Technology

Low Reflective Black Resist Ink for LCD Display

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Abstract

Strong sunlight shines directly and indirectly into the interior of a car, and if the light is reflected on the in-car LCD display, the visibility of the displayed content can be reduced. Therefore, we added a low refractive index filler to the black resist ink used in the color filters of liquid crystal displays to create a low reflective black resist ink. This low-reflection black resist ink does not require any special process. It can be used in the same way as conventional products to effectively reduce the reflectance on the glass surface, suppressing glare caused by external light and improving visibility. This technology has demonstrated that adding low refractive index fillers to black resist inks is effective in obtaining low reflective color filters, and that low refractive index fillers are an important key item for controlling the reflectance of LCD displays.

1. Introduction

Regarding liquid crystal displays, the white light (backlight) passes through the color filters to display color images. To manufacture a color filter, a grid-like black matrix (BM) is formed on a glass substrate using black resist ink and the three primary colors (red (R), green (G), and blue (B)) are arranged so as to form a pixel. Important roles of the BM are to prevent the RGB from blending in each pixel and improve the contrast by blocking backlight between the pixels.

In-car LCDs, represented by car navigation systems, are now widespread and there is increasing demand for center information displays (CIDs) with stylish design for which the boundary between the display section and the bezel section was eliminated to create one body. In general, large CIDs tend to glare by sunlight coming through window glass and indoor lights and such glare lowers the visibility. Accordingly, there is need for low-reflective properties. In addition, TVs used indoors are also upsizing and the visibility tends to be lower due to the influence of sunlight coming through window glass and indoor lights, which demands low-reflective properties.

For a representative high-resistance black resist ink of Nippon Steel Chemical & Material Co., Ltd., when the OD [/μm],[*1] which is a unit indicating the light blocking degree, is 3.6, the reflectance is approximately 6.0%. Reducing the amount of carbon black (CB) having a high-refractive index to be added can achieve low reflectance. However, at the same time the light blocking degree becomes lower and thereby this method is not practical (**Fig. 1**). Achieving low-reflective properties while maintaining the light blocking degree has been requested so as to improve the visibility of displays.

2. Main Body

This study has confirmed that using a low-refractive index filler lowers the reflectance of black resist ink. This paper introduces the

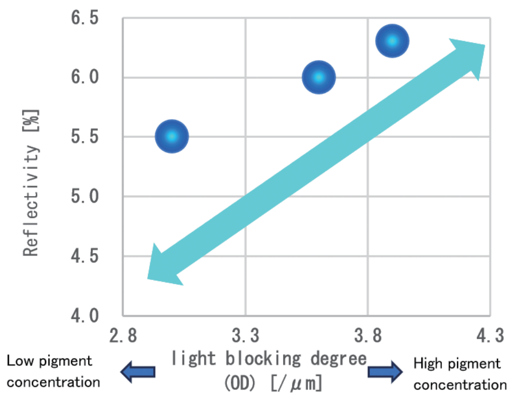

Fig. 1 Relationship between light blocking degree (OD) and reflectivity

[*1] Although transmissivity (%) is used to indicate the light transmission amount, optical density (OD value) is a common logarithm of the reciprocal of the transmittance. OD [/μm] is an OD value per film thickness of 1 μm.

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details. Low-reflective panels involving such black resist ink do not glare even when external light comes in and thereby their visibility is higher. The ink is highly valued by panel manufacturers. The details are outlined below.

2.1 Concept of lower reflectance

The surface reflectance on the glass surface side is calculated with the Fresnel equations shown in **Fig. 2**. The equations show that to reduce the reflectance at the interface between a glass piece and a BM, the difference in the refractive indexes between the glass and the BM must be reduced. While the refractive index of glass is 1.53, that of BMs including CB (refractive index of 2.3) is approximately 1.8. Accordingly, the refractive index of BMs needs to be reduced. **Figure 3** shows the concept.

2.2 Low-reflective black resist ink involving a low-refractive index filler

To bring the refractive index of a BM closer to that of a glass piece so as to reduce the reflectance at the interface between the glass and the BM, we considered using low-refractive index fillers having a low-refractive index to achieve lower reflection. Silica, aluminum oxide, magnesium fluoride, and cryolite were selected as low-refractive index fillers. **Table 1** lists the refractive indexes of these fillers.

The low-refractive index fillers listed in Table 1 were added to black resist ink to fabricate low-reflective black resist ink and the reflectance of each type was evaluated. In the first step, the four types of black resist ink were applied to glass substrates and they underwent vacuum drying, prebaking, exposure, development, and heat burning to form a cured BM film on them. The reflectance was measured from the glass surface side of the BM. **Table 2** lists the obtained results.

Figure 4 shows the relationship between the light blocking degree and the reflectance of the low-reflective black resist ink types for which the low-refractive index fillers listed in Table 1 were used.

