

A New Reflective Display Mode for Antiferroelectric Liquid Crystal

Won Sang Park, *Student Member*, Sung Chul Kim, *Student Member*, Gi Dong Lee, *Student Member*,
Tae Hoon Yoon and Jae Chang Kim, *Member*

Abstract

In this work, we proposed a reflective antiferroelectric liquid crystal display (AFLCD) using a half-wave cell whose in-plane tilt angle is 22.5°. To check the validity of our design, we fabricated a reflective half-wave AFLC cell of which in-plane tilt angle is 24.9°, and measured VIS reflection spectra, contrast ratio and response time. In the results, the half-wave AFLC cell in the reflective configuration exhibits high brightness, high contrast ratio of 20:1, and fast response time of 700 μs.

Keywords : AFLC, reflective LCD, half wave cell, poincare sphere

1. Introduction

With the increasing demand for hand-held devices with light-weight and low-power-consumption display, reflective liquid crystal displays(LCDs) have been implemented in various configurations in order to achieve high brightness as well as high contrast. The single polarizer modes have been considered as a suitable structure for reflective LCDs because it can provide high brightness [1-2]. However, the reflective LCDs based on a single polarizer mode suffer from low contrast ratio and slow response. In order to overcome these problems, we need to make the reflected light linearly polarized over the whole visible spectra by using a wide-band quarter-wave film [3]. In this work, we proposed a reflective antiferroelectric liquid crystal display (AFLCD) using a half-wave cell whose tilt angle is 22.5°. By applying a AFLCD to a single polarizer reflective mode, we can also achieved the very high speed response time as well as the high contrast ratio. To check the validity of our design, we fabricated a reflective half-wave AFLC (CS-4001 from Chisso Co.) cell of which tilt angle is 24.9°, and measured contrast ratio, VIS reflection spectra and response time.

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W. S. Park, S. C. Kim, G. D. Lee, T. H. Yoon and J. C. Kim are with the Department of Electronics Engineering, Pusan National Uni versity, San 30, Jangjeon-dong, Kumjung-ku, Pusan 609-735, Korea. **E-mail** : pws@hyowon.pusan.ac.kr **Tel** : +51 510-1703 **Fax** : +51 515-5190

2. Etheory(Operation Principle)

Reflective AFLCD is composed of a polarizer, a LC cell, a wide band quarter wave film, and a metallic diffuse reflector, as shown in Fig 1. In our configuration, the rubbing direction of LC cell is parallel with the transmission axis of polarizer, and oriented at 45° with respect to the optic axis(slow axis) of the quarter wave film. Then, the dark state and the bright state are obtained at antiferroelectric-state (AF-state) and at ferroelectric-state (F-state), respectively.

Below the threshold voltage, LC layer will go to the AF-state. Then, linearly polarized incident light will keep the state of polarization when the light propagates through LC cell. The linearly polarized light becomes circularly polarized light after passing through the quarter wave film. The reflected light rotated by an angle 90° as passing through the quarter wave film again. The 90°- rotated light will maintain the state of its polarization during passing through the LC cell. Finally, the polarizer will block the reflected light, because the

