optoel 2013

VIII REUNIÓN ESPAÑOLA DE

Optoelectrónica

www.optoel2013.fgua.es

10-12
Julio de 2013

Alcalá de Henares
Madrid

LIBRO DE COMUNICACIONES

Grupo de Ingeniería Fotónica de la Universidad de Alcalá
GRIFO

Departamento de Electrónica
Universidad de Alcalá

Universidad de Alcalá

Publicado por:

Grupo de Ingeniería Fotónica
Departamento de Electrónica
Universidad de Alcalá

ISBN: 978-84-88754-21-9
Depósito legal: M-20974-2013

Orthoconic Antiferroelectric Liquid Crystals for non-display applications

Noureddine BENNIS[(1)], Amanda GARCIA-GARCIA[(1)], Roman DABROWSKI[(2)], Michal CZERWINSKI[(2)], Morten ANDREAS GEDAY[(1)]

1. CEMDATIC, ETSI Telecomunicación, Universidad Politécnica de Madrid, Avda Complutense 30, 28040 Madrid, Spain
2. Institute of Chemistry, Military University of Technology, 2 Kaliskiego Str., 00–908 Warsaw, Poland

Contact name: Noureddine (n_bennis@tfo.upm.es).

ABSTRACT:

Antiferroelectric liquid crystals are attractive for microdisplay applications, because of their fast switching and wide viewing angle; however the pretransitional effect reduces the contrast of the display. As a promising alternative orthoconic antiferroelectric liquid crystals (OAFLC) with a cone angle of 90º provide a good dark state between crossed polarized independently of the cell rotation. These materials are properly surface stabilized in 1.5μm thick cell required for π retardation, which limits their use in display applications. In this work, new OAFLC mixtures have been surface stabilized in thick cells. This achievement may open a new area of OAFLC applications in photonic devices.

Key words: Antiferroelectric liquid crystals, nematic, smectic, display, photonic devices

1. - Introduction

Liquid crystals are becoming crucial components in most flat panel display applications. Nowadays, lots of nematic liquid crystals are used to develop a wide range of portable, lap-top and desk-top PC and TV displays with different performance, especially related to contrast and viewing angle. The main drawback of nematic liquid crystals is the slow response time responsible for a trailing effect often observed in video displays [1]

Smectic liquid crystals feature low switching times, high contrast, wide viewing angle and bistability, all these properties being highly interesting in applications where video frequency and high resolution are required. These materials tend to order themselves in layers. The smectic C (SmC) class is characterized by a fixed angle between the layer normal and the director. A subclass of SmC is the chiral smectic C (consisting of SmC* and SmC_A*) where the director tends to rotate slightly from layer to layer describing a cone (or a helix). In the synclinic SmC* ferroelectric liquid crystal (FLC), the directors in successive layers are approximately parallel while in the anticlinic SmC_A* antiferroelectric liquid crystal /AFLC) the directors are approximately at opposite positions in odd and even layers within the cone generatrix, in the direction normal to the smectic layers. The pitch is in the order of 1-2μm [2]. AFLC displays show similar switching times as FLCs. Although they are strictly monostable in the absence of electric field, they can be stabilized at any transmission level by means of a constant holding voltage (bias voltage), therefore being effectively multistable. Indeed, AFLCs develop an analogue greyscale whose dynamic range is affordable with standard electronics. Moreover, AFLC configuration in alternating layers averages out the internal electric field of these materials in the absence of voltage. This significantly increases the stability of

AFLC displays in comparison with FLC displays. Antiferroelectric liquid crystals (AFLC) attracted attention of display manufacturers for many years, as a promising alternative to active matrix LCDs in applications where video frequency and high resolution are required [3]. However, AFLC materials show reduced contrast due to alignment problems and to the presence of pretransitional effect (PE) [4]. An alternatives to solve the dark state problem is the use of orthoconic AFLCs having a half cone angle of 45°. This property makes them isotropic for normal incident light and increases successfully the cell contrast of the device [5].

