

Reactive Mesogen Mixtures for Integrated Optical Films

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Abstract

TFT LCD mode has some well-documented performance limitations, namely limited viewing angle, inversion of the gray scale levels and poor luminance efficiency because of the necessity of using crossed polarisers attached to the display cell. During the last few years many initiatives have been undertaken to solve these problems by incorporation birefringent films of various designs into the LCD module. Controlling the optical performance of LCDs often requires combination of liquid crystal material properties, cell parameters and optical films. Such optical films have traditionally been made with stretched polymer materials such as polycarbonate, but recently coated liquid crystalline materials have been used to give improved optical films which can greatly enhance the performance of LCDs. We have now developed reactive mesogen materials to add ultra-thin optical layers into the display structure, and these allow the potential for many new applications.

Introduction

Many state-of-the-art LCDs require a number of optical films to be added to the outside of the display to optimize the optical performance.^{1,2,3} Typically these films will include polarisers, diffusers, compensation films and brightness enhancing films. These films always add considerable thickness to the final display module. These films are made by traditional techniques like casting, extrusion or stretching so they exhibit a uniform optical effect across the panel, and it is not possible to provide optical properties which are patterned to give specific optics to individual pixels of the display. In this paper we would like to present the concept of ultra-thin integrated optical films which can be prepared as part of the structure of an LC display either on the glass

inside or outside of the LCD.

Process of Reactive Mesogen layer preparation

We have developed a wide range of novel liquid crystalline materials that are called Reactive Mesogens (RM s). These chemical structure of these liquid crystals includes reactive or polymerisable groups, for example acrylate groups which can be polymerized readily by UV photo-polymerisation. We have further developed a large number of Reactive Mesogen Mixtures, which comprise blends of a number of RM with one or more reactive groups, UV sensitive photoinitiators, and also other additives to control liquid crystal alignment, surface energies, and other physical properties. Several types of alignment are possible with RM mixtures, as shown schematically in Figure 1.

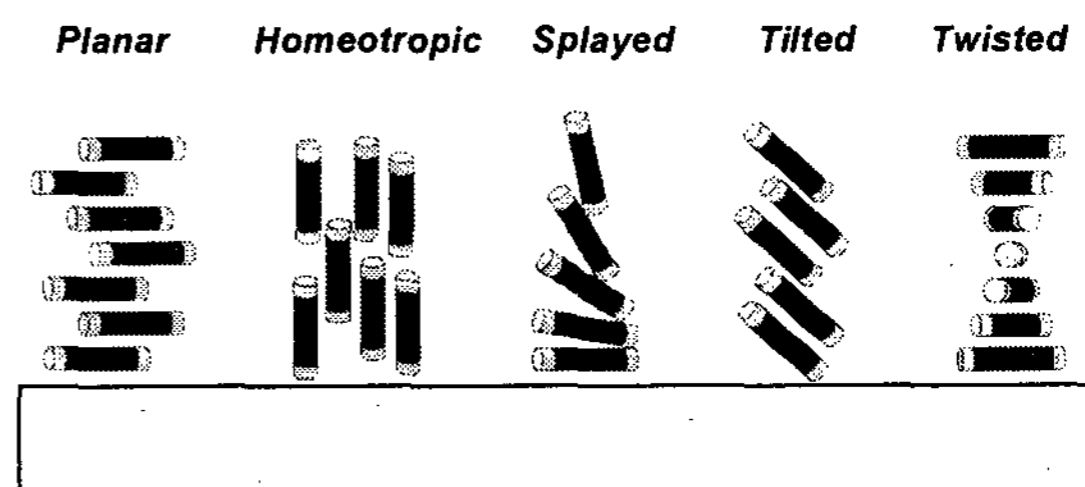


Figure 1 Examples of liquid crystal director distribution possible in aligned RM layers

Reactive mesogen mixtures can easily be coated and aligned in a liquid crystalline phase as a thin film. Upon irradiation with UV light, the photoinitiators will break down to form free radicals, which then start a rapid polymerization process. This will chemically bond the acrylate groups in the RM mixtures, causing

the formation of a cross-linked network of carbon-carbon bonds as shown in Figure 2. The liquid crystal core structures of the RM materials will remain ordered, but cease to move freely in the liquid crystal phase. In this way a solid polymer film is formed with similar optical properties to those of the liquid crystal phase prior to polymerisation and very high durability.

