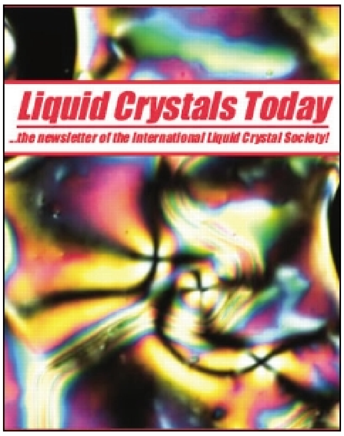

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OPTICALLY CONTROLLED ALIGNMENT OF LIQUID CRYSTALS

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Newsletter of the International Liquid Crystal Society

LIQUID CRYSTALS *Today*

Vol. 4, No 2, September 1994

A Presidential Message

The 15th International Liquid Crystal Conference in Budapest proved to be just as successful as its predecessors. The number of participants was certainly high in keeping with the enormous number of posters. This, together with the quality of the science, both pure and applied, provided a rich feast and indicates just how active and vibrant our multidisciplinary subject is. For me, the best measure of this was the presentation this year of four Glenn Brown Awards and the outstanding lectures which the four laureates gave.

In between all this activity and heat, the Board of Directors found time to meet on two occasions. During these we were forced to find a replacement for the Secretary of the Society, Professor David Dunmur. David has been our Secretary since the inception of the Society in 1990. Much of our success is due to David's considerable talents and sheer hard work. He will clearly be a hard act to follow and so I am especially pleased that Professor Giancarlo Galli from Pisa has accepted the invitation to be the new Secretary. The other Officer to complete his term is Professor Lui Lam who has been the Chairman of the Conference Committee. Lui had much to do with the founding of the Society in its

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OPTICALLY CONTROLLED ALIGNMENT OF LIQUID CRYSTALS

from Wayne M Gibbons, Paul J Shannon and Shao-Tung Sun, Hercules Inc. Research Center, Wilmington, DE 19808-1599, USA.

Alignment of the liquid crystal director is important for many liquid crystal applications. Many techniques have been developed to provide macroscopic homogeneous alignment of liquid crystals: mechanical rubbing of alignment polymers [1]; oblique deposition of inorganic materials [2]; gratings [3]; and non-rubbed orientation films [4].

All these techniques have their unique advantages and disadvantages but share in common the inability to generate erasable, high spatial resolution patterned alignment of the liquid crystal director. A new technique uses specially designed materials that are optically altered to create homogeneous, high spatial resolution alignment of the liquid crystals [5-9].

Although the physical mechanisms may vary for the optically controlled alignment, all systems revealed to date require polarized light and result in a net homogeneous orientation of the liquid crystal perpendicular to the incident light polarization (see Figure 1). The majority of the optically controlled alignment systems can be erased by rotating the incident light polarization by 90 degrees [5,8,9]. Some systems are irreversible, and thus are limited on the number of write/rewrite cycles. [6,7].

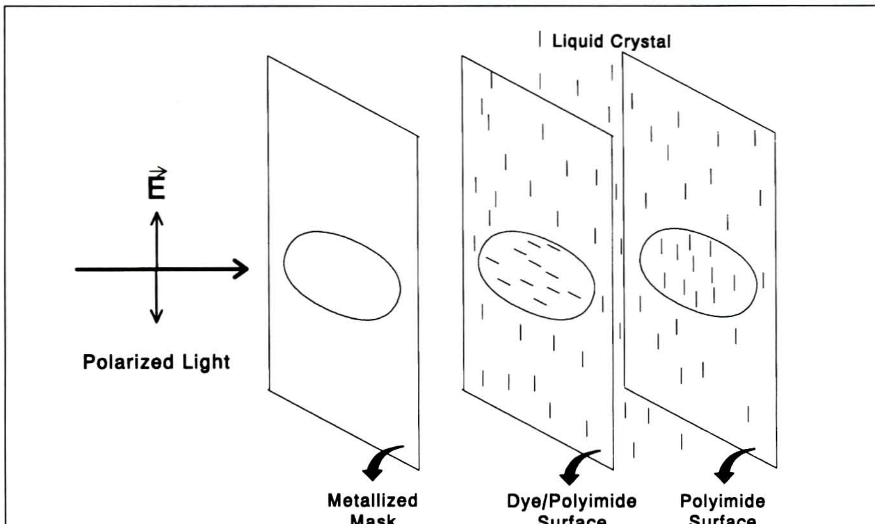

Figure 1. *The geometry of the illuminated liquid crystal cell. The glass substrates of the cell are not shown for clarity. The rods represent the liquid crystal orientation near the substrates before and after illumination. In this example, a twisted alignment of the liquid crystal results since the back alignment is not optically active.*

