Technology

Resist Ink for Mini/μ-LED Display

Takashi KONNO*

Abstract

The development of display panels using mini/μ-LEDs has been active in recent years, and commercialization is progressing with public information displays as an example. LED panels are bright and colorful, so they are used as backlights for LCD panels or as display devices themselves. Reflective walls are essential for the former, and partition walls for color conversion layers and light-shielding walls are essential for the latter, and we develop the photoresists for forming these at Optical & Display Materials Center. This report introduces the background to the development of the products and the lineup.

1. Introduction

Placing blue LEDs on the market completed the three primary colors (red, green, and blue) and thereby the application of LEDs, as mini/μ-LEDs, to the display sector has accelerated recently. LEDs consisting of inorganic substances with strong luminescence and high color purity are stable and do not deteriorate much. Due to these characteristics, screens are expected to become brighter and more colorful and the service life to become longer. With these expectations, LEDs are being actively applied to in-vehicle, information, and TV panels because such panels are exposed to environments where sunlight and indoor light enter and the temperature and humidity are high.

Light emitted from surface emitting LEDs travels in all directions and thereby, without covers, the LED colors of one pixel mix with those of adjacent pixels. Accordingly, partition walls are required to surround each pixel to confine the light.

Partition walls that bring such confinement effect need to reflect light to designated directions and shield light by absorbing it as their required performance. White walls are used for the former and walls colored in black are used for the latter as they are considered to be optimum.

Partition walls must be equal to or higher than LEDs. Although the sizes of LEDs vary, they are classified, based on the length of the short sides of the rectangle when an LED mounted on a foundation electrode is viewed from above, as follows: Mini-LED for which the short sides are 30 μm or longer and μ-LED for which the short sides are smaller than 30 μm. The height of mini-LEDs and μ-LEDs is 7 μm or higher in general and thereby the height of partition walls must be at least 7 μm. In addition, recent development mainly aims to enhance the definition of display panels, so study involving μ-LEDs is the mainstream.

Appropriate methods to form walls that match the size of μ-LEDs are the screen printing, ink jet printing, and photolithographic method. For the application to displays requiring high definition, the photolithographic method, for which the dimension accuracy is in the order of several μm, is considered to be optimum.

Nippon Steel Chemical & Material Co., Ltd. has been working to develop resists for photolithography for many years. With regard to black matrix resists for color filters to be mounted on liquid crystal displays, we found a high pattern shape control technology and resists that would be able to maintain the dimension accuracy and that had toning capability, and to put such resists into the market. Thus, we have been contributing to the advancement of high-performance display panels. We started developing black and white resists for partition walls based on our technologies and knowledge cultivated through the development of black matrix resists.

2. Main Subject

As μ-LED panels and displays, which are the main development targets as of now, there are three types: Backlight panels having white reflective walls (**Fig. 1**), three-primary color displays having black light-shielding walls (**Fig. 2**), and QD color-conversion displays that have white partition walls and for which quantum dots convert the light of blue LEDs to red or green to make the three primary colors (**Fig. 3**). White or black resists are used for them.

In addition, as described above, the supposed height (film thickness) of partition walls must be at least 7 μm because the height of μ-LEDs to be mounted is 7 μm or higher. This height is seven times or more the standard film thickness (1 μm) of the black matrix resists developed by NIPPON STEEL Chemical & Material (**Fig. 4**).

In addition to this height, the shape when viewed from the cross section needs to be formed to be forward, vertical, or reverse ac-

* Dr. Eng., Senior Manager, Optical & Display Materials Center, Nippon Steel Chemical & Material Co., Ltd.
15-7 Shinminato, Kisarazu City, Chiba Pref. 292-0836