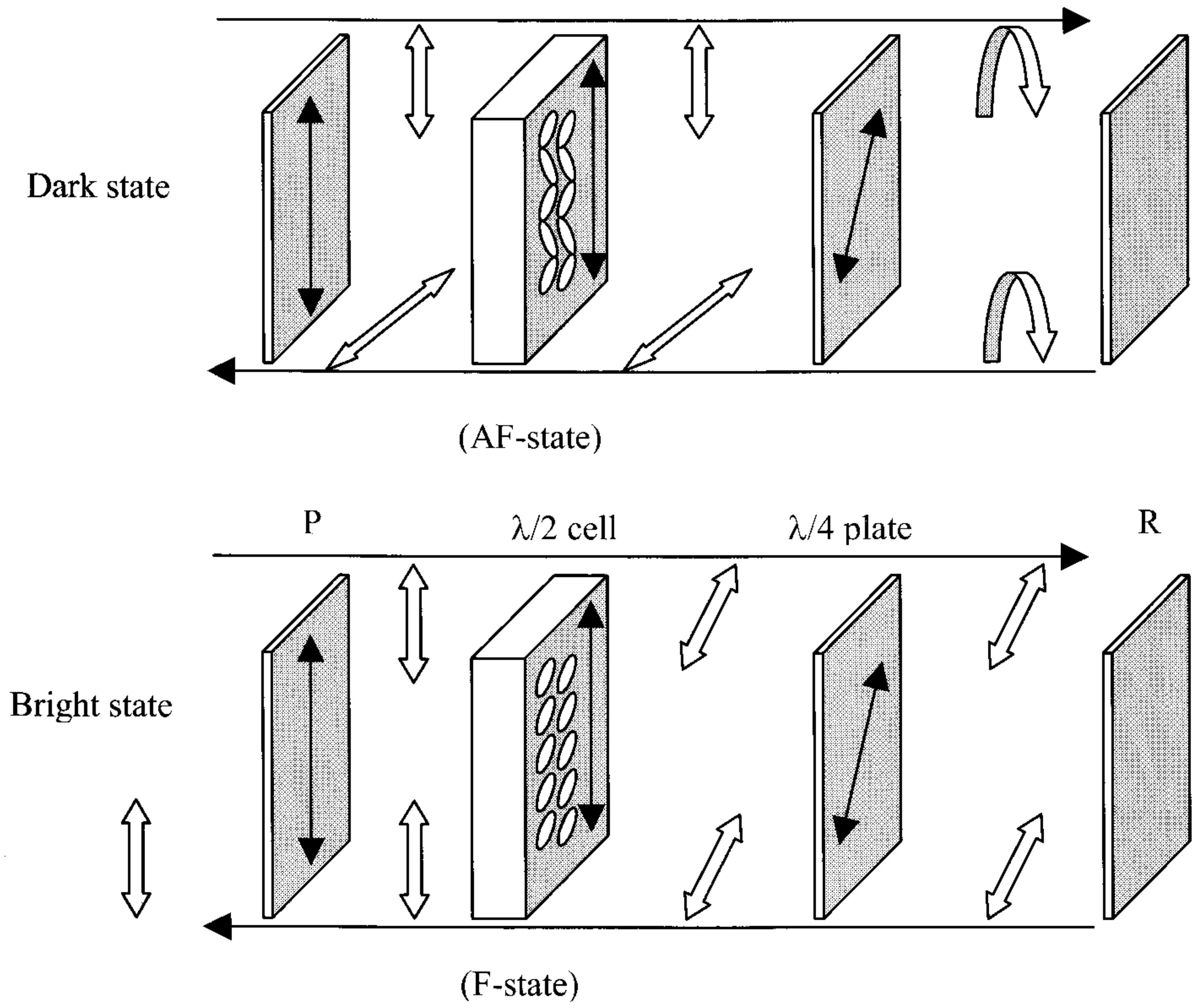

Fig. 1. The configuration and optical principle of a single polarizer reflective AFLCD

