Ultra-Thin High-Dichroic-Ratio Polarizer Generated by Photoalignment

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Abstract
A dichroic polarizer with a high dichroic ratio of up to 60 is achieved by photoalignment induced anisotropic azo dye ordering. The film thickness is well controlled in 200 nm, and it is 500 times thinner than a conventional iodine Polaroid polarizer, which is desirable for ultra-thin high performance liquid crystal display applications.

Keywords
Polarizer, dichroic ratio, photoalignment, azo dye.

1. Introduction
Polarizers are indispensable thin films in liquid crystal displays, and have a significant influence on the display's brightness and contrast. Dichroic polarizers are based on the selective absorption of anisotropic materials like organic dyes. Dichroic ratio (N) is one of key performance indexes, which is the ratio of the two orthogonal directions' absorbance,

$$N = \frac{A//}{A\perp}, \qquad (1)$$

where A// and A⊥ are defined as the absorbance parallel and perpendicular to the average orientation of the long axis of the chromophores, respectively. For high end liquid crystal displays, polarizers with a dichroic ratio of more than 50 are required.

Conventional polarizers are based on anisotropic absorption by uniaxially stretched Polyvinyl alcohol (PVA) dipped with iodine [1-2]. These polarizers possess high transmission, and a high polarization efficiency and dichroic ratio. However, additional layers, like triacetylcellulose (TAC) film, are requisite to protect the PVA from moisture and heat. Besides this, adhesive layers are needed to laminate the iodine polarizers to the display. Such additive layers unavoidably result in an increase in thickness and deterioration of performance.

Coatable polarizers are proposed to be situated in liquid crystal cells, which eliminate the need for the additive layers mentioned above and avoid a complicated manufacturing process. These polarizers are mainly based on guest host systems. Dichroic dyes are doped liquid crystal polymers and the mixing is coated on a substrate. The film thickness is in the order of submircometers [3-7]. However, the dichroic ratio is not high enough, so such polarizers are not satisfactory for practical use.

A high-dichroic-ratio polarizer with a 5 μm thickness, also based on the guest host system, has been reported but it is not coatable and the fabrication process is not compatible with liquid crystal display manufacturing [8].

In this work, we propose a dichroic polarizer based on the photoalignment method to achieve both a thin thickness and high dichroic ratio. The photoalignment technique is regarded as a promising method in liquid crystal alignment because of the high anchoring energy, good uniformity, small residual current and large voltage holding ratio [9-10].

Azo dyes are one kind of excellent materials for photoalignment and show better thermal stability compared to other photoalignment materials, like photo-crosslinkable materials. Azo dyes can be aligned by linear polarized light and the average orientation of the molecules is perpendicular to the polarization of light. The light of polarization parallel to the direction of the molecules' chromophores is absorbed while light perpendicular to the absorption axis is transmitted. Consequently, the dichroic ratio depends on the anisotropy of the molecules' ordering. Therefore, azo dyes with a high aspect ratio are beneficial. The chemical structure of photoalignment material AD1 is illustrated in Figure 1.

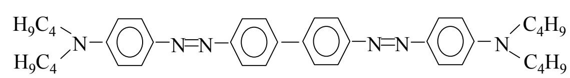

Figure 1. Chemical structure of azo dye AD1.

2. Azo dye polarizer by photoalignment

Uniform AD1 thin film is evaporated on clean bare glass and illuminated by a linear polarized blue laser whose central wavelength is at 442 nm. The film thickness is 200 nm and its optical performance is characterized by a UV/VIS Spectrophotometer Perkin Elmer (Lambda 20). The configuration measurement setup is demonstrated in Figure 2. The light source is deuterium and tungsten-halogen lamps with automatic source change. The size of the light beam is 10 mm by 2 mm. A commercial PVA/iodine polarizer is placed between the light source and the proposed azo dye polarizer to get a linear polarized incident light. The azo dye polarizer is placed parallel or perpendicular to the first polarizer to measure the corresponding transmission and absorbance, which are shown in Figure 3-6.

The absorption of the AD1 is in the blue region, and peak absorbance is at around 450 nm, where a dichroic ratio of up to 60 is achieved. The dichroic ratio is above 50 from 400 nm to 480 nm. T// and T⊥are defined as the transmission of linear polarized light with polarization parallel and perpendicular to the polarization axis of the azo dye polarizer, which can be interpreted as bright state and dark state, respectively. In the bright state, transmission of the whole visible range is higher than 90%, which is quite bright. The contrast ratio is defined as (T//)/(T⊥), and the maximum is more than 300. For high contrast applications, the thickness of the azo dye layer can increase to 300 nm, while the transmission decreases about 5 % accordingly.

