

60.2: Novel Optically Addressable Photochiral Displays

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Abstract

We show for the first time, a novel optically written bistable cholesteric display using a simple electrode structure and reversible photo addressable azo binaphthyl chiral materials. These displays are inherently high resolution, require no drive electronics and can be made flexible.

1. Introduction

The optically addressable photochiral displays discussed here are based on bistable cholesteric display technology, which has high brightness, low power, excellent viewing angle, and can be flexible.[1,2] Cholesteric liquid crystal displays (ChLCDs) are typically updated using a passive matrix addressing scheme. Although low cost in comparison to active matrix drive schemes, it still requires significant drive electronics to enable a display module. For instance, in a complete module, the display electronics can cost as much as six times the cost of the display itself. This is the primary motivation for the novel optically addressable photochiral displays. An optically addressable display has the advantage that there can exist one set of drive electronics

separate from the display that can be used to address many displays.

These photochiral displays are based on novel azo binaphthyl chiral compounds with high twisting power and the ability for molecular conformational changes upon light irradiation.[3] These displays are inherently high resolution since the limiting size of an addressable element is the domain size for the cholesteric textures, approximately 1 μm . Based on these materials, we created a new kind of display architecture where the driving electronics are completely decoupled from the display itself. As such, the display can be installed in applications such as badges, store shelves, etc. Figure 1 illustrates a photo addressed plastic display, based on the polymerization induced phase separation (PIPS) process.[4]

In comparison to previous attempts at optically written cholesteric displays, these displays have no complex electrode structure.[5, 6] Simple unpatterned transparent electrodes on the front and back substrates are sufficient. Once optically written, a simple single pulse at a single voltage is required to show the image. The details of optical addressing, material response, electro-optical behavior, and flexible display development are presented.



Figure 1: A flexible optically addressed photochiral display. The display shown here is flexed and based on flexible ChLCD technology.

2. Results

Several displays were built with various configurations. All of these display configurations consists of two substrates with continuous conductors and ChLC, Figure 2. The conductors can be any transparent conductive material, we have built working

displays with both ITO (indium tin oxide) and PEDOT/PSS (poly (3,4) ethylenedioxythiophene / polystyrenesulfone acid) as the conductor. The ChLC layer can be either unencapsulated ChLC on glass substrates or polymer encapsulated ChLC on plastic.

The primary method to write an image on a display and store it indefinitely resides in the use of shifted electro-optical curves

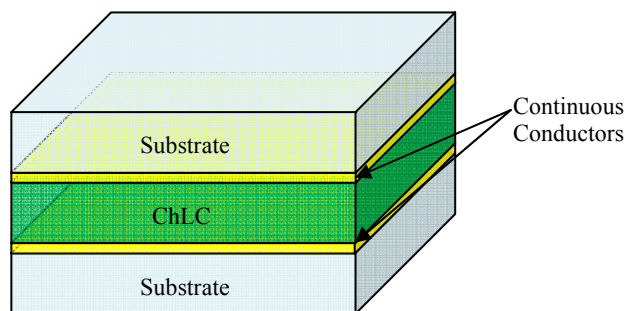


Figure 2: Illustration of the simple display cross-section. The conductors are unpatterned, where only a single voltage is used to switch the entire display.

resulting from the two conformations of the chiral materials. The shift in the curves comes from the fact that the different HTP values result in different pitch length. The drive voltage of cholesteric displays is inversely proportional to the pitch length, Figure 3. Here, the electro-optical curves for the exposed region (green reflection) and the unexposed region (red reflection) are shown. Applying a voltage between V_i and V_k will result in the exposed regions going to the focal-conic texture and the unexposed region going to the planar texture. As such, a bistable image is created. It should be pointed out that the planar and focal-conic textures remain stable even though the photoactive chiral dopants relax to the unexposed state due to thermal energy.

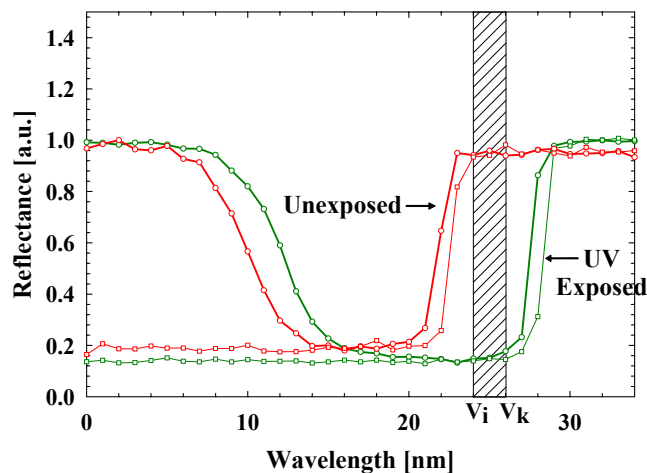


Figure 3: Electro-optical curves for the exposed (green reflection) and the unexposed (red reflection) parts of a display. Applied voltage in the range from V_i to V_k results in switching the exposed regions of the display to the focal conic state while the unexposed regions switches to the planar state.