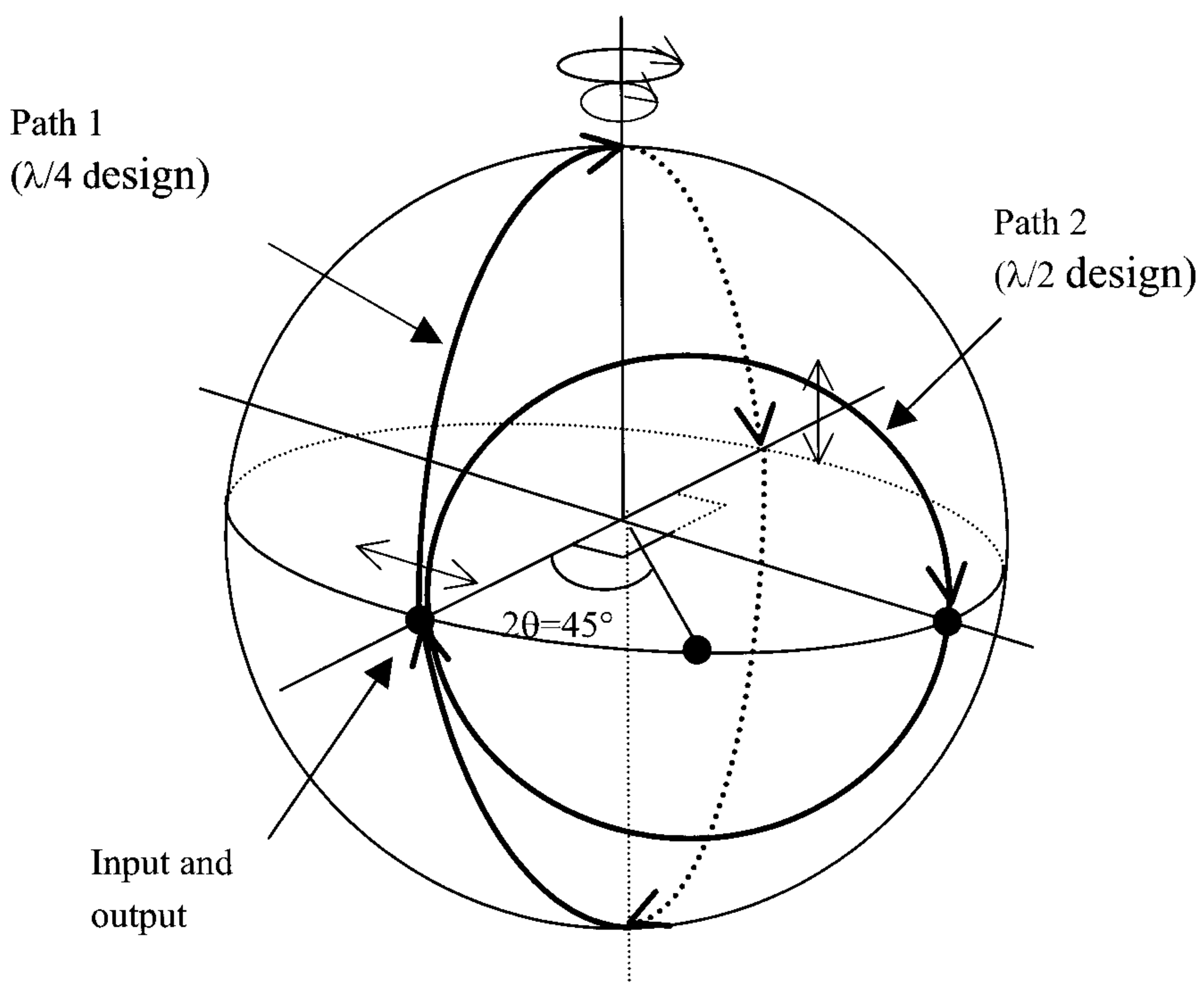

Fig. 2. Poincare sphere representation of the polarization path for the bright state (Path 1 and path 2 represent polarization path ι cell and a λ/2 cell, respectively.)

