Latest Trend of High Definition LED Printheads

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Electrophotographic printers are used widely in offices. There are two types of the electrophotographic printers: light emitting diode (LED) printer and laser printer. The LED printer has LED printheads as light sources. In the LED printhead, LEDs are arrayed in a row in high density (LED array). The length of the LED array is equal to the printing width of the LED printer. In the LED printer, each LED in the LED array provides each light spot on a photosensitive drum to create each image spot in printings. This is of great advantage to high-resolution, high-speed, and large width printings using the LED printer. We have developed successively new high definition LED printheads for higher-resolution and higher-speed printings. In this paper, first, our systematic development of the LED-array technologies will be described and then the latest results of our innovative development of the high definition LED printhead will be described in detail.

Developments of LED-array technologies

Oki is a pioneer of the LED printhead technology. We have been developing innovative LED array chips to greatly upgrade the LED printhead. We have developed the world's first 1200 dpi (dots per inch) LED array chips[1)] by using high density impurity diffusion technique[2)]. We have also been succeeded in developing a new LED array chip that provides one order of magnitude higher light-emission efficiency than our conventional LED array chip by using our unique LED structure[3)]. These new LED array technologies have lead to higher printing resolutions and printing speeds in the LED printer.

In the conventional LED printhead, the LED array chips and IC driver chips are individually mounted on a printed circuit board and are connected by wire bonding (W/B). When the LED printhead is of a static control type, the number of LEDs is equal to the number of bonding wires in the LED printhead. Therefore increasing the LED array density results in increasing densities of the bonding wires and W/B pads. This leads to the increase of both sizes of the LED array chip and the IC driver chip and limits the LED array density in the conventional LED printhead. In order to decrease the number of the bonding wires in the LED printhead, we have developed a chip-matrix control type LED array chip. In the new 1200dpi LED printhead using the chip-matrix LED arrays, the numbers of the bonding wires and IC driver chips and the width of the LED array chip have been much decreased[4)].

Recent digital color imaging technologies require higher printing resolutions and printing speeds for the LED printhead. The LED printhead is also required to be more compact for saving space in the color LED printer, since the color LED printer uses four LED printheads. In order to meet these requirements, we will have to change the conventional design concept of the LED printhead. From this point of view, we have developed the unique LED array technology to integrate the LEDs and IC drivers. We have been succeeded in producing the world's first LED printheads in high volume using the unique LED array technology[5), 6)]. In the following sections, this new technology and the new LED array chip fabricated using this technology will be described in detail. Characteristics of the new LED printhead will also be described.

EF-LED array

(1) Design and fabrication process

Figure 1 shows the micrograph of the new LED array chip that is fabricated by integrating the LEDs and IC drivers. The epifilm (EF) LED indicated in **Fig. 1** shows the thin-film LED bonded on the IC drivers. The epifilm LED bonded on the IC drivers is called “EF-LED”. The pitch of the EF-LED array shown in **Fig. 1** is 600 dpi.

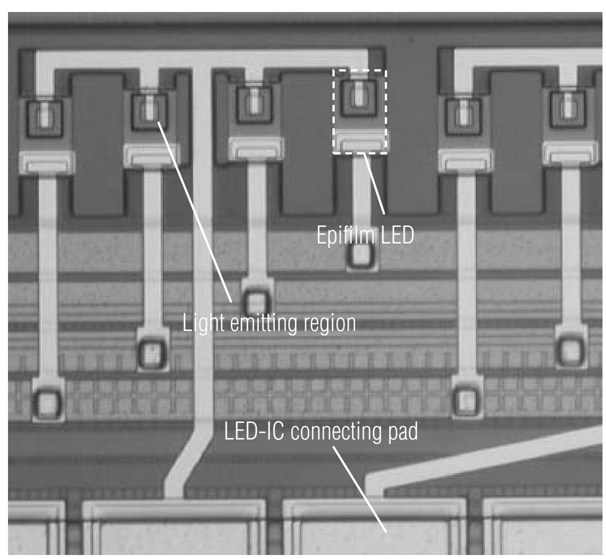

Fig. 1 Micrograph of the EF-LED array.

