Advances of High Temperature Countermeasures in Automotive LCD Technology

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ABSTRACT

Since launching the world's first LCD for automotive, we have devoted to improve LCD reliability and supplied LCD to various automotive interior parts. In recent HUD, luminance and temperature have been increasing, and light leakage may occur as a specific problem. As a result of investigation, it was found that the uneven distribution of the temperature on the polarizer could be the root cause of the shrinkage. Proper introduction of wire-grid substrate can be an effective countermeasure to improve the light leakage.

1 INTRODUCTION

We succeeded in mass production of the world's first LCD (Liquid Crystal Display) for automotive in 1980 (Fig. 1), we have improved the reliability of LCD and supplied LCD to various automotive interior parts. In contrast to the current 95 ° C guarantee required for general automotive interior applications such as clusters, recent LCD have advanced in both components and manufacturing technology to the level causing no problem in practical use, but still higher reliability is required for some applications.

Fig. 1 The world's first LCD clock for automotive

One of those applications is the electronic mirror. In the electronic mirror, the LCD is generally arranged behind the half mirror. Since the quantity of light is reduced by the half mirror, high luminance of about several 100,000 cd/m2 is required for the backlight. Since a high luminance backlight is included in the mirror housing and the mirror unit receives direct sunlight through the front window, a higher temperature guarantee is required. Conventionally a rectangular panel is used and a part of the mirror is displayed, but recently there is an increasing demand for an outer shape of LCD close to the outer shape of the mirror so that the entire surface of the mirror can be displayed (Fig. 2). High manufacturing quality is required because reliability such as cracks due to free-form glass can be a problem.

Fig. 2 Example of mirror shaped LCD

Another application is HUD (Head Up Display) (Fig. 3). The LCD for HUD is installed in the car, but because of its optical structure, it is easy to receive concentrated sunlight, and the heat resistance is required more than typical automotive LCD. Therefore, it is required that the polarizer and the liquid crystal material also have high temperature resistance.

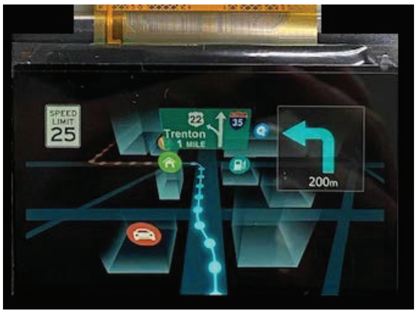

Fig. 3 Example of LCD for HUD

Furthermore, in recent AR-HUD (Augmented Reality HUD) and 3D-HUD, the panel size and the magnification respectively tend to be wider and higher in order to project a larger virtual image in a more distant position. The backlight used in HUD needs to be larger in size and higher in luminance as a result, which generates the higher temperature. This is apparently not the case in conventional LCD.

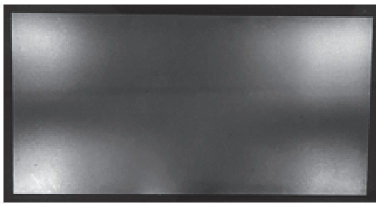

Fig. 4 Light Leakage with HUD backlight

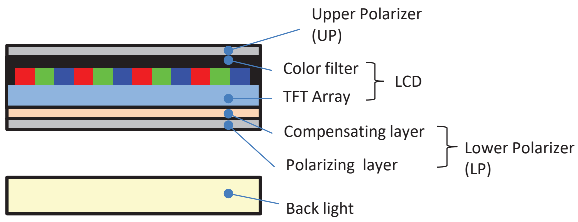

Fig. 5 Configuration of LCD and polarizer

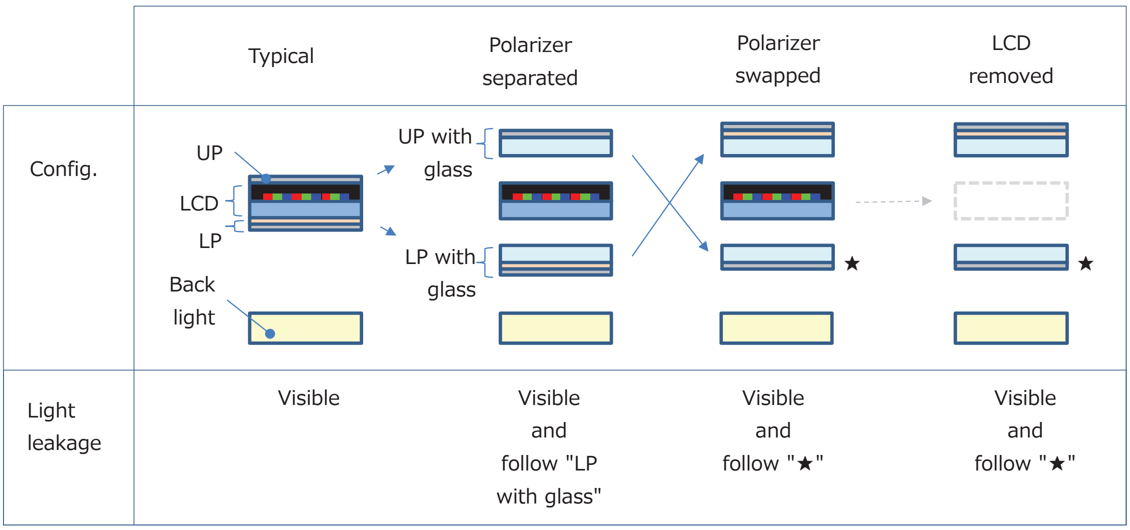

Fig. 6 Result of root cause analysis by changing configuration of polarizer and LCD

