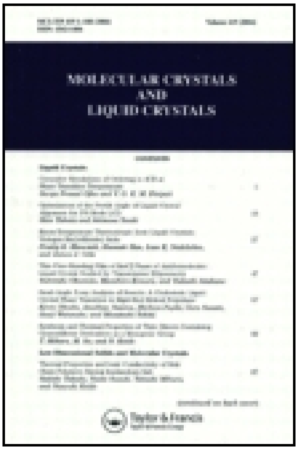
This article was downloaded by: [Tomsk State University of Control Systems and Radio]
On: 18 February 2013, At: 09:05
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Design and Synthesis of Ferroelectric Liquid Crystals. 25. An Approach to New Materials for Ultra-Fast Electronic Electro-Optic Modulators

David M. Walba [a], Daniel J. Dyer [a], Xin Hua Chen [a], Uwe Müller [a], Peter Cobben [a], Renfan Shao [b] & Noel A. Clark [b]

[a] Department of Chemistry and Biochemistry, University of Colorado, Boulder, CO, 80309-0215

[b] Department of Physics and Optoelectronic Computing Systems Center, University of Colorado, Boulder, CO, 80309-0215

Version of record first published: 24 Sep 2006.

To cite this article: David M. Walba, Daniel J. Dyer, Xin Hua Chen, Uwe Müller, Peter Cobben, Renfan Shao & Noel A. Clark (1996): Design and Synthesis of Ferroelectric Liquid Crystals. 25. An Approach to New Materials for Ultra-Fast Electronic Electro-Optic Modulators, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 288:1, 83-91

To link to this article: http://dx.doi.org/10.1080/10587259608034586

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

Mol. Cryst. Liq. Cryst., 1996, Vol. 288, pp. 83–91
Reprints available directly from the publisher
Photocopying permitted by license only

© 1996 OPA (Overseas Publishers Association)
Amsterdam B.V. Published in The Netherlands
under license by Gordon and Breach Science
Publishers SA
Printed in Malaysia

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

DESIGN AND SYNTHESIS OF FERROELECTRIC LIQUID CRYSTALS. 25. AN APPROACH TO NEW MATERIALS FOR ULTRA-FAST ELECTRONIC ELECTRO-OPTIC MODULATORS[1]

DAVID M. WALBA,*[†] DANIEL J. DYER,[†] XIN HUA CHEN,[†] UWE MÜLLER,[†] PETER COBBEN,[†] RENFAN SHAO,[‡] AND NOEL A. CLARK[‡]
[†]Department of Chemistry and Biochemistry, [‡]Department of Physics and Optoelectronic Computing Systems Center, University of Colorado, Boulder, CO 80309-0215[1]

Abstract Combining excellent processibility on silicon integrated circuits with a thermodynamically stable polar structure, ferroelectric liquid crystals (FLCs) provide an attractive potential approach to synthesis of materials for second order nonlinear optics (NLO). In order for this potential to be realized, however, adequate magnitude of the second order susceptibility $\chi^{(2)}$ must be obtained. Recent results of experiments demonstrating orientation along the FLC polar axis of functional arrays with large molecular second order susceptibility, such as those found in the NLO dyes Disperse Red 1 and dimethylaminonitrostilbene, are described.

INTRODUCTION

Ferroelectric liquid crystals (FLCs) are LCs with polar symmetry and a switchable macroscopic electric dipole moment (the ferroelectric polarization). While several theoretical and experimental studies have been aimed at creation of smectic A[2] and discotic[3] FLCs with polarization along the director, evidence for the existence of such a "longitudinal" polar structure in LCs is not yet absolutely compelling. Chiral tilted smectics, however, are clearly ferroelectric in the surface stabilized geometry, are helielectric in bulk, and can exhibit a high degree of polar stereocontrol in the thermodynamic global minimum configuration.[4]

This combination of LC processibility and polar structure makes FLCs an attractive class of materials for electronic second order nonlinear optics (NLO) applications, since a polar structure assures the presence of a non-zero bulk second order susceptibility $\chi^{(2)}$. Herein are described recent results of a project aimed at design and synthesis of FLCs for NLO applications, the critical issue being creation of FLCs with $\chi^{(2)}$ values large enough for use in ultra-fast integrated electro-optic modulators.

