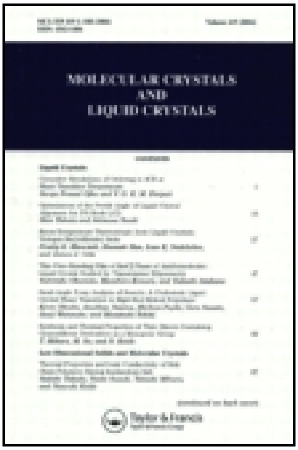

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Physical and Electro-Optical Properties of New Nematic LC Mixtures for Highly Multiplexed TN-Displays

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A set of new, blended nematic liquid crystal mixtures to improve the performance of highly multiplexed TN-displays are presented. The physical and electro-optical properties of new LC mixtures have been investigated, along with the frequency and temperature dependence of threshold voltage about newly developed liquid crystals. The multiplexable mixtures are completely miscible and can be blended, thus leading to new mixtures covering a wide range of threshold voltages $1.2<V_{10}<2.0$ V, nematic-isotropic phase transition temperatures $60<Tc<100$°C, and/or optical anisotropies $0.13<\Delta n<0.18$.

Keywords: liquid crystal mixtures; optical anisotropy; phase transition temperature; threshold voltage

INTRODUCTION

Among various kinds of flat panel displays, LCDs are the leading devices in this field. The performance of LCDs strongly depends on the physical and electro-optic properties of LC mixtures. And the LC mixtures have to be optimized for the different technologies and applications. Modern liquid crystal mixtures for twisted nematic liquid crystal displays (TN-LCDs) [1] almost inevitably consist of components belonging to different liquid crystal classes whose specific physical properties have to be combined such that a desired electro-optical behavior results. The widespread use of twisted nematic liquid crystal displays and the corresponding diversity of display parameters and addressing schemes has led to a demand for nematic liquid crystals with widely differing physical properties. However in a specific application the tolerances of the various material parameters are usually rather narrow. To adjust these parameters it is desirable to have a set of nematic mixtures available which can be blended in arbitrary proportions without damaging their mesomorphic properties. Thus, by blending suitable basic mixtures the physical properties of the blend and hence its electro-optical parameters can be turned precisely. A prerequisite for the development of suitable mixtures is the knowledge of a number of LC-materials, their dependence on molecular structure, and their influence on the static and dynamic electro-optical performance over the operating range of LCDs. For the applications liquid crystal materials having a wide nematic temperature range and a low driving voltage are required. At the same time, to keep the driving voltage at a constant value within operating temperature range of LCDs, temperature dependence of Vth must be minimized. In this paper, we try to show the new liquid crystal mixtures which are blended using various single components, and to mention some improvements of liquid crystal material properties.

EXPERIMENTS

The several representative classes of LC components for the new liquid crystal mixtures are as follows; PCH, ester of Demus, boroxane, NCS, tolan, pyrimidine, and laterally F-substituted compounds (Table 1). The representative examples of developed LC mixtures by blending liquid crystals are tabulated in Table 2. Table 2 shows the properties like nematic-isotropic temperature, optical anisotropy, dielectric anisotropy, and threshold voltage. The electro-optical measurements were made using 90° twisted test cell with 7 μ m cell thickness.