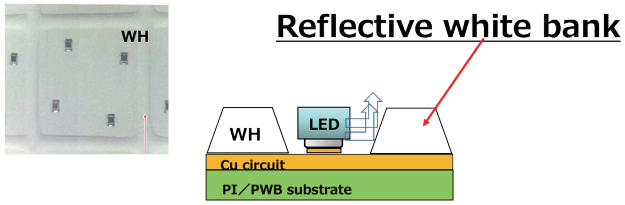


Fig. 1 Example of the structure of a μ-LED backlight panel

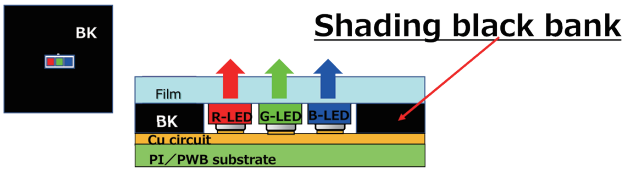


Fig. 2 Example of three-primary-color μ-LED display structure

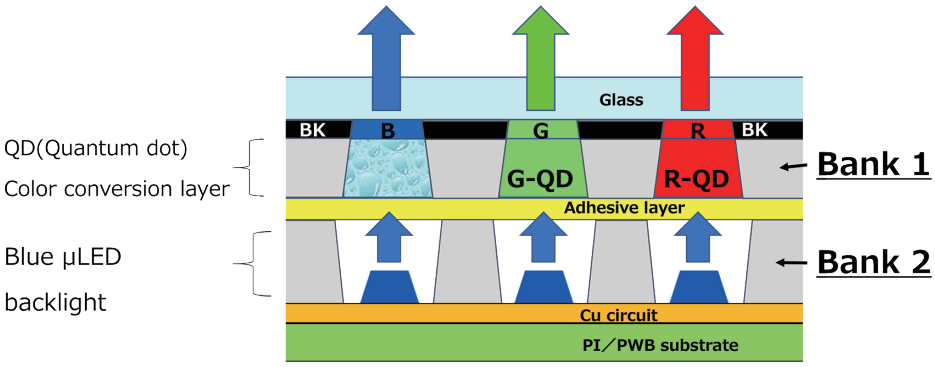


Fig. 3 Example of QD color conversion type μ-LED display structure

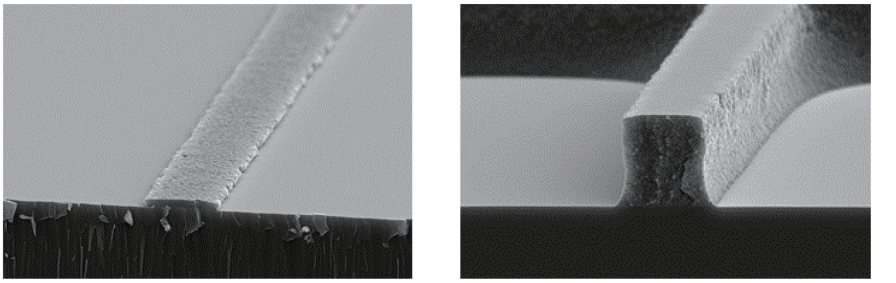


Fig. 4 Difference between black matrix and white bank

cording to customer needs so as to exert the target optical characteristics. At the same time, it is necessary to adjust the light blocking property so as to be high or low and the color so as to be black, gray, or white.

To achieve these, we freely used our blending and design technologies that we had cultivated through resist development and repeatedly arranged the types of colorants, alkali soluble resin, photopolymerizable monomers, and photoinitiator, which form the resist materials, and the blending quantities of them. As a result, we obtained prototype formulas (**Table 1**).

3. Conclusion

The study to apply LED displays to in-vehicle devices, signage, and TVs has just begun and LED displays for these purposes are under development. Although their markets are expected to be created from now on, LED displays have high potential toward higher resolution and higher definition and thereby the application range is expected to expand. As recently released concepts, there are flexible three-primary color mini-LED displays and tiling three-primary color μ-LED displays. The required light-shielding walls and partition walls vary according to display types and thereby we are working to increase our resist types so as to satisfy wide-ranging customer

Table 1 Characteristics of the prototype bank

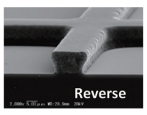
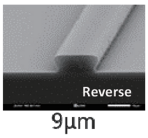
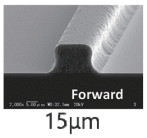
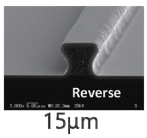
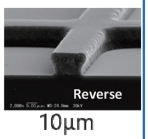
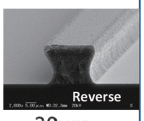
Bank resist color	Black	White
Thickness [μm]	10	
Transmittance [%] (at 450 nm)	0.005	23
OD/μm range	3.6	0.04
Reflectance [%] (at 450 nm)	15	80
Post bake temp. [℃]	230	
Pattern shape	 Forward	 Reverse

Table 2 Lineup of various bank resist

Bank resist color	Black		Gray		White		Transparent
Thickness range [μm]	1-15	←	1-15	←	1-50	←	1-25
Transmittance [%] (10 μm, at 450 nm)	<0.1	←	<10	←	<20	←	90<
OD/μm range	0.2-1.0	1.5-3.6	0.08-0.20	←	0.03-0.10	←	-
Reflectance [%] (10 μm, at 450 nm)	<10	5-15	40<	←	70<	←	7<
Post bake temp. [℃]	<230	230	230	<150	230	<150	150-230
Pattern shape (Pattern thickness)	 9μm	 10μm	 15μm	 15μm	 10μm	 20μm	 20μm

• OD (Optical density) indicates optical density, and if the value is large, it indicates that the degree of shading is high.

needs (**Table 2**). We will continue to increase our product types also in the future to contribute to advancing LED displays.

Takashi KONNO
Dr. Eng., Senior Manager
Optical & Display Materials Center
Nippon Steel Chemical & Material Co., Ltd.
15-7 Shinminato, Kisarazu City, Chiba Pref. 292-0836