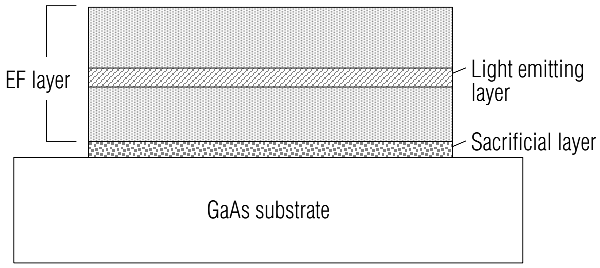

Fig. 2 Schematic drawing of the EF layer and the sacrificial layer formed on the GaAs substrate.

Figure 2 shows the outline of the epitaxial layer structure to fabricate the EF-LED array chip. As shown in **Fig. 2**, the EF layer and sacrificial layer are formed on the GaAs substrate. The EF layer is of the double hetero structure having the active layer for light emission. The sacrificial layer is used to release the EF layer from the GaAs substrate. The sacrificial layer is formed between the EF layer and the GaAs substrate. An etching solution is used to etch only the sacrificial layer, but this etching solution etch neither EF layer nor GaAs substrate. The speed etching the sacrificial layer in the etching solution is extremely higher than the speeds etching the EF layer and GaAs substrate. As the result, only the sacrificial layer is etched out and the EF layer is released from the GaAs substrate[7]. The EFs (2μm in thickness) that are released from the GaAs substrate, as described above, are bonded on the IC drivers with no adhesive. The EF is bonded by the intermolecular force. The intermolecular force is the attractive force acting between the bonding pair surfaces when they are extremely close each other. No damage and no crack are appeared in the bonded EFs during the releasing and bonding processes.

After the bonding process, the EF LED array is formed. The EFs are mesa etched to form the LED array structure. The insulating thin film and the electrodes are formed on the mesa etched EFs. The EF LEDs and IC drivers are connected using the thin metal wirings. The thin metal wirings can easily be done because the thin film LEDs bonded on the IC drivers are used. During the LED array fabrication process, no EFs are come off from the bonded surface. This indicates that the entire EF bonding surface is well bonded on the IC driver bonding surface.

Thin metal layers are formed under the EF bonding regions to reflect light emitted backward from the EF LEDs. The emitted light power efficiency by forming the reflection layer is expected about twice as high as that by forming no reflection layer. This is another merit to use the EFs.

Figure 3 shows the scanning electron micrograph image of the EF-LED array bonded on the IC driver wafer. The light emitting region indicated in **Fig. 3** shows the mesa etched island region of the EF-LED. This island region includes the active layer for light emission indicated in **Fig. 2**.

The EFs are bonded only on the LED array areas. The LED array width is much smaller than the conventional LED array chip width. Therefore employing the EF-LED array technology increases the number of

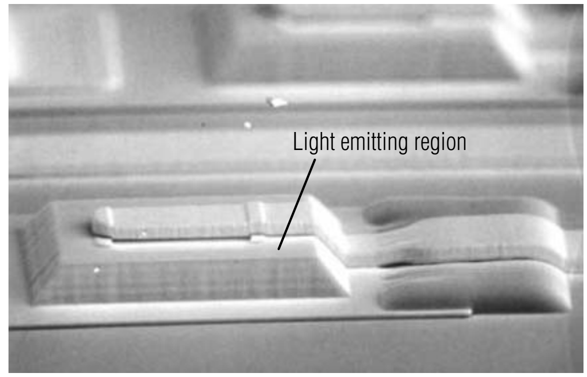

Fig. 3 Scanning electron micrograph image of the EF-LED array.

LED array chips that we can fabricate using one GaAs wafer; 5 times as many as the number of the conventional LED array chips on one GaAs wafer.