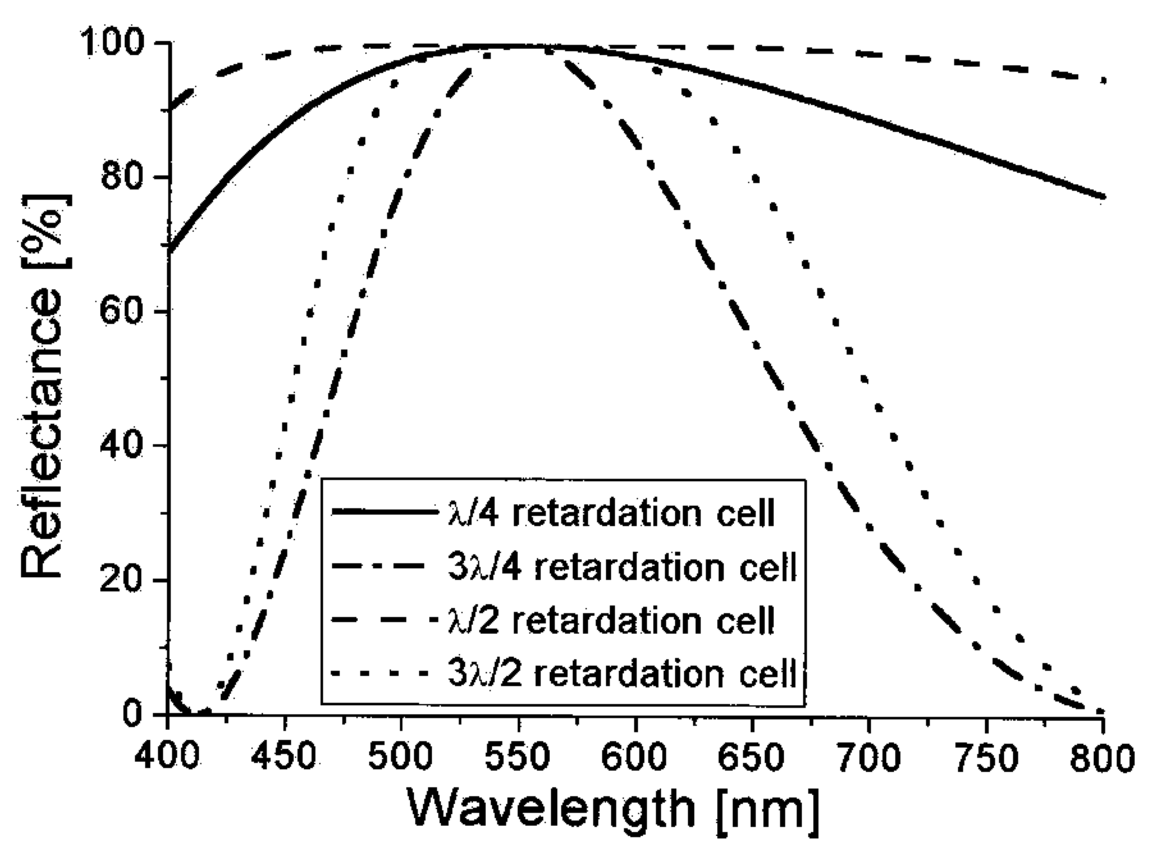

Fig. 3. Calculated reflection spectra of the bright states with a various retardation of a LC cell at the 550nm

