institute, Tokyo University of Science, Yamaguchi, Japan
[5]Liquid Crystal Institute, Tokyo University of Science, Yamaguchi, Japan

The LC material showing fast response characteristics at a low temperature is needed in the current LCDs. LCDs embedded with metal nanoparticles of Ag/Pd show a short response time by 3 to 5 times compared to those without nanoparticles.

This phenomenon is shown to be attributed to the reduction of rotational viscosity be 70% at room temperature and be 30% at a low temperature (−20°C) and also to the alteration of elastic constants by doping nanoparticles.

Keywords: nanoparticle; nematic liquid crystal; low temperature; rotational viscosity

1. INTRODUCTION

The objective of our present research is to fabricate dot matrix LCDs showing fast electrooptical response particularly at the low temperature, say, at −30°C, that is needed in the current LCDs particularly in the automobile applications, mobile phones, and personal LC-TVs. Our solution to this requirement is to dope metal nanoparticles into the LCD host media using especially synthesized metal nanoparticles that are particularly useful materials for dot matrix LCDs. To this purpose we selected special NLCs for ligand molecules that cover

Address correspondence to K. Miyamoto, Kogakuin University, 2665-1 Nakano-cho, Hachioji, Tokyo 192-0015, Japan. E-mail: cm07045@ns.kogakuin.ac.jp

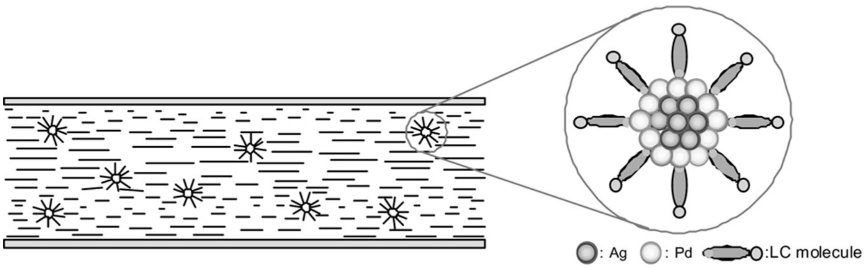

FIGURE 1 Conceptual scheme of STN-LCD doped with metal nanoparticles.

metal nanoparticles and special NLC as a host medium. We research the source of response speedup by measured rotational viscosity of the nanoparticle doped and non-doped LCDs at low temperature.

2. EXPERIMENTALS

2.1. Sample Preparation

Figure 1 shows the conceptual scheme of in an STN-LCD embedded with metal nanoparticle. A mixture of NLC ($\Delta\varepsilon > 0$:DIC) doped with silver and palladium bimetallic nanoparticles was used. STN cell has a 240° twist structure by doping chital molecules (S-811:Merck). The cell has 6 micrometers thickness. As alignment films, a polyimide (Nissan Chem.) of high pretlit are used. Silver (Ag) and palladium (Pd) nanoparticles are covered with 5CB or an NLC mixture that are called ligand molecules.

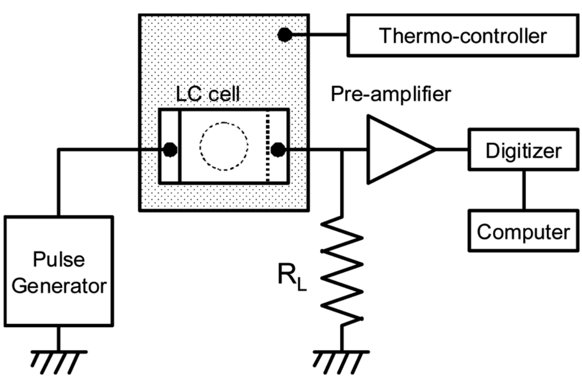

FIGURE 2 Experimental setup for measurement of transient current.

2.2. Experiments

In order to examine the mechanism of the LCs response speed are quickened at low temperature, the rotational viscosity of the NLC doped or non-doped nanoparticle are measured by using the transient current measurement method [1]. The experimental setup for the measurement of transient current is shown in Figure 2.

3. RESULTS

3.1. Electrooptical Performance of STN-LCD Embedded with Metal Nanoparticles

Figure 3 demonstrates how our STN-LCD doped with Ag/Pd metal/ nanoparticles shows fast response speed compared with that without doping nanoparticles [4]. Above 0°C significant difference is observed, however, below 0°C, say, at −30°C, both the rise time (τ_{on}) and the decay time (τ_{off}) become over 3 times shorter in our STN-LCD in comparison with those of an STN-LCD without doping metal nanoparticles.

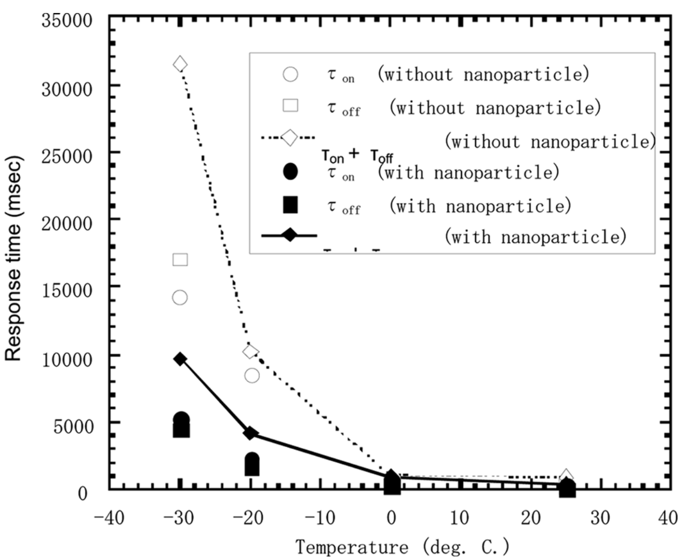

FIGURE 3 Temperature dependence of response time of with and without nanoparticle STN-LCDs.

