P-153: Flexible Photoaligned Optically Rewritable LC display

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Abstract

Flexible optically rewritable reflective TN LC display based on photoalignment technology has been demonstrated. The rewritable display does not require any electronic scheme, power supply, or conductive layers, when operating. Such a display can erase and write images for many times because of LC alignment reorientation onto one photoalignment layer under exposure of a polarized UV light. The image can be saved with a very high contrast for a long time.

1. Introduction

Today, there is an increasing demand for flexible liquid crystal display (LCD) in many applications such as mobile phones, smart cards, electronic newspaper and integrated display. Compared to traditional glass LCD's, flexible displays benefit from being thin, lightweight and more mechanically robust. They also offer a clear advantage in design, since it allows integration into devices of non-rectangular and curved nature. Among various technologies, reflective liquid crystal display has great potential. Bistable LCD is also desirable for many applications, since it results in low power consumption. Several bistable technology fabricated with plastic substrates have been demonstrated. Li et. al[1] reported flexible bistable display using π-BTN and photoaligned technologies. The uniformity of the cell gap is critical in this case, which complicates the fabrication process. Huang et.al[2] employs cholesteric liquid crystals technology for flexible bistable display. But flexible cholesteric displays require high driving voltages and that is far away from market requirements. Rumiko Yamaguchi et. al.[3] proposed crosslinkable photosensitive polymers and unpolarized light for optical security devices. Latent images with continuous gray levels and high spatial resolution can be written by controlling an azimuthal anchoring of the LC alignment film. However, the image cannot be rewritable, as crosslinkable photosensitive polymers undergo the irreversible photochemical reaction during UV illumination.

Recently, we have reported the new principle of the optically rewritable devices based on azo-dye photoaligned material, which can operate and save information with a very high contrast for long time without any driving scheme, conductive layers or semiconductor layers[4]. Our main idea is to employ this novel principle for flexible reflective TN LCD, which target is for a smart card display. The manufacturing process is highly simplified since no ITO substrates are required. It also increases the durability and cost efficiency issues. We used two different materials as alignment layers. The low baking temperatures of the materials make them perfectly suitable for plastic substrates. One of the materials is the azo-dye SD-2 (Fig.1), newly synthesized by Dainippon Ink and Chemicals Inc. [5] SD-2 molecules can be purely reoriented under a polarized UV light (~365nm). The other can be any kind of alignment material which has a low temperature of baking and no photosensitive alignment properties.

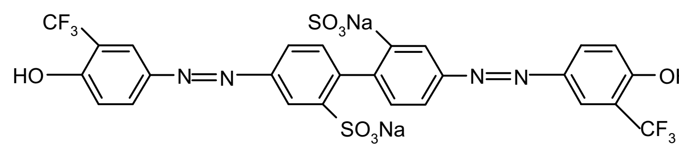

Figure 1. Structure of azo-dye SD-2

The device can erase and write image for many times without any driving scheme, power supply and conductive layer. The lifetime for saving images has no limitations. This method may be employed in the display for both such applications as security cards, credit cards, ID cards, as well as rewritable devices including electronic paper, rewritable paper, paper-like display etc.

2. Experimental

Fig. 2 shows the cross section of our flexible optically rewritable TN LC display.

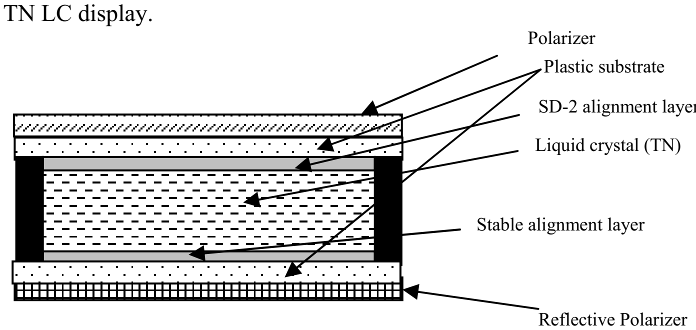

Figure 2. Cross section of flexible optically rewritable LC display

The commercially available plastic substrates have a thickness of 200μm. The upper substrate is coated with 1% SD-2 in N,N-dimethylformamide (DMF). After spin coating, the substrates are baked in 100^0 C during 10 minutes to remove DMF. Further the one substrate coated with 1% SD-2 is illuminated by a polarized UV light for 5 minutes to form the initial SD-2 orientation (500 Wt Hg lamp with interferometric filter, λ_{exp}=365 nm, P_{exp}=1.6 mWt/cm²). The SD-2 orientation can be easy changed after the cell assembling. The bottom substrate was treated to achieve the the LC alignment layer with a high anchoring energy, which direction is perpendicular to the SD-2 layer alignment. After assembling using 5μm spacer, the LC ZLI 5700-000 from Merck is injected.