The figure shows that adding the low-refractive index fillers reduces the reflectance without lowering the light blocking degree.

$$\text{Reflectivity} = \frac{(n_2 - n_1)^2 + (k_2 - k_1)^2}{(n_2 + n_1)^2 + (k_2 + k_1)^2}$$

Fig. 2 Fresnel equations

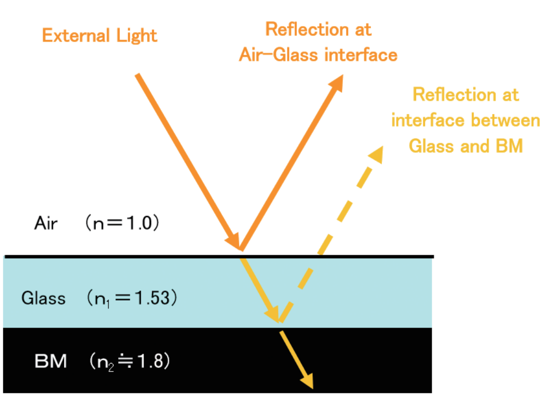

Fig. 3 Schematic diagram of the reflected light process

Figure 5 shows the reflectance spectra of the low-reflective black resist ink adopting the silica filler listed in Table 2 and conventional black resist ink.

The figure shows that the reflectance of the low-reflective black

Table 1 Low refractive filler types and refractive index

Low refractive filler type	Refractive index
Silica	1.47 [1]
Aluminum oxide	1.65 [1]
Magnesium fluoride	1.38 [1]
Cryolite	1.34

Table 2 Low refractive filler types and reflectance

Low refractive filler type	Reflectivity (%)
Silica	4.9
Aluminum oxide	4.8
Magnesium fluoride	5.5
Cryolite	5.5

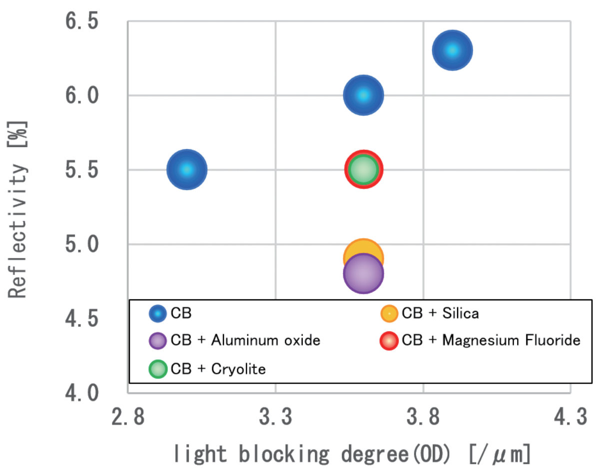

Fig. 4 Relationship between light blocking degree (OD) and reflectance

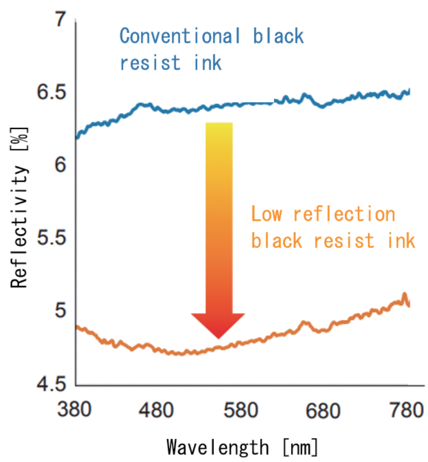

Fig. 5 Reflectance spectra of conventional and low reflectance BK

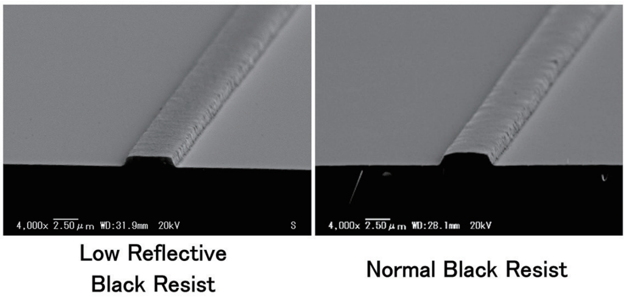

Fig. 6 SEM images of low reflection black resist ink with and without silica filler added after film formation

resist ink is lower than that of the conventional black resist ink in the wavelength range of 380 to 780 nm.

2.3 Evaluation results of the platemaking properties of the low-reflective black resist ink adopting the silica filler

The black resist ink was applied to glass substrates, then platemaking properties were evaluated in vacuum drying, prebaking, exposure, development, and heat burning, and a BM was formed. Black resist ink and low-reflective black resist ink were used to form BMs. **Figure 6** shows their SEM images.

The linearity of BM lines and residue in the unexposed sections affect the decrease in the brightness of the panel and the degradation of the image quality, and BM lines in a vertically tapered shape affect the deterioration of the color purity due to parallax and color mixture for each RGB pixel. Accordingly, excellent linearity, the absence of residue in the unexposed sections, and vertical shape are required. It has been confirmed that the characteristics of the BM involving the low-reflective black resist ink are at the same level as those of the normal black resist ink.

2.4 Low-reflective LCDs

The low-reflective black resist ink described in this paper has been adopted for applications for in-car displays and the mass-production of such displays has begun. The reflectance of normal panels is 4.6% while that of panels for which the developed low-reflective black resist ink was used and for which an anti-reflection film was attached to the panel surface is lower at 0.6%. As a result, the low-reflective panels do not glare even when external light enters and the visibility is higher while white glare is seen on conventional panels when external light enters.

3. Conclusion

LCDs adopting low-reflective black resist ink are expected to be widely used also in the future as low-reflective panels for smartphones and tablets, in addition to in-car devices and TVs. In addition, as autonomous driving of automobiles advances, there is growing demand that the interior of the cockpit space be more stylish. Accordingly, there is a strong possibility that low-reflective black resist ink that can realize both functions and stylish surface design will become an important technology in the future.

Reference

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