AN APPROACH FOR OBTAINING FLCS WITH HIGH $\chi^{(2)}$

Rationale—FLC Integrated Optical Chips

FLC integrated optical chips—silicon very large scale integrated (VLSI) circuit write-only memories with optical read-out—are among the pioneers in a new family of devices poised to revolutionize information display and processing.[5] The current generation of VLSI/FLC chips are electro-optic modulators with 256 x 256 = 64 K channels running in parallel at 10 kHz, providing about 0.5 Gbits/sec of data throughput. Next generation devices will drive 1280 x 1024 = 1 M channels at 10 kHz to afford 10 Gbits/sec of throughput. These modulators leverage the power of VLSI silicon with the processibility of FLCs, the latter enabling integration of optical quality organic electro-optic thin films on silicon in a highly efficient manner.

For many obvious applications, however, a single channel running at 10 Gbits/sec or faster is desirable. The response speeds required for such ultra-fast modulation precludes the use of conventional LC or FLC electro-optics, which involve collective molecular motions induced by applied electric fields. One promising approach for achieving such modulation frequencies involves exploitation of the linear electronic electro-optic (EEO) effect in organic films with electronic second order NLO susceptibility $\chi^{(2)}$.[6] Since FLCs possess a thermodynamically stable polar supermolecular structure they indeed show non-zero $\chi^{(2)}$. This, combined with the above-mentioned processibility on silicon suggests VLSI/FLC integrated optics could also provide high bandwidth per channel modulators.

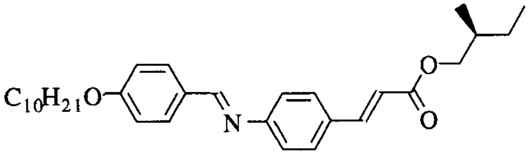
Design of FLCs with High $\chi^{(2)}$

In order to create FLC-based ultra-fast EEO modulators, FLCs with improved $\chi^{(2)}$ are required, since known materials possess EEO coefficients too small to be useful in this application. For example **DOBAMBC** (Figure 1), the first demonstrated FLC,[7] and the first FLC evaluated for $\chi^{(2)}$,[8] has been shown to possess effective $\chi^{(2)}$ on the order of 0.002 pm/V by angle phase matched second harmonic generation (SHG) from 1064 nm light (type 1 eeo d_{eff} = 0.001 pm/V).[9] Since values of $\chi^{(2)}$ on the order of 50 pm/V are required for fabrication of EEO modulators, **DOBAMBC** is clearly useless in this application. Even FLCs of the α-chloroester family with high ferroelectric polarization have been shown to possess small $\chi^{(2)}$ values on the order of 0.02 pm/V by SHG.[10]

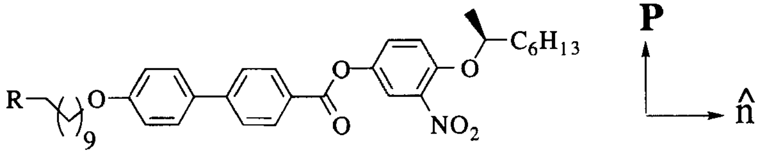
Efforts directed at design of FLCs with increased $\chi^{(2)}$ have focused on two key issues: 1) Improving the molecular second order susceptibility β of the FLC mesogens; and 2) Achieving the correct supermolecular stereochemistry for $\chi^{(2)}$. Thus, mesogens wherein donor and acceptor groups coupled by an aryl ring conjugating spacer are oriented

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

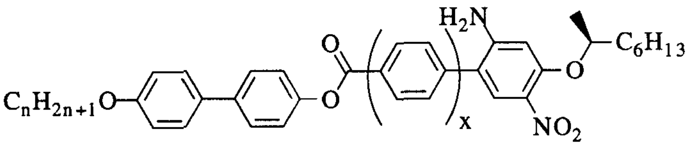
Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013



DOBAMBC



R = H; **W314**
R = Si(OEt)$_3$; **W399**



x = 0, n = 10; **W341**
x = 1, n = 9; **Roche 1**

FIGURE 1 Some previously studied FLCs for NLO.