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3. Results and Discussions

3.1 Principle of optically rewritable device

When liquid crystal (LC) is sandwiched between the two different alignment layers, SD-2 alignment layer gives a possibility to change twist angle in LC cell. We used the structure with a zero twist angle for a dark state and the twist angle close to 90^0 for the bright state between two crossed polarizers ($P \perp A$) as shown in Fig 3. We can also use close 90^0 twist as dark state and zero angle as bright taking two parallel polarizers. But the contrast ratio in the latter case is lower.

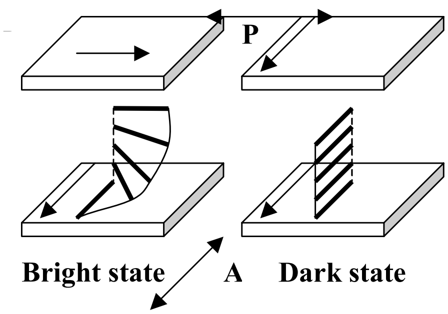


Fig.3 Principle of optically rewritable LC device

We use a mask to create image. Two- step process is necessary to use in this case (Fig.4).

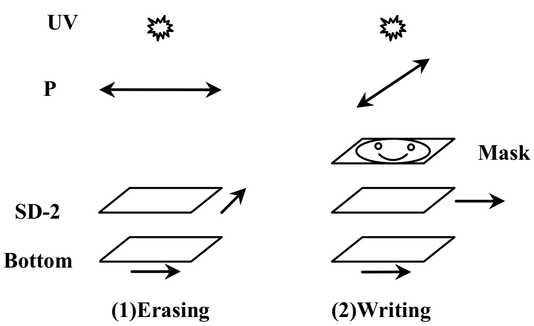


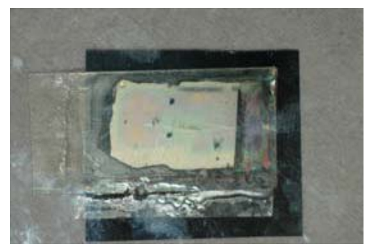
Fig.4 Principle of writing images in two processes

First we should erase the previous image (switching all the display to a uniform state). For the bright case the polarization UV light should be parallel to the alignment direction on the bottom substrate, and no mask is needed during illumination. So the alignment direction of SD2 will be perpendicular to the stable alignment direction. Liquid crystal will assume the twist structure and the device will be in bright state under two crossed polarizers. Second, we write the image by illumination through a mask and the activating light polarization changed to 90^0. So the SD2 direction of the exposed area will reorient parallel to orientation on bottom substrate. The information symbols will become dark, while the other unexposed region is still bright. We can also select switching to the dark state for the process of erasing previous images and to the bright state in the writing process.

3.2 Experiment results

Fig 6 shows the demonstration for rewriting image on the optical rewritable reflective TN LC cell. The part (a) shows the first image "HK" on the cell. Then, we erase the image using polarized UV light as (b). Finally, we write another image "2" on the cell.

(a)First image



(b) Erasing Image

(c) Second Image

Fig.6 Process of rewriting image on flexible reflective TN LC cell in two steps

Fig 7 shows the demonstration of manual bending the product. Since uniformity of cell gap is not critical and drivers are not required for our rewritable TN cell, we have no problems for bending or curving. The image can be saved for a long time with a high contrast.

Fig.7 Demonstration of bending flexible optical rewritable reflective LCD

One of the possibilities of a mask is a TN display with any information to be registered by UV light passed through it. As azo-dye SD-2 can change its alignment reversibly without any photochemical transformations and photo-chemical reactions, our procedure will allow us to erase and write images at unlimited number of times. For a polarized light of about 365nm, the usual UV lamp with a polarizer can erase and write the image very fast. The image can be kept for infinitely long time, provided that UV polarized light of 365 nm is avoided and can be readable only, if a polarizer is used. The latter is quite reasonable for such application, as security displays for credit cards.

Since no ITO layer or driving circuit is needed for the rewritable TN LCD, the device size can be very small, that is also important for smart card displays. The resolution is limited only by the thickness of a liquid crystal layer and can be 20 μm that is enough for many applications. The contrast can be very high, in our case it was 20:1, but if we use a special cover on the polarizer it can be over 100:1.

4. Conclusions

This paper proposes a new principle of the flexible rewritable devices, which can operate and save information with a very high contrast for long time without any driving scheme, power supply, or conductive layers. The optical rewritable device is based on a twist nematic structure and photoalignment technology and makes fabrication process simpler then for normal TN LCD. The plastic substrates without ITO can be used. We present a new concept for LC alignment and LC display. The method may be employed in the display for both security cards such as credit cards, ID cards etc. and rewritable devices including electronic paper, rewritable paper, paper-like display etc.

5. Acknowledgements

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