In this work, a study of the electrooptical performance of a new orthoconic antiferroelectric liquid crystal mixture (W-296) has been carried out in different cell geometries varying their thickness to extend their use to photonic applications.

2. - Experimental procedure

Orthoconic antiferroelectric liquid crystals (OAFLC) with a cone angle of 90º provide a good dark state between crossed polarizers independently of the cell rotation, since its birefringence on the substrate plane cancels out as long as the molecular director remains on the plane. Consequently the dark state is independent of the thickness and of the quality of alignment layer (Fig.1).

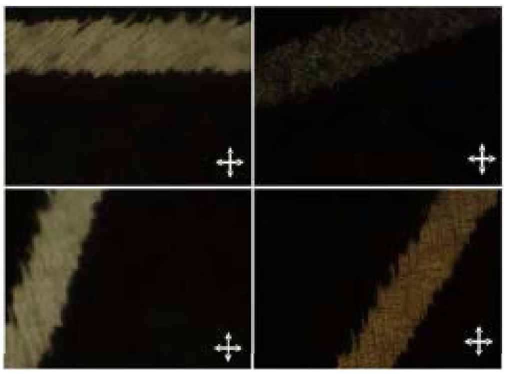

Fig. 1: Polarizing microscopic optical picture at 35 ºC when a cross rubbed OAFLC cell is rotated between crossed polarizers. The bright stripe is an interpixel gap.

Their very short pitch of the helix, induced by molecular chirality, characterizes those materials. This short pitch compromises the surface stabilization of the OAFLC in cell thicknesses higher than 2 μm, Consequently, this small pitch may jeopardize the electrooptical performance of the cell.

Test cells were prepared using 0.7mm ITO-coated polished glass plates; the pixels were imprinted on the ITO coating by photolithography. Eventually, a SiO2 isolating barrier layer was deposited onto the ITO. Homogeneous planar alignment was induced on the ITO coated glass plates with spin-coated Nylon6 dissolved in trichloroethanol (14 g/l) followed by curing and rubbing steps. The buffing process induces a preferential direction on the polyamide layer of the glasses, which eventually will determine the orientation of the normal of the smectic layers. The thickness of the cells was about 1.5μm, thin enough to allow surface stabilization of the material. The studied OAFLC mixture shows the cooling phase transition sequence as below:

Cr <-10 SmC_a* 97.1 SmC* 101.3SmA 103 Iso

The characterization procedure applied to the cells filled with OAFLC consisted of low frequency (0.1Hz) hysteresis curve using AC triangular voltage signals with different amplitudes (Fig.2). When the optical axis of the OAFLC state is aligned parallel to one of the polarizers, such cells show an electro-optical response where the Voltage-Transmission curve is symmetric about 0V, i.e., the optical response for a positive voltage is identical to that of a negative voltage.

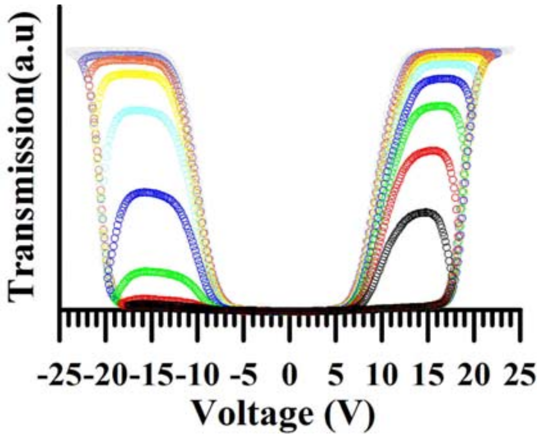

Fig. 2: The transmission of light in W-296 OAFLC driven by a low frequency (0.1 Hz) AC triangular wave and placed between crossed polarizer.

However, asymmetrical response, as observed in Fig. 2, usually occurs when the pitch is lower than the cell thickness; this situation may lead to flickering in multiplexed driving schemes.