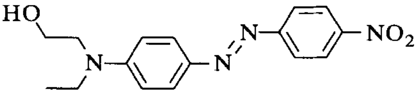
in the C* phase such that the charge transfer axis has a large component along the FLC polar axis (normal to n̂) were designed. In the first application of this approach an alkoxy donor grouping was oriented ortho to a nitro acceptor.[11] The required polar orientation of these functional arrays was achieved by steric coupling of the 1-methylheptyloxy chiral tail[12] with the nitro grouping.[13] This structural class provided materials with demonstrated electronic electro-optic (EEO) coefficients on the order of 1 pm/V for modulation of 633 nm light at 100 MHz (**W399**)[14] and d coefficients on the order of 0.6 pm/V for SHG from 1064 nm light (**W314**).[15]

In order to increase $\chi^{(2)}$, introduction of an improved donor (an amino grouping) para to the acceptor was accomplished, as indicated for the FLC dopant **W341**.[16] The desired orientation of the p-nitroaniline grouping along the polar axis with excellent supermolecular stereocontrol in this system was demonstrated by measurement of large ferroelectric polarization in C* mixtures containing **W341**.[1b] This interpretation was confirmed experimentally with the characterization of the **W341** analog **Roche 1**,[17] which exhibited d_{eff} = 5 pm/V by SHG in an electric-field induced tilted smectic phase. Thus, an improvement of about a factor of 5,000 in the $\chi^{(2)}$ of FLCs has been achieved since the

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

initial work with **DOBAMBC**. Further improvements are required, however, if the required EEO coefficients on the order of 50 pm/V are to be realized.

The most promising approach for achieving larger $\chi^{(2)}$ in FLCs involves orientation of "large β" functional arrays along the polar axis.[18] Conventional large β structures include a donor-substituted aromatic ring and an acceptor substituted aromatic ring joined by a conjugating spacer unit such as a double bond. The prototype of this class of molecules is the classic NLO dye Disperse Red 1 (DR1)—in this case the donor is a dialkylamino group, the acceptor is a nitro group, and the conjugating spacer is the azo linkage.



Disperse Red 1

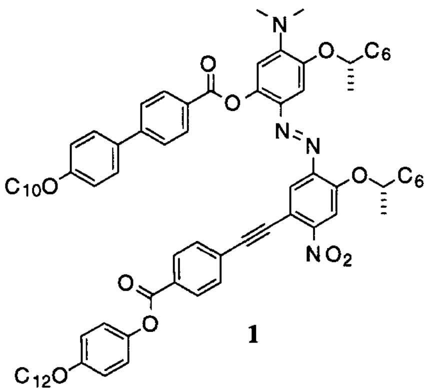
Excellent supermolecular stereocontrol is achievable in FLCs (on the order of 60% polar excess has been demonstrated as evidenced by ferroelectric polarization measurements),[19] and "large β" functional arrays are easily incorporated into LC structures.[20] Even **DOBAMBC** is expected to possess reasonable β (between that of DR1 and p-nitroaniline). However, in all previously known cases such functional arrays orient along the liquid crystal director n̂, while the FLC polar axis is normal to the director.[21] This incorrect supermolecular structure leads to small $\chi^{(2)}$.

Side-by-Side Dimer Mesogens for NLO

In order to obtain mesogens possessing large β units and the correct supermolecular structure for large $\chi^{(2)}$, a molecular structural motif was explored wherein two chiral smectic mesogenic units, one substituted with a donor and the other with an acceptor, are joined by a conjugating spacer. Initial synthetic work in this area produced the azo dye **1**, with a phenyl biphenylcarboxylate donor unit, a phenyl tolancarboxylate acceptor, and the azo linkage as conjugating spacer, as shown in Figure 2.