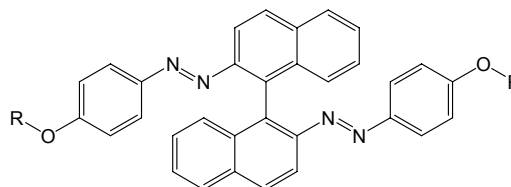
We present results on two classes of azo binaphthyl compounds, where compounds of Class 1 have an ether linkage to the alkyl chain and compounds of Class 2 have an ester linkage to the alkyl chain, Figure 4. We selected the azo binaphthyl

compounds because of their photoresponsiveness, high twisting power, and solubility with nematic liquid crystals. Both classes of photochiral dopants have high helical twisting powers (HTP) and reversible conformational changes. The twisting powers are in the range of $50\mu\text{m}^{-1}$ to $60\mu\text{m}^{-1}$ in a variety of nematic host mixtures as measured using weight concentrations. The trans-trans conformation is the most stable. Light irradiation leads to a conformational change to the trans-cis and cis-cis isomers that have very different HTP values, Figure 5.

(1) **1a** $R = C_{14}H_{29}$

1b $R = C_{10}H_{21}$

1c $R = C_8H_{17}$



(2)

2a $R = C_{11}H_{23}$

2b $R = C_2H_5$

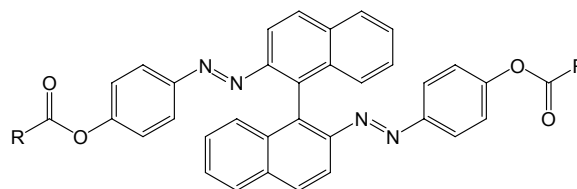


Figure 4: Azo binaphthyl compounds with azo linkages studied in this work. Compounds of Class 1 were synthesized to explore the effect of end chain length. Compounds of Class 2 were synthesized to explore the effect of the ester linkage as well as chain length on optical response and thermal relaxation.

Optical writing can take place within seconds and is highly dependent on light irradiance as well as wavelength. It has been found that photoactive chiral dopants with ether linkages are more sensitive than ester linkages, this sensitivity is linked to the removal of the carbonyl group from the alkyl chain thereby rendering the ester compounds slower, as shown in Figure 6. The chiral dopants of Class 1 have ether linkages and the tail chain length is longest for 1a and shortest for 1c. The chiral dopants of Class 2 have ester linkages and the tail chain length is longest for 2a. For the chiral dopants investigate the typical HTP values can go from unexposed (trans-trans state) of $60\mu\text{m}^{-1}$ to about $16\mu\text{m}^{-1}$ in the exposed state (trans-cis and cis-cis). This large change in HTP is the reason for the over 200nm shift in reflection wavelength within a few seconds of exposure to less than $1\text{mW}/\text{cm}^2$ of UV light.

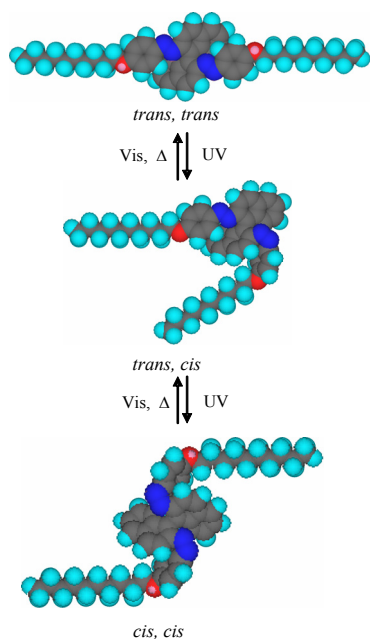


Figure 5: Illustrations of molecular trans-trans, trans-cis and cis-cis isomers for the Class 1 material (3D ChemDraw, space filling model).

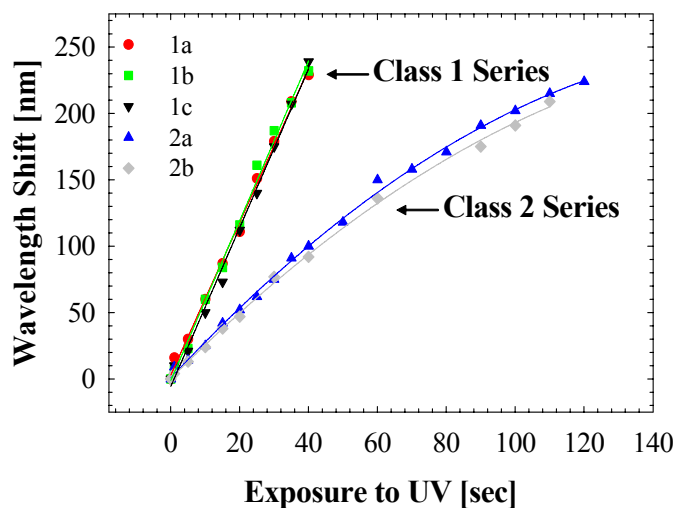


Figure 6: Comparison of the reflective wavelength shift with UV exposure time for several chiral dopants in the nematic host E7. The light irradiance is $440 \mu\text{W}/\text{cm}^2$ (at $\lambda_{\text{max}}=365 \text{ nm}$).