One of the specific problems associated with the increase of the temperature in the backlight is light leakage which locally occurs in the black mode due to the heat applied to the LCD panel.

The live reality of the HUD display image is mainly based on the black-mode. Therefore, when the light leakage occurs locally, this reality is deteriorated, and its countermeasures must be put in place. In the IPS (In-Plane Switching) mode represented by the FFS (Fringe Field Switching) mode [1], it has been known that the light leakage occurs when the LCD is bent [2], while it has been unknown whether or not the light leakage caused by high temperature shares the same root cause as of the bent-LCD case.

This is to report the mechanism of the light leakage caused by high temperature, the review of the structure including backlight, and a series of results that led us to the improvement.

2 RESULT

Fig. 4 is a photograph of the light leakage that occurs when a HUD backlight is used. The backlight luminance is about 500,000 cd/m2, the screen size is 4.1 inch, and LCD mode is FFS. The light leakage occurs within a few minutes after the backlight is turned on, and when the backlight is turned off, the light leakage also disappears.

As you can see in the picture, the light leakage occurs in four corners of the active area. The picture of the light leakage was taken directly from straight above the panel, but the light leakage is also visible in the projected virtual image of the HUD.

It has been known that the light leakage of a similar shape occurs when the LCD is bent [2]. However, this LCD for HUD shows the light leakage without having a bending force, so it is necessary to investigate the root cause. The LCD and polarizers used in this HUD are shown in Fig. 5. The LCD glass is 0.5mm thickness and the polarizers are iodine-based, and a retardation layer is attached to the polarizer on the backlight side to compensate another light leakage in the oblique viewing angle.

Fig. 6 shows the results of the investigation. In order to identify the root cause, the upper and lower polarizers were removed from the LCD and replaced with new polarizer bonded with glass, and the light leakage occurred in the same manner as in the case of a typical state. In addition, we also checked which side of polarizer would influence the light leakage to find the fact that the light leakage follows the movement of the lower polarizer near the backlight. However, as shown in Fig. 5, the lower polarizer comes with a compensating retardation layer, and it is not clear which of those two materials is the root cause. When the upper and lower polarizers were swapped, the light leakage followed the changed polarizer on the backlight side, that is to say, the polarizer without the retardation layer. This result explains that the retardation layer is not the root cause. Next, we removed the LCD panel to use only glass-attached polarizers upper and lower. The light leakage nevertheless occurred in the lower polarizer.

A typical iodine-type polarizer is produced by stretching PVA (Poly Vinyl Alcohol) in order to orient iodine in a certain direction to develop a polarizing function, but PVA shrinks at high temperatures. Fig. 7 is a plot of the change in the dimension ratio in the direction of the stretching axis of the polarizer bonded to glass with respect to the storage time at 105 ° C. As can be seen from this figure, in a high temperature environment, the polarizer immediately shrinks and the shrinkage saturates in about 100 hours. At this time, tensile stress is generated in the glass bonded to the polarizer, and birefringence is generated by the photoelastic effect [3].

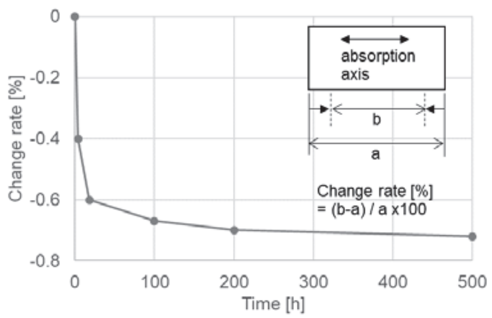

Fig. 7 Change rate of polarizer length in absorption axis after 105degC storage time

We presumed that the birefringence of the glass was caused by the difference in the surface temperature between the upper and lower polarizers, and the surface temperatures of the two polarizers were measured by thermocouples. Fig. 8 shows the surface temperature of the upper and lower polarizer with respect to the backlight lighting time. Contrary to the expectation, the temperature difference between the upper and lower polarizers was as small as 4°C, which is unlikely to be the root cause of the birefringence of the glass.

Following above, we presumed that the birefringence of the glass was caused by the temperature difference in the same plane, and the in-plane thermo-distribution in the polarizer surface was measured by a thermocouple. Fig. 9 shows the surface temperature with respect to backlight turn-on time. After 10 minutes of lighting, the in-plane thermo-distribution of the surface reaches approximately 20 °C, which is larger than the temperature difference previously measured between the upper and lower polarizers. This in-plane distribution may be the cause of the birefringence of the glass.

