OLCD in Automotive Applications – Enabling Curved and Non-Rectangular Form Factors with Conformable Displays

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ABSTRACT

We will describe recent development of shaped and curved OLCDs and describe the process used for fabricating the array and cell using existing FPD equipment types, and show examples of the resulting displays that can be shaped, curved and seamlessly integrated into curved automotive surfaces. We will also show how the LC optical films based on TAC can be 3D biaxially curved to follow the contours of almost any surface, including windows.

1 Introduction

Trends in the automotive industry point towards a future of ever greater functionality through connectivity and automation. An increase in the quantity and size of displays is now demanded in the vehicle, which is a challenge for car designers. Display technologies capable of curved and shaped form factors can be integrated seamlessly into the curved surfaces of new vehicles in a way that isn't possible with glass-based FPD technologies.

One flexible display technology that is being considered in automotive applications is OLED. However this has limitations in automotive with a fundamental trade-off in brightness lifetime and very high manufacturing costs that is exacerbated at larger display sizes.

FlexEnable have developed the glass-free technology Organic Liquid Crystal Display (OLCD) which utilizes an Organic TFT (OTFT) backplane on a rugged flexible substrate. This platform offers the freedom in form factor that comes with using flexible plastic substrate and retains the key performance benefits (brightness, lifetime, cost, size) of conventional LCD, the most common display technology used in automotive

OLCD technology has been developed to deliver the requirements of low cost scalability through utilizing existing FPD manufacturing equipment [1]. Manufacturing lines developed for conventional LCD can be converted to production of OLCD.

2. OLCD Structure

The OLCD manufacturing process uses organic TFTs as a replacement for conventional a-Si. The OTFT manufacturing process has been developed to be performed entirely at low temperatures (<100°C) using conventional a-Si TFT LCD production line equipment.

The development of the low temperature process for OLCD includes a specific material set for the OTFT backplane. FlexiOM™ is the name for the key organic materials that enable this manufacturing approach which are supplied by FlexEnable. The FlexiOM polymer materials have been specifically engineered so organic thin film transistor (OTFT) backplanes can be fabricated in standard flat panel display factories which are repurposed for the novel material set

LCD has particularly demanding substrate requirements because polarized light must be able to pass through the substrate material unaffected. The low processing temperatures used in OLCD fabrication (sub 100°C) enable the use of TAC (triacetate cellulose) as the substrate. This material has near identical optical properties to glass in key specifications including birefringence, colour and transmission [2], whilst being much thinner and flexible

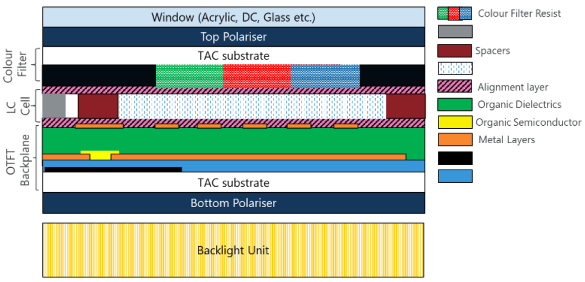


Fig. 1 Cross Section of OLCD display stack including TAC substrate

Figure 1 shows a schematic cross section of a typical OLCD single cell structure. The OTFT array is built directly onto a 40µm TAC film substrate which is mounted onto a glass carrier during fabrication. The stack consists of a top-gate OTFT structure connected to a pixel electrode for a conventional IPS pixel structure. The cell shown in figure 1 has a thickness of <100µm (including the TAC substrates but excluding the polarizers) and OLCD modules incorporating this cell have been demonstrated with a bend radius down to R10.

As well as being flexible and conformable to surfaces, the resulting TAC-based liquid crystal cells can be easily cut into non-rectangular shapes using technologies that are widely available in existing LCD display manufacturing facilities such as blade or laser cutting.

