Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713926090

Dopant effect on threshold electric field of antiferroelectric liquid crystal switching

K. Murashiro[a]; M. Kikuchi[a]; H. Inoue[a]; M. Fukushima[a]; S. Saito[a]
[a] Research Center, Chisso Petrochemical Corporation, Ichihara, Chiba, Japan

To cite this Article Murashiro, K. , Kikuchi, M. , Inoue, H. , Fukushima, M. and Saito, S.(1993) 'Dopant effect on threshold electric field of antiferroelectric liquid crystal switching', Liquid Crystals, 14: 2, 371 — 380
To link to this Article: DOI: 10.1080/02678299308027652
URL: http://dx.doi.org/10.1080/02678299308027652

LIQUID CRYSTALS, 1993, VOL. 14, NO. 2, 371–380

Dopant effect on threshold electric field of antiferroelectric liquid crystal switching

by K. MURASHIRO*, M. KIKUCHI, H. INOUE, M. FUKUSHIMA and S. SAITO

Research Center, Chisso Petrochemical Corporation, 5-1 Goi Kaigan, Ichihara, Chiba, Japan 290

The influence of dopants on the threshold electric field for switching antiferroelectric liquid crystals was determined from the optical response curve obtained by using a triangular wave. The effect of dopant concentration on the transition temperatures of the mixtures with a host material was also investigated. The threshold electric field was diminished depending on (i) the chemical structure of the additive and (ii) increasing amounts of the additive. The upper limits of the temperature region of the $S^*_{C_A}$ phases also decreased with increasing amount of additive, and these phases disappeared at 40 mol% of additive in all cases. Compound (C) is the most effective with respect to the threshold electric field. It is a two ring compound and has a chiral part similar to that of the host antiferroelectric liquid crystal compound.

1. Introduction

Antiferroelectric liquid crystals are paid much attention as materials which have potential for new liquid crystal displays, and antiferroelectric liquid crystal displays in fact have already been reported [1, 2]. The particular characteristic of an antiferroelectric liquid crystal is its sharp DC threshold and double hysteresis loop [3–6]. The threshold electric field is an important technological parameter in the antiferroelectric liquid crystal switching mode, but there is no report at all concerned with threshold electric field [7].

We have reported [8] that the threshold electric field for various antiferroelectric liquid crystal compounds considerably depends on chemical structure, i.e. alkyl chain lengths of the terminal groups, the nature of the chiral part, and also the core structure.

We synthesized 4-(1-methylheptyloxycarbonyl)phenyl 4′-octyloxybiphenyl-4-carboxylate (MHPOBC) and found chiral smectic phases [3]. Chandani *et al.* [9] later proved the existence of the antiferroelectric chiral smectic C ($S^*_{C_A}$) phase in the same compound; the properties of this phase are dealt with in [10–13].

In this paper we report the influence of several kinds of additives, which are in themselves *not* antiferroelectric liquid crystals, to the threshold electric field of the host compound MHPOBC.

2. Experimental

The structures of MHPOBC and the additives used, and their transition temperatures are shown in the table; MHPOBC was the host liquid crystal and compounds (A)–(D) were the additives. The threshold electric fields of the mixtures were determined from the optical response curve obtained by employing a triangular

* Author for correspondence.

0267–8292/93 $10·00

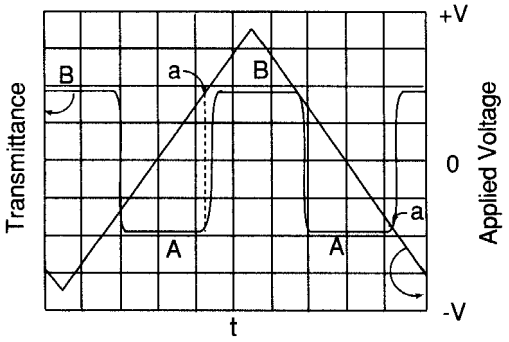


Figure 1. Typical curve for optical response with applied voltage. A, B and a relate to the antiferroelectric state, ferroelectric state and threshold electric field respectively.

wave (0·05 Hz) and the use of a polarizing microscope (Nikon) [12]. A function generator (Wavetek Model 275), a digital oscilloscope (Gould Type 4035), a regulated DC power supply (Hamamatsu Model HTV C448A), a central processor (Mettler FP 80), and a power amplifier (Yamabishi) were also used in these measurements. A typical curve for optical response with applied voltage is shown in figure 1.

