

## Creating a Neo-Outdoor Work Style

# Low-Temperature Polysilicon TFT Reflective Color LCD

- **Freely mobile, even outdoors**  
Power consumption reduced to 1/8\*<sup>1</sup> of previous levels by using external light.
- **ECB\*<sup>2</sup> mode reflective color LCD**  
Achieves the industry's highest reflection ratio of 34% and a contrast ratio of 19:1.
- **BDM\*<sup>3</sup> technology**  
Provides brilliant natural colors and the ability to display pure whites.
- **RMP\*<sup>4</sup> structure diffusing reflective electrode**  
Provides clear images with no loss of sharpness.
- **High-efficiency frontlight system**  
Assures visibility in dim environments.

\*1: When compared to 4.0-inch transmissive LCD modules.

\*2: Electrically Controlled Birefringence

\*3: Birefringence Dispersion Matching

\*4: Random Multi Profile

— Towards a display device that is always bright, attractive, and low-power at all times —

In addition to audio and video equipment such as portable television sets and video cameras, due to the spread of the use of the internet and email and improvements to the communications infrastructure, the market for battery operated electronic information equipment for outdoor use, such as PDAs and subnotebook PCs, is expected to grow rapidly. Furthermore, rapid advances in the mutual integration of these various devices are also expected. This means that it will no longer suffice for displays, which form the center of the user interface in these devices, to only function for either still or moving images, but rather that the ability to provide high-resolution color images with excellent picture quality will be required in all environments.

However, since conventional transmissive LCDs use a backlight, it is impossible for them to get around the problem of reduced visibility in bright ambient

lighting conditions.

Sony has now developed low-temperature polysilicon TFT reflective color LCDs that can be used even in bright environments such as the outdoors since they use the ambient light itself as the illumination light source. These products are based on low-temperature polysilicon TFT technology, which is effective at providing increasingly higher resolutions, and they support longer battery life in application products by significantly reducing power consumption (to 1/8 of that required by conventional products) since they do not require a backlight. The development of the built-in diffusing reflective electrode ECB (electrically controlled birefringence) mode allows these devices to provide clear color images that overturn previous common sense ideas about reflective LCDs. The highly efficient frontlight system promises color images with a high picture quality in dim ambient lighting environments.

Sony's low-temperature polysilicon TFT reflective color LCDs create a neo-outdoor work style and can implement truly mobile information tools.

■ **Table 1 Product Specifications**

Item	8.6-inch, 1.18M dots	4.0-inch, 230K dots
Number of active pixels (H × V)* <sup>5</sup>	1024 × 384 pixels	320 × 240 pixels
Pixel arrangement	Stripe	Stripe
Dot pitch (H × V)	67.0 × 201.0 μm	84.0 × 252.0 μm
Dimensions (W × H × D)* <sup>6</sup>	214.8 × 86.8 × 3.9 mm	89.6 × 70.8 × 3.9 mm
Aperture ratio	92 %	94 %
Reflection ratio	34 %	
Contrast	19 : 1	
Response time	ton* <sup>7</sup> = 4 ms, toff* <sup>8</sup> = 14 ms	
Number of colors	6 bits for each RGB color (262,144 colors)	
Display format	1/2 XGA	1/4 VGA
Power consumption	0.7 W (Including the drive substrate)	0.13 W (Including the drive substrate)

\*5: One pixel corresponds to three dots (RGB).

\*6: When no frontlight is used.

\*7: The time for the reflection factor to fall from 100% to 10% from a point when the voltage is applied.

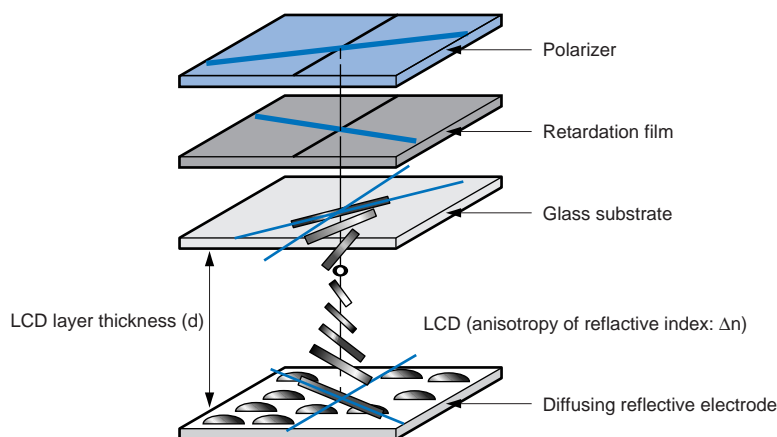
\*8: The time for the reflection factor to rise from 0% to 90% from a point when the voltage is not applied.