In order to study the electrooptical performance of the OAFLC due to the bulk director geometry, we have performed measurements in cells with different thicknesses. Good alignment in cells of thickness of 3μm and 5μm has been achieved. This is the first time we have seen a surface-stabilized OAFLC in such thick cells using OAFLC mixture W-296 obtained at the Military University of Technology.

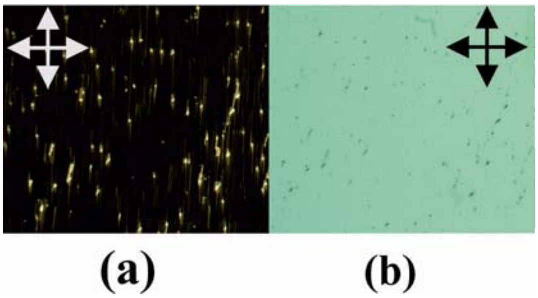

Fig. 3: Microscopic texture of OAFLC aligned in 5 μm cell.

Fig. 3 shows the microscopic texture of OAFLC aligned in 5 μm cell. The photograph has been taken in a polarizing microscope when square waveform of 60Hz is applied to the cell, and the voltage is: (a) 0V and (b) 40V. This cell has a phase shift well over π, therefore, the cell cannot be characterized in the same way as in thin cells, since transmission decreases rather than increasing over a certain voltage. A new protocol for characterizing OAFLC in thick cells must be designed in order to stabilize the intermediate transmission levels.

Depending on the optical thickness of OAFLC layer one can build a number of devices such as polarization switches or phase only modulators. In the second case, the device optical thickness must be thick enough to induce phase levels over 2π phase shifts between the fast and slow polarization of the impinging light in transmission mode.

The temperature dependence of the cone angle in the OAFLC mixture has been measured with a square waveform switching the cell between the two ferroelectric states. The sample is placed in the rotating stage of a polarizing microscope and set at an angular position whereby one of the FLC states (strictly, one of the extreme tilt angle positions) coincides with one of the crossed polarizer giving null transmission. When the liquid crystal is switched to the other tilt angle position (FLC state), the transmission would be minimum again as long as the cone angle is 90°, otherwise the transmission becomes to increase. In this case, the stage is rotated until the new minimum is found, and the angle between minima is taken as the angle between synclinic states (Fig. 4).

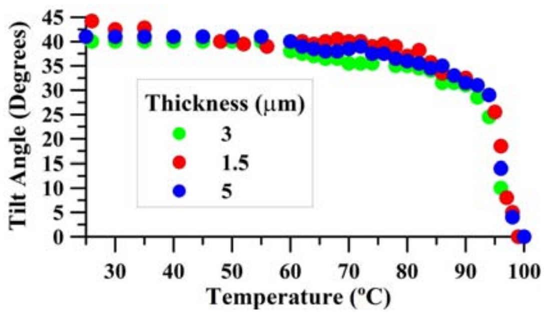

Fig. 4: The half cone measurement vs. temperature for cells with thickness 1.5, 3 and 5 μm.

The measured half cone angle is slightly below orthoconic condition about 43.5º. Those results show that no dependence of the cone angle on the thickness is observed and the angle reduces slowly until the SmC_a* – SmC* phase change at about 95-100ºC.

The dynamic performance of this orthoconic material has been evaluated by performing electrooptical studies on cells having thicknesses of 1.5 and 3µm.

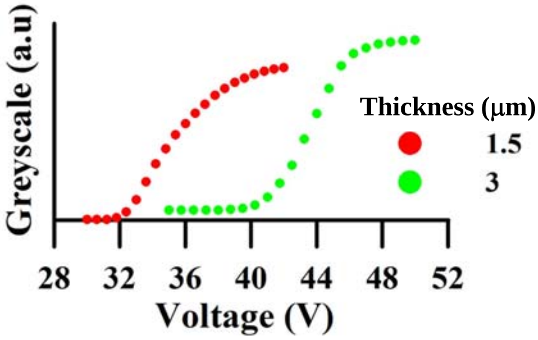

Fig. 5: Grayscales developed from dark to bright for cells with thickness 1.5 and 3µm.