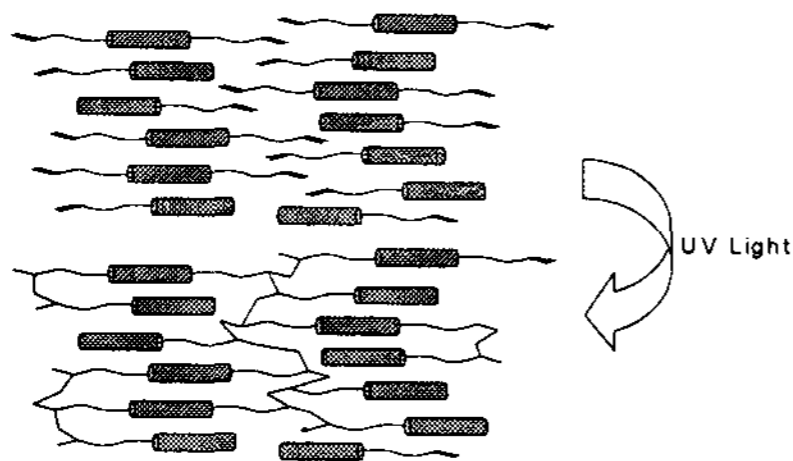


Figure 2 Photo-polymerization in LC phase

Photopolymerisation of reactive mesogens provides a technique for direct preparation of optical films on a wide range of surfaces. In order to provide the simplest application of these materials we have developed solutions of reactive mesogens mixtures which can be directly coated for example onto polyimide coated glass by conventional spin coating techniques. After applying the RM solution onto polyimide coated glass in a controlled thickness, the solvent evaporates leaving a very thin layer of reactive mesogen mixture. This aligns instantly to form a liquid crystal layer with controlled alignment. By curing with UV light this is polymerized and fixed leaving an anisotropic or birefringent film.

Reactive Mesogen Mixtures for Integrated Optical Films

A typical reactive mesogen solution (RMS) consists of an RM mixture in an organic solvent such as propylene glycol 1-methyl ether 2-acetate (PGMEA). The first example of a reactive mesogen solution, RMS03001 is designed for spin coating and provides uniform planar alignment of the reactive mesogen material as shown in Figure 3, ideal for preparation of half wave ($\lambda/2$) retardation films. The RM mixture is designed with controlled liquid crystal phase, optical properties, and surface energies for optimized coating and alignment.