While dimer **1** is not itself mesogenic (mp 139-140°C), smectic C* mixtures up to 30% by weight of **1** in the C phase host racemic **W314**[22] were characterized as indicated in Figure 2. The data show that indeed the azo unit is oriented at a large angle from the director (negative visible light dichroism). Furthermore, the sign and magnitude of the ferroelectric polarization of the mixtures are consistent with the desired supermolecular structure, suggesting a polar excess for orientation of the DR1 chromophore of about 10% assuming an average dipole moment normal to the director of about 5 D.[23]

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013



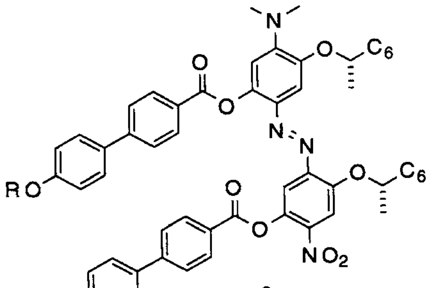
1

Phase sequence of the mixture (30% by weight) of **1** in racemic host (temperatures in degrees C):
X ← 35 — C* ← 90 — A* ← 120 — I
X — 70 → C*

P_{obs} = +26.6 nC/cm^2 @ 40°C, θ = 31.5°
P_{ext} = +88.5 nC/cm^2 ~ 0.5 D/molecule ~ 10% pe
Negative Dichroism

FIGURE 2 Structure and properties of side-by-side dimer FLC dopant **1**.

Further synthetic work provided the bis-phenyl biphenylcarboxylate dimers **2**, which are mesogenic, as indicated in Figure 3. Thus, azo dye **2a**, with two decyloxy achiral tails, shows a broad monotropic smectic A* phase, while analog **2b**, with polyunsaturated achiral tails, possesses A* and smectic B phases, with a narrow enantiotropic A* phase range.[1a]



2

2a; R = n-Decyl; Phase sequence:
X ← <25 — A* ← 99-97 — I

2b; R = (Z,Z)-9,12-Octadecadienyl;
Phase sequence:
X ← <25 — S_B ← ≅40 — A* ← 74 — I
X — 72 → A* — 74 → I

FIGURE 3 Structure and phase sequence of the first side-by-side smectic mesogens.

Compound **2b** was further characterized as shown in Figure 4. Thus, **2b** is miscible in all proportions with host racemic **W314**, as shown by the phase diagram on the left in Figure 4; the mixtures exhibiting a C* phase up to 60% by weight. The ferroelectric polarization of these C* mixtures is well-behaved, as indicated by the plot on the right in Figure 4, showing an extrapolated polarization of +65 nC/cm^2 (~ 0.4 D/molecule) for **2b**. Again, this is consistent with a polar excess of ~ 10% for orientation of the DR1 unit based upon a

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

calculated dipole moment normal to the director of ~ 4 D (MOPAC with the AM1 Hamiltonian).

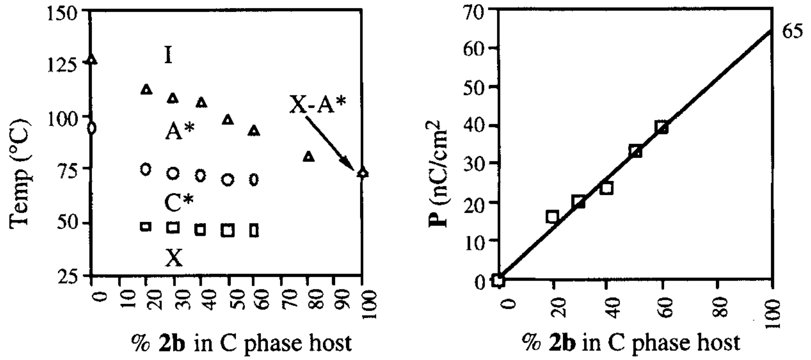
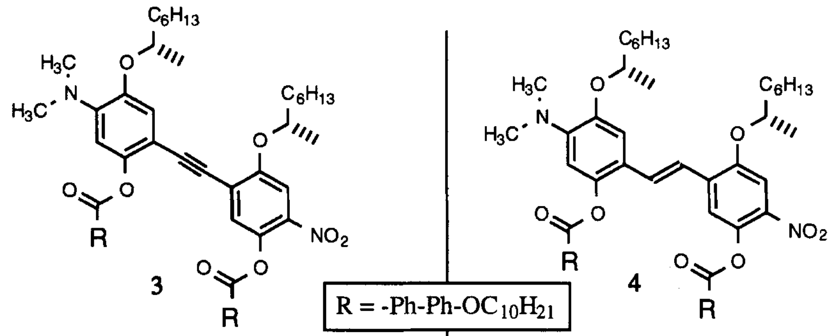


FIGURE 4 Phase diagram and measured "saturation" ferroelectric polarization for mixtures of **2b** in racemic **W314**.

