Biaxial integrated optical film for VA mode LCD's made from in-situ photopolymerised reactive mesogens.

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Abstract

For high end, large area displays, all current LC modes require some degree of optical compensation to improve the front of screen viewing experience. Currently most optical films are laminated to the outside of the LCD cell, between the glass and polariser. In this paper we wish to show how it is possible to integrate the compensating optical film within a VA mode LCD cell. The paper will describe the process of making the biaxial film through the process of in-situ photopolymerisation of an aligned film of reactive mesogens in the cholesteric phase using polarised UV light. The film can be made on the colour filter array side of the LCD panel. In addition the process of fabricating a VA mode LCD containing this film will be described and the performance of this module will be presented

1. Introduction

Large area, VA mode LCD's, are increasingly being manufactured with polarisers that contain at least one compensation film layer. To reduce the manufacturing costs of LCD's, there is an advantage to move the compensation films from the outside to the inside of the display. This is sometimes termed the "incell" approach. The methods of optically compensating a VA display are well known, and require a negative C plate and a positive A plate. These optical elements can either be included as two uniaxial films, or as is increasingly the trend, one or more biaxial films. In this paper we wish to present our work on incorporating a biaxial film as an incell layer in a VA cell.

The requirements for an incell compensator are numerous. Not only should it, as much as possible, be compatible with current production techniques, and have the desired optical effect, but it should also fit into the cell. Based on these requirements, the compensator should contain a minimum number of layers and each layer should be as thin as possible. It is well known that reactive mesogen films can produce very thin compensation layers, for example, the thickness of a typical reactive mesogen quarter wave plate is approximately 1.2mm. However it is difficult to construct a display containing two separate compensation layers, therefore there was a clear need to develop a biaxial reactive mesogen layer for VA in-cell compensation.

The use of dichroic photoinitiators for curing reactive mesogen films was first proposed by Broer *et al*[1] in which a method of integrating a quarter wave plate into a broadband cholesteric film was described. The film was processed using plane polarised UV light. The reactivity of the dichroic photoinitiator is dependent upon the direction of polarised light, and maximum reactivity is achieved when both the transmission axis of the polariser and the long axis of the dichroic photoinitiators are parallel. A typical example of a dichroic photoinitiator is shown in Figure 1. It is also well known that VA mode LCD can be compensated by a combination of an A plate and a negative C plate. We have previously reported that a negative C film can be prepared using cholesteric RM mixtures in which the pitch of the cholesteric mixture is in the UV. In this paper we describe how such a film made from tight pitch cholesteric mixture can be transformed into a biaxial film by incorporating a dichroic photoinitiator in the mixture, and polymerising using plane polarised light.

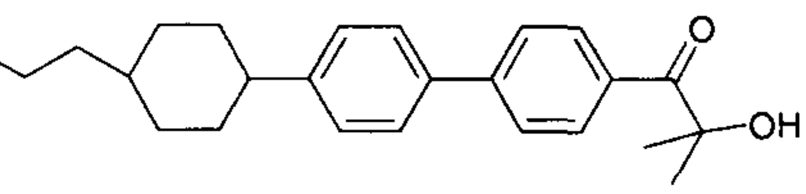


Figure 1: The structure of a dichroic photoinitiator used to make biaxial RM films

2. Experimental

2.1 Preparation of the biaxial RM film

A mixture was prepared containing reactive mesogen monoacrylates, diacrylates, a chiral dopant with a high helical twisting power and a liquid crystal, or dichroic photoinitiator and additives to aid alignment. This mixture was dissolved in Propylene glycol methylethyl acetate (PGMEA) by gently heating the suspension until fully dissolved. After cooling to ambient temperature, the mixture was coated onto 2.5cm^2 PI coated glass using a Commax Precima spin coater at 2000rpm for 30seconds. The film was annealed for 1 min at 60°C on a hot plate to improve the alignment quality and subsequently transferred to a nitrogen box that was fitted with a quartz window. This film had the optical property of an uniaxial negative C film. A UV polariser was placed between sample and the UV lamp and the film was irradiated with UVA light for 60s. The power of the polarised light was 47mW/cm^2. The retardation profile of the polymerised film was measured and the film was found to have the optical property of a biaxial negative C film. The degree of polymerisation was measured by FTIR and found to be 92.4%.

