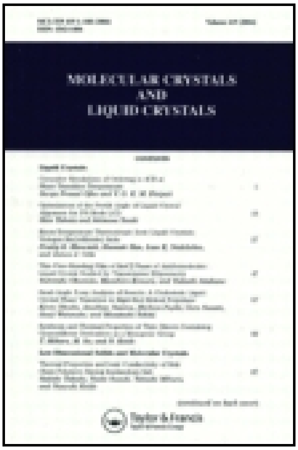

Molecular Crystals and Liquid Crystals

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

Possible Transition of Fullerene-containing Nematic Liquid Crystal to Smectic Phase

N. V. Kamanina [a] , M. M. Mikhailova [a] , A. I. Denisyuk [b] & I. Yu. Sapurina [c]

[a] Vavilov State Optical Institute, St. Petersburg, Russia

[b] 5th year student of State Institute of Fine Mechanics and Optics (Technical University), St. Petersburg, Russia

[c] Institute of Macromolecular Compounds, St. Petersburg, Russia

Version of record first published: 31 Aug 2006

To cite this article: N. V. Kamanina, M. M. Mikhailova, A. I. Denisyuk & I. Yu. Sapurina (2005): Possible Transition of Fullerene-containing Nematic Liquid Crystal to Smectic Phase, Molecular Crystals and Liquid Crystals, 426:1, 129-135

To link to this article: http://dx.doi.org/10.1080/15421400590891029

Mol. Cryst. Liq. Cryst., Vol. 426, pp. 129–135, 2005
Copyright © Taylor & Francis Inc.
ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400590891029

Possible Transition of Fullerene-containing Nematic Liquid Crystal to Smectic Phase

N. V. Kamanina
M. M. Mikhailova
Vavilov State Optical Institute, St. Petersburg, Russia

A. I. Denisyuk
5th year student of State Institute of Fine Mechanics and Optics (Technical University), St. Petersburg, Russia

I. Yu. Sapurina
Institute of Macromolecular Compounds, St. Petersburg, Russia

Self-organization in liquid crystal compounds based on the charge-transfer complexes between an organic donor and a fullerene has been first investigated. The switch-on time of 50 μs has been obtained. The results are discussed from the viewpoint of the transition from the nematic phase to the smectic one, which is caused by a complex formation.

Keywords: charge-transfer complexes; fullerene; liquid crystal; self-organization; switching

Electrically- and light-addressed liquid crystal (LC) systems are being intensively investigated and improved in last decade. The reason is that they are of low (up to 100 V) operating voltage, good threshold characteristics, and high uniformity, as well as of high sensitivity, resolution, and speed. Moreover, these devices are easily controllable.

The authors would like to thank Dr. I. Yu. Denisyuk (Vavilov State Optical Institute, St. Petersburg, Russia) and Dr. N. M. Schmidt (Ioffe Physical Technical Institute, St. Petersburg, Russia) for their help in the microscopic measurements. This work was supported by RFBR grant No. 04-03-32249-a.

Address correspondence to N. V. Kamanina, Vavilov State Optical Institute, 12 Birzhevaya Line, St. Petersburg, 199034 Russia. Tel.: 7-812-377-3422, Fax: 7-812-1017, E-mail: kamanin@ffm.ioffe.ru

The speed is a very important characteristic of LC devices. To enhance the speed various cases are applied. Apart from changing geometric dimensions of the structure and characteristics of the supply voltage, the modification of the physical-chemical properties of nematic liquid crystal (NLC) is used. In particular, photosensitive substances (e.g., dyes [1,2]) are introduced into NLC. They increase the absorption of the compound and its photoconductivity. In this case, the photorefractive effect is observed, resulting in an efficient modulation of a laser beam transmitted through LC sensitized with the dye.

Charge-transfer complexes between an organic donor (monomer, polymer, nanoparticles) [3–6] and fullerenes can be as the photosensitive component. The new complex has a high dipole moment [7] and hence it increases the polarizability of the compound. This effect improves the control of the NLC structure. The re-orientation of the NLC dipoles is schematically presented in Figure 1.

In the present paper the 10 μm NLC cells with the fullerene complexes based on 2-cyclooctylamine–5-nitropyridine (COANP) [3,4] and polyaniline [6] were investigated. As a result, the unique effect was established. It was found that the exposure in a few days resulted in the self-arrangement of the NLC system with the fullerene complex.