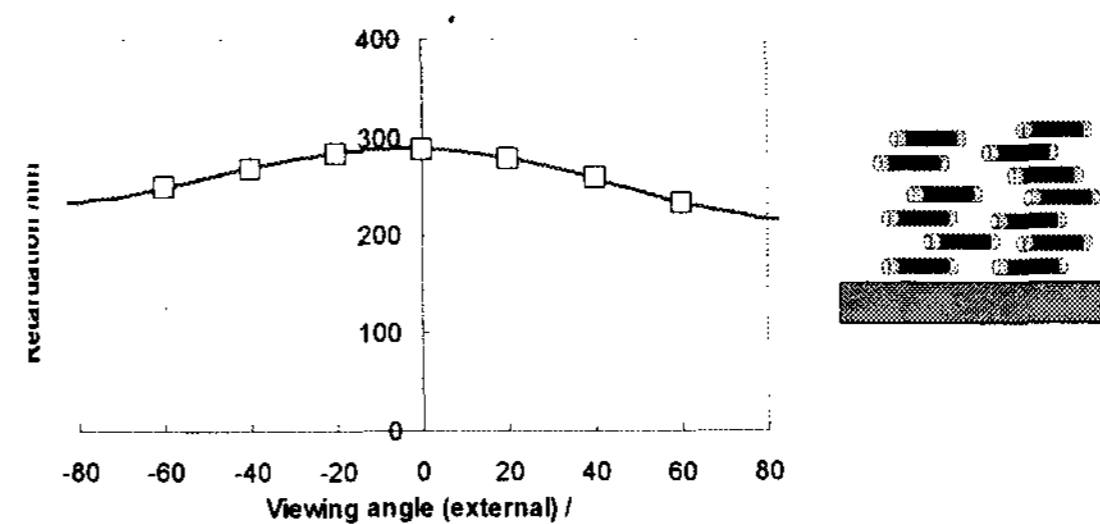


Figure 3 Retardation data of RMS03001

The optical effect or retardation of such a film can be directly controlled by the processing conditions of the RMS. In particular the retardation is directly related to the film thickness, which can be adjusted by control of spin speed during coating as shown in Figure 4. In this case higher spin speed produces thinner films, and therefore lower retardation value. Further adjustment of the retardation can be achieved through dilution of the RM solution.

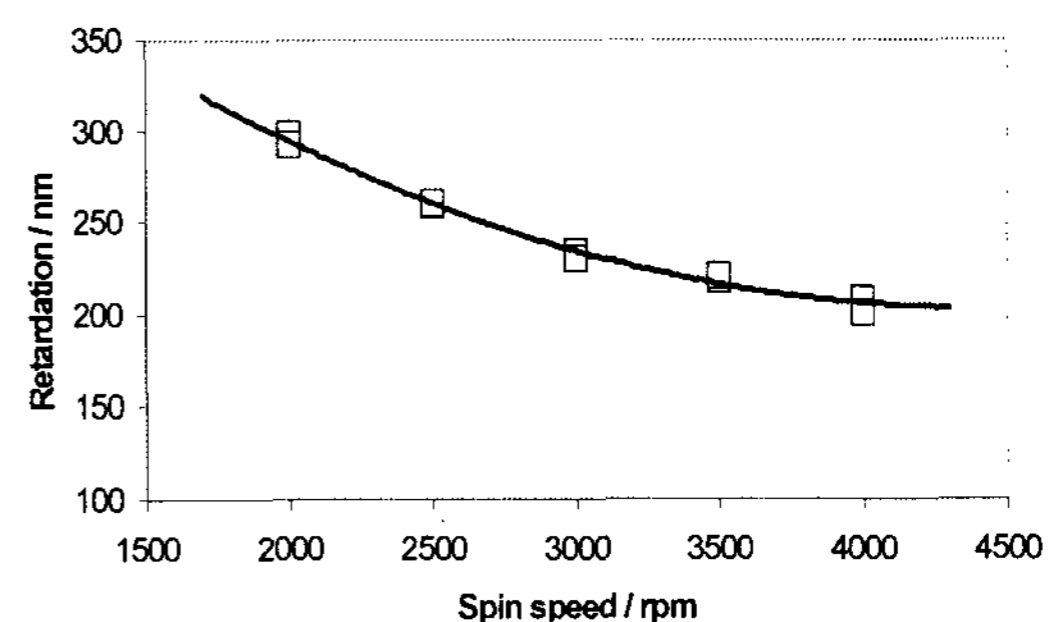


Figure 4 Control of retardation by spin speed

After evaporation of the solvent the RM mixtures instantly forms a planar aligned liquid crystal layer on rubbed polyimide. The optical effect is therefore similar to a uniaxial stretched film for example polycarbonate, with on-axis retardation reducing with increasing viewing angle along the rubbing direction or long molecular axis. The polymerized mixture has a birefringence of approximately 0.155, and therefore a film of 1.0 microns thickness would show a retardation of 155nm showing a 80 fold reduction in thickness compared to stretched films. The optical dispersion is very similar to most LC materials, and this gives potential advantages when matching the optical properties of the LC display to the optical films.