3. Results and discussion

3.1 RM biaxial film

The requirements for a mixture that can be used to prepare a biaxial film are the following.

- A cholesteric phase at ambient temperature.
- A pitch that is shorter than the wavelength of visible light.
- A dichroic photoinitiator.
- Can be aligned on only one substrate.

If a mixture which has the above requirements is polymerised using unpolarised UV light, a uniaxial film is formed. However if plane polarised light is employed, a biaxial film is formed. The differential activation of the dichroic photoinitiator by polarised UV light which is parallel, rather than orthogonal to the long axis of the molecule leads to a localised concentration of radicals in one direction in the x,y plane of the film. This in turn leads to the formation of the biaxial film. The mechanism for the formation of the biaxial film is believed to be associated with local diffusion of birefringent molecules into the region of the cholesteric helix that is preferentially activated by the polarised light. This is schematically depicted in Figure 2.

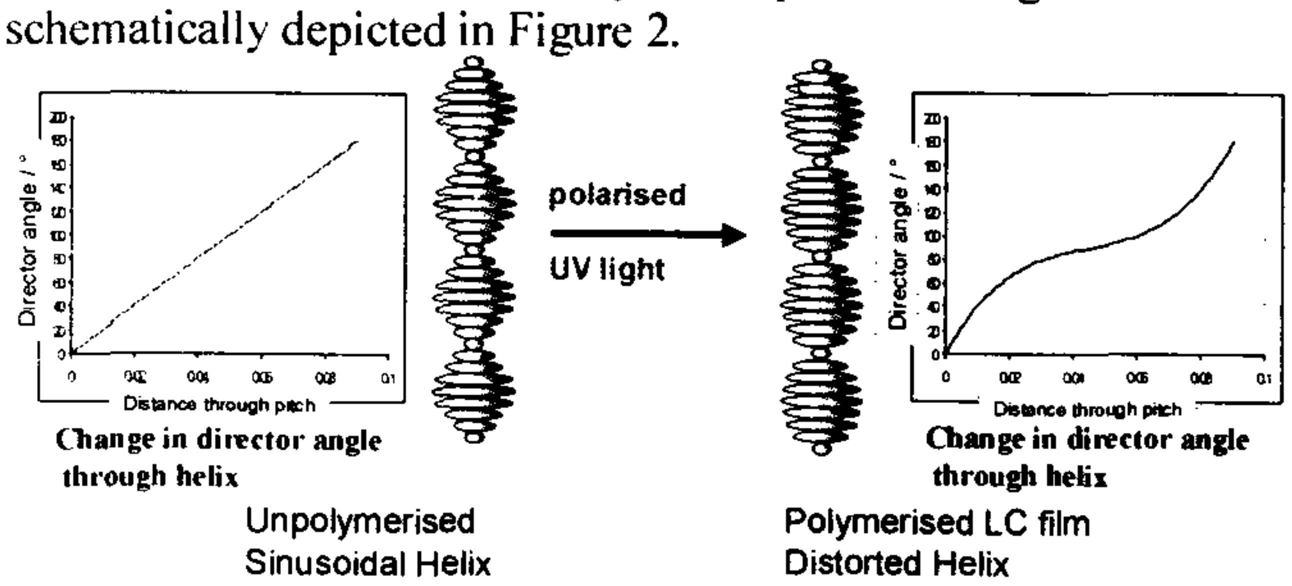


Figure 2: Schematic representation of the potential structure of the helix in the uniaxial and biaxial films

The transition axis of the polarised light therefore determines the slow axis of the biaxial film. Rotating the UV polariser can therefore change the slow axis direction. This is depicted in Figure 3.

