Patterned grating alignment of reactive mesogens for phase retarders.

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Abstract

Patterned alignment of reactive mesogens on a grating was investigated for use in phase retarders. The relative importance of the topology and the surface energy of the grating for RM alignment is discussed. Possible mechanisms of RM alignment for different grating pitches are discussed.

1. Background and objectives

Patterned optical phase retarders can be used in a number of display applications, such as in polarisation conversion optics in projectors and in 3D displays.

3D displays using parallax barriers rely on presenting a slightly different image to each of the viewer's eyes and then allowing the brain to fuse the two images, producing a sensation of depth. The parallax barrier consists of regions which alternately transmit and block light. It allows the different images to be directed into spatially limited viewing zones, as shown in Fig.1.

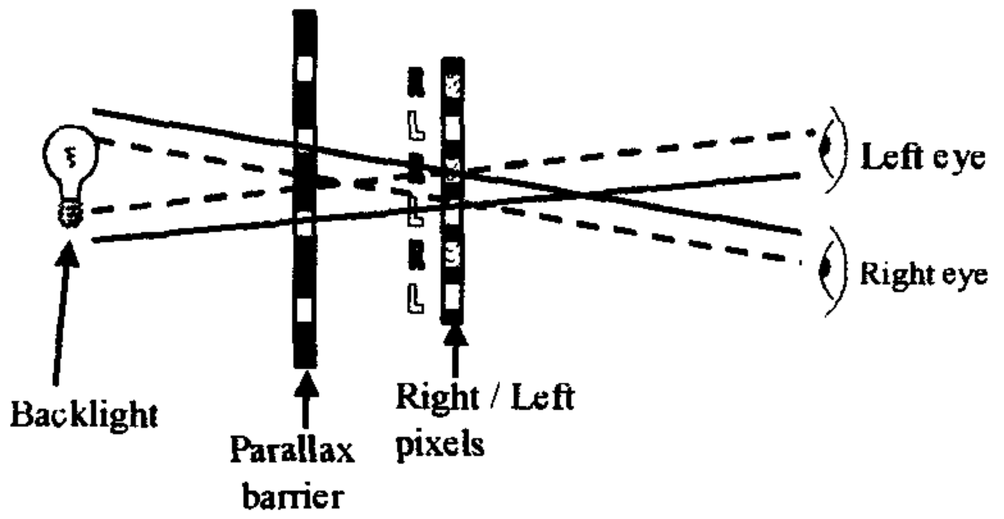

Figure 1. Use of a parallax barrier to form a 3D display.

Using an LCD offers the opportunity to use polarisation as a mechanism to switch between 2D and 3D display operation (by switching the parallax barrier on and off) [1]. If the parallax barrier is made as a half-waveplate retarder with patterned optic axis orientations at 45° to each other (as shown in Fig. 2a), then for one input polarisation the patterned retarder will transmit light from both regions. This forms the 2D mode as the parallax barrier doesn't have any effect. If the input polarisation is rotated by 45°, the patterned retarder will transmit light polarised such that from one region it is parallel to the to the input polariser of the TFT LCD panel, while from the other region it is perpendicular to it. Hence, light from one region of the patterned retarder is blocked, the other transmitted. This allows the parallax barrier to "develop" and a 3D image to be produced which is shown in Fig. 2b.

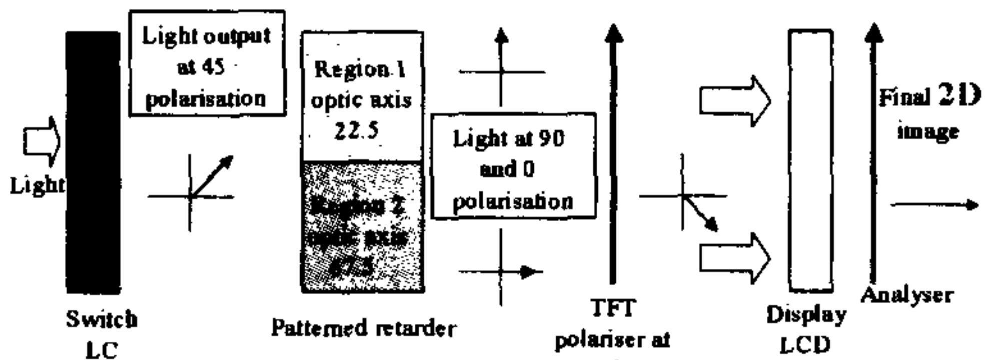

Figure 2(a)