The samples used were aligned by rubbing one of the glass plates coated with polyimide. The cell thickness was $5{\cdot}2 \pm 0{\cdot}05\,\mu$m. The threshold electric field was averaged between the values measured with a + voltage and a − voltage because of the small difference between these values.

The transition temperatures were measured by observing the texture during the heating process at a rate of $1^{\circ}C\,min^{-1}$, using a polarizing optical microscope, and melting points were obtained by DSC (Rigaku DSC 8240) on heating cycles at a rate of $5^{\circ}C\,min^{-1}$.

3. Results and discussion

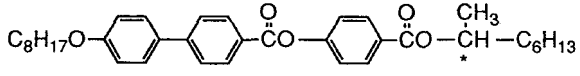
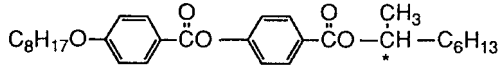
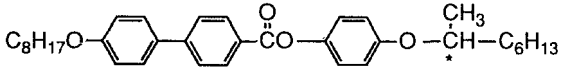
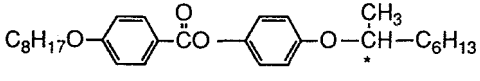
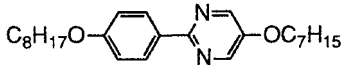
3.1. *Transition temperatures*

Figures 2–5 show the phase diagrams for the mixtures of the host MHPOBC and the additives (A)–(D). The upper limits of the temperature region of the $S^*_{C_A}$ phases decrease with increasing amount of additive, and $S^*_{C_A}$ phases disappear at 40 mol % of additive in all cases. In the case of additive (B), the $S^*_{C_A}$ phase is better preserved compared with the others and the temperature region of the S^*_C phase extends as the content of (B) increases. The stability of the $S^*_{C_A}$ phase decreases in the additive sequence (B), (A), (C), (D). This result seems not to be related to the phase sequences of the additives, but more to their molecular shape or structure. The best stabilization of the $S^*_{C_A}$ phase is obtained with molecules similar in shape to MHPOBC.

3.2. *Threshold electric field*

Figures 6–9 show the influence of additive concentration. The threshold fields of the mixtures are smaller than that of MHPOBC and tend to decrease as the additive concentrations increases. Comparing mixtures containing the additives at 10 mol % or 20 mol %, the threshold field increases in the additive order (C), (D), (B), (A) (see figures 10 and 11, respectively). The threshold fields of mixtures containing (A) are higher than those of (B), although (A) is a two ring compound. This is because (A) has the same partial structure as MHPOBC which has an antiferroelectric liquid crystal phase.

The structures of MHPOBC and additives (A)–(D), and their transition temperatures.

No.	Compound	Transition temperature
Host compound		C 68°C $S^*_{I_A}$ 66°C $S^*_{C_A}$ 119·8°C $S^*_{C'}$ 120·7°C S^*_C 122·2°C S_A 149·8°C I
(A)		C 42°C S_A 19·6°C I
(B)		C 66°C S_H 83°C S^*_C 108°C S_A 149°C I
(C)		C 25°C S_A 18·5°C I
(D)		C 53°C S_C 81·5°C S_A 88·3°C N 95·4°C I

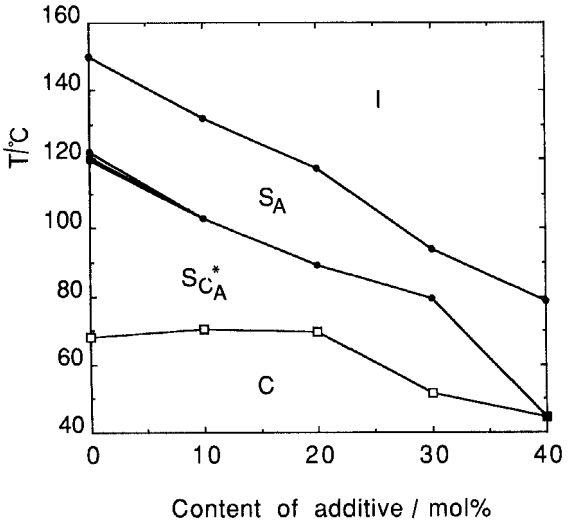


Figure 2. Phase diagram of MHPOBC and additive (A).