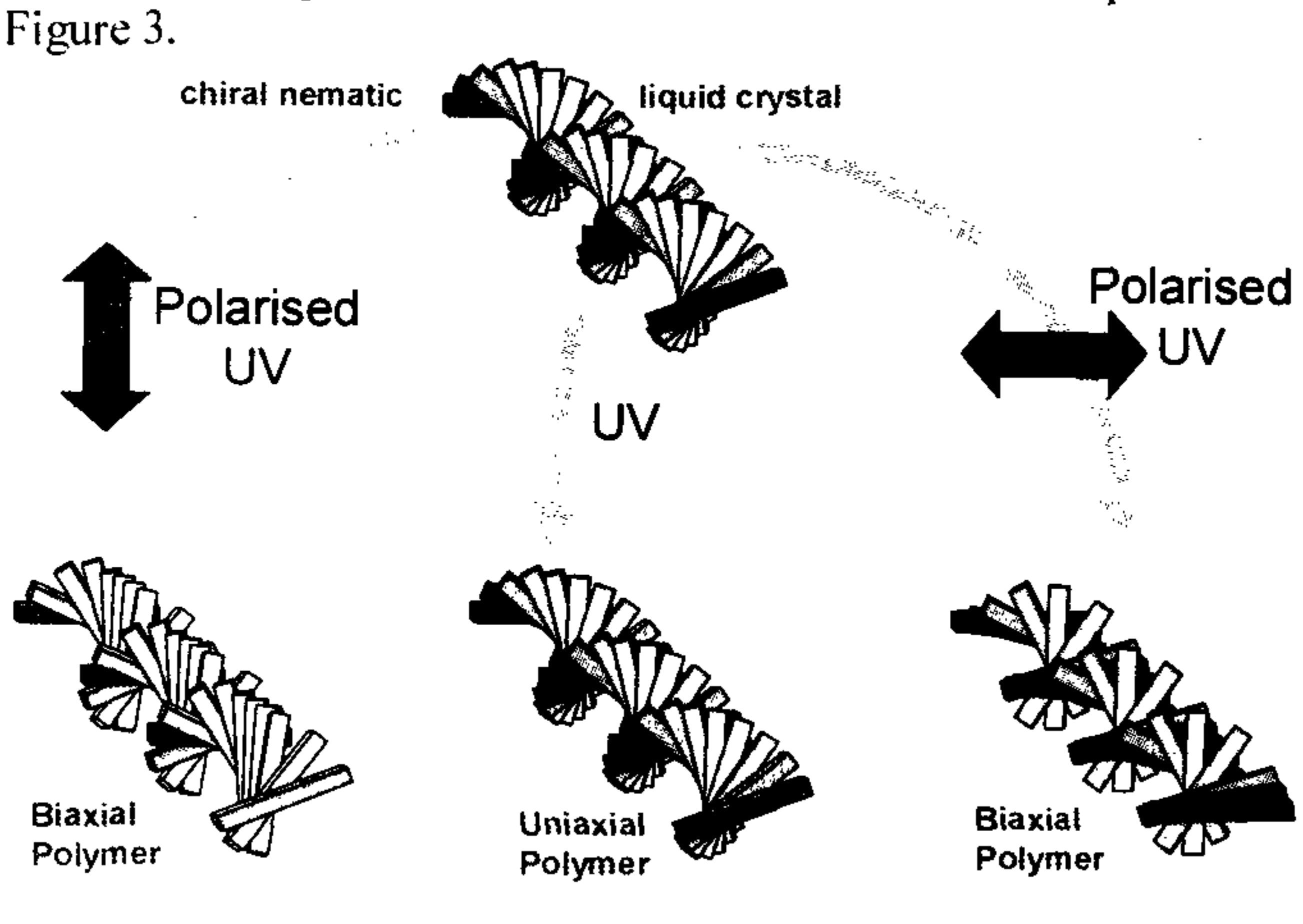


Figure 3: Diagram showing how different forms of UV light can be used to change the optical properties of a tight pitch, cholesteric RM film. The direction of plane polarised light defines the slow axis of the biaxial film.