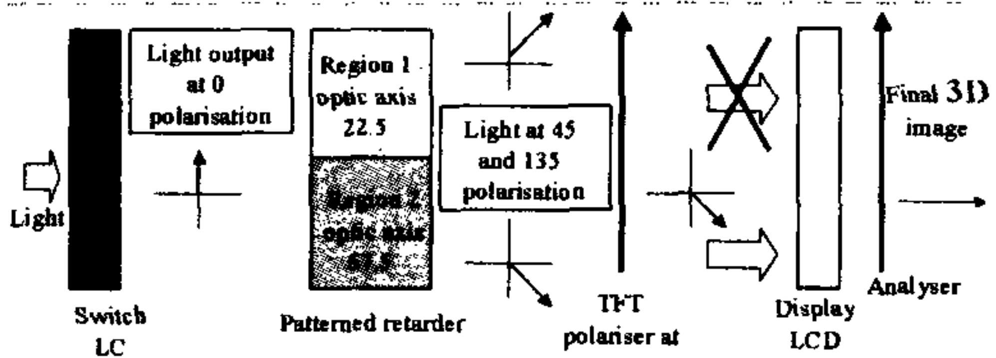

Figure 2(b)

Figure 2. Use of a patterned waveplate retarder in a 2D/3D switchable LCD.

Waveplate patterned retarders may be formed from a polymerised liquid crystal, such as reactive mesogen (RM), on a single substrate, so allowing a reduction in overall thickness and weight of the display. The difference in optic axis orientation of the retarder layer is produced by patterning of the aligning surface which may be by photoalignment or multi-rubbing of polyimide [1].

Multi-rubbing involves many processing steps, as shown in Fig 3. There is obviously benefit in reducing the processing cost of patterned retarders.

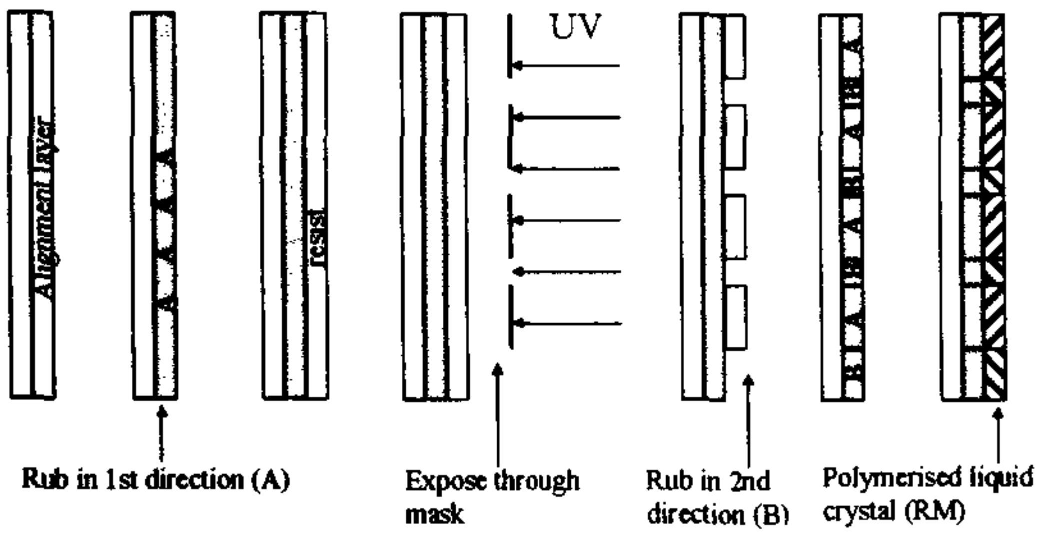

Figure 3. Multi-rubbing process.

This work describes how a grating may be used for RM alignment in patterned retarders [2]. The grooves of the grating produce the RM director orientation. Such a method involves fewer processing steps than the multi-rubbing technique and the main operations are shown in Fig. 4.

