# Flexible Liquid Crystal Film Using Continuous Process

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**Keywords: micro-cell LC film, PNLC, continuous process**

## Abstract

*Micro-cell LC film and polymer network liquid crystal (PNLC) film by using continuous compatible process have been developed. A high-contrast micro-cell LC film has a strong potential as a high-performance flexible device. PNLC film has the low driving voltage. Both films show the characteristics of lightness, thinness and mechanical stability.*

## 1. Introduction

Flexible electronics present both new challenges and new opportunities to areas from materials, equipment, and processing to applications. At present, flexible electronics have mainly been applied in entertainment and medical diagnosis functions, with the technology trend driving toward multi-functional, wireless, light-weight, thin, low-cost and ergonomic solutions. Especially, flexible display encompasses more applications.

Several display technologies have recently been developed including electrophoretic[1], liquid crystal[2-4], electrochomeric[5] and liquid powder[6]. These technologies can provide light-weight, curved, roll-up portable products, and have the advantage of implementing a roll-to-roll manufacturing process. There are many promising applications such as e-books, signage, bulletin boards, smart cards and shelf edge labels, where being easy to read and rewriteable is a big advantage over traditional alternatives.

In this paper, a novel flexible micro-cell LC film with a high contrast ratio was developed through a reliable process, which was compatible with the roll-to-roll manufacturing process. Moreover, a novel PNLC film fabricated by a cost-effective continuous process was presented, which had the potential to realize a light-weight flexible electronic device.

## 2. Experiments and Results

### 2.1 Micro-cell LC film

The schematic structure of micro-cell LC film is shown in Fig. 1. The substrates in micro-cell LC films were 120-μm-thick films of indium-zinc-oxide (IZO) coated polycarbonate (PC). Crossed ultra-thin polarizers covered the exterior sides of plastic substrates. In order to resist the vertical and horizontal strain as the display is bent, the cross-shaped spacer was chosen. The height of the spacers is 5 μm. The total thickness of the micro-cell LCD film was about 520 μm. Figures 2(a) and 2(b) show the microscopic textures of the TN-mode micro-cell LC film observed under a polarizing microscope at 0 and 5 V, respectively, where the pitch of the spacers is 100 μm.

The transmission versus applied voltage (*V-T*) curves of the micro-cell LC film were measured between 0 and 5 V using Otsuka LCD5100 at various bending curvatures and shown in Fig. 3. The curvatures of radius were 2.5 cm, 5 cm, 7.5 cm, 12.5 cm and plane. The electro-optical characteristic remains almost the same under different bending curvatures, which shows very good mechanical stability against external bending.

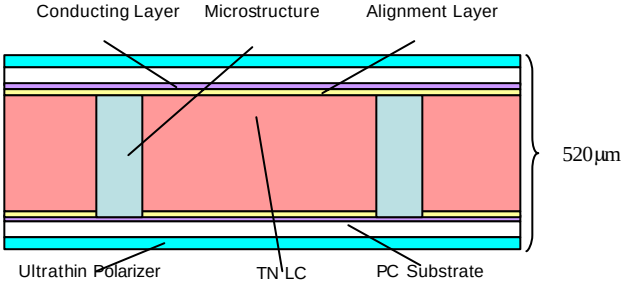
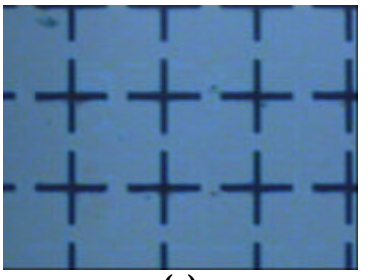
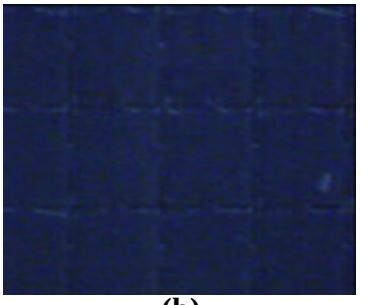



Figure 1 Cross-sectional view of flexible micro-cell LC film.



**(a)**



**(b)**

Figure 2 (a) Bright state of TN micro-cell LCD at 0 V and (b) dark state driven at 5 V observed by polarizing microscope.

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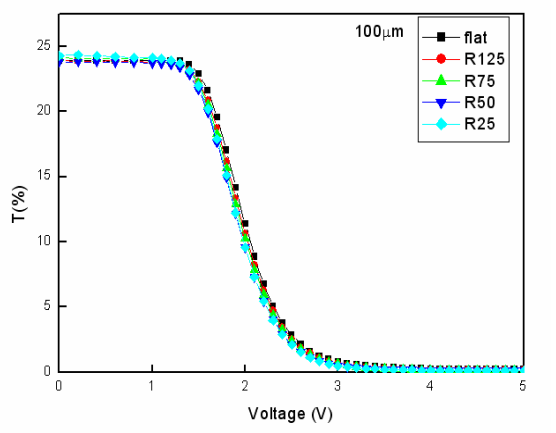


Figure 3 V-T curves with different bending condition (Pitch 100um).