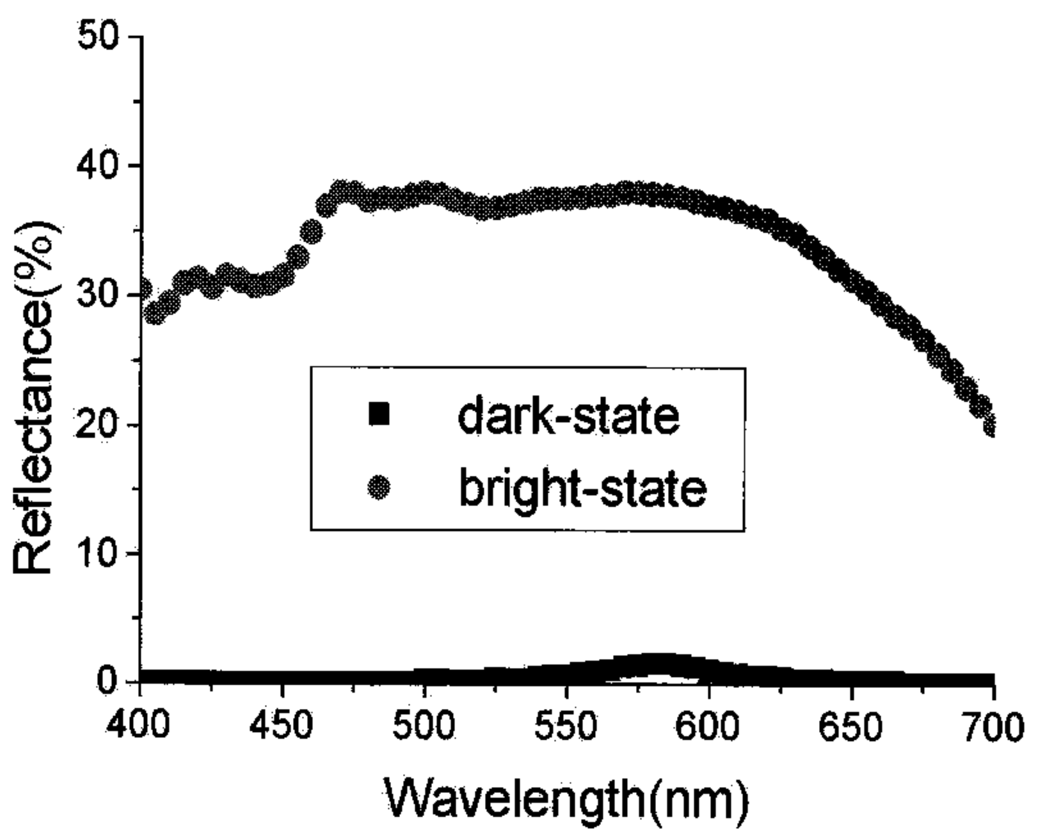

Fig. 4. The reflection spectra for a reflective AFLCD

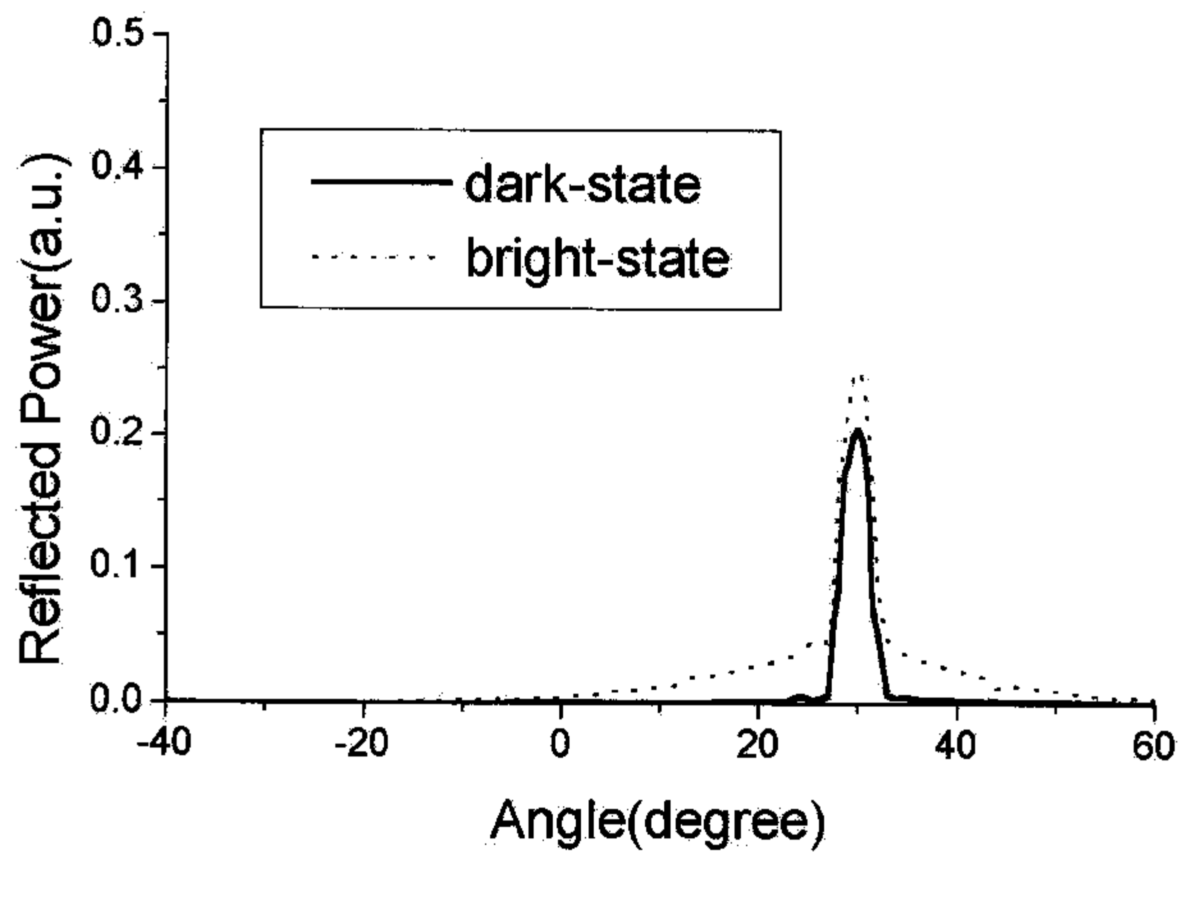

Fig. 5. Measured viewing angle dependent reflectance of a reflec tive AFLCD

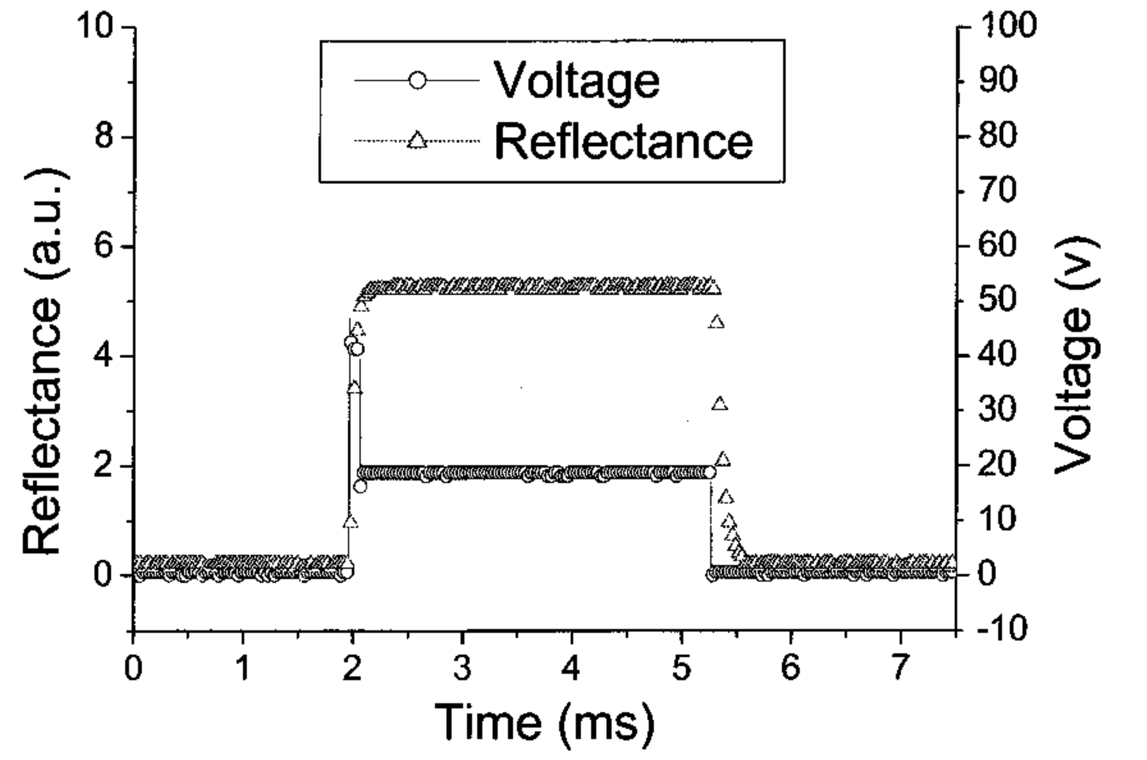

Fig. 6. Measured response time of a reflective AFLCD

polarization is perpendicular to the transmission axis of the polarizer. On the other hand, if it is greater than the saturation voltage, LC layer will go to the F-state. Then, linearly polarized incident light will be rotated by an angle 45° after propagating through LC cell. The 45°-rotated light will maintain the state of its polarization light after passing through the quarter wave film twice. The polarization of reflected light will be rotated by an angle -45° after propagating through the LC cell. Finally, the reflected light will pass through the polarizer, because the polarization is parallel to the transmission axis of the polarizer.

Fig. 2 shows the Poincare sphere representation of polarization in the bright state. In the figure, length of path 2 is shorter than that of path 1. It imply that phase dispersion of reflective light in λ/2 reflective cell could be smaller than the λ/4 reflective cell. As a result, we can achieved the high reflectance by using