New Liquid Crystal Mixtures of Fast Response Time and High Temperature for moving picture on LCD-Device Application

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Abstract

Liquid crystal molecules with a new fluoro-isothiocyanate moiety were synthesized. They showed remarkably high T_{NI} (>190 °C), wide mesophase range of 170 °C, high dielectric anisotropy (>14) and high optical anisotropy (>0.28). New LC Mixtures of the high T_{NI} (>85 °C) was blended with the novel fluoro-isothiocyanate containing LC molecules, phenylcyclohexanes, bicyclohexanes and ester compounds.
The LC mixtures show a fast speed (<10ms) of the below one frame rate in 17" WXGA panel.

1. Introduction

The slow electro-optical response time of LCD panels has been the major roadblock for the LCD market to expand beyond notebook and computer monitors. TFT-LCDs is widely progressed to notebook PCs, monitor, mobile phone or PDA, and so on. Next ambitious target of TFT-LCDs is LCD-TV application. Liquid crystal response time applied to current LC device ranges from 20 to 30 msec. In principle, liquid crystal response time should at least faster than one frame time, 16.7 ms for moving picture. Therefore, final targets in LCD-TV are a fast speed and wide temperature range, low power consumption and a wide viewing angle. These properties are closely related to the physical properties, which depend on molecular structure of liquid crystal materials. In order to achieve the requirements, we developed fluoro-isothiocyanated liquid crystals, which are reported in a variety of peculiar physical properties in comparison with SFMs (super fluorinated materials) [1~2]. They have high nematic-isotropic temperature, wide nematic range, high dielectric anisotropy and high optical anisotropy. The response time depends on pitch of liquid crystal [3].

In this paper we will discuss the physical properties of a new single materials and a new LC mixtures.

2. Experimental

The fluoro-isothiocyanated liquid crystals, which are listed in Table 1, were synthesized through reported references [1~2]. The chemical structures and purities of synthesized materials were confirmed by $^{1}H/^{13}C$-NMR spectroscopy, mass spectroscopy and gas chromatogram. The purities were more than 99.9%. The cell gap was 3.7, 4.2μm, the cell retardation was 0.37μm and the applied voltage for electrooptic properties was 0-5volt at 25°C.

3. Results and Discussion

3.1 Physical properties of liquid crystal molecules

As shown in Table 1, all the homologues of M1~M8

series show remarkably high nematic-isotropic transition temperature (T_{NI}) points (175.3 ~ 237.4 ^{O}C) and wide nematic temperature ranges (up to 169.9 ^{O}C for M3).

Also, in homologous series the thermal stabilities decrease with increasing the number of the fluorine atom substituted in benzene ring, and the nematic ranges shift to lower temperature area. In other words, introducing one fluorine atom induces 10 ~ 25 ^{O}C decrease in T_{NI} points.

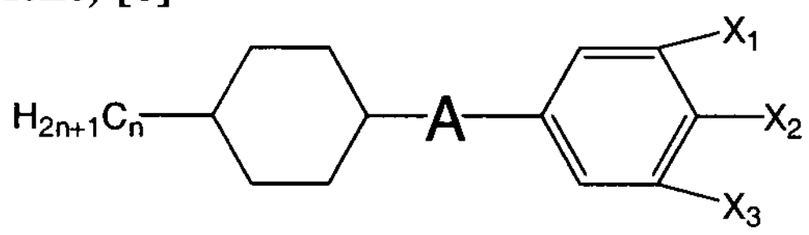
Table 1. The physical properties of synthesized materials

Material Code	T_{CN}	T_{NI}	$\Delta\varepsilon$	Δn
M1	81.5	237.4	11.7	0.198
M2	65.7	215.7	14.1	0.183
M3	56.9	226.8	9.7	0.174
M4	62.9	202.4	12.1	0.199
M5	72.9	189	9.8	0.163
M6	81.1	175.2	14.2	0.169
M7	60.9	186	9.2	0.164
M8	50	175.3	11.1	0.167
M9	29.5	44	8.1	0.151
N1	98	192	12	0.302
N2	109	227	14.7	0.288

*Extrapolated values from 17wt% solution in commercial liquid crystal mixture at 25°C

The thermal stability is strongly influenced by the molecular parameters such as rigidity, length-to-breadth ratio (*l/d*), packing density, polarizability and enhancement of polarity by conjugation. These can rationalize how fluoro-substitution affects on the thermal stability of liquid crystal molecule.