A biaxial reactive mesogen film was prepared according to the method described in Section 2.1. Irradiation of such mixtures with unpolarised and polarised UV light results in a film with the retardation profile as shown in Figure 4

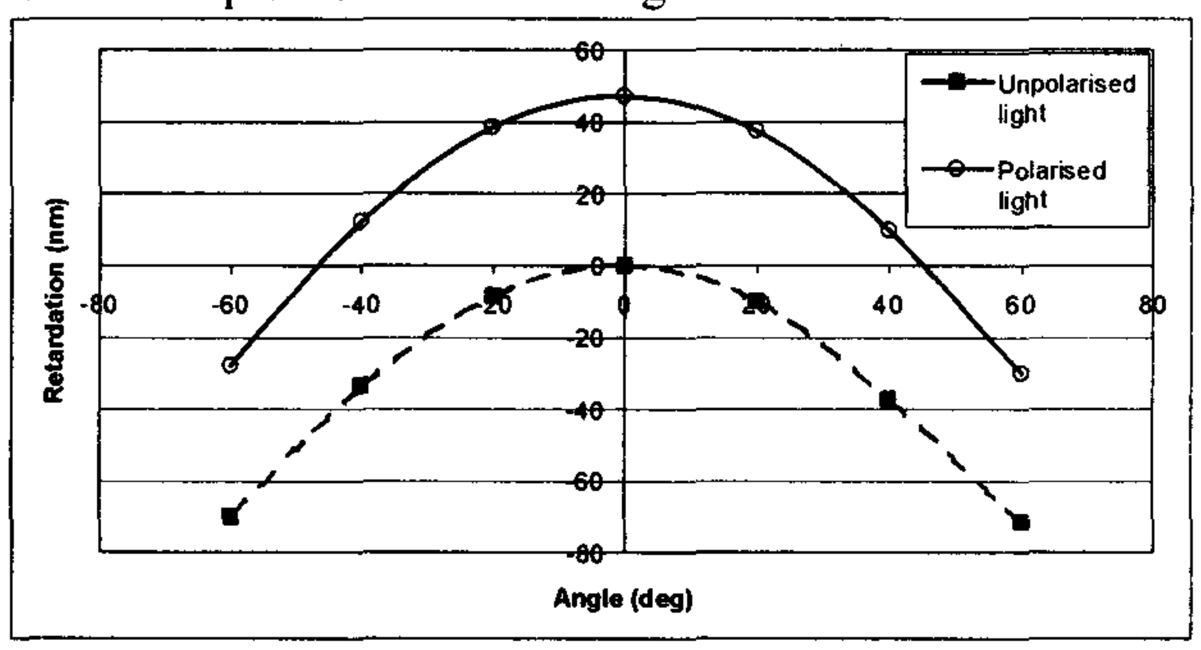


Figure 4: Retardation profile of an Uniaxial and a biaxial tight pitch cholesteric RM film.

The retardation profile in Figure 4 shows that the film irradiated with unpolarised UV light behaves like a normal tight pitch cholesteric film, and has the optics of a negative C film. However when the same mixture was irradiated with polarised light, the film has some on-axis retardation, and between crossed polarisers, it can be clearly seen that the film has a slow axis. Further ellipsometry measurements have confirmed that this film is biaxial.

3.2 Preparation of incell RM biaxial compensator containing PVA prototype.

Retardation films formed from reactive mesogens have the potential to be used as optical films that can be positioned inside the liquid crystal cell. Reactive mesogen films can be directly coated or printed onto the desired substrates and cured using photopolymerisation. With typical film thickness of between 1 and 3 μm, the films are thin enough for such incell applications. The preferred location for the film is directly on top of the colour filter array. Alternatively, the biaxial film can be coated onto the overcoat layer if needed. To help with the alignment, a polyimide film can be coated on top of the colour filter array or overcoat layer. Subsequently ITO can be deposited directly on the polymerised biaxial film, and after patterning, a 17" SXGA prototype VA display can be produced. The structure of the display is shown in Figure 5.