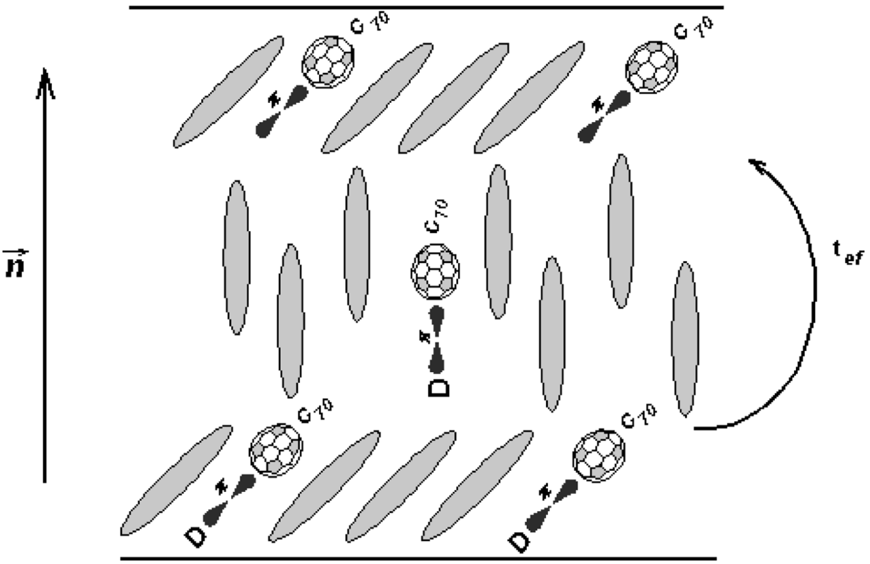

FIGURE 1 The re-orientation mechanism of the NLC-compound with the charge-transfer complex between an organic donor and fullerene under an external action. Fullerene C_{70} is used as the acceptor.

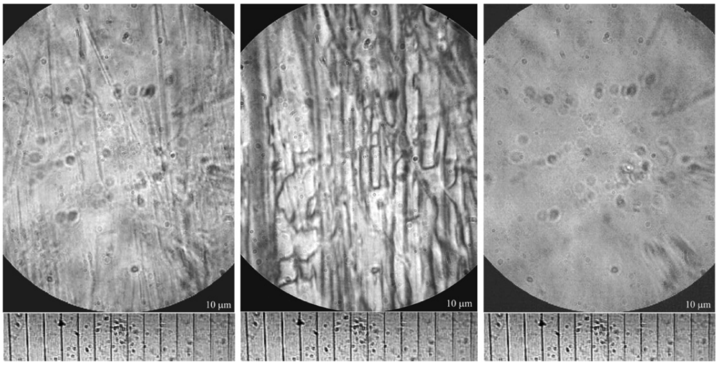

FIGURE 2 The optical microscopic images of the structures based on: pure NLC (*left*); the mixture of LC, COANP and C_{70} (*center*); and the mixture of LC and COANP (*right*). Below is shown the scale (1 point is equal to 10 μm).

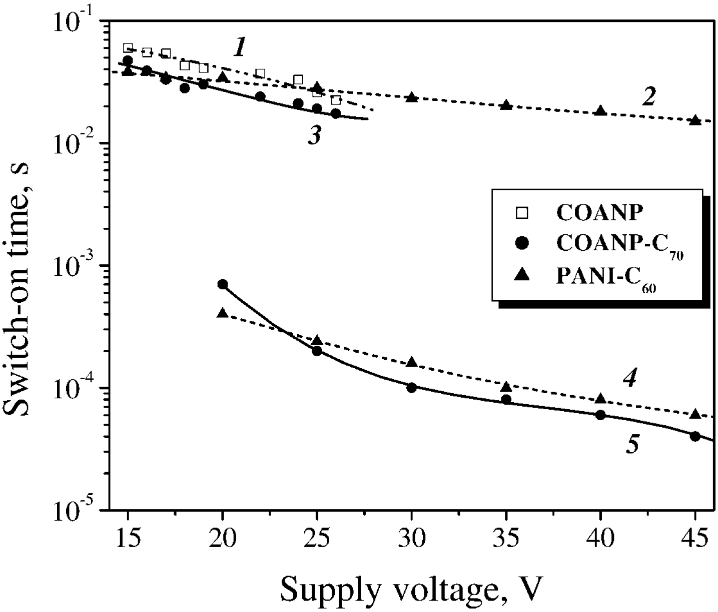

FIGURE 3 The dependence of the time-on on the amplitude of the supply voltage pulse for the LC-systems with the complexes based on: (1) — pure COANP; (2,4) — PANI–C_{60}; and (3,5) — COANP–C_{70}. The initial characteristics (1–3) and the ones after the self-arrangement (4–5).

The microscopic study allowed the transition to be revealed from the nematic phase to the smectic one. The optical microscopic images are shown in Figure 2.