 ISSN 0097-966X/16/4702-0596-$1.00

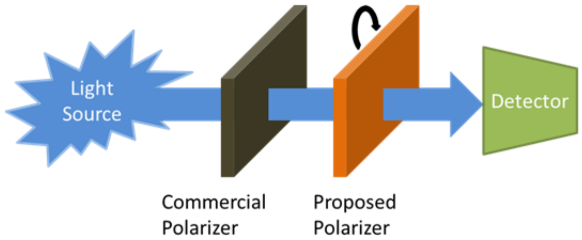

Figure 2. Configuration of the measurement setup.

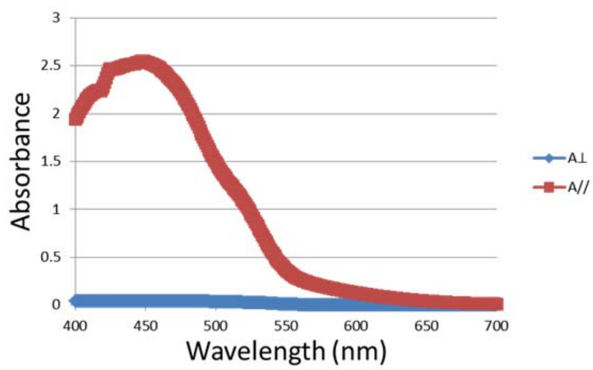

Figure 3. Measured absorbance of the azo dye polarizer.

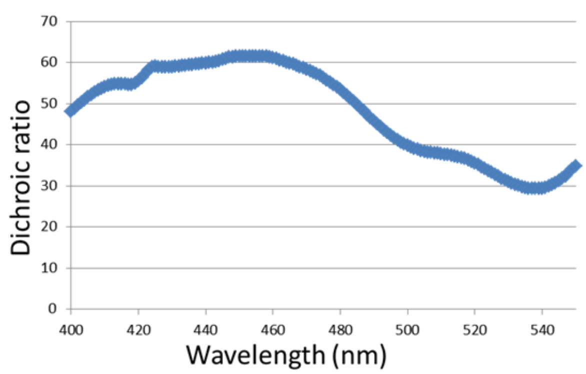

Figure 4. Dichroic ratio of the azo dye polarizer in the absorption region.

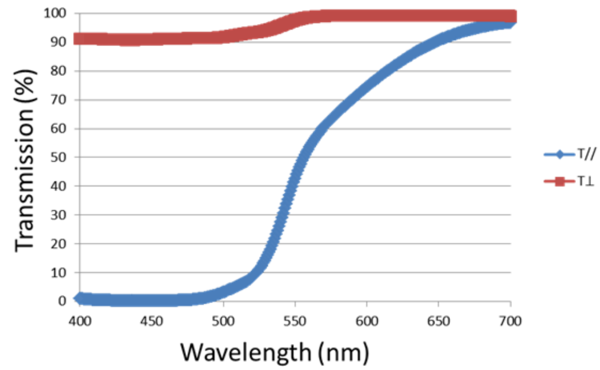

Figure 5. Transmission spectra of the azo dye polarizer.

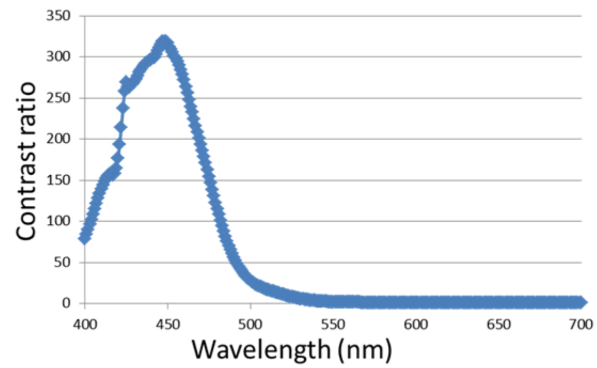

Figure 6. Contrast ratio of the azo dye polarizer.

3. Broadband polarizer with iodine

For liquid crystal displays, a broadband polarizer with an absorption spectrum from 400 nm to 700 nm is essential. To widen the absorption spectrum of the above azo dye polarizer, other chromophores with complementary colors are necessary. Iodine is chosen because of its broad absorption spectrum and simplicity to process. Iodine is sublimated to the AD1 thin film. The optical characteristics of this broadband polarizer are exhibited in Figure 7 and Figure 8.