Table 1

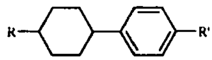
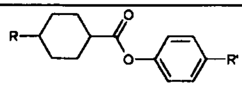
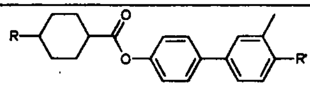
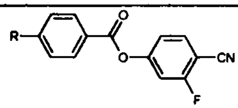
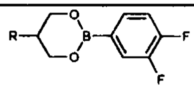
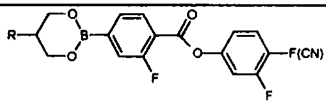
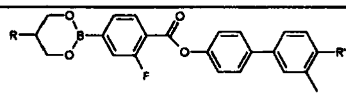
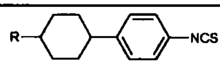
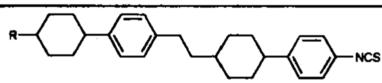
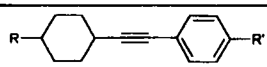
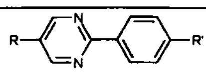
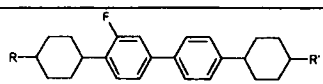
No	Structure	
1		R: C_3H_7, C_5H_{11} R': OC_2H_5, C_3H_7
2		R: C_3H_7, C_5H_{11} R': OC_2H_5, C_3H_7
3		R: C_4H_9 R': C_3H_7, C_5H_{11}
4		R: C_2H_5, C_3H_7
5		R: C_3H_7
6		R: C_5H_{11}
7		R: C_5H_{11} R': C_5H_{11}
8		R: $C_{3\text{-}8}$
9		R: C_6H_{13}
10		R: C_5H_{11}, C_4H_9 R': C_4H_9, O C_2H_5
11		R: $C_{5\text{-}7}$ R: $OC_{5,6,9}$
12		R: C_3, C_5 R: C_5

Table 2.

Mixture	T_{N-I}(°C)	Δn	$\Delta \varepsilon$	V_{10}	V_{50}	N_{max}
A	77.2	0.145	11.01	1.56	1.80	49
B	87.5	0.138	11.95	1.54	1.79	45
C	66.5	0.133	15	1.36	1.58	45
D	73	0.133	11.6	1.63	1.86	58
E	110.7	0.175	20.4	1.36	1.59	42
F	85	0.152	13.82	1.46	1.69	47
G	84.1	0.173	13.68	1.51	1.77	40
H	90	0.150	12.91	1.52	1.76	47
I	90.1	0.15	14.06	1.58	1.85	41
J	67.3	0.157	13.19	1.45	1.69	43

RESULTS AND DISCUSSION

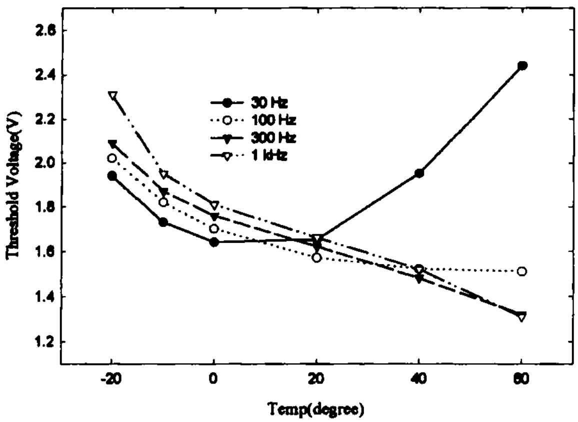
A demand to liquid crystals, which has recently become of increasing importance, is their applicability to TN-displays with high multiplexing rates. High multiplexing rates have as a precondition steep electro-optical characteristics. Theoretical calculations and experimental investigations have shown that the electro-optical characteristics of a TN-LCD become sharper when the ratio of K_{33}/K_{11} of the liquid crystal becomes smaller. On the basis of the very small ratios K_{33}/K_{11} and the broad nematic phase ranges, the alkyl-alkoxy-phenylpyrimidines (11 of Table 1.) are outstandingly suitable for mixtures which can be applied to TN-displays with high multiplexing rates. [2]

To improve nematic mesomorphic range, we have applied the doping by long molecules (three ring or four ring system) for raising of clearing temperature and combination of stable components for a thermodynamically stable mixed system. [3] As dopants for raising the value $\Delta \varepsilon$ and Δn, we have adopted boroxane, NCS and tolan compounds. And we have selected cyclohexyl-phenyl ring and ester of Demus contained LC's as nonpolar components of mixture and added laterally F-substituted four ring contained LC's.