The data shown in Figure 4 for compound **2b** are consistent with the desired structure in the C* phase; specifically that the dimer orients with the phenyl biphenylcarboxylates along the director and the azo dye at about 60° from the director. Proof of this structure was readily obtained by measuring the visible light dichroism of **2b** in the smectic A* phase. While the neat sample was too strongly absorbing to afford good data, in a 10% mixture of **2b** in a room temperature A* host,[24] the absorbence as a function of incident angle is well behaved, and a dichroic ratio (absorbence parallel to $\hat{n}$/absorbence normal to $\hat{n}$) of 0.52 is observed. This leads to a calculated angle of 63° between the director and the azo dye transition moment—in good agreement with expectation. In addition, compound **2b** exhibits negative birefringence in the neat A* phase; also consistent with the proposed supermolecular structure. To our knowledge this material is the only known smectic mesogen with negative birefringence.

Since dimethylaminonitrostilbene (DANS) is known to possess a larger β value that DR1, the carbon analogs **3** and **4** of the azo dyes were synthesized. As indicated in Figure 5, the tolan bis-phenylbiphenylcarboxylate **3** shows excellent mesogenicity, with enantiotropic N* and A* phases. Unfortunately, the DANS dimer **4** is not mesogenic. Not surprisingly, characterization of **4** in a mixture with racemic **W314** suggests that the supermolecular structure obtained with the DANS dimer is similar to that obtained in the DR1 case, with a 10% polar excess for orientation of the chromophore indicated by the observed ferroelectric polarization.



3

R = -Ph-Ph-OC$_{10}$H$_{21}$

4

Phase sequence of neat sample:

Sx ← 72.6 — A* ← 78.5 — N* ← 91.8 — I
X — 73 → A* — 78.5 → N* — 92 → I

12% in racemic **W314** :

X ← 53 — C* ← 88 — A* ← 123 — I
$P_{ext} \cong 50$ nC/cm^2 (10% pe)

FIGURE 5 Structure and some properties of compounds **3** and **4**, containing the dimethylaminonitrotolan and dimethylaminonitro stilbene (DANS) NLO chromophores, respectively.

CONCLUSIONS

In the context of electronic second order NLO in FLCs, initial results with side-by-side dimer structures are highly encouraging, suggesting that it will prove possible to obtain C* materials with large β NLO chromophores oriented along the polar axis. Critical issues to be dealt with include most importantly improvement of the degree of polar stereocontrol achievable in the dimer mesogens, with a very realistic target being realization of 30% polar excess in orientation of the DR1 or DANS chromophores in the C* phase.

ACKNOWLEDGMENT

This work was supported in part by the Office of Naval Research, and by the National Science Foundation (DMR-9224168).

REFERENCES

1. Previous papers in the series: (a) D. M. Walba, D. J. Dyer, T. Sierra, P. L. Cobben, R. Shao and N. A. Clark, J. Am. Chem. Soc., (in press). (b) D. M. Walba, D. J. Dyer, P. L. Cobben, T. Sierra, J. A. Rego, C. A. Liberko, R. Shao and N. A. Clark Ferroelectric Liquid Crystals for Nonlinear Optics Applications: Can we Really Do It?; in: Thin Films for Integrated Optics Applications, edited by B. W. Wessels, S. R. Marder and D. M. Walba (Materials Research Society, Pittsburgh, PA, 1995), pp. 157-162 and references therein.

