# Stable Chiral Hybrid In-Plane-Switching Mode for Transparent Display

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## Abstract

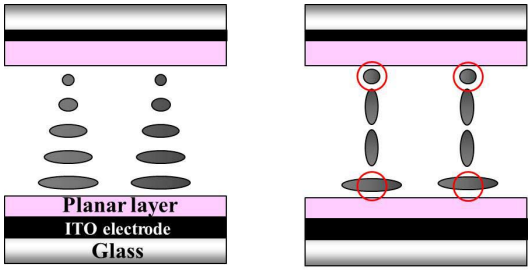
*We demonstrate a transparent display using a chiral hybrid in-plane-switching (CH-IPS) mode with high transmittance. To obtain the stable alignment in the CH-IPS mode, the vertical alignment layer mixed with reactive mesogen was used. High transparency and excellent dark state for the transparent display applications were achieved.*

## 1. Introduction

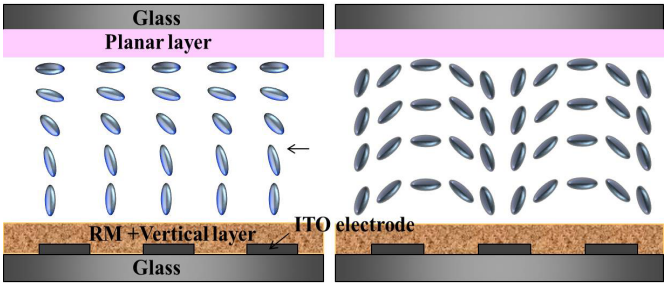
Over last decade, flat panel display (FPD) market is rapidly prospered with development of many FPD devices such as liquid crystal display (LCD) and plasma display panel (PDP) [1-3]. Among them, LCDs are widely used device because of its simple manufacturing process, high optical configuration, and low fabrication cost. Recently, new type of display technology is issued which can see-through object behind the display panel and information is displayed onto the transparent display panel. This kind of device is commonly imagined in science fiction movie but it can be realized using LCDs due to the mass-productibility and high contrast ratio.

In addition, the feature of the transparency plays an important role to realize the transparent display (TPD). Among the various LCD modes, the twisted nematic (TN) mode is known as the brightest LC mode using the wave guiding effect [4]. However, the TN mode shows the poor dark state because the LC molecules are strongly anchored by the surface area even though the electric field induced between common and pixel electrodes (see red circles on Fig. 1(a)). To compensate this phenomenon, we studied about the chiral hybrid in plane switching (CH-IPS) mode [5]. The CH-IPS mode adopts the chiral hybrid structure at initial state and the transmittance is optimized comparable to the TN mode by control the twist angle of the LC molecules. In dark state, LC molecules are perfectly arranged perpendicular to the interdigitated electrode direction by the in-plane field as shown in Fig. 1(b). Therefore, CH-IPS mode shows the higher contrast ratio than conventional TN mode. Even though the CH-IPS mode shows the excellent black level compare to the TN mode, it has a non-uniform alignment characteristics due to the reverse domain and we attempted to overcome this problems using surface modification method.

In this paper, we attempt to obtain the TPD using the CH-IPS mode which has a high transparency and complete black level. To obtain the uniform alignment of LC molecules, we mixed the reactive mesogen in the vertical alignment layer and we fabricate the proto type sample to indicate the performances of TPD compare to the TN mode.




(a) TN mode




(b) Proposed CH-IPS mode

**Figure 1. The schematic diagrams of (a) TN mode, (b) CH-IPS mode**

## 2. Experimental

First, we fabricated inter-digital indium-tin-oxide (ITO) electrodes by using photo-lithography process. After that, a planar alignment material (SE7492 from Japan Synthetic Rubber) was spin-coated on the top substrate. The spin-coated alignment layer of the top substrate layer was pre-baking at 100 °C for 10 min to evaporate the solvent in alignment material and the cured at 210 °C for 1 h to complete imidization. The reactive mesogen (RM) monomer and photo-initiator (Ciba Chemical IRGACURE651) was mixed in vertical alignment material

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(AL60702 from Japan Synthetic Rubber). The mixed alignment layer was spin-coated on the bottom substrate and pre-baking at 100 °C for 10 min and cured at 180 °C for 1 h. Bottom was rubbed in perpendicular to the direction of the electrodes. Top and bottom substrates were assembled anti-parallel. The $d/p$ and cell gap were set to 0.33 and 4.5 μm The LCs and chiral dopant which were used in this work were MLC-6875 ($\Delta n$ = 0.1114, $\Delta\varepsilon$ = 7.8, from Merck Co.) and R-811 (HTP = 10.3 $\mu m^{-1}$, from Merck Co.). The LC was injected by capillary action at isotropic phase ($T_{ni}$ = 91 °C) in Fig. 1(b). Then, the RM monomers on the bottom layer were exposed to the UV light ($\lambda$ = 365 nm) for 30 minutes. Through UV exposured, the RM monomers were polymerized along the LC alignment.