## 2.2 PNLC film

Figure 4 demonstrates the schematic structure of PNLC film. In order to keep the uniform cell gap, the spacer with 8 μm height was formed on the PET substrate by roll-to-roll screen printing process. Then, LC/monomer composite materials were filled between two substrates. After UV exposure, the PNLC film was fabricated due to polymerization-induced phase separation mechanism.

Figure 5 shows the *V-T* curves of the PNLC film. It has low driving voltage. An A4 size PNLC film with 3 V driving voltage was demonstrate d in Fig. 6.

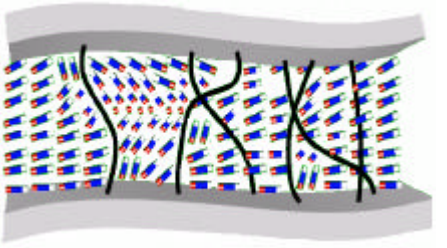

Figure 4 Cross-sectional view of PNLC film

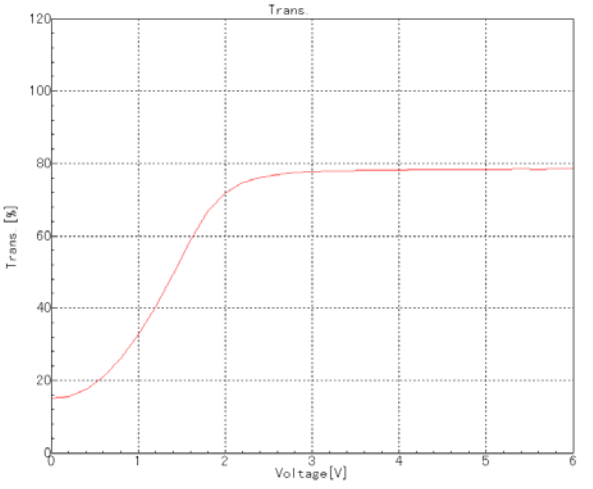


Figure 5 V-T Curve of PNLC film.

**(a)**

**(b)**

Fig. 6 (a) dark state of PNLC film at 0 V and (b) bright state of PNLC film driven at 3V.

## 3. Flexible Liquid Crystal Film Special Interest Group

In order to precipitate the development of Taiwan flexible display industry, ITRI and the Ministry of Economic Affairs strongly advocated forming the Flexible Liquid Crystal Film Special Interest Group (SIG), including five local companies: Chimei, Taiflex Scientific, Kuosen, Contrel and Shinkong in December 2006. The SIG is an R&D alliance of companies from up and down of the LCD supply chain, whose major focus is on developing technologies for producing LC film using roll-to-roll manufacturing process. These companies represent a vertical integration of supply chain from materials to application which is shown in Fig. 7. In the near future, a roll-to-roll pilot line of the LC film process will be built up. This pilot line can demonstrate not only the PNLC film but also the polarized mode LC film for high-end applications.

## 4. Summary

We have fabricated TN LC and PNLC films by roll-to-roll compatible process, which have the potential for light-weight and low-cost flexible electronic applications. Moreover, we had formed the Flexible Liquid Crystal Film SIG with five local companies, which will focus on developing new roll-to-roll manufacturing process, materials and equipments.

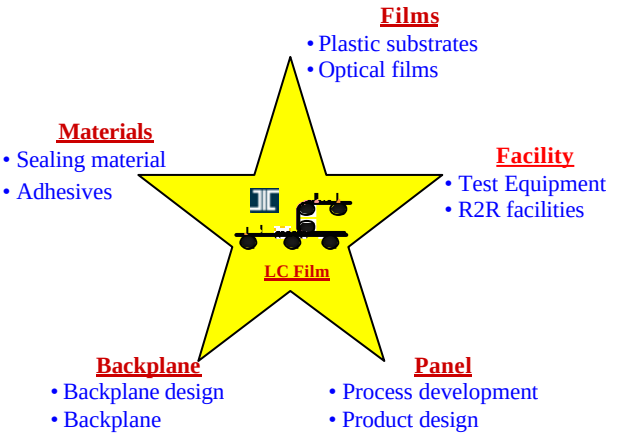


Fig. 7 Frame diagram of Flexible Liquid Crystal Film Special Interest Group.

## 5. Acknowledgements

This work was supported in part by the Ministry of Economic Affairs of R. O. C. government through EOL/ITRI and the Flexible Liquid Crystal Film Special Interest Group including Chimei, Taiflex Scientific, Kuosen, Contrel and Shinkong. We also appreciate Nitto Denko to support ultra-thin polarizers.

## 6. References

[1] E-ink Corporation, Cambridge, MA 02138, USA.

[2] V. Vorflusev and S. Kumar: Science **283** 1903 (1999).

[3] H. Sato et al. IDW proceedings 605 (2006).

[4] Kent Display, Inc., Kent, OH 44240, USA.

[5] M. Edwards et al, SID Symposium Digest 570 (2003)

[6] R Hattori et al, SID Symposium Digest **35**, 136-139 (2004)