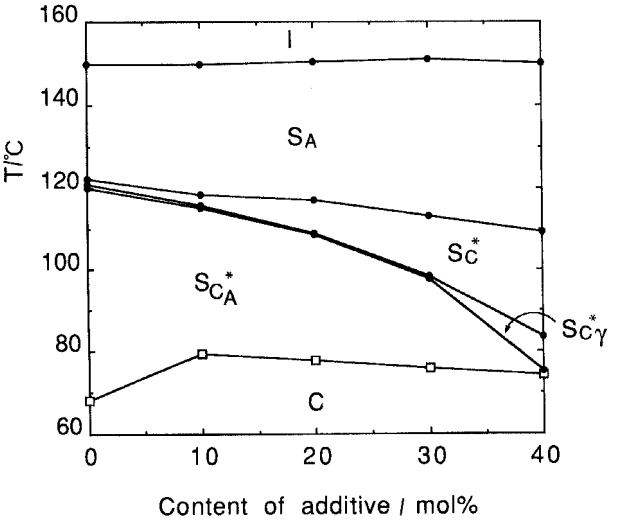


Figure 3. Phase diagram of MHPOBC and additive (B).

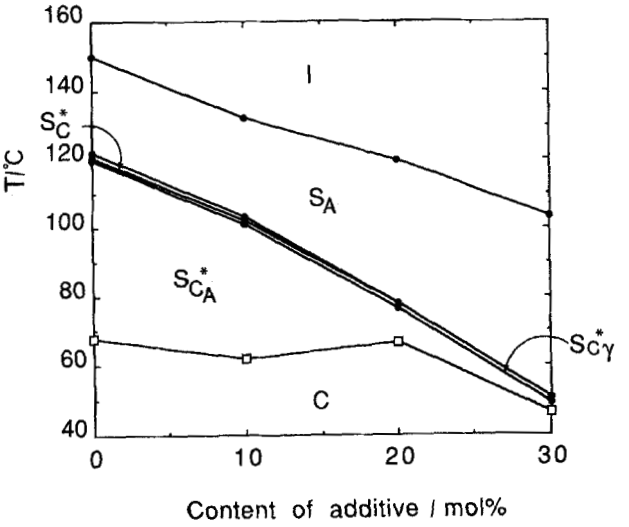


Figure 4. Phase diagram of MHPOBC and additive (C).

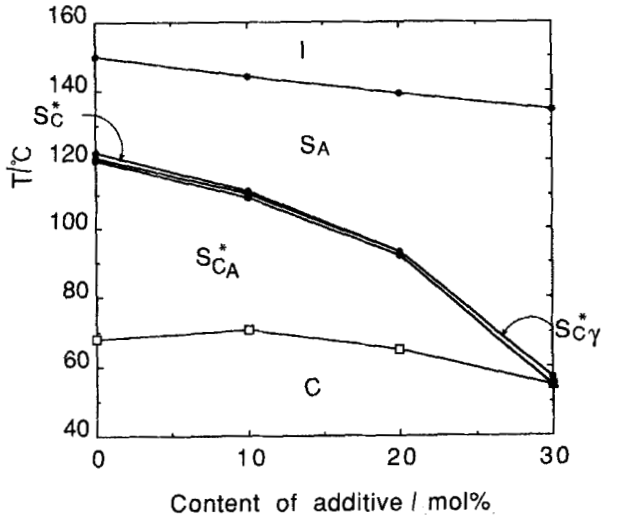


Figure 5. Phase diagram of MHPOBC and additive (D).