After the iodine sublimation, the transmission of the dark state is quite low except for a small leakage from 650 nm to 700 nm. To suppress such red leakage, more iodine is desirable. However, this will result in a decrease of the transmission in the bright state, especially in the blue region, because iodine not only has strong absorption in short wavelengths but also disturbs the alignment of azo dyes, which is indicated by Figure 9 and Figure 10. So the iodine gas density and sublimation time are optimized to balance the transmission and contrast of the whole spectrum.

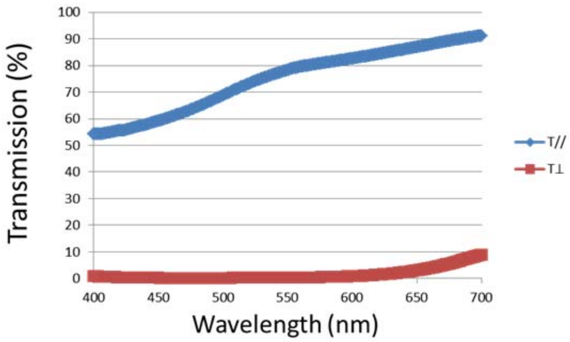

Figure 7. Transmission spectraof the broadband iodinepolarizer.

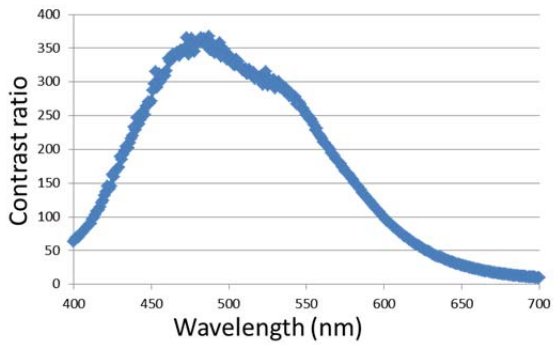

Figure 8. Contrast ratio of the broadband polarizer.

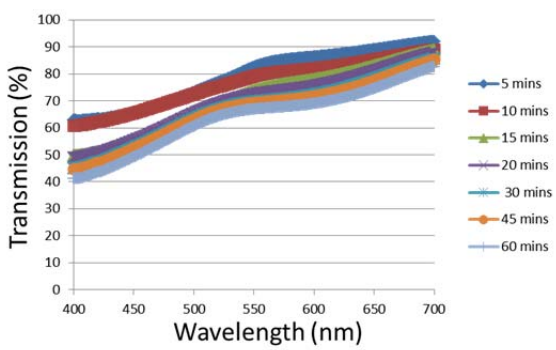

Figure 9. Transmissions of bright state with different iodine sublimation times.

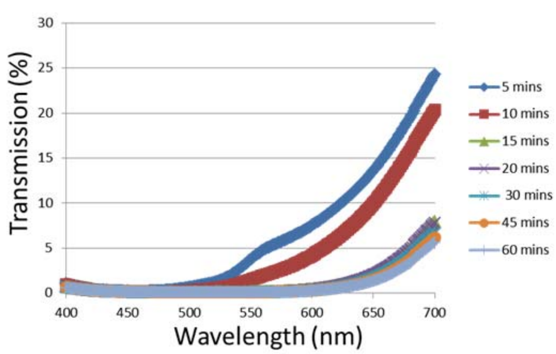

Figure 10. Transmissions of dark state with different iodine sublimation times.

4. Conclusion

An ultra-thin azo dye polarizer with a high dichroic ratio of up to 60 at 450 nm is achieved by photoalignment. Iodine is incorporated to obtain a broadband polarizer with a contrast ratio of up to 350. The film thickness is 200 nm, which is much thinner than a conventional iodine Polaroid polarizer. Such a thin polarizing film is able to be utilized in liquid crystal cells to improve the display's performance and reduce the whole thickness of the display module, which is difficult for the Polaroid polarizer. Moreover, the proposed polarizing thin film is capable of being used for versatile applications like patterned polarizers, benefitting from the flexibility of the photoalignment technique.

5. Acknowledgements

This work was supported by the funding from State Key Laboratory on Advanced Displays and Optoelectronics Technologies and Hong Kong Government Research Grants Council Grant Number 614413.

6. References

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