Table 2. The affects of the core group on T_{NI}, dielectric and optical anisotropy values of liquid crystal molecules. (Cy: Cyclohexane, Et: Ethylene) [6]



Core(A)	n	X1	X2	X3	TCN	TNI	$\Delta\varepsilon$	Δn
Cy	3	F	F	F	65	94	8.3	0.073
Cy-Et	3	F	F	F	51	83	7.8	0.069
Phenyl	3	F	F	F	48	52	11.8	0.129

The dielectric and optical anisotropy values of the liquid crystal molecules with a fluoro-isothiocyanate moiety are higher than that of the SFMs [4] and vary according to core, terminal group and alkyl spacer length [5].

As shown in Fig.2 T_{NI} of liquid crystal molecule has the odd-even increasing effect on the length of the alkyl chain. Otherwise, introducing one fluorine atom on X1, X2 induces 20~25 ^{O}C decrease in T_{NI} points [6].

Table 2 has shown that physical properties of liquid crystal molecules have an effected on a core group. The effect of the core group on dielectric and optical anisotropy values of liquid crystal molecules has an increased to according to Cy-Et, Cy, phenyl in core group. But T_{NI} is decreased to according to Cy, Cy-Et, phenyl in core group [6].

Therefore we introduced to phenyl group in core so that increase the dielectric and the optical anisotropy values of liquid crystal molecules relative to Cy-Et, Cy. In other words the optical anisotropy values of N1~N2 was higher than that of the M1~M9. It is induced to pi electron of the LC molecules. Also we assume they have a low viscosity relative to Cy-Et, Cy group.