## 3. Results

Figure 2 shows the voltage-transmittance curve of CH-IPS mode and TN mode. The CH-IPS mode shows the 89 % transmittance than the TN mode without surface modification. As shown in the inset image in Fig. 2, we can see that the reverse domains. When the voltage applied, it is hardly to get the uniform gray level and dark state due to the reverse domain. After, surface modification with RM, the azimuthal anchoring strength is increased, and therefore, we can obtain the uniform alignment without reverse domain. As a result, we can obtain the 98 % transmittance than the TN mode. And proposed CH-IPS mode shows the high contrast ratio (~745:1) due to the excellent black level in contrast to that of the TN mode (~317:1). It comes from the perfectly aligned LC directors with electric fields.

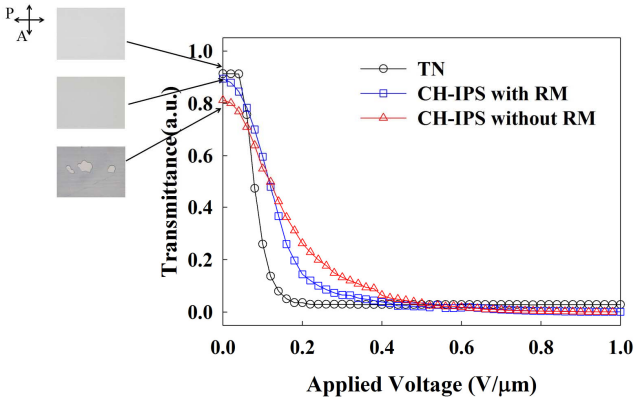


**Figure 2. Measured voltage-transmittance curve for various conditions**

To indicate the possibility of the CH-IPS mode in TPD, we fabricate the proto type samples of the CH-IPS mode using the surface modification and TN mode sample. Each sample is located in same position from the object [see Fig. 3(a)]. We compare the two samples in two different condition with 400 lux and 1500 lux which are similar luminance of one fluorescent light and outside in afternoon, respectively. In case of the, 400 lux condition, those two devices do not show the significant different in white and black state. However, in bright conditions about 1500 lux condition, the image shows the difference in black state. In case of the TN mode, the objects behind the panels are seen faintly due to the poor black state. In case of the CH-IPS sample, the object image is clearly blocked by the LCD panel. Therefore, we can conclude that the proposed CH-IPS mode is more efficient in TPD display in terms of the transparency and black level.

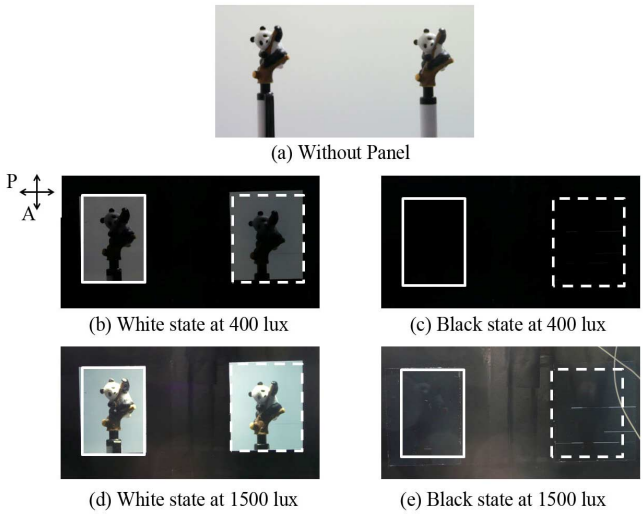


**Figure 3. Proto type of the TN and CH-IPS samples for TPD (a) Objects without panel, Comparison (b), (c) at 400 lux circumstance, (d), (e) at 1500 lux circumstance. Solid white line indicates the TN mode and dashed line indicate the CH-IPS mode, respectively**

## 4. Conclusions

We attempt to obtain the TPD using the CH-IPS mode which has a high transparency and complete black level. To obtain the uniform alignment of LC molecules, we mixed the reactive mesogen in the vertical alignment layer and the polymerized reactive mesogen help the uniform alignment of LC by the increased azimuthal anchoring energy. And also, we fabricate the proto type sample to indicate the performances of TPD compare to the TN mode.

## 5. Acknowledgements

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