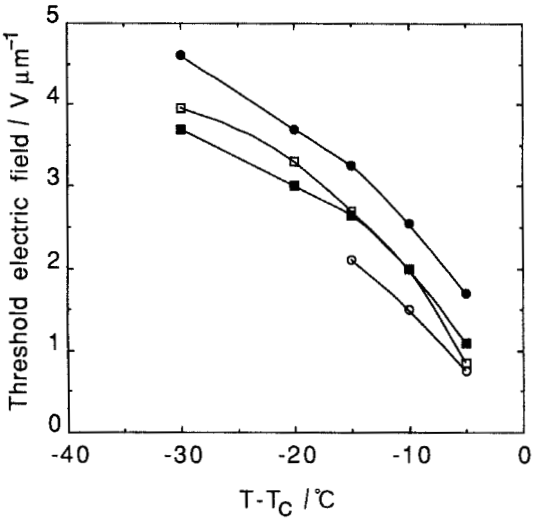


Figure 6. Influence of concentration of additive compound (A) on the threshold electric field shown by MHPOBC. ●, MHPOBC; □, 10 mol%; ■, 20 mol%; ○, 30 mol%.

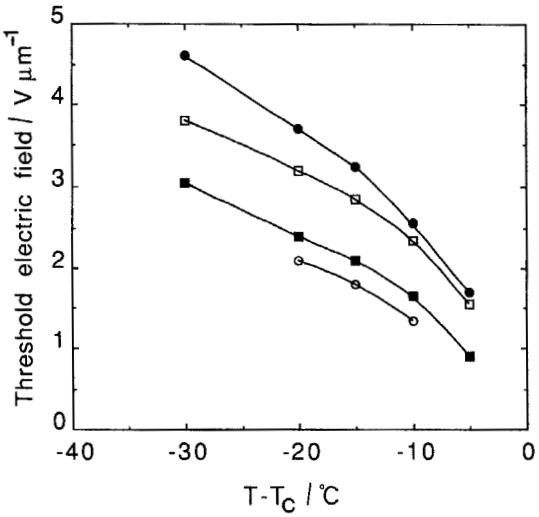


Figure 7. Influence of concentration of additive compound (B) on the threshold electric field shown by MHPOBC. ●, MHPOBC; □, 10 mol%; ■, 20 mol%, ○, 30 mol%.

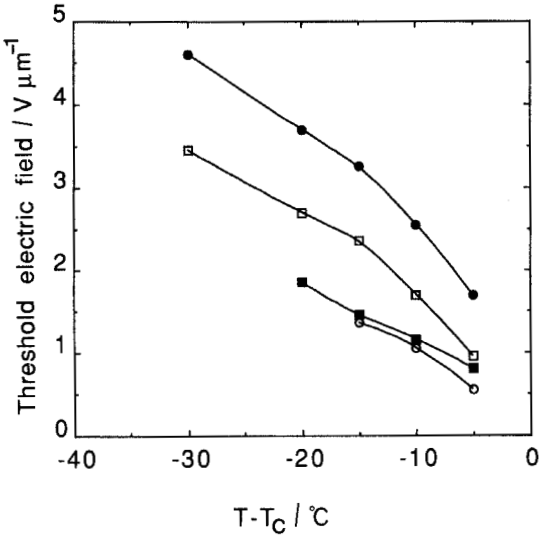


Figure 8. Influence of concentration of additive compound (C) on the threshold electric field shown by MHPOBC. ●, MHPOBC; □, 10 mol %; ■, 20 mol %; ○, 30 mol %.

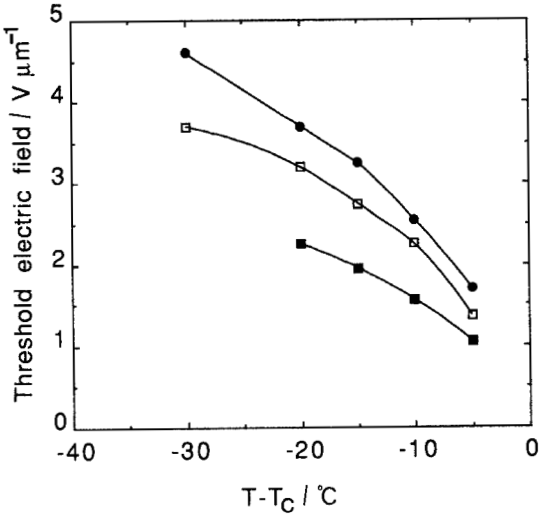


Figure 9. Influence of concentration of additive compound (D) on the threshold electric field shown by MHPOBC. ●, MHPOBC; □, 10 mol %; ■, 20 mol %.