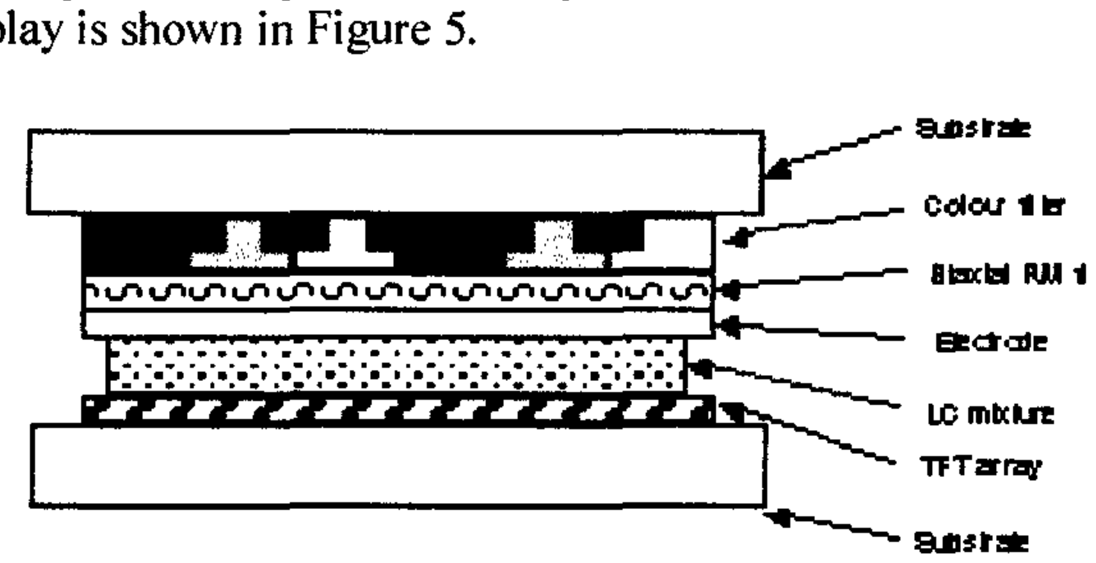
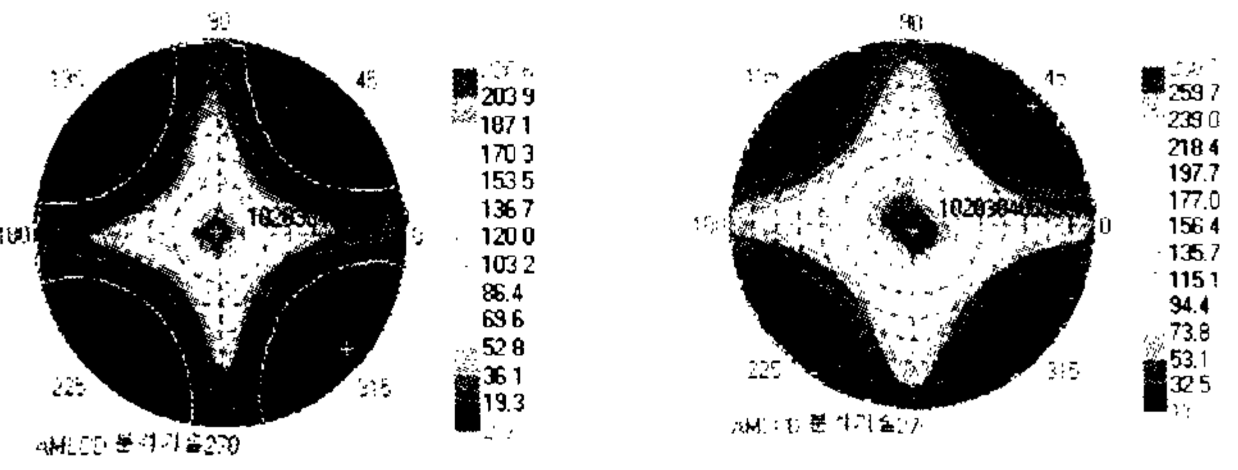


Figure 5: Schematic representation of the prototype PVA cell containing an incell RM biaxial retarder film.

The completed display was prepared by the process outlined in the experimental section. A significant challenge in the cell making process was the high temperature processes typically used in LCD manufacturing, and the effect these had on the durability of the reactive mesogens retardation film. A combination of mixture formulation and process optimisation gave a film which had the correct optical properties.