Our initial work was with guest-host liquid crystal systems [10]. A poly(azo) dye was incorporated into a host cyanobiphenyl liquid crystal, ZLI1982 (EM Industries) at 1.8 wt% concentration. The alignment polymer was Huls America SPI2000 polyimide mechanically buffed to give a uniform alignment of the guest-host liquid crystal system along the buffing direction. The filled cell was illuminated as depicted in ***Figure 1*** with 514.5nm Argon laser light for 120 minutes at 8W/cm2. In this case the mask was a metallized resolution target.

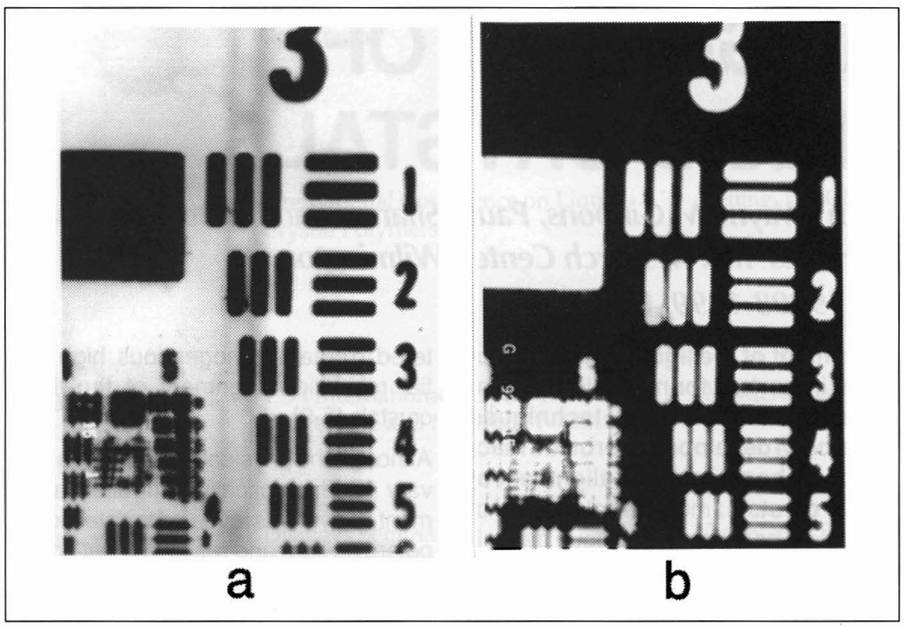

Figure 2*. An optically aligned resolution chart in the guest-host liquid crystal cell as viewed through a single polarizer with the transmission axis a) perpendicular and b) parallel to the rubbing axis.*

Figure 2 shows the guest-host liquid crystal cell as viewed through a single polarizer at 0 and 90 degrees to the mechanical buffing direction. The illuminated numbers and bars are seen to be aligned 90 degrees to the initial buffed background alignment. Resolution was limited by diffraction through the metallized mask. The fact that the reoriented guest-host liquid crystal system remains aligned after terminating the illumination indicates that the polyimide/liquid crystal interface has been permanently altered by the polarized light.

Experiments performed without the dye present yielded no realignment of the liquid crystal. From these experiments, it became clear that the dye and alignment layer/liquid crystal interface were crucial to the observed effect. With this in mind, we incorporated a diazodiamine dye at 33 wt% loading into the polyimide alignment layer [5]. The advantages of this technique over the guest-host liquid crystal approach include the ability to optically process the alignment layer before cell assembly and to use this process to align other liquid crystal systems besides guest-host mixtures. The front plate of a cell was coated with the diazodiamine/polyimide alignment layer and optically aligned with the laser polarization parallel to the short side of the cell. A subsequent exposure was made through a mask of a Hercules logo and with the laser polarization parallel to the long side of the cell (perpendicular to the initial exposure). The back plate was coated with polyimide and mechanically buffed parallel to the long side of the cell.