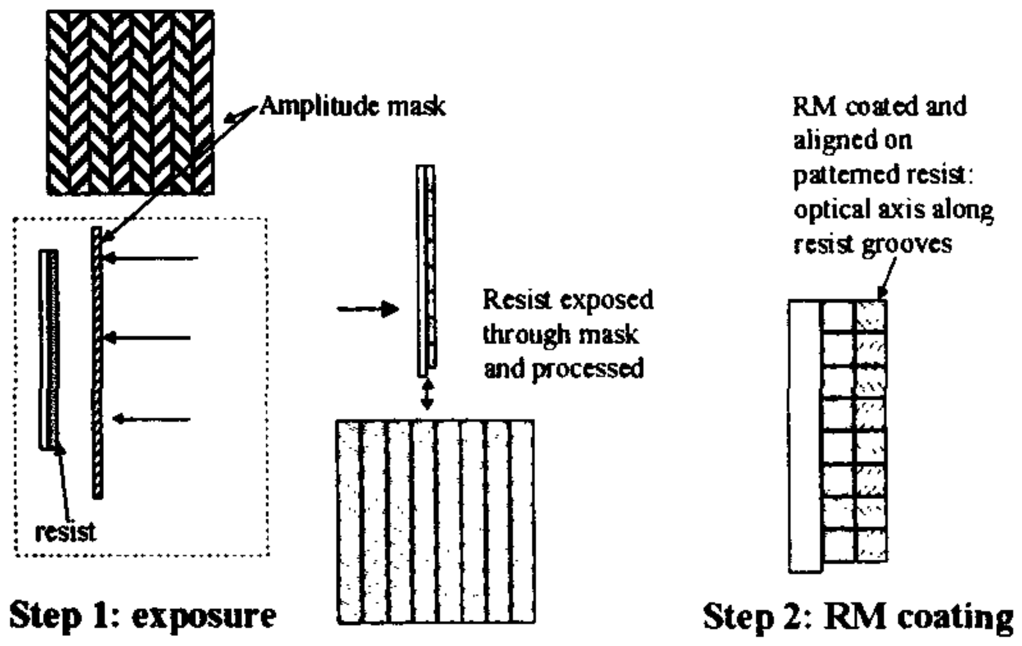

Figure 4. Forming the patterned retarder on a grating aligning surface.

The objectives for this work were:

- To fabricate grating aligned RM patterned retarders with broad-band transmission and extinction characteristics, identical to that made by the multi-rubbing technique.
- Fabricate a multi-domain aligning surface by single-step lithography through an amplitude mask.
- Study the alignment mechanism and identify process tolerances – by investigation of the correlation between the surface topology, surface energy, and the RM retarder characteristics.
- Investigate structures with larger pitch (up to 20µm) as the aligning surface. This minimises mask cost and maximises manufacturing tolerances.

The alignment mechanism of a liquid crystal upon a grating surface is described by Berreman [3, 4]. His explanation was related to grating topology – the grating structure would cause distortions in the LC director. Energetic considerations lead to minimisation of the distortion, and hence determine the preferred LC alignment.

Recently, there has been much interest in using gratings for alignment of LCs, for example, in bistable displays [5]. In these studies, the pitch of the grating forming the aligning surface is typically 1µm or less and the results show good correlation with Berreman topological theory. This work presents experimental results which demonstrate that for large pitch, shallow grating structures (pitch ~10µm, depth ~1µm) interactions between the grating material and RM dominate over the topological mechanism for RM alignment.

2. Results and discussion

The resist used to produce the grating structure had to meet certain requirements. These were:

1. The processed resist is optically transparent as it is included in the device.
2. The processed resist forms a chemically, thermally and photo-stable structure.
3. The resist produces small and large pitch structures reproducibly.
4. The resist is compatible with RM and with RM solvent for spin coating
5. The resist will work with existing lithographic equipment.

As a result two resists were selected for further investigation:

Resist 1 – a solvent processable negative resist
Resist 2 – an alkali processable positive resist.

Optimisation of the processing allowed both resists to produce identical topologies over a wide range of feature sizes as shown in Fig. 5.

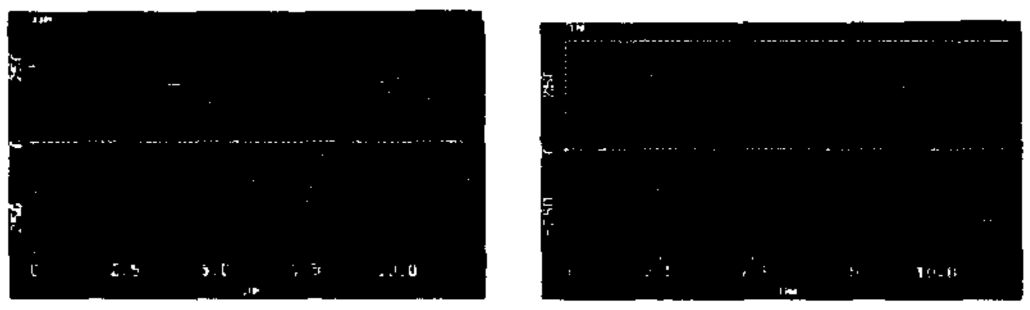

Figure 5(a) Figure 5(b)

Figure 5. Similar topology gratings measured by AFM. 5(a) shows Resist 1: 3 micron line & gap. 5(b) shows Resist 2: 3 micron line & gap, post baked.