## ECB Mode Reflective Color LCD

There are five main display modes used in reflective color LCDs.

- TN (twisted nematic)
- STN (super twisted nematic)
- GH (guest host)
- PCGH (phase changed guest host)
- PDLC (polymer dispersed liquid crystal)

Of these, the modes that use two polarizers and provide a diffusing reflector on the back of an LCD with the same structure as a transmissive color LCD, such as the TN and STN modes, suffer from the problem of only being able to provide extremely dark displays. This is because the quantity of light pass through the polarizers a total of four times resulting in large losses. Additionally, these devices have an inherent problem with double images appearing due to parallax. The GH and PCGH modes have inherent limitations in the two-color contrast they can provide in coloring matter. In addition to not being appropriate for direct-viewing displays due to the fact that they are basically devices that switch between a transmitting state and a diffusing state, PDLC mode LCDs require a high drive voltage, and they have not yet reached the level of practical application.



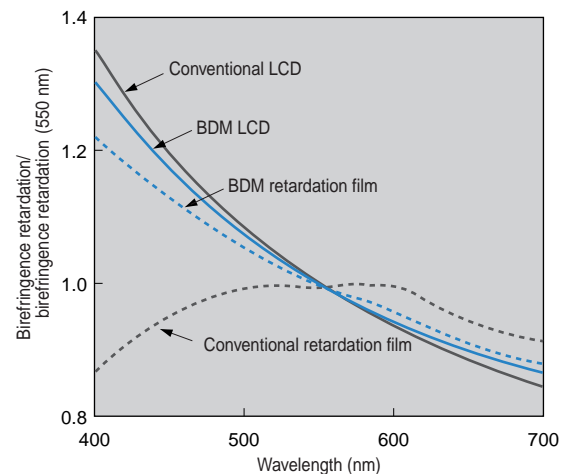
■ Figure 1 ECB Mode

Sony has developed a single polarizer ECB (electrically controlled birefringence) mode LCDs that provide adequate brightness in actual use and also features contrast ratio, response time, reliability, and process stability characteristics that are superlative for reflective color LCDs. (See figure 1.) The polarizer and retardation film axis directions, the liquid crystal twist angle and orientation direction were optimized by computer simulation. Furthermore, by combining with the BDM technology and RMP structure diffusing reflective electrode described later in this article, Sony achieved the industry's highest level of reflection ratio (34%) and a contrast ratio of 19:1. Additionally, due to the development of liquid crystal materials with high response time, these devices achieve a response time with a  $t_{ON}$  of 4 ms and a  $t_{OFF}$  of 14 ms at room temperature, 25°C. Thus these devices can provide attractive moving image with no image retention.

## BDM Technology

These devices feature reduced optical leakage at both short and long wavelengths due to the development of Sony's unique BDM (birefringence dispersion matching) liquid crystal and retardation film, in which the wavelength distributions of the birefringence retardation are matched. This allows them to achieve a contrast ratio of 19:1. (See figure 2.)

At the same time, Sony was also able to significantly improve the color purity in these devices, a characteristic that is a significant technological problem in reflective LCDs. Thus these devices provide brilliant natural colors and the ability to display pure whites.