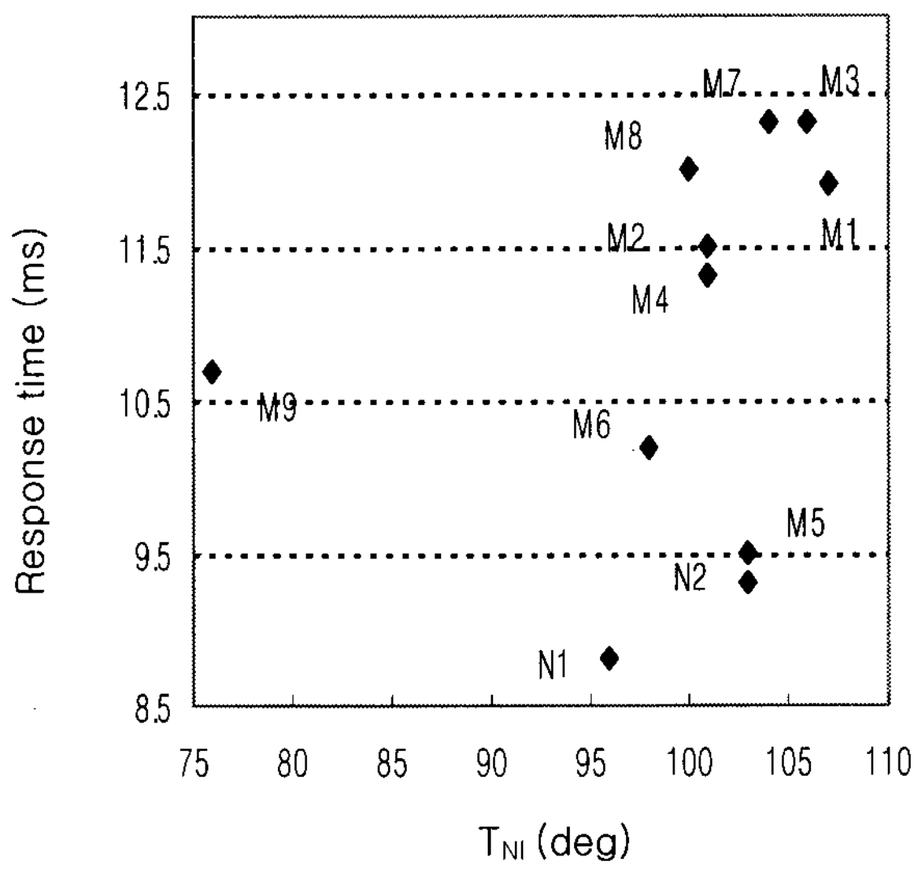


Fig. 2 Relation between T_{NI} and response time of the LC mixture. They were blended single materials (17%) to host mixture

A relationship between nematic isotropic transition temperature (T_{NI}) and response time shown in Fig.2. The new LC mixture manufactured with single key material to host LC mixture. Response time of the new blended LC mixture is increased with an increased in nematic isotropic transition temperature (T_{NI}). They have shown general trend. However, M5, N1 and N2 have shown a high T_{NI} and fast response

time relative to other materials
Host LC mixture have mesophase range of the -25~80 °C, response time of the 16~18ms in test cell. However they have the response time of the 20~25ms in a real panel. Therefore it is not responsible to moving picture. But, the new LC mixture have response time of the 9.5~12.5ms and high T_{NI} of the 95~110 °C except for two ring compounds as key material. These appearances assumed that rotational viscosity to elastic constant of NCS Series have samll relative to Fluoro series compound. Also a New LC molecules (N1, N2) have response time of the 8.5~9.5ms and high T_{NI} of the 95~105 °C. It is assume that pi electron in core group of the LC molecules has effect rotational viscosity.

3.2 Mixture including fluoro-isothiocyanated materials

The physical properties of the new mixture including fluoro-isothiocyanated materials are shown in Table 3.

They have high T_{NI}, fast response time, and suitable threshold and saturation voltage. Fluoro-isothiocyanated materials, phenyl-cyclohexanes, bicyclohexanes and ester compounds were blend for LCD-TV application. In order to improve wide nematic phase range we considered the eutectic temperature from Schroder-van Laar's law.
The new LC Mixture has a fast speed of the below the one frame in 17" panel. That is, SM6 and SM8 have the response time of the 14ms at 3.7μm cell gap. Also NM1 and NM2 have the response time of the 10ms at 4.4μm cell gap. It is responsible to moving picture for LCD-TV, Monitor application.

Table 3. The physical properties of mixture including fluoro-isothiocyanated materials

	SM6	SM8	NM1	NM2
T_{CN}	<-30	<-30	<-30	<-30
T_{NI} (℃)	103	100.5	85	89
Δε	6.2	6.4	6.5	6.3
Δn	0.095	0.103	0.093	0.094
Δnd	0.35	0.38	0.41	0.41
V_{th}	1.5	1.5	1.5	1.5
V_{sat}	2.6	2.6	2.6	2.5

17wxga (ms/μm)	14ms /3.7μm	14ms /3.7μm	-	-
17sxga (ms/μm)	-	-	10ms /4.4μm	10ms /4.4μm