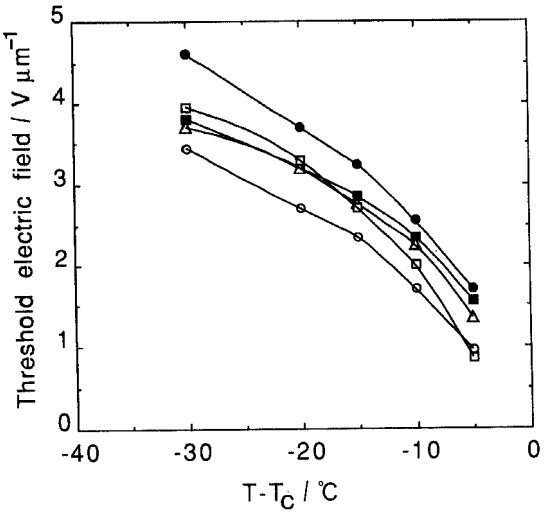


Figure 10. The temperature dependence of the threshold electric field. 10 mol % of each additive in MHPOBC. ●, MHPOBC; □, (A); ■, (B); ○, (C), △, (D).

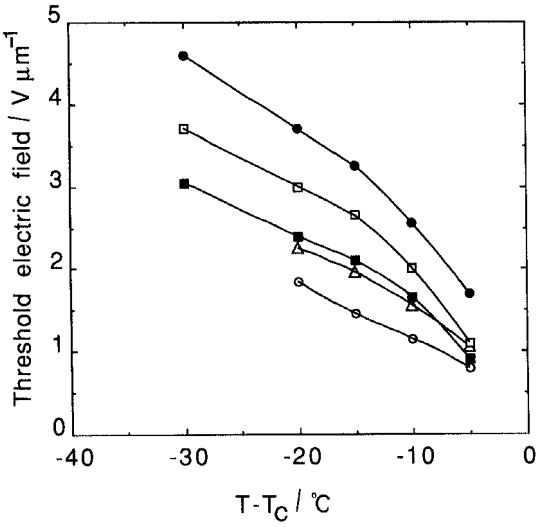


Figure 11. The temperature dependence of the threshold electric field. 20 mol % of each additive in MHPOBC. ●, MHPOBC; □, (A); ■, (B); ○, (C); △, (D).

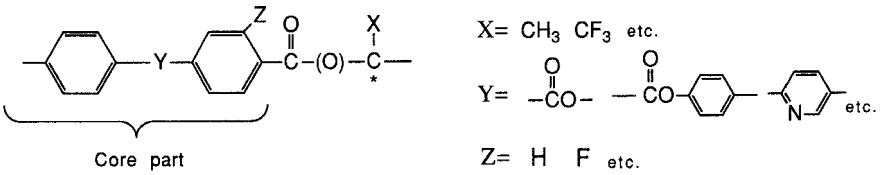


Figure 12. Characteristic partial structures of compounds showing the antiferroelectric liquid crystal phases.

Characteristic partial structures of compounds which exhibit antiferroelectric liquid crystal phases are shown in figure 12 [8, 14–16]. There is commonly an ester or ketone bond between the core part and the chiral carbon, and a polar group as indicated by *Y* in the core. The ester bond near the chiral carbon seems to contribute to the existence of the antiferroelectric liquid crystal phase and the magnitude of the threshold electric field. The threshold field of the mixture containing (C) is the lowest of all the mixtures investigated. This may also be because the structurally similar additive (C) is a two ring compound which acts like a lubricator, able to mix easily without partially breaking the layer structure of the antiferroelectric liquid crystal phase.

4. Conclusion

To the antiferroelectric host MHPOBC, different compounds which do not exhibit antiferroelectric behaviour have been added. In all cases, the threshold electric field was diminished depending on the chemical structure of the compound; it also decreased with increasing amounts of the additives. The threshold electric field of a host may therefore be decreased by adding compounds, which are not in themselves antiferroelectric liquid crystals.