The time required for optical writing varies depending on the amount of UV irradiance incident on the display. A commercially viable product requires that the time for exposure be small enough so that many displays can be written in a short period of time. For photochiral 1a, optical writing can occur at 10 seconds or less if the UV intensity is greater than or equal to $5 \text{ mW}/\text{cm}^2$, Figure 7. Faster exposure times can be achieved with higher irradiance UV light or other photochiral dopants.

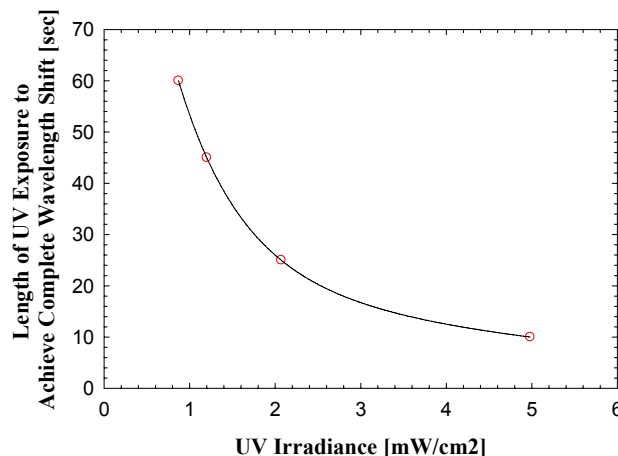


Figure 7: The length of UV exposure required to achieve nearly full wavelength shift for various UV irradiances (at $\lambda_{\text{max}}=365 \text{ nm}$) with photochiral 1a.

All photochirals investigated thermodynamically revert back to the trans-trans isomer over time. The time required for thermodynamic relaxation at room temperature is shown in Figure 8. As can be seen, the two classes of dopants relax after approximately the same time in the dark. The room temperature relaxation times are between 40 and 75 hours. The relaxation time can be greatly decreased by heating the display, where the higher the applied temperature the quicker the relaxation time. The relaxation time can be decreased to less than 1 minute with this technique. A commercial product would utilize the faster relaxation time created by heating the displays.

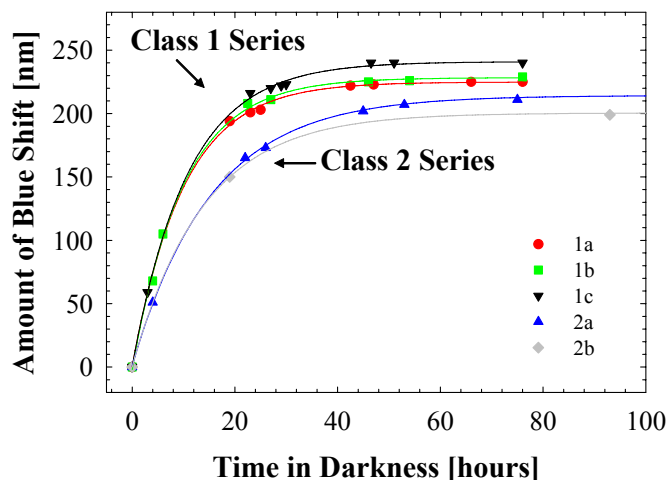


Figure 8: Comparison of the reflective wavelength shift upon relaxation from UV exposure versus the amount of time elapsed after UV exposure. This data is for several chiral dopants in the nematic host E7. The initial light irradiance before relaxation began was $440 \mu\text{W}/\text{cm}^2$ (at $\lambda_{\text{max}}=365 \text{ nm}$).

This photochiral display technology can be easily transferred to the flexible display manufacturing process at Kent Displays. It simply involves using a ChLC material doped with a photochiral material and then proceeds through the typical flexible display manufacturing processes. This yields a flexible display with a ChLC and photochiral dopant encapsulated in a polymer shell.

Although the data presented here is from an unencapsulated ChLC in glass substrates, similar results are found in encapsulated systems and will be presented later this year. This new display architecture easily lends itself to a flexible display format, particularly for full color photochiral displays. The possibilities for such a display architecture are great, considering this can create full color, flexible, switchable, high resolution, low cost electronic media.

5. Conclusions

The broader impact of the optically written photochiral displays is from the low cost aspect. These displays facilitate new applications of the ChLCD technology that previously were not

possible. These applications can now be made possible from the fact that the optically written displays, particularly in their flexible form, can be very low cost with all the electronics residing in a few optical writers.[5]

An example of two identical displays driven differently is shown in Figure 9. One display is addressed with the standard multiplexing electronics while the second display is optically addressed. Notice that the overall size of the display module is reduced and the potential cost savings can be up to six times the cost of just the display alone. This type of simplification of the final product can make markets such as security badges, small point of sale advertisements, and other applications that require a very low cost module that is updated infrequently now possible.



Figure 9: A conventional display (left) with attached bulky and costly electronics compared with an optically addressed display (right) with the same image without the added electronics.

6. Acknowledgements

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7. References

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