A cell was assembled from these plates and capillary-filled with the guest-host liquid crystal mixture mentioned previously. ***Figure 3*** is a photograph of the optically aligned cell as viewed through a single polarizer with its transmission axis perpendicular to the background alignment. Optical reconfiguration of the alignment director was demonstrated by this example since two exposures (background then logo) were made and the second logo exposure overwrote the initial background exposure.

High spatial resolution of the process was demonstrated by generating high frequency liquid crystal gratings. A cell with polyimide/diazodiamine alignment layers was assembled and subsequently illuminated with a two-beam, plane-wave interference pattern with the angle between the plane waves chosen to give an interference fringe periodicity of 10μm [5]. The cell was filled with ZLI1982 nematic liquid crystal and studied using a polarization microscope. ***Figure 4*** is a photograph of the 10μm period liquid crystal grating as viewed between crossed polarizers.

The combination of high spatial resolution, the high birefringence of liquid crystals, and write/rewrite capability of optical alignment provides many opportunities for improving the quality and performance of existing liquid crystal applications as well as creating new applications. For example, optical alignment is a non-contact, static- and dust-free process of aligning liquid crystals which would improve the yield, quality and performance of active matrix and super-twisted liquid crystal displays. Multi-domain displays [11] with improved viewing angle can be optically generated using this technology. In addition, optically controlled liquid crystal displays with no electrodes can be realized if optical energy thresholds and re-orientation times become small enough. The switching of optically controlled displays would be performed by rotating the inci-

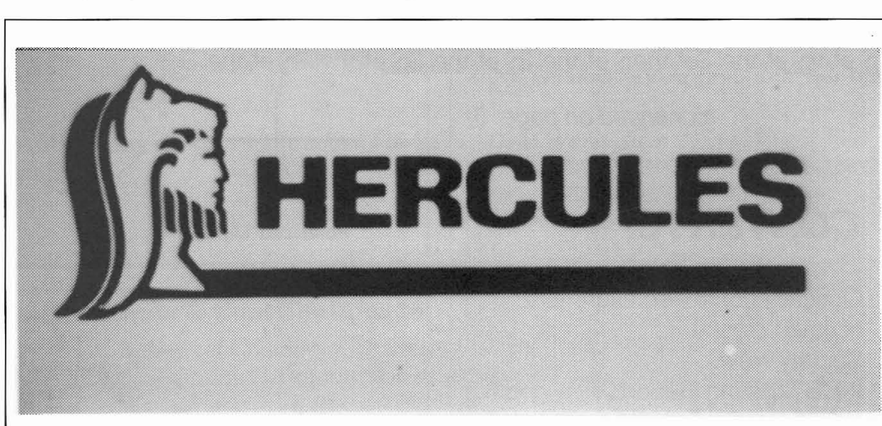

Figure 3*. An optically aligned company logo as viewed with a single polarizer. The background of the cell was optically aligned and the logo written with the light polarization rotated 90 degrees prior to filling the cell with the guest-host liquid crystal mixture.*