a λ/2 cell over the whole wavelength ranges in the bright state. Fig. 3 shows the calculated reflection spectra of single polarizer mode reflective AFLCD in the bright states. In conclusion, reflective AFLCD using half-wave LC cell provides the high brightness in the bright state in addition to high contrast ratio.

3. Experiments

In a half-wave AFLC (Chisso CS4001) cell, the two rubbed substrates were separated by spacers to maintain the uniform cell thickness d=1.7μm. For planar alignment, polyimide solution RN-1175 (Nissan Chem Co.) was spin-coated onto ITO glass, and baking temperature is 250°C. The liquid crystals were injected into parallel alignment cells in isotropic phase. To fabricate a half-wave AFLC cell, we have to get the optical anisotropy of AFLC molecule. However, we have the difficulty of measuring the optical anisotropy of AFLC because of its biaxial property. Therefore, we measured effective Δn of AFLC in the normal direction from surface. The effective anisotropy(Δn_{eff}) was measured by 'Rotational Polarizer Method' and 'Phase Compensation Method' [4]. The measured value was 0.167 ± 0.01.

Fig. 4 shows the VIS reflection spectra of dark state and bright state for the AFLCD, respectively. The metallic diffuse reflector is used as reference for the spectra characteristics. Thought the in-plane tilt angle of CS-4001 used in this study is not 22.5°, the dispersion of bright state is small. Fig. 5 shows the viewing angle dependent reflectance of a reflective half-wave AFLCD with a wide band quarter wave film, when the incident angle of the light source is –30°. Maximum brightness can be observed at 30°. However, the contrast is very low because of the high reflection from the surface of the AFLCD. Maximum contrast can be achieved by observing the image at 20°. We achieved high brightness as well as high contrast ratio of 20:1. Fig. 6 shows the response time of a reflective half-wave AFLCD. Although the response time varies as driving waveform, a rising time and a falling time are about 200 μs and 500 μs, respectively.

4. Conclusion

We proposed a reflective AFLCD using a half-wave cell whose in-plane tilt angle is 22.5°. To check the validity of our design, we fabricated a reflective half-wave AFLC cell of which in-plane tilt angle is 24.9°, and measured VIS reflection spectra, contrast ratio and response time. In the results, the half-wave AFLC cell in the reflective configuration exhibits high brightness, high contrast ratio of 20:1, and fast response time of 700 μs.

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