■ Figure 2 Birefringence Retardation Wavelength Distribution

## RMP Structure Diffusing Reflective Electrode

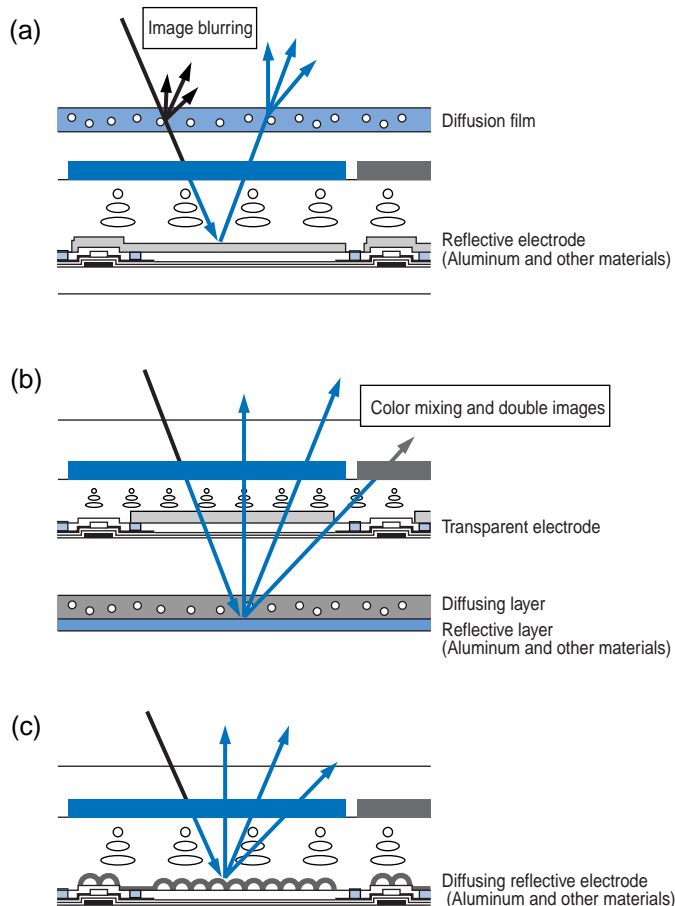
There are two basic structures that have been proposed for reflective color LCDs.

- (a) Applying a diffusing film to the outside of the opposite substrate and providing a reflective electrode on the TFT as the specular surface. (See figure 3-a.)
- (b) Applying a diffusing reflective film to the outside of the TFT substrate. (See figure 3-b.)

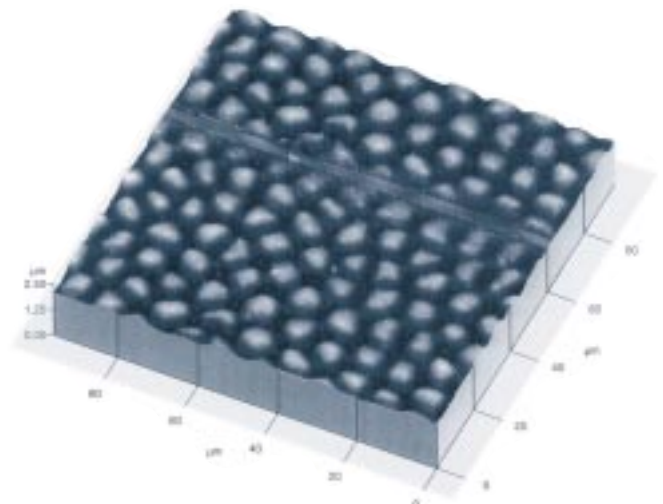
However, both of these structures have inherent problems. The former structure (a) has the problem that the light scattered backwards from the diffusing film

is superimposed on the reflected light, making it difficult to provide clear images with a high apparent resolution. The latter structure (b) has the problem that due to the thickness of the glass, the light entering through one pixel may exit from another, thus creating color mixing or double images. This makes it difficult to provide higher resolutions. To overcome these problems, Sony uses a built-in RMP (random multi-profile) structure diffusing reflective electrode which integrates the functions of diffusion, reflection, and the electrode and in which the reflecting electrode is formed with extremely fine random depressions and protrusions. (See figures 3-c and 4.)