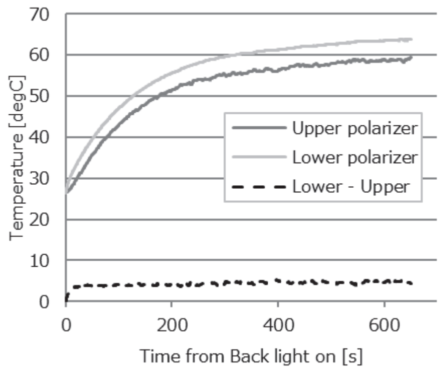

Fig. 8 Temperature of upper and lower polarizer after turning on the backlight

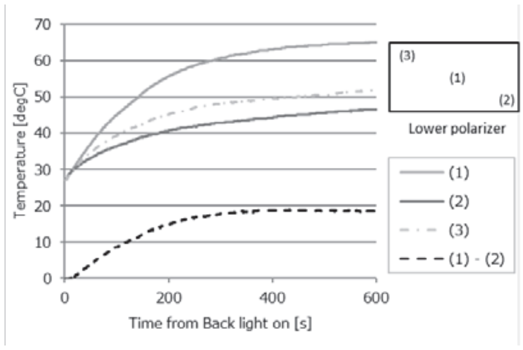

Fig. 9 Temperature of lower polarizer 3 position after turning on the backlight

Based on the results of the above-mentioned temperature measurement, we thought that the lower polarizer should be cooled down, and the in-plane thermo-distribution of surface should be equalized enough to suppress the birefringence of the glass, and we examined the material. Table 1 shows the thermal conductivity of materials that does not significantly influence LCD optical performance. Al has the highest thermal conductivity and the side effect on the transmittance can be minimized by making the same polarization as the polarizer on the backlight side with wire grid process. Thus, the wire grid using Al was adopted. As for the base material, we selected glass because it is much thicker than film and is advantageous in terms of heat insulation and heat capacity.

Table 1. Thermal conductivity of materials.

Reflective polarizer	<1
ITO	5 - 10
Al (Wire gird)	236

Unit : W/mK

Fig. 10 shows two types of configurations, in which a wire grid is differently mounted. It also shows the appearance of each light leakage in each configuration. In Type A of the left hand side, wire grid and glass of 0.5 mm thickness were mounted under the diffusion film of the backlight. The temperature of the central portion of the lower polarizer was reduced to about 50 ° C, but the light leakage in the corner portion remained. On the other hand, in Type B of the right hand side, on the diffusion film the wire grid are mounted so that the lower polarizer and glass can face each other. The temperature at the center of the lower polarizer was 50 ° C. as in Type A, and it was confirmed that the light leakage was greatly improved in this configuration.

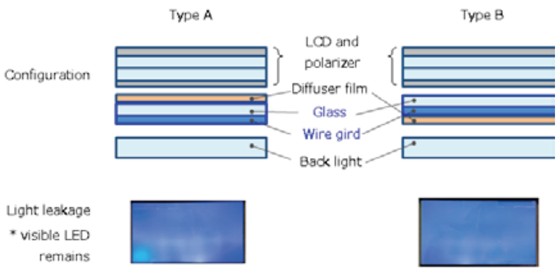

Fig. 10 Configuration of wire grid and light leakage

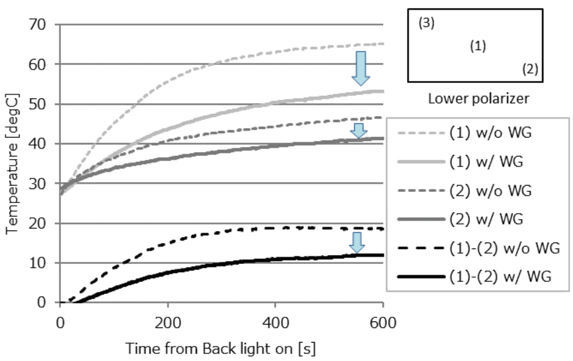

Fig. 11 Temperature of lower polarizer with and without WG after turning on the backlight

Fig. 11 shows the surface temperature of the lower polarizer with respect to the backlight lighting time in the case of type B. By mounting the wire grid, the temperature at the corner is also reduced, but the temperature at the center is reduced more than that, so the difference between the center and the corner is reduced from about 20 ° C to 11 ° C. As expected, we were able to confirm the heat shielding and equalization of the wire grid with Al.

3 CONCLUSIONS

The investigating of the light leakage generated in a HUD panel using a large high-luminance backlight found the fact that photo-elastic effect of glass attached with lower polarizer is main cause of light leakage. It was also found that the in-plane distribution of temperature can be equalized and light leakage can be improved by mounting a glass substrate with a wire grid so that the glass faces the backlight side of polarizer.

4 REFERENCES

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