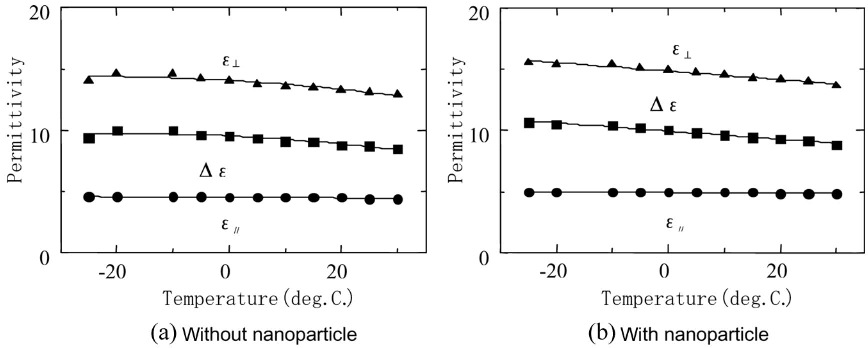

FIGURE 4 Temperature dependence of Δε.

3.2. Measurement of Rotational Viscosity of NLC

At first, we measured the temperature dependence of Δε necessary for the transient current measurement method by with an LCR meter. A vertically aligned cell and a horizontal by aligned cell were fabricated for the measurement of the dielectric constants on the LC with the nanoparticle and without the nanoparticle; with a voltage of 300 mV at a frequency of 1000 Hz. The results are shown in Figure 4.

The typical example of the transient current measurement is shown in Figure 5, where the applied voltage was 25 V.

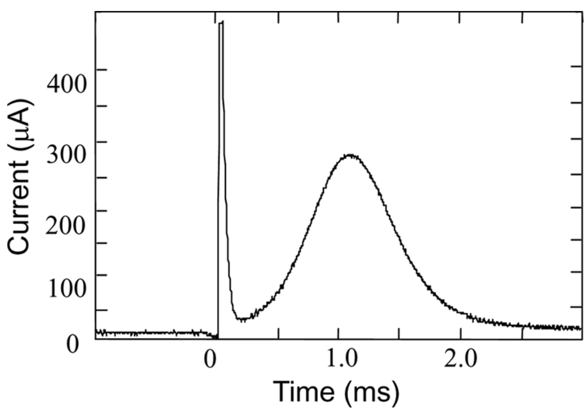

FIGURE 5 Typical example of the transient current measurement (at 25°C, DC:25 V).

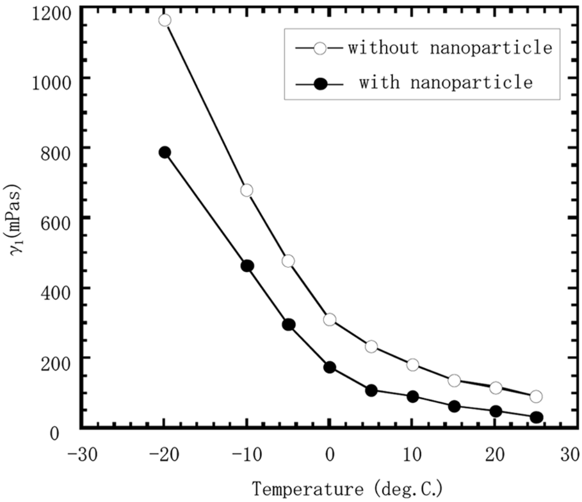

FIGURE 6 Rotational viscosity of LC with or without doping the metal nanoparticles at the various temperatures.

It is possible to measure the rotational viscosity (γ_1) of the LC from the position of broad peak in Figure 5. We used the equation given as

$$\gamma_1 \approx \frac{S(\varepsilon_0 \Delta\varepsilon)^2}{2I_p}\frac{V^3}{d^3}, \quad (V >> V_{th}).$$

Where S is the area of the electrode, V is the amplitude of the applied voltage, d is the cell thickness, L_p is the peak value of measured current, $\Delta\varepsilon$ is the dielectric anisotropy of the LC, and V_{th} is the threshold voltage of the homogeneously oriented LC cell [2,3].

We measured the rotational viscosity of LC with or without containing the metal nanoparticles at the various temperatures, as shown in Figure 6.

From Figure 6, it is found that the rotational viscosity of nanoparticle doped liquid crystal is lower than that of non-doped LC at any temperature. It is known that the response time of STN-LCDs, is proportional to the viscosity of the LC ($\tau \propto \gamma_1$ d^2/π^2K; where d is the cell thickness, K is the elastic constant of LC). It can be consider that the response speed of our nanoparticle doped STN-LCD become faster because of the viscosity of the LC become lower. Through an independent investigation, it is shown that elastic constants are altered by the existence of nanoparticles such that K_{11} decreases, K_{22} remains almost constant, and K_{33} increases [5]; and K_{33} rapidly increases as temperature is lowered. These effects also give an influence for reducing response times.

4. CONCLUSIONS

The measurement of the viscosity was confirmed that the viscosity of the LC became lower at any temperature by doping the metal nanoparticles into the LC. It can be considered that the response speed of LCD become fast by the viscosity of the LC lower by doping the metal nanoparticles to LC and also alteration of elastic constants by doping nanoparticle and their temperature dependence. Fast response speed at very low temperature achieved by our present research may give a great impact to LCD industries such as automobile displays, mobile phones, and mobile LC-TVs that will be operated in a low temperature outdoor condition.

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