# Grating Aligned Ferroelectric Liquid Crystals and their use in Fast Switching Displays

PJM Wyatt, J Bailey, NV Solodkov, M Nagaraj, and JC Jones

## Introduction

- Calamitic nematic liquid crystals (LCs) are commonly found in modern displays.
- Ferroelectric LCs (FLCs) are also successful. Particular interest in 90's, such as the surface stabilised FLC device [1].
- This allows ultra-fast optical response times of under 200 µs, which is a magnitude faster than nematic displays [2].
- FLCs are harder to align, and not resistant to shock-induced flow.
- A revolution in new alignment geometries has reopened interest in FLCs — can they be shock stable?

## Developed Fabrication Techniques

- Vapour phase deposition of silane:
  - Characterisation of homeotropic alignment induced by $C_8$ and $C_{18}$ silanes.

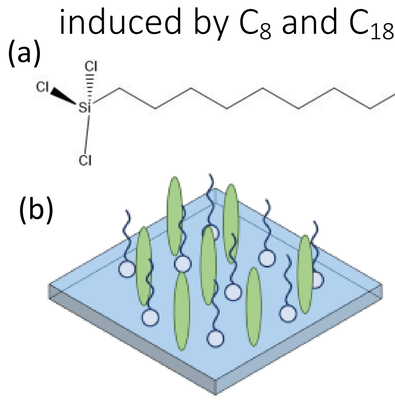



Figure 1: (a) A trichloro-(octadecyl)silane ($C_{18}$) molecule and (b) a schematic diagram of homeotropic alignment.

- Direct-write lithography (DWL) using negative photoresist SU-8 to fabricate variable pitch and amplitude sinusoidal-like gratings.
  - peak-to-peak amplitude controlled by varying SU-8 to solvent concentration and exposure dose to 375 nm UV light.
  -pitch limited by design and focal spot size.
  -scanning electron microscopy (SEM) to determine grating feature characteristics (Figure 2).

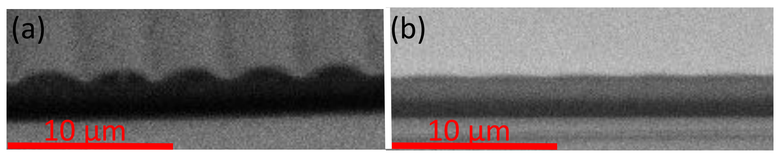



Figure 2: SEM images of two SU-8 gratings fabricated using different UV exposures: (a) 500 mJcm$^{-2}$ and (b) 1200 mJcm$^{-2}$.

- Fabrication of in-plane electrodes:
  -DWL of positive photoresist Shipley Microposit S1813.
  - Acid etching using HCl to pattern ITO glass.

## The FLC Device

We present a novel alignment system for FLCs, achieved by:

i. Homeotropic surface treatment:
   - aligns the smectic layer normal, ***a***, in a homeotropic geometry.

ii. A sinusoidal-like grating with micron-sized features:
   - aligns the ***c*** director perpendicular to the grating vector, ***g*** (Figure 3a),
   - appears dark/black when viewed between crossed polarisers, if ***g*** is aligned parallel to the analyser/polarizer.

iii. In-plane switching (IPS) electrodes:
   - positioned at 45° to ***g***,
   - ***c*** director aligns perpendicular to applied ***E*** due to the characteristic spontaneous polarisation, $P_s$,
   - this satisfies the half wave plate condition, appearing bright/white (Figure 3b).