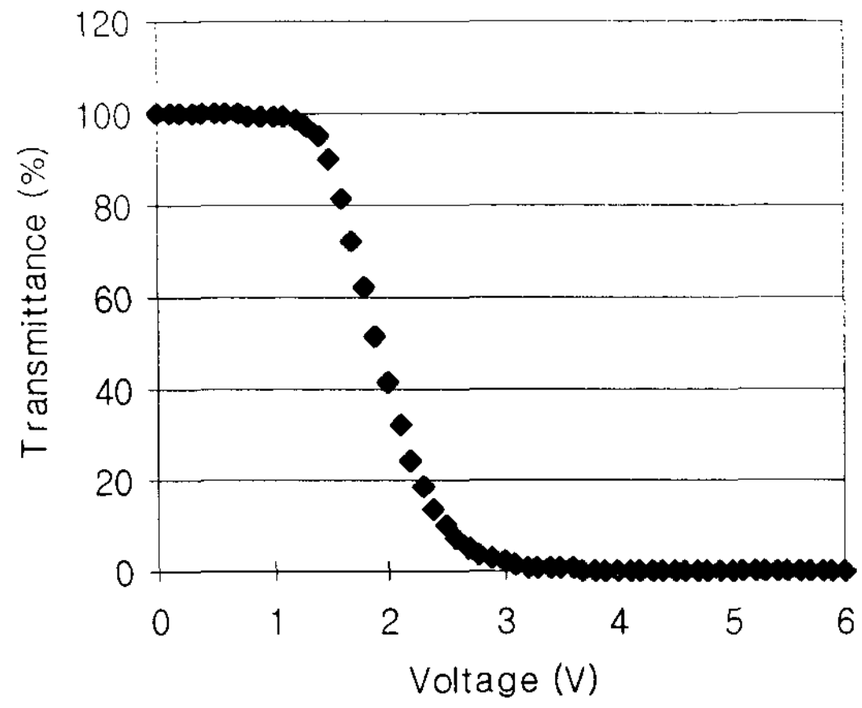


Fig. 3 A relation between transmittance and applied voltage on the new LC mixture.

A relation between transmittance and applied voltage on the new LC mixture has shown in Fig. 3. It has low operating voltage with the new liquid crystal mixture.

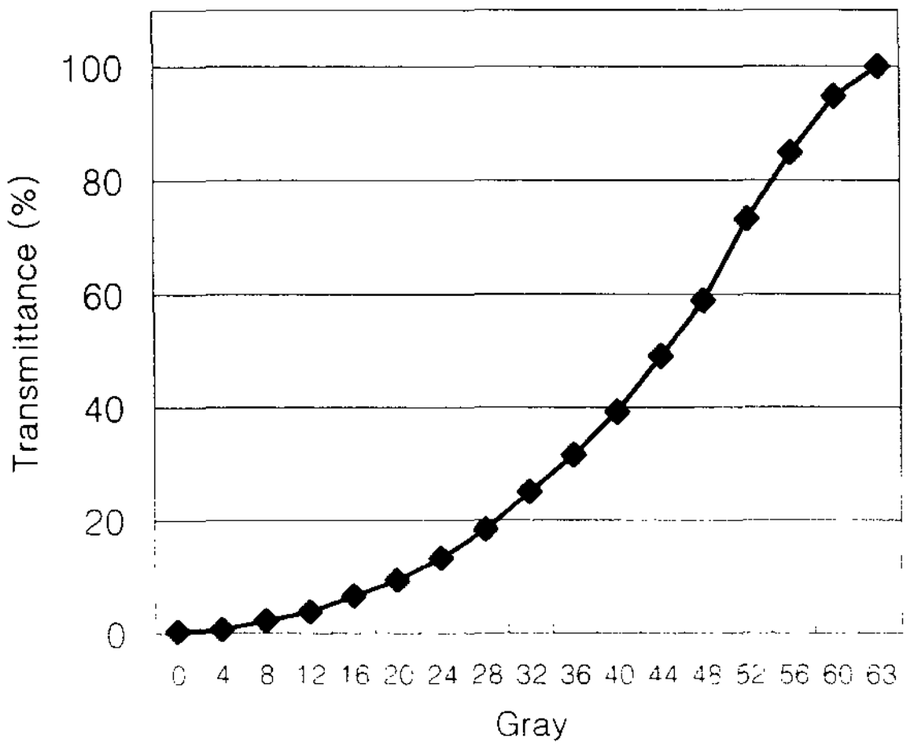


Fig. 4 A relation between transmittance and gray level on the new LC mixture

Also the response time on real panel has an effect on gray level.
A relation between transmittance and gray level on the new LC mixture has shown in Fig. 4

4. Conclusion

A new fluoro-isothiocyanated liquid crystals have remarkable physical properties as wide nematic range, high dielectric and optical anisotropy.
The New LC mixture with a new fluoro-isothiocyanate liquid crystals have wide temperature range of the -30~ 85 °C and fast speed of the about 10ms in 17" real panel.
It is responsible to moving picture for LCD-TV, Monitor application.

5. References

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