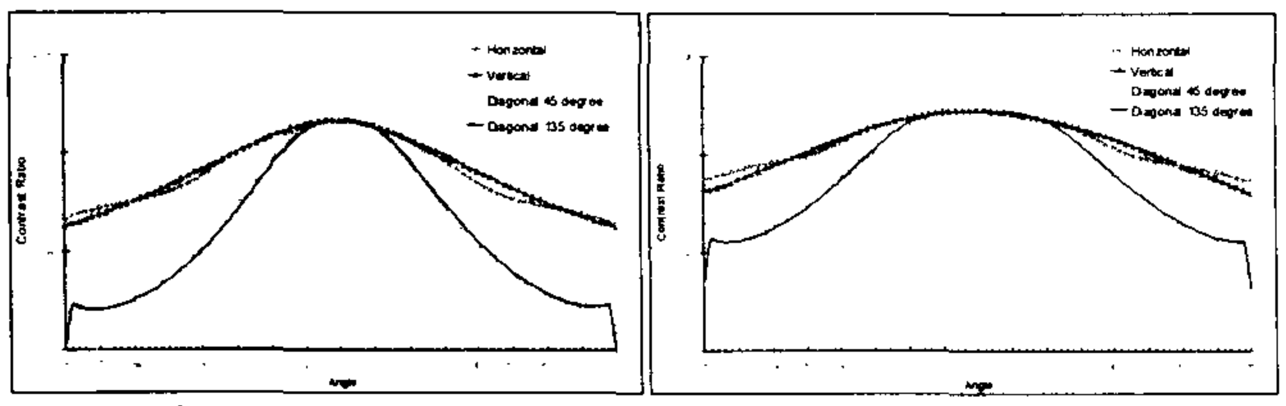
The viewing angle properties of the compensated and uncompensated test cells are shown in Figure 6. The results show a significant increase in the off axis contrast ratio especially in the 45° and 135° directions, indeed a contrast ratio of greater than 10:1 is achieved up to 80° in all viewing directions.



Without compensator *With incell compensator*

Figure 6: Isocontrast plots of the prototype with and without incell RM biaxial compensator

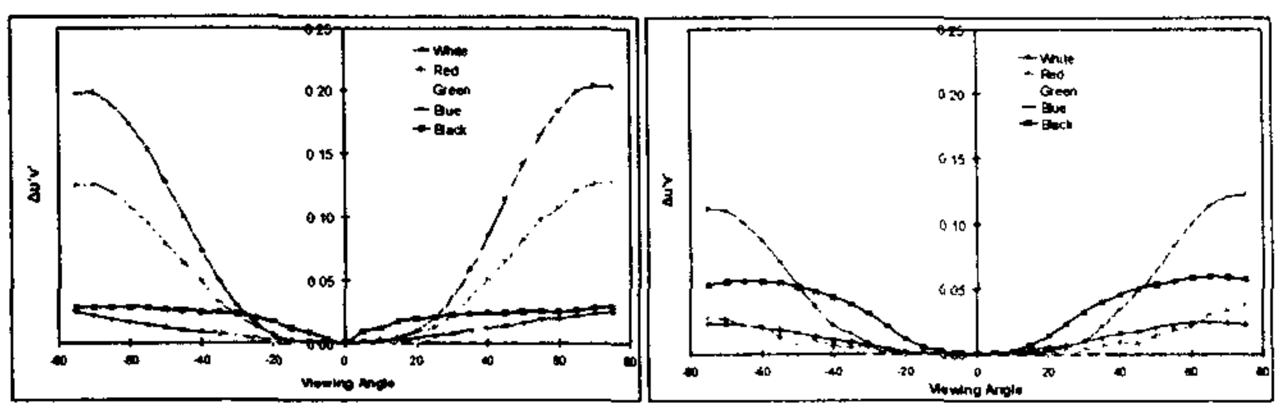
The contrast ratio performance of the compensated and uncompensated is shown in Figure 7. The on-axis contrast ratio of the compensated and uncompensated prototype cells are similar indicating that the alignment of the reactive mesogen layer has the necessary quality required for this application.



Without compensator. *With incell compensator*

Figure 7: Contrast ratio against incident angle for a PVA panel with and without an incell biaxial RM compensator.