References

[1] YAMAWAKI, M., YAMADA, Y., YAMAMOTO, N., MORI, K., HAYASHI, H., SUZUKI, Y., NEGI, Y. S., HAGIWARA, T., KAWAMURA, I., ORIHARA, H., and ISHIBASHI, Y., 1989, *Proceedings of 9th International Display Research Conference*, Vol. 3 (Society for Information Display and The Institute of Television Engineers of Japan), p. 26.

[2] YAMADA, Y., YAMAMOTO, N., MORI, K., NAKAMURA, K., HAGIWARA, T., SUZUKI, Y., KAWAMURA, I., ORIHARA, H., and ISHIBASHI, Y., 1990, *Jap. J. appl. Phys.*, **29**, L1757.

[3] FURUKAWA, K., TERASHIMA, K., ICHIHASHI, M., SAITOH, S., MIYAZAWA, K., and INUKAI, T., 1988, *Ferroelectrics*, **85**, 451.

[4] CHANDANI, A. D. L., HAGIWARA, T., SUZUKI, Y., OUCHI, Y., TAKEZOE, H., and FUKUDA, A., 1988, *Jap. J. appl. Phys.*, **27**, L729.

[5] JOHNO, M., CHANDANI, A. D. L., OUCHI, Y., TAKEZOE, H., FUKUDA, A., ICHIHASHI, M., and FURUKAWA, K., 1989, *Jap. J. appl. Phys.*, **28**, L119.

[6] JOHONO, M., OUCHI, Y., TAKEZOE, H., FUKUDA, A., TERASHIMA, K., and FURUKAWA, K., 1990, *Jap. J. appl. Phys.*, **29**, L111.

[7] TAKEZOE, H., LEE, J., CHANDANI, A. D. L., GORECKA, E., OUCHI, Y., FUKUDA, A., TERASHIMA, K., and FURUKAWA, K., 1991, *Ferroelectrics*, **114**, 187.

[8] MURASHIRO, K., KIKUCHI, M., INOUE, H., FUKUSHIMA, M., SAITO, S., and TERASHIMA, K., 1991, *Preprints of the 17th Liquid Crystal Conference*, Japan, 3F313, L260.

[9] CHANDANI, A. D. L., GORECKA, E., OUCHI, Y., TAKEZOE, H., and FUKUDA, A., 1989, *Jap. J. appl. Phys.*, **28**, L1265.

[10] CHANDANI, A. D. L., OUCHI, Y., TAKEZOE, H., FUKUDA, A., TERASHIMA, K., FURUKAWA, K., and KISHI, A., 1989, *Jap. J. appl. Phys.*, **28**, L1261.

[11] GORECKA, E., CHANDANI, A. D. L., OUCHI, Y., TAKEZOE, H., and FUKUDA, A., 1990, *Jap. J. appl. Phys.*, **29**, L131.

[12] JOHNO, M., ITOH, K., LEE, J., OUCHI, Y., TAKEZOE, H., FUKUDA, A., and KITAZUME, T., 1990, *Jap. J. appl. Phys.*, **29**, L107.

[13] HIRAOKA, K., TAGUCHI, A., OUCHI, Y., TAKEZOE, H., and FUKUDA, A., 1990, *Jap. J. appl. Phys.*, **29,** L103.
[14] INUI, S., KAWANO, S., SAITO, M., IWANE, H., TAKANISHI, Y., HIRAOKA, K., OUCHI, Y., TAKEZOE, H., and FUKUDA, A., 1990, *Jap. J. appl. Phys.*, **29,** L987.
[15] YAMAMOTA, N., YAMADA, Y., MORI, K., NAKAMURA, K., ORIHARA, H., ISHIBASHI, Y., SUZUKI, Y., NEGI, Y. S., and KAWAMURA, I., 1991, *Jap. J. appl. Phys.*, **30,** L2380.
[16] HARA, M., UMEMOTO, T., TAKEZOE, H., GARITO, A. F., and SASABE, H., 1991, *Jap. J. appl. Phys.*, **30,** L2052.