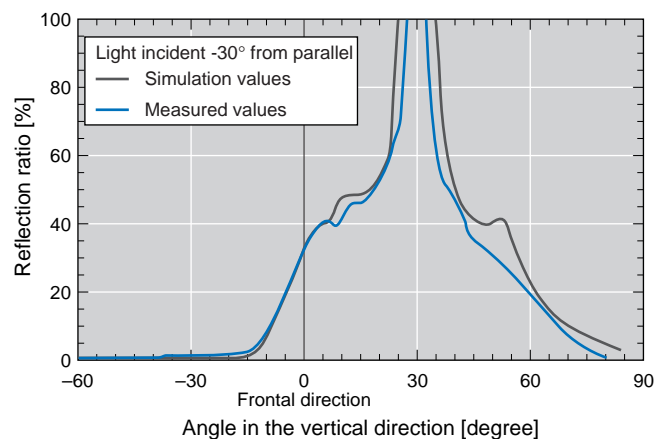
The characteristics desired in an RMP structure diffusing reflective electrode include the provision of a white light without a metallic tint, strong optical convergence, full reflectivity to minimize the amount of light trapped behind the LCD panel, and a minimal loss of polarization. However, while larger amounts of diffusion are effective for minimizing metallic tints and providing a pure white color in the reflected light, inversely, the optical convergence and polarization loss characteristics are improved by a lower degree of diffusion. Sony used computer simulation to determine the optimal balance between these characteristics and achieved a reflection ratio of 34%. (See figure 5.)



■ Figure 3 Structural Comparison of Reflective LCDs



■ Figure 4 Pixel Area Diffusing Reflective Electrode (\* AFM based)



■ Figure 5 Diffusing Reflective Characteristics

## Highly Efficient Frontlight System

To allow these reflective LCDs to be used without stress even in dim ambient lighting environments, Sony, in a joint development project with Stanley Electric, has developed the industry's thinnest (1 mm) parallel flat panel high-efficiency frontlight system. (See figure 6.)

When the ambient light is dim, light from the frontlight is distributed through the light guide plate and reflected towards the LCD by the prisms to provide even incident light to the LCD and thus assure good visibility. (See figure 7.)

This system provides the following main features.

- High brightness (15 cd/m<sup>2</sup> \*<sup>9</sup>) and good uniformity (±25%) were achieved by optimizing the prism thickness by simulation.

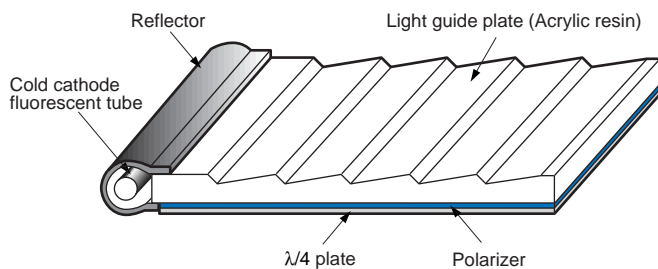
- Reflections from the LCD panel surface were cut by incorporating the polarizer and retardation film on the light guide plate, thus assuring good contrast.
- Loss of picture quality when the frontlight system is not used was prevented by using high-transparency prism material and fine fabrication technology.

By incorporating a frontlight system in this manner, these Sony reflective LCDs promise color image with excellent picture quality anywhere and at any time.

\*9: In 4-inch LCDs.

## Future Developments

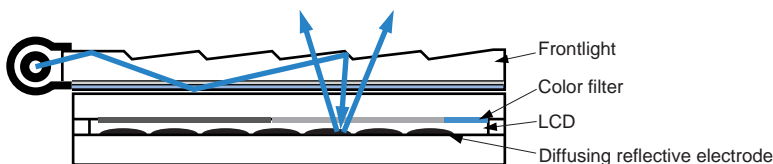
Sony plans to release commercial products based on this technology by the spring of 1999. In the future, Sony will respond with a wide range of products to meet market needs due to the rapidly growing market portable information terminals and similar product, in particular by providing an extensive lineup of both transmissive and reflective color LCD products based on the low-temperature polysilicon TFT technology. Keep your eyes on Sony LCD products that are always focussed on the future.



■ Figure 6 Frontlight Structure

■ Table 2 Frontlight Specifications

Item	4-inch 1/4 VGA	8.6-inch 1/2 XGA
Lamp power consumption	0.7 W	1.2 W
Screen brightness	15 cd/m <sup>2</sup>	10 cd/m <sup>2</sup>
Brightness uniformity	Within ±25 %	Within ±25 %
Light guide plate thickness	1 mm	1 mm



■ Figure 7 Structure of Reflective LCD with Frontlight System