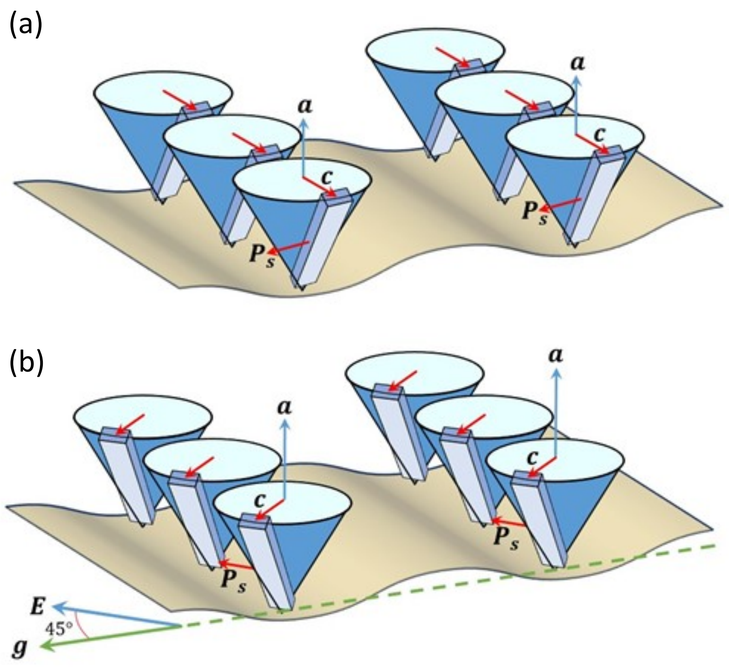
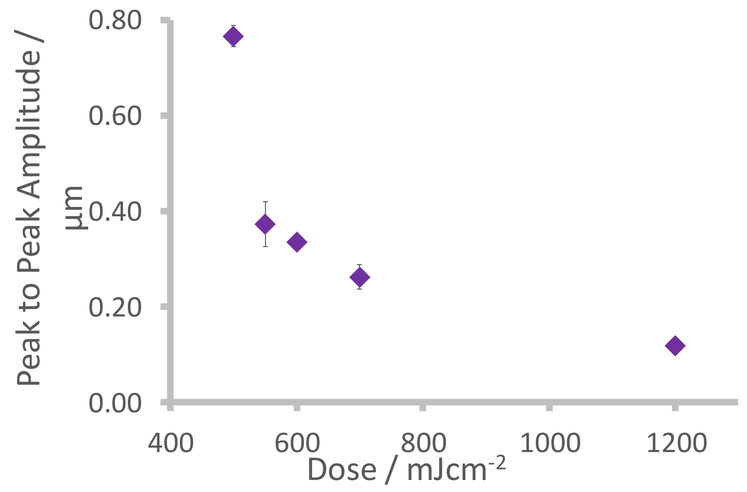



Figure 3: The alignment of a FLC on a homeotropic grating with (a) no field, and (b) an electric field, denoted by ***E***. The field is applied at 45° to the grating, in-plane, which aligns the ***c*** director by the characteristic spontaneous polarisation, $P_s$. The layer normal is depicted by ***a*** and the grating direction by ***g***.

## Current Results

- Gratings fabricated with varying peak-to-peak amplitudes, shown in Graph 1, by SEM.




Graph 1: Varying exposure dose of 375 nm UV light can influence the gratings' peak-to-peak amplitude.

- Polarising light microscopy determines that the ***c*** director is aligned perpendicular to ***g***.

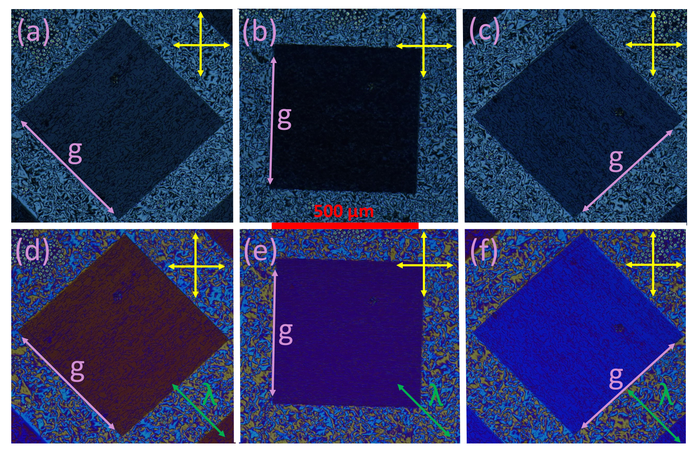



Figure 4: The alignment of SCE13-R on a (0.77 ± 0.02) µm peak-to-peak amplitude grating (2a), at (a) –45°, (b) 0° and (c) +45° between crossed polarisers. Figures 4 (d)-(f) show the same as (a)-(c) but with a full wave plate, ***λ***, at 45° to the polarisers. This confirms that the ***c*** director is lying perpendicular to ***g***.

- Initial tests indicate that the gratings retain ***c*** director alignment after shock.
- Future work will test ferroelectric switching on IPS electrodes and shock stability optimisation.

## Acknowledgements

The author would like to thank Dr Guy Bryan-Brown of DisplayData for advice, and the EPSRC for funding though the SOFI CDT. JCJ thanks the EPSRC [grant number EP/ L015188/1].

## References

[1] N. Clark, S. Lagerwall, "Surface-stabilized ferroelectric liquid crystal electro-optics: New multistate structures and devices", Ferroelectrics, Vol. 59, pp. 25-67, 1984.

[2] J.C. Jones, "On the biaxiality of smectic C and ferroelectric liquid crystals", Liquid Crystals, Vol. 42, pp. 732-759, 2015.

E: p.wyatt@leeds.ac.uk
E: info@soficdt.ac.uk | www.soficdt.ac.uk | facebook.com/softmattercdt