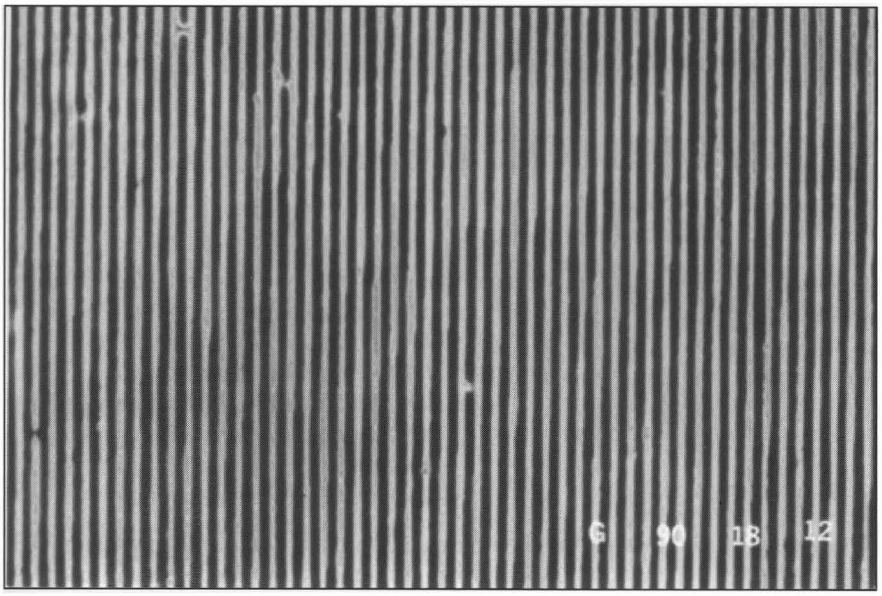

Figure 4. *An optically aligned 10μm period liquid crystal grating as viewed between crossed polarizers. The cell was illuminated prior to filling with the liquid crystal.*

dent light polarization by (in the plane of the substrate) resulting in a rotation of the local liquid crystal director by θ +90 degrees.

New applications include liquid crystal holograms and binary phase optics [12]. Creating high spatial resolution variations in the local liquid crystal director results in refractive index patterns that diffract light. The high birefringence of the liquid crystals allows for high diffraction efficiencies from very thin liquid crystal layers. Electro-optical modulation of the liquid crystals can be used to modulate the strength of the diffracted signal. These liquid crystal holograms and binary phase optics may be optically reconfigured to produce new diffracted images and/or beams.

Figure 5 is a schematic drawing of a chirped (spatial frequency of the grating changes), liquid crystal binary phase grating that can be electro-optically modulated. With no electric field, the optically generated chirped liquid crystal grating focuses the incident optical beam to a line (chirp is along one dimension). When the electric field is applied to the grating, the liquid crystal molecules align along the field which removes the spatial variation in the refractive index and, thus, the light beam passes through the cell unaffected.

Erasable optical memory/ data storage [13] is another potential application for the optical alignment of liquid crystals. Information can be written into the optical alignment polymer with high spatial resolution. The small refractive index and absorptive changes in the optical alignment layer are then amplified by the reorientation of the local liquid crystal director which can generate larger optical read signals.

By making the liquid crystal monomers photopolymerisepolymerizable, we demonstrated that optically patterned liquid crystal polymer films can be created [14]. In this case, two diazodiamine/ polyimide coated glass substrates were illuminated with polarized light to create a uniform background alignment. One plate was subsequently illuminated through a metallized resolution target with light polarized at 90 degrees to the background alignment polarization. The cell was capillary-filled with the polymerizable liquid crystal monomers. As expected, the monomers aligned in the pattern dictated by the polarized illumination of the optical alignment layers. The monomers were photopolymerized using unpolarized ultraviolet light to form a patterned liquid crystal polymer film which was removed from the coated glass substrates. ***Figure 6*** is a photograph of the free-standing 50μm film as viewed between crossed and parallel polarizers. Applications in optical storage, stereo displays, and holography can be envisaged for the patterned liquid crystal polymers.

We have provided an overview of the optical alignment of liquid crystals. This technology provides many opportunities for scientific research (e.g. the chemistry and photochemistry of the

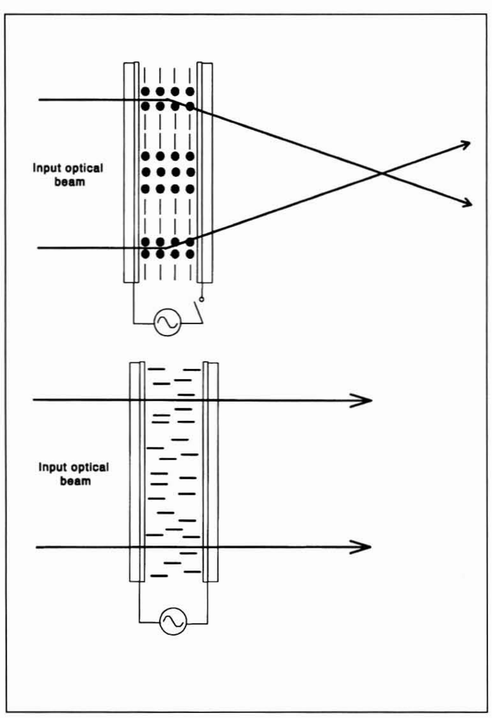

Figure 5. *Schematic of a chirped liquid crystal grating. The electric field removes the spatial variation in liquid crystal orientation and, thus, prevents the diffraction of the incident beam.*