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

2. (a) R. G. Petschek and K. M. Wiefling, Phys. Rev. Lett., 59, 343-6 (1987). (b) F. Tournilhac and J. Simon, Ferroelectrics, 114, 283-7 (1991). (c) F. G. Tournilhac, L. Bosio, J. Simon, L. M. Blinov and S. V. Yablonsky, Liq. Cryst., 14, 405-14 (1993).
3. (a) H. Zheng, P. J. Carroll and T. M. Swager, Liq. Cryst., 14, 1421-9 (1993). (b) A. G. Serrette and T. M. Swager, Angew. Chem., 106, 2378-80 (1994).
4. D. M. Walba Ferroelectric Liquid Crystals: A Unique State of Matter; in: Advances in the Synthesis and Reactivity of Solids, edited by T. E. Mallouk (JAI Press Ltd, Greenwich, Connecticut, 1991), pp. 173-235.
5. (a) M. A. Handschy, H. Chase, L. K. Cotter, J. D. Cunningham, A. M. Pattee, T. J. Drabik and S. D. Gaalema, "One-Transistor DRAM Ferroelectric-Liquid-Crystal Spatial Light Modulator," Optical Pattern Recognition V, D. P. Casesant and T.-H. Chao, Editors, Proc. SPIE 2237, 432-438 (1994). (b) D. M. Walba, Science, 270, 250-251 (1995).
6. D. J. Williams, Angew. Chem., Int. Ed. Engl., 23, 690-703 (1984).
7. R. B. Meyer, L. Liebert, L. Strzelecki and P. Keller, J. Phys., Lett. (Orsay, Fr.), 36, L-69-L71 (1975).
8. A. N. Vtyurin, V. P. Ermakov, B. I. Ostrovskii and V. F. Shabanov, Phys. Status Solidi B, 107, 397-402 (1981).
9. N. M. Shtykov, M. I. Barnik, L. A. Beresnev and L. M. Blinov, Mol. Cryst. Liq. Cryst., 124, 379-390 (1985).
10. M. Ozaki, M. Utsumi, T. Gotou, Y. Morita, 1. K. Daido, Y. Sadohara and K. Yoshino, Ferroelectrics, 121, 259-274 (1991).
11. (a) D. M. Walba, M. B. Ros, N. A. Clark, R. Shao, K. M. Johnson, M. G. Robinson, J. Y. Liu and D. Doroski Design of Ferroelectric Liquid Crystals for Electronic NLO Applications; in: Materials for Nonlinear Optics: Chemical Perspectives, edited by G. D. Stucky (American Chemical Society, Washington, DC, 1991), pp. 484-496. (b) D. M. Walba, M. B. Ros, N. A. Clark, R. Shao, K. M. Johnson, M. G. Robinson, J. Y. Liu and D. Doroski, Mol. Cryst. Liq. Cryst., 198, 51-60 (1991). (c) D. M. Walba, J. A. Rego, N. A. Clark and R. Shao "Studies on Ferroelectric Liquid Crystal Tolan Derivatives Designed for Nonlinear Optical Applications;" in: "Macromolecular Host-Guest Complexes: Optical and Optoelectronic Properties and Applications," edited by S. A. Jenekhe (Materials Research Society, Pittsburgh, PA, 1992), pp. 205-216. (d) D. M. Walba, D. A. Zummach, M. D. Wand, W. N. Thurmes, K. M. More and K. E. Arnett, "Synthesis of Ferroelectric Liquid Crystal Oligomer Glasses for Second Order Nonlinear Optics," in "Liquid Crystal Materials, Devices, and Applications II," M. D. Wand and U. Efron, Eds, Proc. SPIE 1911, 21-28 (1993). (e) H. Kapitza, R. Zentel, R. J. Twieg, C. Nguyen, S. U. Vallerien, F. Kremer and C. G. Willson, Adv. Mater., 2, 539-543 (1990).
12. (a) K. Terashima, M. Ichihashi, M. Kikuchi, K. Furukawa and T. Inukai, Mol. Cryst. Liq. Cryst., 141, 237 (1986). (b) T. Inukai, S. Saitoh, H. Inoue, K. Miyazawa, K. Terashima and K. Furukawa, Mol. Cryst. Liq. Cryst., 141, 251 (1986).
13. M. A. Glaser, V. V. Ginzburg, N. A. Clark, E. Garcia, D. M. Walba and R. Malzbender, Molecular Physics Reports, 10, 26-47 (1995).
14. K. E. Arnett, D. M. Walba and J. A. Drewes "Technique for Measuring Electronic-Based Electro-Optic Coefficients for Ferroelectric Liquid Crystals;" in: Thin Films for Integrated Optics Applications, edited by B. W. Wessels, S. R. Marder and D. M. Walba (Materials Research Society, Pittsburgh, PA, 1995), pp. 135-146.
15. D. M. Walba, M. B. Ros, N. A. Clark, R. Shao, M. G. Robinson, J.-Y. Liu, K. M. Johnson and D. Doroski, J. Am. Chem. Soc., 113, 5471-5474 (1991).
16. D. M. Walba, M. B. Ros, T. Sierra, J. A. Rego, N. A. Clark, R. Shao, M. D. Wand, R. T. Vohra, K. E. Arnett and S. P. Velsco, Ferroelectrics, 121, 247-257 (1991).