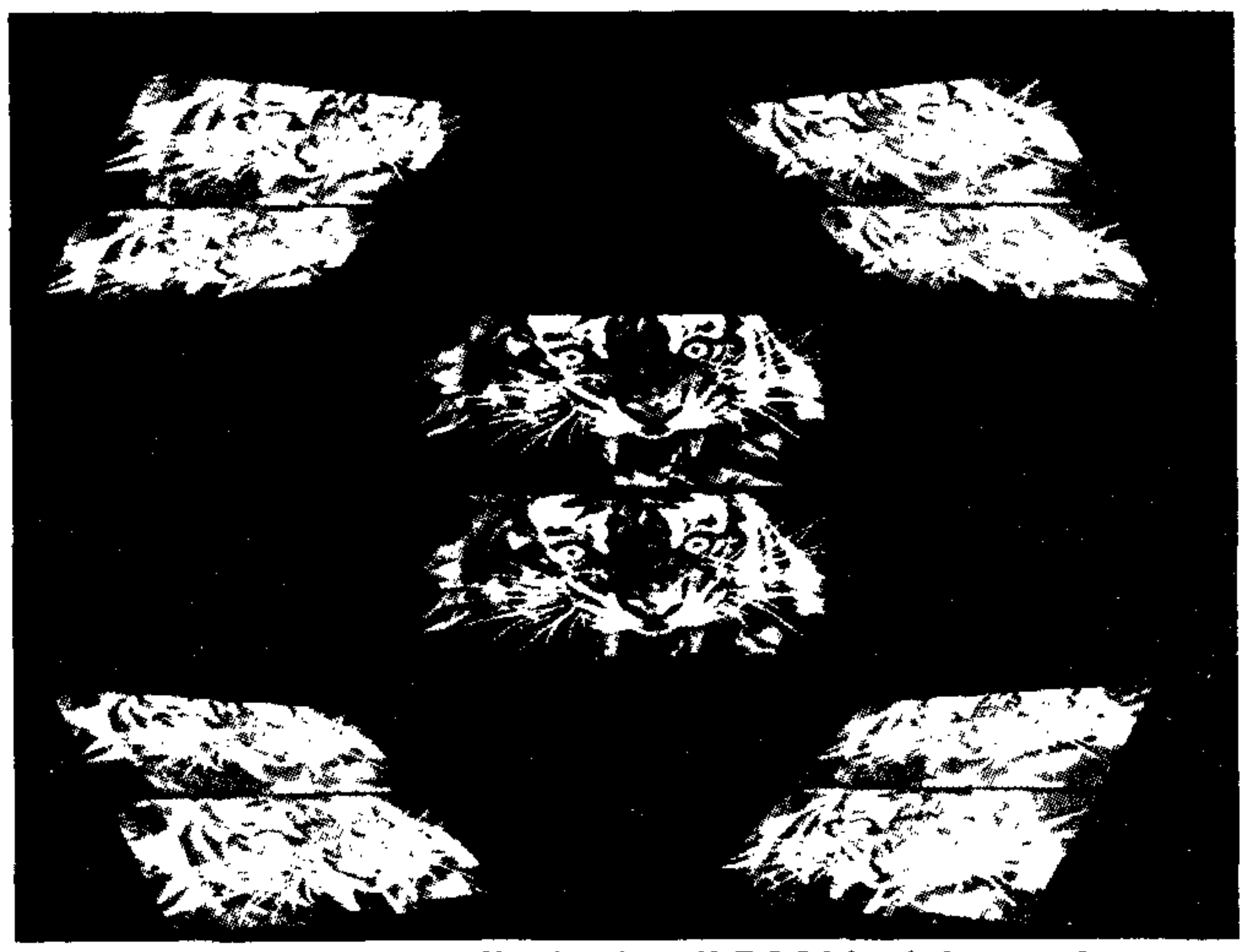
The colour shift properties of the compensated and uncompensated test panels are shown in Figure 8.