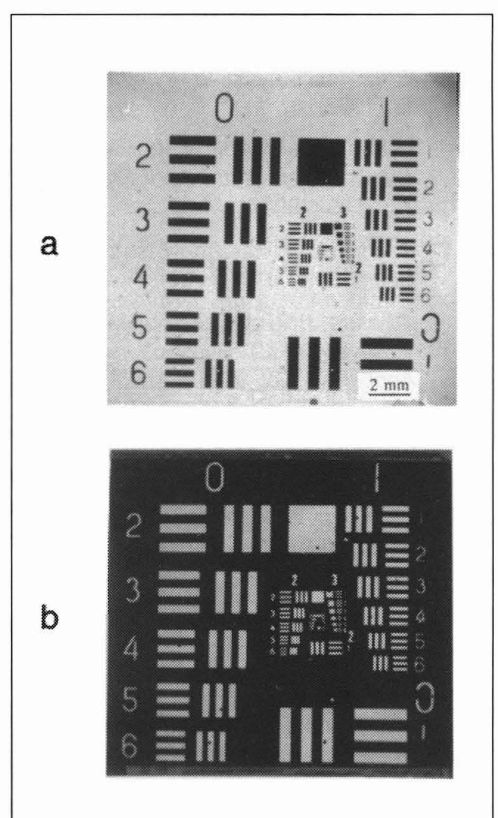

Figure 6. *An optically aligned resolution chart in a free standing liquid crystal polymer film as viewed between a) parallel and b) crossed polarizers.*

alignment polymers, the liquid crystal/ alignment polymer interaction, the physics of interfaces etc.) as well as potential commercial applications in liquid crystal displays, holography, and optical storage. Many scientific and technical hurdles must be addressed before the commercial benefits of this technology will be fully realized. We are currently performing research and development to make the optical alignment of liquid crystals useful for commercial applications.

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SOCIETY NEWS

Elections and New Board Members

At the 15th ILCC in Budapest it was announced that the President (***Geoffrey Luckhurst***) and Vice-President (***Shunsuke Kobayashi***) had been re-elected unopposed for a further term of 2 years. In accordance with the Society's Bylaws, new Regional Representatives and National Representatives of affliliated Liquid Crystal Societies were appointed, and the full list of new Officers and Board Members is given below.

New Officers

The Treasurer ***Bill Doane*** and Membership Secretary ***Charles Rosenblatt*** have both agreed to continue for further terms. As announced elsewhere in Liquid Crystals Today, ***David Dunmur*** has resigned as Secretary, but will continue for the time being as editor of *Liquid Crystals Today*. The new Secretary is ***Giancarlo Galli*** from Pisa.

Officers and Board Members of the ILCS

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Past President: **S Chandrasekhar**,
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e-mail: cxr@po.cwru.edu

National Society Representatives:

G W Gray:British Liquid Crystal Society
D J Pusiol: IberoAmerican Liquid Crystal Society
F Simoni : Italian Liquid Crystal Society
V Titov :Russian Liquid Crystal Society

Regional Representatives:

D J Broer (The Netherlands); **A Buka** (Hungary); **S H Chen** (ROC Taiwan); **E Chiellini** (Italy); **P E Cladis** (USA); **R Dabrowski** (Poland); **R Y Dong** (Canada); **H Finkelmann** (Germany); **D Guillon** (France); **C C Huang** (USA); **P Palffy-Muhoray** (USA); **I P Pinkevich** (Ukraine); **M Schadt** (Switzerland); **R Shashidhar** (USA); **B Stebler** (Scandanavia); **H-R Trebin** (Germany); **H Yokoyama** (Japan); **S Zumer** (Slovenia).

Chairmen of Committees:

Conferences - **H-R Trebin**, Inst. für Theor. und Angew. Physik, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, GERMANY

Honours and Awards - **S T Lagerwall**, Physics Dept, Chalmers University of Technology, S-41296 Göteborg, SWEDEN

Co-chairman - **G W Gray**, Merck Ltd, West Quay Road, Poole, Dorset BH12 4NN, UK

Publications & Editor of Liquid Crystals Today - **D A Dunmur**, Dept of Chemistry, University of Sheffield, Sheffield S3 7HF, UK