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

Downloaded by [Tomsk State University of Control Systems and Radio] at 09:05 18 February 2013

17. K. Schmitt, R.-P. Herr, M. Schadt, J. Fünfschilling, R. Buchecker, X. H. Chen and C. Benecke, Liq. Cryst., 14, 1735-1752 (1993).

18. (a) Quantum Chemical Computational Calculation of Nonlinear Susceptibilities of Organic Materials; J.-L. Bredas, A. F. Garito and Y. Ito, Eds.; Gordon & Breach: Basel, Switzerland, 1994; Vol. 6(3-4), pp 135. (b) D. R. Kanis, M. A. Ratner and T. J. Marks, Chem. Rev., 94, 195-242 (1994). (c) F. Meyers, S. R. Marder, B. M. Pierce and J. L. Bredas, J. Am. Chem. Soc., 116, 10703-14 (1994).

19. S. Kobayashi, S. Ishibashi and S. Tsuru, Mol. Cryst. Liq. Cryst. Letters, 7, 105-110 (1990).

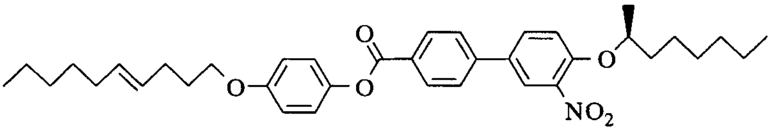
20. Intersting examples include: (a) C. Fouquey, J. M. Lehn and J. Malthete, J. Chem. Soc., Chem. Commun., 1424-6 (1987). (b) P. Berdagué, J. P. Bayle, M.-S. Ho and B. M. Fung, Liq. Cryst., 14, 667-674 (1993). (c) T. Ikeda, T. Sasaki and K. Ichimura, Nature, 361, 428-430 (1993). (d) T. Sasaki, T. Ikeda and K. Ichimura, J. Am. Chem. Soc., 116, 625-628 (1994).

21. Some examples of LC dopants with negative dichroism, wherein dye units orient at a large angle relative to the LC director upon dissolution in an LC host, have been reported: (a) A. V. Ivashchenko, O. S. Petrova and V. V. Titov, Mol. Cryst. Liq. Cryst., 108, 51-60 (1984). (b) V. G. Rumyantsev, A. V. Ivashchenko, V. M. Muratov, V. T. Lazareva, E. K. Prudnikova and L. M. Blinov, Mol. Cryst. Liq. Cryst., 94, 205-212 (1983).

22. V. V. Ginzburg, R. Shao, N. A. Clark and D. M. Walba, "Theory of chiral-racemic mixtures near the Smectic C - Smectic A transition point: Dependence of spontaneous polarization and transition temperature on enantiomeric excess," Editor, Proc. SPIE 2175, 102-107 (1994).

23. D. M. Walba, D. J. Dyer, P. L. Cobben, T. Sierra, J. A. Rego, C. A. Liberko, R. Shao and N. A. Clark Ferroelectric Liquid Crystals for Nonlinear Optics Applications: Can we Really Do It?; in: Thin Films for Integrated Optics Applications, edited by B. W. Wessels, S. R. Marder and D. M. Walba (Materials Research Society, Pittsburgh, PA, 1995), pp. 157-162

24. The room temperature A* material (S)-4"-(1-Methylheptyloxy)-3"-nitro-4'-biphenylyl-4-(4-E-decenyloxy)benzoate (**5**) was used as host in this experiment. Details of the properties of this material will be reported elsewhere.



5