Fig. 5 shows the results of the grayscale developed under passive multiplexing conditions [5]. The 1.5µm and 3µm cells show an excellent behavior except for a lower contrast in the 3µm case. Reaching the bright state requires a higher addressing voltage in the case of thicker cells, although the dynamic data range (DDR) of the grayscale remains substantially constant. It is worth mentioning that too wide DDRs may be an issue in practical applications, since they may preclude the use of standard CMOS electronics in the column drivers that generate the grayscale data pulses.

4.- Conclusion

We have performed measurements in new orthoconic antiferroelectric liquid crystal cells with different thicknesses. Our preliminary results show good alignment in thick cells up to 5µm has been achieved, keeping the orthoconic condition feasible. This opens the possibility of preparing a number of photonic devices such as polarization switches and phase only modulators using OAFLCs

Acknowledgements: This work has been supported by the Spanish Ministerio de Ciencia e Innovación, project TEC2008-00147 and Madrid Regional Program FACTOTEM S2009/ESP1781.

References

[1] Yuning ZHANG, Kees TEUNISSEN, Wen SONG, Xiaohua LI, "*Dynamic modulation transfer funtion: a method to characterize the temporal performance of liquid-crystal displays*", Opt. Lett., 33, (6), 533-535, 2008.

[2] Ji Li HiDEO Takezoe, Atsuo FUKUDA, *"Novel Temperature Dependences of Helical Pitch in Ferroelectric and Antiferroelectric Chiral Smectic Liquid Crystals"*, Jap. J. Appl. Phys., 30, 532-536, 1991.

[3] José Manuel OTÓN, Xabier QUINTANA, Pilar Lopez del CASTILLO, Alvaro LARA, Virginia URRUCHI, Noureddine BENNIS, *"Antiferroelectric liquid crystal displays"*, Optoelectron. Rev. 12, 236–269, (2004).

[4] Romeo BECCHERELLI, Stephen J. ELSTON, *"Evaluation of optical anisotropy in the pretransitional regime in antiferroelectric liquid crystals"*, Liq. Cryst., 25, 573–577, 1998.

[5] [4] Xabier QUINTANA, Pilar Lopez DEL CASTILLO, José Manuel OTÓN, Noureddine BENNIS, Alvaro LARA, Virginia URRUCHI, Roman DĄBROWSKI, *"Video rate multiplexed driving scheme for passive antiferroelectric liquid crystlas displays"*, Optoelectr. Rev., 12, (3), 291-297, 2004.

Lugar de celebración:

Universidad de Alcalá
Alcalá de Henares (Madrid)

Secretaría Técnica de la Reunión:

Fundación General de la Universidad de Alcalá
C/ Imagen, 1 - 3
28801 Alcalá de Henares. Madrid
Tel.: 91 879 74 30
Fax: 91 879 74 55
E-mail: optoel2013@fgua.es

www.optoel2013.fgua.es

Organizado por:

GRIFO — Grupo de Ingeniería Fotónica de la Universidad de Alcalá

Departamento de Electrónica, Universidad de Alcalá

Universidad de Alcalá

Con la colaboración de:

SEDOPTICA — Sociedad Española de Óptica

Comité de Optoelectrónica, Sociedad Española de óptica

Alcalá de Henares Ayuntamiento
www.ayto-alcaladehenares.es
www.alcalacultura.es

OMCA — Oficina Municipal de Congresos de Alcalá de Henares

FACTOTEM — Fotónica Aplicada para la Creación de Tecnologías Ópticas y su Transferencia a Empresas Madrileñas

La Suma de Todos — Comunidad de Madrid
www.madrid.org

Unión Europea — Fondos Estructurales
Invertimos en su futuro