16.5 / Invited

To provide a highly stable film, the polymerization must continue to a high level of cure. This means that all acrylate groups are polymerized and no further change can happen to the film under normal conditions after polymerization. By measuring with Fourier Transform Infra Red (FTIR) spectroscopy using Attenuated Total Reflection (ATR) the percentage of cure (or conversion to polymer) can be examined. Under standard polymerization conditions (60 seconds, 20mWcm^{-2} UVA) the conversion is typically to more than 96%.

This high level of polymerization gives a very good thermal stability, and because there is no stretching involved in the process, there is very little internal stress on the optical film. Typical polymerized films of RM show less than 1% variation in retardation with 500hrs baking at 90°C , and even at 120°C show less than 1% variation with 100hrs baking. This is clearly much greater stability than is seen with typical stretched films, and is far greater than for example conventional stretched polarisers.

Patterned or Pixelated Integrated Optical Films

For some applications it may be desirable to provide optical properties of a film that are patterned or pixelated. For example the ideal film properties for red light may be different to those for blue light, and conventional optical films will only provide an average uniform property for all areas of the display. Furthermore, even if it were possible to provide an optical film with suitable patterned properties it would suffer from parallax problems if it were attached outside of the display glass, and this could severely impair viewing angle performance. If such a pixelated film were prepared inside the LC display cell there would be no such parallax problem.

There are many potential ways to provide different optical properties from the same RM film, and one possibility is to consider the effect of polymerisation temperature at which the UV polymerization takes place. The birefringence of the film can be reduced, and by polymerization above the clearing temperature of the RM mixtures, even an isotropic film can be prepared.

By UV polymerization through a photomask it is therefore possible to fix certain areas of the RM film with one optical property, whilst keeping other areas in the liquid crystal state. The uncured areas can then be polymerized with different optical properties, for example with lower birefringence, or even isotropic areas with zero birefringence as shown in Figure.5.