The drastic change in the time-on of the cells became the main result of the self-arrangement. The dependence of the time-on on the amplitude of the supply voltage pulse is presented in Figure 3. As the result of the self-arrangement, the ultra-short time-on was obtained. For the initial compounds, the time-on fell in the range 40–160 ms, which was typical of the nematic liquid crystals. After the self-arrangement, the time-on was up to three orders of magnitude shorter. Thus, the time-on was obtained to be typical of the smectic liquid crystals.

In this case, the re-orientation of the LC dipoles can be schematically presented in Figure 4. It should be noticed that the close values of the time-on were observed at the supply voltage pulse amplitude of

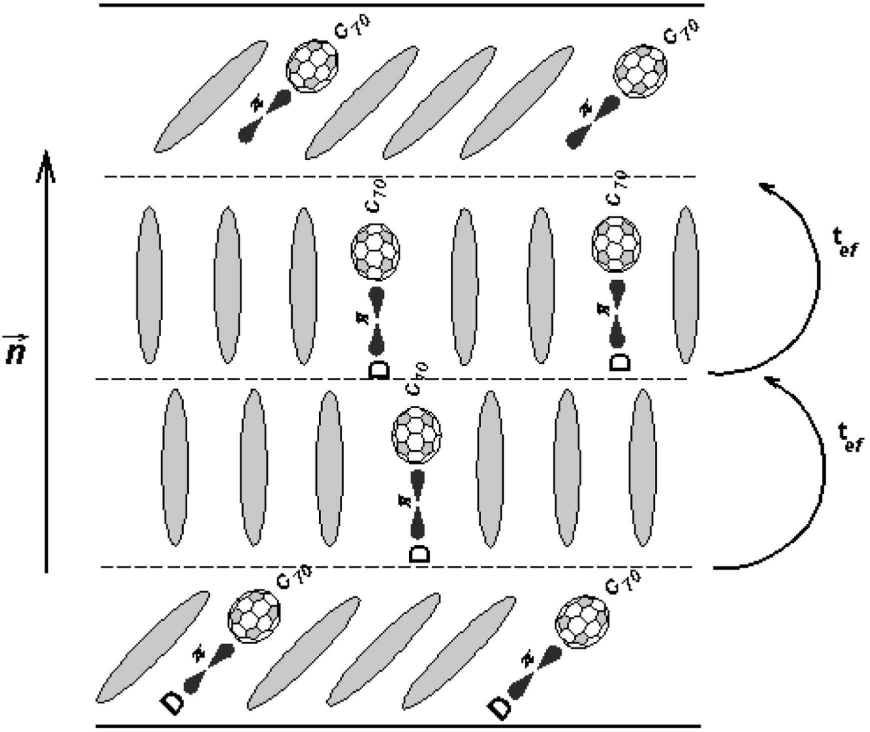

FIGURE 4 The re-orientation mechanism in the smectic phase of the fullerene-containing LC compounds investigated.

TABLE 1 Speed of Modified Liquid Crystals

Modified LC compound	Layer thickness, μm	Laser wavelength, nm	Supply voltage	$t_{\mathrm{on}}/t_{\mathrm{off}}$, ms	Ref.
NLC + orange dye	30	514.5	—	20	[11]
NLC (LC drops of diameter 100 nm in polymer matrix)	12–36			theory	[8]
NLC + dipentaerythrol hydroxy penta acrylate (DPHPA) + stabilizer	13–36	632.8	Positive pulse $1/T = 100$ Hz	0.5/0.7	[12]
NLC + PMMA + azodye	36	Ar^+ – record 633 – readout	$A = 100$ V $1/T = 100$ Hz;	5/5	[13]
NLC + PMMA + dye	36	514.5		seconds	[2]
NLC + dye (DRed-1)	32	532 and 670		74	[14]
NLC + rhodamine 6 G; LC-polymers; separated systems of photolayer-LC	15	532	cw 10 V	10 ms-1 s/100 ms	[1]
Photolayer-LC, sensitization with a fullerene mixture $C_{60} + C_{70}$		532		5–10	[15]
COANP + C_{60} + NLC	10–12	633	30–50 V; 30–60 ms $1/T = 50$ Hz	6–2.5/15–10	[16]
COANP + C_{70} + NLC + plasticizer	10–12	633	—"—	4–2/12–8	[16]
COANP + C_{70} + NLC	10–12	532		Possible model	[3]
COANP + C_{70}; *N*-(4-nitrophenyl)-*L*-prolinol	10–12	532; 805			[17]
NLC + phthalocyanine + C_{70}	10–12	633	30–50 V; 1–100 ms 0.2–100 Hz	1/3	[5]
NLC + polyaniline + C_{60}	10–12	633	—"—	30–17/90–70	[18]
NLC + COANP + C_{70} (after self-organization)	10	633	to 2000 Hz	0.2/0.05	present
NLC + polyaniline + C_{60} (after self-organization)	10	633	to 2000 Hz	0.22/0.07	present

about 25 V. This fact was indicative of negligible contribution of the organic donor and directly agreed with the data of Ref. [8]. In that paper it was theoretically demonstrated that, in this range of the supply voltage pulse amplitude, the order parameter of the system increased that was associated with correspondence of the order parameter within the LC drop with the close surrounding of the mesophase.