The main methods used in the work were:

- AFM to study the surface topology
- contact angle to evaluate the surface energy
- transmission and extinction in polarised light to asses the RM alignment.

The performance of the patterned retarder in the 3D display was assessed by measuring crosstalk, brightness and colour. (3D crosstalk is a measure of how much of the left eye image gets into the right eye and vice versa.)

2.1 Alignment results

RMM34 from Merck Chemicals Ltd has been used in this study. RMM34 exhibits good planar alignment when a half waveplate thick layer is spun from solution on rubbed polyimide. Fig. 6 summarises the alignment on grating structures with similar topology.

Figure 6. Alignment on gratings with similar topology.

Pitch (µm)	**Resist 1**	**Resist 2**
2	Planar alignment	Planar alignment
2 to 10	Planar alignment	Splay or homeotropic alignment
>10	No alignment	No alignment

Figure 6 shows that for the gratings with 2µm pitch substantially identical planar alignment can be achieved on both materials. However, for the larger pitch gratings, Resist 1 demonstrates good planar alignment while topologically identical structures in Resist 2 are splayed or homeotropic. This indicates that the mechanism of the RM alignment on smaller pitch gratings is different from that on larger pitch ones.

2.2 Contact angle measurements

To confirm the assumption that for large pitch gratings material interactions are more dominant in RM alignment than the topology of the aligning surface, the surface energy of aligning materials was analysed. These measurements were carried out on processed substrates and the results are shown in Fig. 7. Resist 1 is more hydrophobic than Resist 2 for given processing conditions, but is similar to the rubbed polyimides. The rubbed polyimides give reproducible planar alignment of RMM34.

It suggests that a low surface energy material is required for planar alignment of RMM34 for large pitch gratings.

Figure 7. Contact angle measurements on processed gratings.

	Rubbed polyimides	**Resist 1**	**Resist 2**
Water contact angle (°)	High 72-80°	High 70-75°	Lower 47-55°

To test this hypothesis, surface modification of Resist 2 was attempted. Baking of the fabricated Resist 2 grating increases the degree of crosslinking of the resist and, as a result, changes its surface energy. A series of tests to optimise the RM alignment were conducted by baking processed Resist 2 (with similar topology) for range of temperatures of 230, 250 and 280°C and baking time of 20 and 60 minutes. Baking at 230°C for 20 minutes considerably improved the alignment. Increases in baking temperatures above 230°C or times longer than 20 minutes did not have any further effect on RM alignment. The contact angle results are shown in Fig. 8. The hydrophobicity of the Resist 2 gratings was found to increase on baking, approaching the value of Resist 1. This experiment showed that increasing the hydrophobicity of the processed resist surface improves the alignment quality of RM layers for the same grating topology.

Figure 8. Contact angle measurements on processed gratings.

	Unbaked Resist 2	Baked Resist 2	Resist 1
Water contact angle (°)	47-55°	66-67	70-75°

2.3 3D display characteristics

To compare the characteristics of the 3D display, two types of displays were fabricated - one using a grating aligned patterned retarder and one using a multi-rubbed patterned retarder. The performance of each type is illustrated in Fig. 9.

The 2D and 3D brightness are similar for both displays. No colour differences, within the error of the measurement, were found.

The crosstalk of the 3D system using the grating aligned patterned retarder was found to be slightly higher. This may be improved by process optimization but could be caused by non-conformal coating of the RM.

Figure 9. Characteristics of 3D displays using grating aligned and multi-rubbed patterned retarders.

	2D brightness (arbitrary units)	3D brightness (arbitrary units)	Cross -talk (%)
Grating aligned	100	100	6.7
Multi-rubbed	98-106	95-106	5.2-6.2

3. Conclusions

The use of patterned waveplate retarders has been discussed for switchable 2D/3D display systems.

The fabrication method of the patterned retarders by alignment of RM on a grating has the advantage of a reduction in the number of processing steps compared to other techniques and does not require specialized equipment.

Understanding the alignment mechanism allows material optimization and definition of process tolerances.

A prototype 3D display using a grating aligned RM retarder showed characteristics, such as colour, luminance and crosstalk, similar to displays using multi-rubbed retarders.

The most suprising outcome of this study is that alignment can be induced at all in RM using such large pitch structures. (About 10μm pitch, 1μm depth gratings coated with about 2μm depth of RM.)

4. Acknowledgements

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5. References

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