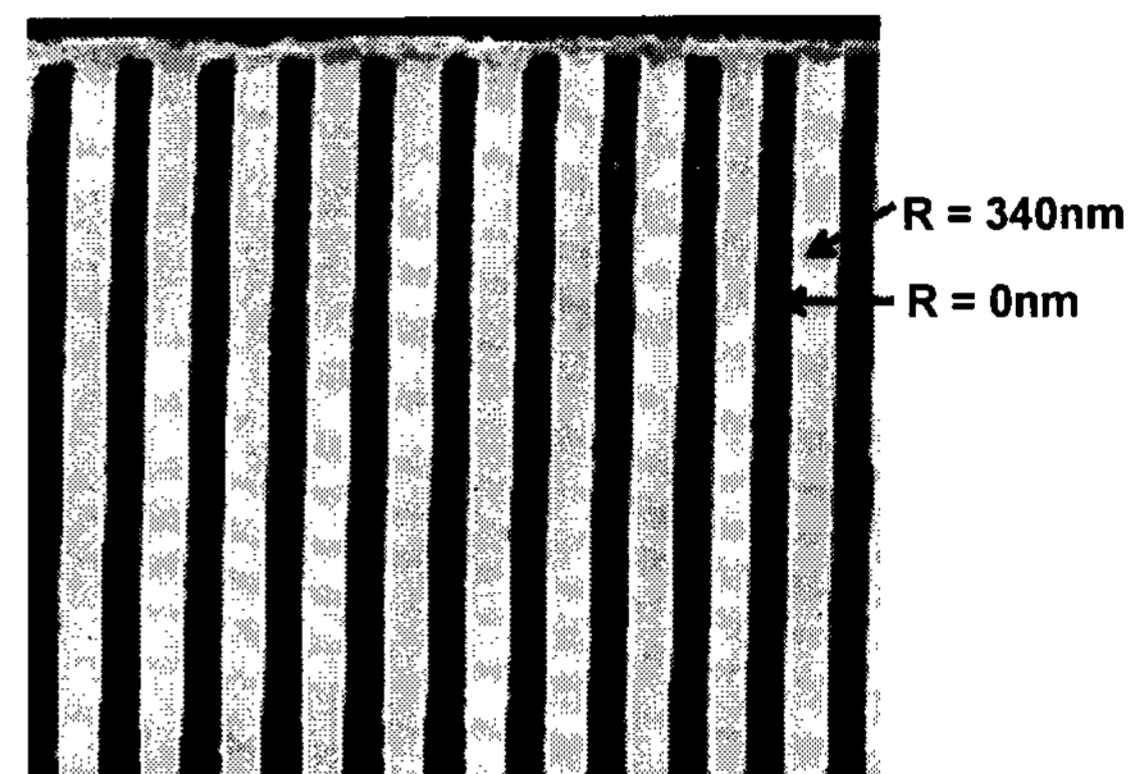


Figure 5 Patterned retardation layer

Another interesting example of a pixelated RM film uses cholesteric or chiral nematic reactive mesogens. When a chiral reactive mesogen is included in the RM mixture then a helical director can be formed, and with sufficient chiral material this can show selective reflection of circularly polarized light. As the chiral content is increased the pitch of the helix is reduced,, and the wavelength of selective reflection becomes shorter, allowing red, green or blue reflection to be achieved. We have developed photosensitive chiral RM which can change their helical twisting power under UV irradiation. Thus a high helical twisting power dopant (giving red selective reflection). Using our new materials this conversion can be achieved by as little as 2 seconds exposure to UV light in an air atmosphere as shown in Figure.6