It follows from our results that the mechanism of the accelerated rotation of the LC dipoles is likely to be caused by the order parameter change during the transition from the nematic to the smectic induced the fullerene-containing complex introduction. The complex formation was supported by the data of absorption and luminescence spectra, mass-spectroscopy, non-linear measurements of light-induced effects, and a quantum-chemical simulation [3,5,7,9,10].

Analyzing our experimental results and literature data, the place of material studied and their dynamic characteristics can be indicated. The results are shown in Table 1.

In conclusion, it should be emphasized that the organic donor – fullerene complex significantly influences the temporal characteristics of the LC compounds investigated. The complex stimulates the self-arrangement of the LC system (the nematic–smectic transition). After the establishment of thermodynamic equilibrium with the new order parameter, the dynamic characteristics of the systems are independent of the organic donor.

Moreover, in our case, the molecular weight of the organic donor affects the rotation time of the LC dipoles. However, this effect calls for future investigations. Nevertheless, the investigations of the new liquid crystal materials with different photosensitive components allow them to be applied in optoelectronics and laser technology.

REFERENCES

[1] Miniewic, A., Parka, J., Bartkiewic, S., & Januszko, A. (1998). *Pure Appl. Opt.*, *7*, 179.

[2] Simoni, F., Cipparrone, G., Mazzulla, A., & Pagliusi, P. (1999). *Chem. Phys.*, *245*, 429.

[3] Kamanina, N. V. (2002). *J. Opt. A: Pure Appl. Opt.*, *4*, 571.

[4] Kamanina, N., Barrientos, A., Leyderman, A., Cui, Y., Vikhnin, V., & Vlasse, M. (2000). *Mol. Mater.*, *13*, 275.

[5] Kamanina, N. V. & Denisyuk, I. Yu. (2004). *Techn. Phys. Lett.*, *30*, 36.

[6] Kamanina, N. V. & Denisyuk, I. Yu. (2004). *Opt. Commun.*, *235*, 361.

[7] Kamanina, N. V. & Sheka, E. F. (2004). *Opt. Spectrosc.*, *96*, 559.

[8] Vicari, L. J. (1997). *Appl. Phys.*, *81*, 6612.

[9] Kamanina, N. V. & Plekhanov, A. I. (2002). *Opt. Spectrosc.*, *93*, 408.

[10] Sapurina, I., Mokeev, M., Lavrentev, V., Zgonnik, V., Trchová, M., Hlavatá, D., & Stejskal, J. (2000). *Eur. Polym. J.*, *36*, 2321.

[11] Simoni, F., Cipparrone, G., Umeton, C., Arabia, G., & Chidichimo, G. (1989). *Appl. Phys. Lett.*, *54*(10), 896.

[12] Lucchetta, D. E., Karapinar, R., Manni, A., & Simoni, F. (2002). *J. Appl. Phys.*, *91*(9), 6060.

[13] Cipparrone, G., Mazzulla, A., Nicoletta, F. P., Lucchetti, L., & Simoni, F. (1998). *Optics Commun.*, *150*, 297.

[14] Wang, Y.-J. & Carlisle, G. O. (2002). *J. Mater. Science: Materials in Electronics*, *13*, 173.

[15] Kamanina, N. V. & Vasilenko, N. A. (2000). *Tech. Phys. Lett.*, *26*(9), 771.

[16] Kamanina, N. V. & Kaporskii, L. N. (2000). *Tech. Phys. Lett.*, *26*(10), 864.

[17] Kamanina, N. V., Putilin, S. E., & Stasel'ko, D. I. (2002). *Synthetic Metals*, *127*(1–3), 129.

[18] Kamanina, N. V., Moskovskikh, D. A., Denisyuk, I. Yu., Mikhaǐlova, M. M., Butyanov, S. V., Pogareva, V. G., Mezenov, A. V., Zubtsova Yu, A., Shulev, V. A., & Sapurina, I. Yu. (2004). *J. Optical Technol.*, *71*(3), 187.