(2) I-P characteristics

Figure 4 shows the emitted light power as a function of the LED current of the EF-LED array (I-P characteristics). The I-P characteristics of the conventional 600 dpi LED array having the high emitted light power efficiency (High-efficiency LED array)[3), 4)] is also potted in **Fig. 4**.

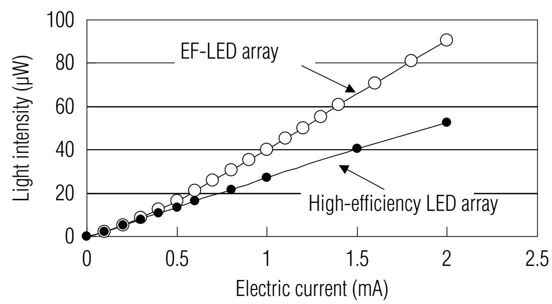

Fig. 4 I-P characteristics of the EF-LED array.

As shown in **Fig. 4**, the emitted light power efficiency of the EF-LED array is higher than that of the high-efficiency LED array of conventional LED arrays. This is because the epitaxial layer structure of the EF is optimized to obtain higher emitted light power efficiency and emitted light reflection on the metal layers below the EFs. In the conventional LED array chip, the GaAs substrate absorbs backward emitted light and thus the light is lost.

EF-LED array unit

In this section, the structure of the EF-LED array chips on the printed circuit board is called "EF-LED array unit". The structure of the conventional LED array chips and IC driver chips on the printed circuit board is called "conventional LED array unit".

Figure 5 shows the micrograph of a part of the EF-LED array unit, and **Fig. 6** shows a part of the

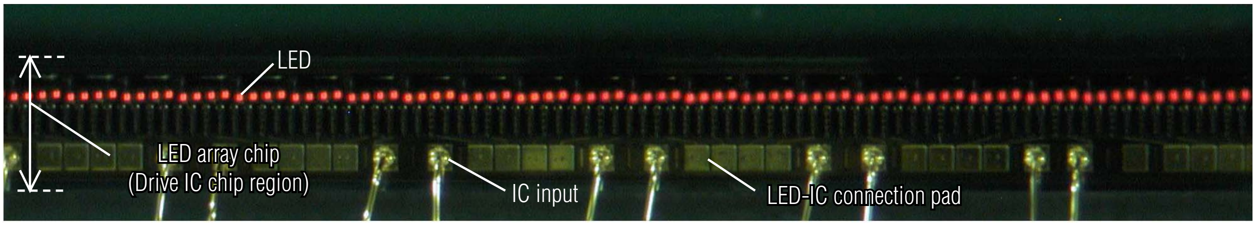

Fig. 5 Micrograph of the EF-LED array unit.

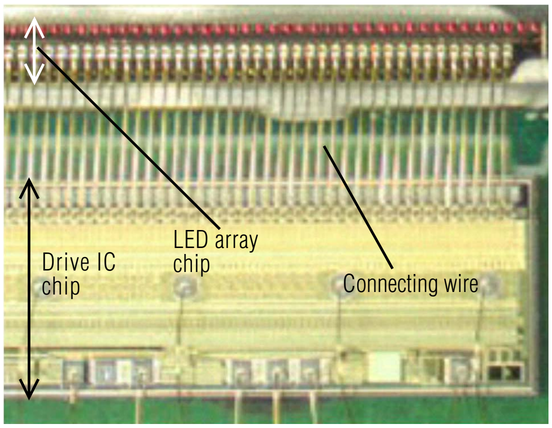

Fig. 6 Micrograph of the conventional LED array unit.

conventional LED array unit (static control type). In **Fig. 5**, all LEDs are switched on, but in **Fig. 6**, every other LEDs are switched on.