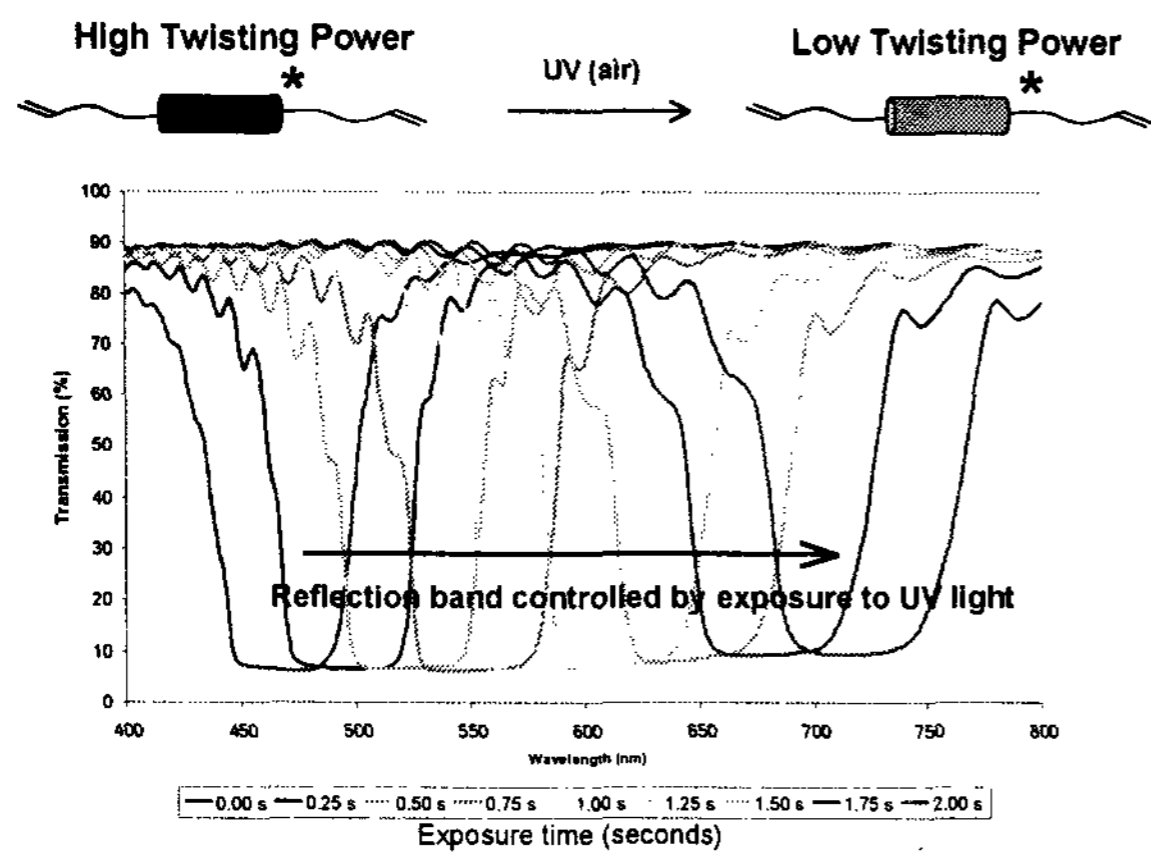


Figure 6 Photo isomerization of Cholesteric RM

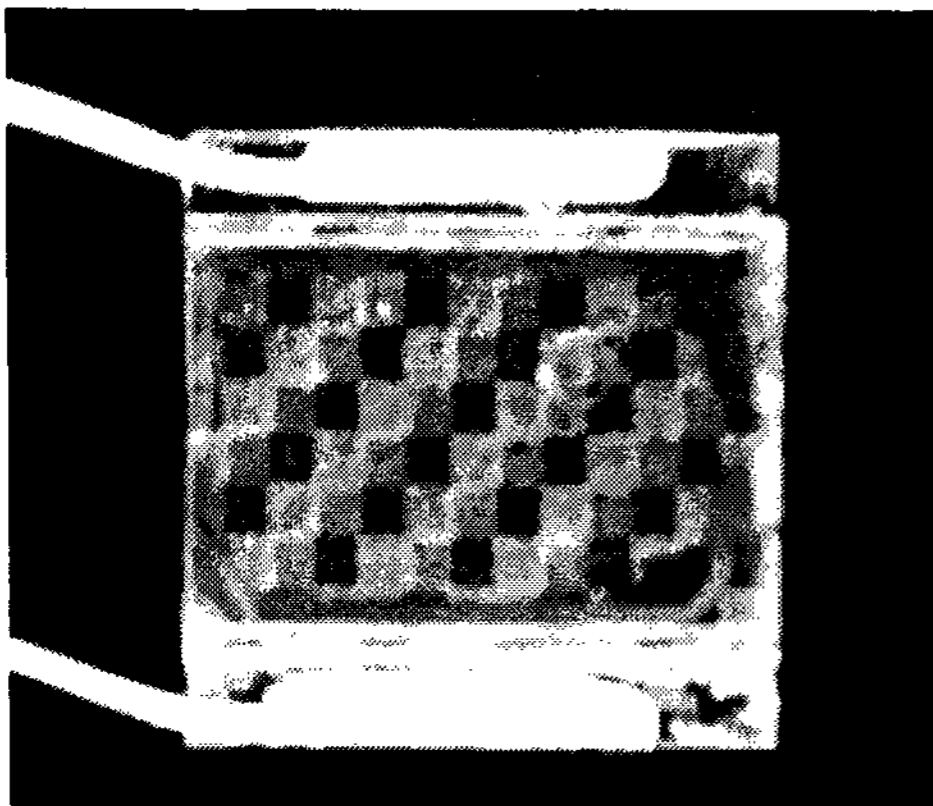


Figure 7 Example of Color filter made of cholesteric RM

Using a photomask with intermediate levels of transmission, it is therefore possible to prepare an array of reflective R/G/B cholesteric colour filters in one layer from a single UV irradiation process as shown in Figure 7. A second UV cure process under nitrogen will fix the colour filter layer permanently. Such a colour filter array can be used for preparing a simple reflective display.

Conclusion

Using reactive mesogen (RM) solutions, ultra-thin optical films can be prepared directly on the LC panel substrates, with typical thickness of around 1 or 2 microns. Optical performance of these RM films is comparable to commercially employed films for example polycarbonate and they exhibit very high stability under the typical durability conditions required for display use. It is possible to create liquid crystal displays with integrated optical films, having reduced thickness and weight compared to conventional displays. Furthermore, RM films can be patterned or pixelated to match the properties of the LC display.

References

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