Encapsulation requirements for OLCD are much less stringent than OLED where highly moisture sensitive materials are employed. This provides the opportunity for narrow cell borders and less substantial barrier properties (WVTR requirements are 2-3 orders of magnitude lower for OLCD)

OLCD display technology offers the possibility of activating almost any surface within the car interior. Prototype display modules produced by FlexEnable have demonstrated curved centre console and curved digital side mirrors [3].

New use cases have been identified for the use of conformable non-rectangular displays. These include the introduction of an invisible A-pillar where external cameras provide visibility through the A-pillar support.

Fig. 2 A pillar concept use for conformal OLCD displays

3. OLCD Cell Technology – additional applications

The approach used by FlexEnable to manufacture an OLCD display can also be applied to alternative cell structures suitable for other applications.

There are a range of applications where flexible, conformable LC cells offer a performance benefit over conventional glass. Flexible LC cells using the same TAC substrate with patterned electrodes and alignment layers on the frontplane and backplane, a liquid crystal cell can be produced offering the same robustness and conformability as OLCD.

Fig 3. Shows a flexible liquid crystal (LC) cell structure which is produced using 40µm TAC. This structure can be used with a range of different LC types to modulate, steer and focus light. The active films can then be integrated into the product in ways not possible with glass LC cells because of thickness, weight and limited flexibility of glass [4].

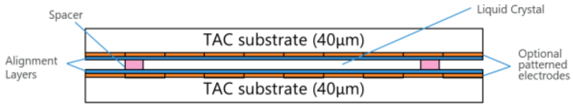


Fig 3. Schematic of an LC cell with TAC substrate

3a. Example application – Smart Windows

Liquid crystal cells offer the optical performance required (fast switching, colourless, and low haze) for use in smart windows where the light transmission of the cell is adjustable with the switching of the LC cell. The transmission range can be adjusted by design of the cell gap.

Flexible LC cells can conform to the biaxial curves commonly required in automotive glazing in a way that is not possible in conventional glass FPD type LC cells. The flexible cell can then be laminated between the layers in automotive glazing.

Figure 4: Concept of a smart window using Flexible liquid crystal cells.

The adjustability of transmission in smart windows offers increased privacy, the opportunity to change the environment within the car and improvement in energy efficiency with less energy required for climate control due to reduction in light, meaning smaller, lighter air conditioning systems can be used. Such that this is a desirable technology in automotive applications.

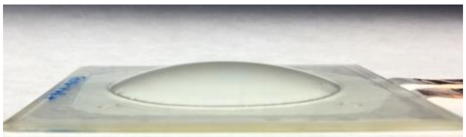
Figure 4. shows a concept of smart window with tunable transmission suitable for a sunroof. FlexEnable have demonstrated cells which can switch rapidly from a clear to tinted state with transmittance ranging from 70% to 30% in one LC architecture and from 35% to 1.5% in another. Other configurations can be used to cover a range of tint levels, transmission modes and cell thicknesses.

This same concept can be used in other applications, for example in AR headsets

4. Thermoforming for achieving more complex curvatures

TAC can achieve a wide range of custom shapes with curvature in one axis, but to achieve more complicated shapes biaxial curvature can be achieved via thermoforming of the TAC substrate.

By heating the TAC substrate above it's T_g (in the region of 120°C) and applying pressure, OLCD and LC cells can be formed to a bend radius <100mm. Due to the low T_g of TAC this can all be achieved whilst avoiding any damage to other materials in the cell (e.g. LC).



Spherical Radius of curvature	75mm
Cap diameter	55mm
Cap height	5.6mm

Fig.5 Example of a Biaxially formed functioning LC Cell on TAC film by example of a Spherical cap formed into a 7cm x 7cm active area test cell.

This process of forming a display into a 3D shape isn't possible with Flex OLED with inorganic TFT's where high T_g substrate is used which cannot be formed at low temperatures.

Fig 6. Concept demonstrating biaxial curved OLCD in a smart speaker application

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5. Summary

OLCD is a flexible display technology which offers the conformability and form factor plus the optical and reliability performance required for the next generation of automotive display applications.

LC cells manufactured on TAC substrate can be applied to other applications including Smart Windows with unique performance benefits over equivalent glass technologies.

References

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