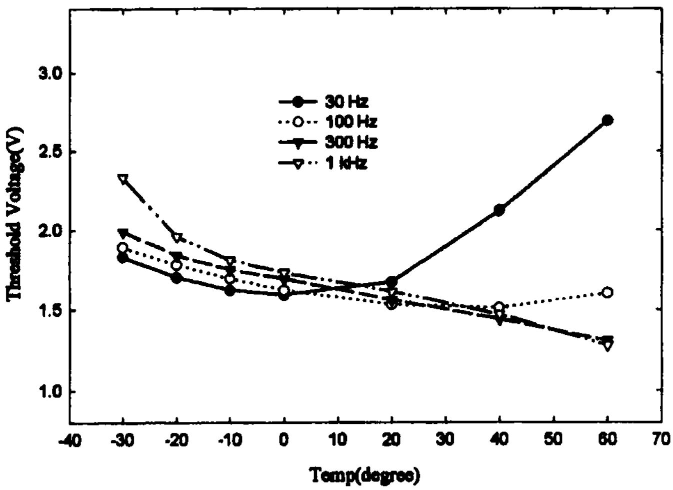
Electro-optical characteristics of the TN-LCD with our mixtures are studied. Figure 1. shows the temperature dependence of the threshold voltage of our developed liquid crystalline materials for various frequencies.[4] To keep the driving voltage at a constant value, temperature dependence of Vth must be minimized. Blending compensated with uncompensated mixtures allows to adjust them to a desired temperature dependence. The liquid crystal mixture having improved temperature dependence could be obtained. For LCD applications we could demonstrate mixtures (D) with improved temperature and frequency dependence of threshold voltage in comparison with A-C mixtures.

Figure 1.

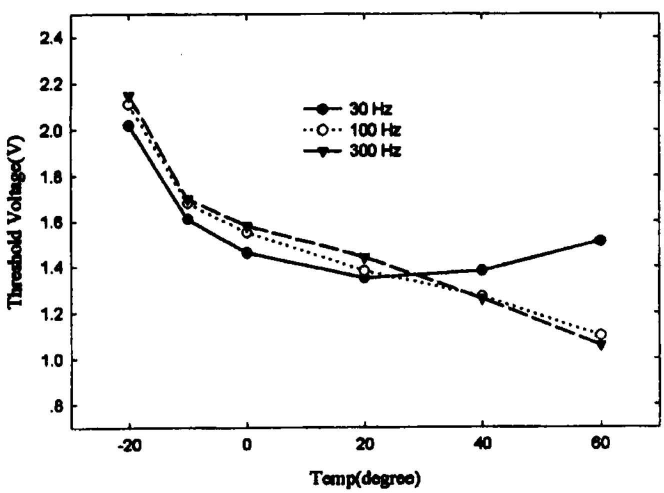
A



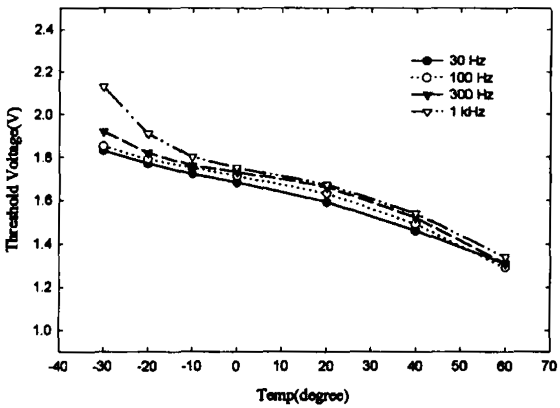
B


30 Hz
100 Hz
300 Hz
1 kHz
Threshold Voltage(V)
Temp(degree)
3.0
2.5
2.0
1.5
1.0
-40
-30
-20
-10
0
10
20
30
40
50
60
70

C


30 Hz
100 Hz
300 Hz
Threshold Voltage(V)
Temp(degree)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
-20
0
20
40
60

D



CONCLUSIONS

We have developed a set of nematic liquid crystal mixtures for twisted nematic displays with distinctly different physical properties. The mixtures are completely miscible and can be blended to cover a wide range of operating voltages, nematic isotropic transition temperatures, dielectric anisotropies and/or optical anisotropies. The newly developed mixtures are useful to improve the temperature dependence of Vth for TN-LCD.

References

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[2] B. S. Scheuble, Japan Display'83, 224 (1983)
[3] K. Toriyama et al. Eurodisplay 31 (1981)
[4] B. Rieger et al. The 5th Merck Liquid Crystal Seminar