In the EF-LED array unit, 26 EF-LED array chips are mounted and the input terminals on the chips are connected to the printed circuit board by wire bonding using gold wires (Au wires). In the conventional LED array unit, 26 LED array chips and 26 IC driver chips are mounted, and the LED array chips and the IC driver chips are connected by high-density wire bonding. (In **Fig. 6**, only the odd bonding pads on the LED array chips and IC driver chips are connected by wire bonding since each more bonding wire is easily visible.) As clearly seen by comparing **Figs. 5** and **6**, the number of the bonding wires in the EF-LED array unit is much less than that of the conventional LED array unit; the number of the bonding wires is decreased to 1/6 to 1/10 in the EF-LED array unit.

EF-LED Printhead

In this section will be described the characteristics of the LED printhead consisting of the EF-LED array unit and rod array lens.

Figure 7 shows the light intensity distribution of the EF-LED printhead when every other LEDs are switched on. As indicated in **Fig. 7**, the light spot diameter is 52μm. The light spot diameter is defined as the width of the light intensity distribution at I_P/e^2, where I_P is the peak intensity and e is the base of the natural logarithm (e=2.718…). We can understand how well the light spots

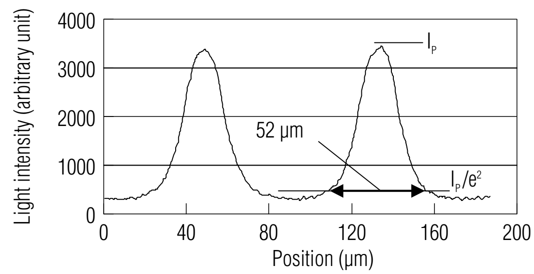

Fig. 7 Light intensity distribution of the EF-LED printhead.

are resolved using MTF values. The MTF value is estimated 85% from the light intensity distribution shown in **Fig.7**. The MTF value is estimated as MTF=$(I_P-I_B)/(I_P+I_B) \times 100$[%], where I_B is the minimum value in the light intensity distribution. Higher MTF values indicate higher resolutions. The light spot diameter of 52μm and the MTF vale of 85% are good enough for the LED printhead to provide higher resolution printings.

Figure 8 shows light power distribution of the EF-LED printhead after correcting the light powers using the IC drivers so that the variations of the light power distribution are decreased as small as possible. As shown in **Fig. 8**, the variations of the light power distribution of the EF-LED printhead are within ± 1%. This is small enough for the printhead to provide higher quality printings.

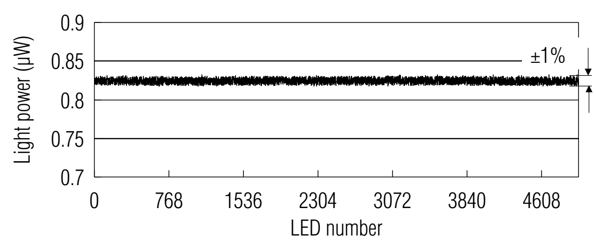

Fig. 8 Light power distribution of the EF-LED printhead.

The specifications of the EF-LED printhead are listed in **Table 1**.The volume of the EF-LED printhead shown in **Table 1** is about 1/2 of that of the conventional LED printhead.

Conclusion

This paper reviews recent trends of the LED printhead technologies and focuses on our new innovative technology to integrate the LED arrays and the

Table 1 Specifications of the EF-LED printhead.

Printhead dimensions	212.12mm (L) × 11.5mm (H) × 10mm (W)
Number of LEDs	4992 (A4 size)
LED array density	600dpi (LED pitch=42.3µm)
Light emitting area	16µm × 16µm
Emitting light wave length	755nm
LED array driving method	Time division

IC drivers for high volume production of the EF-LED array chips and the EF-LED printheds. The employing of the EF-LED array technology leads to more compact LED printheads, higher printing resolutions and higher printing speeds. This technology will open up new possibilities of the LED printheads. So we decided to give a new name to our LED printhead - High Definition LED Printheads. We would like to do further development based on the EF-LED array technology for the innovatings of the LED printhead.

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