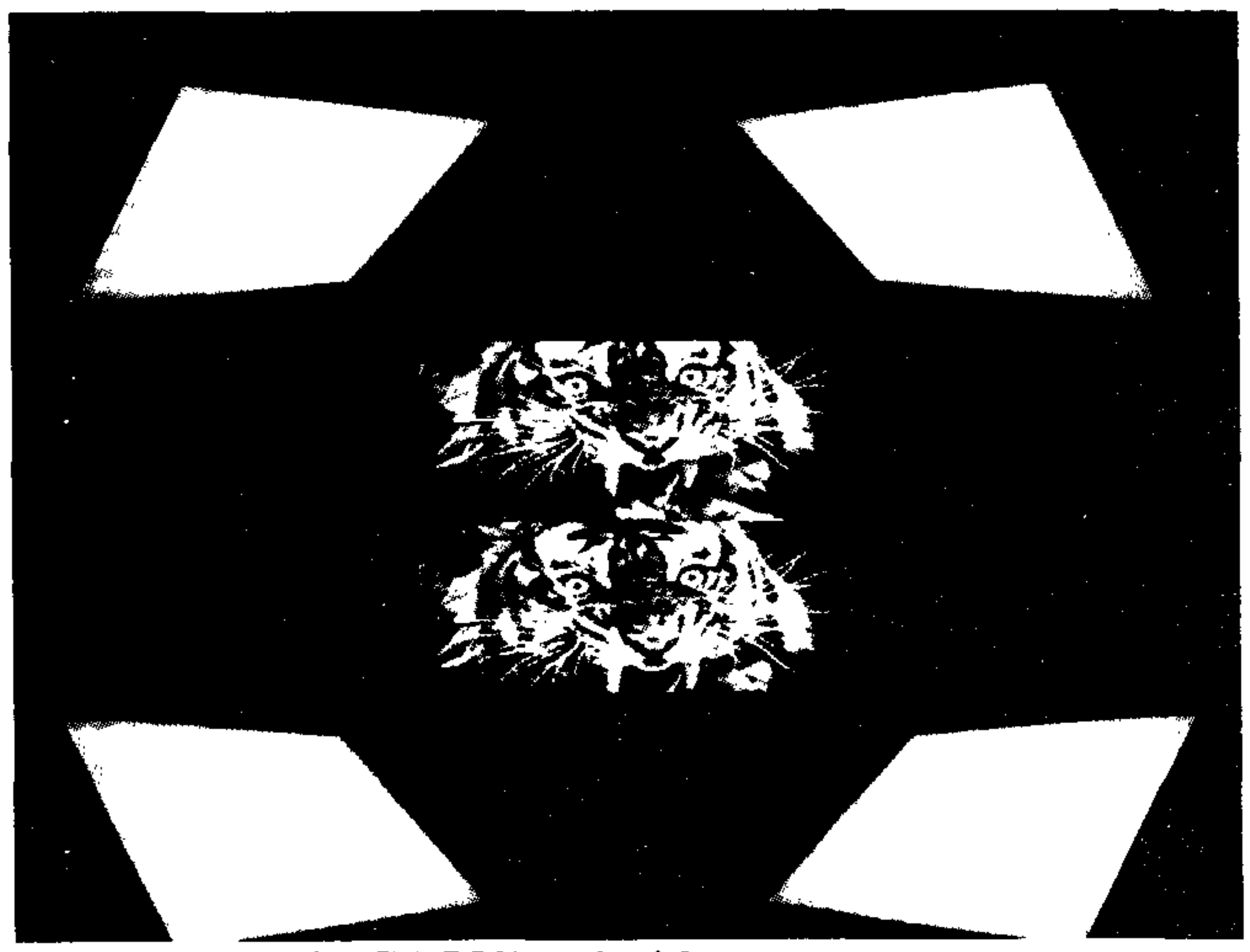
Without compensator. *With incell compensator*

Figure 8: Δu'v' plots in the 45° diagonal direction for the PVA panels with and without an incell biaxial RM compensator.

The pictures in Figure 9 show the improvement in angular performance with the sample with the incell RM biaxial compensator. The viewing angle for each of the four quadrants shown in Figure 9 is 60°. Clearly an improvement in image quality is observed with the cell containing the compensator.



17" SXGA PVA cell with incell RM biaxial retarder



17" SXGA PVA cell without compensator

Figure 9: Pictures of the 17" SXGA PVA cell with and without RM biaxial incell.

4. Conclusion

A biaxial retarder has been prepared from reactive mesogen mixture, which contains a dichroic photoinitiator. Biaxiality is induced by polymerisation of the cholesteric RM layer with plane-polarised light. A biaxial RM film has been incorporated into a PVA display, by coating the RM layer onto the colour filter array, before polymerising and before constructing the LC cell. Clear improvement to the viewing angle of the cell is observed compared to the same LC cell made without a compensator.

5. References

[1] DJ Broer, GN Mol, JAMM van Haaren, J Lub in Advanced Materials, **1999**, 11, No 7