New Printhead Using LED Arrays Integrated with IC Drivers

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Abstract

We are succeeded in developing new LED printheads using new LED arrays integrated with IC drivers. The LED arrays consisting of epitaxial layer of about 2 µm thick are bonded on the IC drivers. The performance test of the LED printhead has shown very promising characteristics in higher printing resolutions and higher printing speeds.

Introduction

LED printheads have demonstrated images with higher printing resolutions and higher printing speeds. The LED printheads has each light source for each light spot on a photosensitive drum. This provides the significant advantage of the LED printhead over the laser system to achieve higher printing resolutions, higher printing speeds, and smaller size. An LED printhead mainly consists of LED arrays, IC drivers, and rod lens arrays. The LED array chip plays a decisive role in achieving higher printing resolutions and printing speeds. Systematic studies to overcome higher printing resolution and higher printing speed issues have been able to lead to our success in developing 1200 dots per inch (dpi) LED array chips [1], high power efficiency LED array chips [2, 3], matrix control LED array chips [4, 5]. Recent digital color imaging technologies require LED printheads to achieve much higher printing resolutions and higher printing speeds. It is necessary to achieve higher printhead performances without increasing sizes of the IC driver chips and the LED array chips that affects printhead size and cost.

Figure 1 shows the schematic drawing of the conventional LED array unit. The LED array unit consists of the LED array chips and the IC driver chips, which are mounted on the printed circuit board. The LED array chips are connected to the IC driver chips by bonding wires. The density and number of the bonding wires are equal to those of the LED array when the LED array is of static control type. Wire bonding needs a larger bonding pad (x= 60 µm and y= 100 µm). Therefore, more than one row of the bonding pads are required, which increases LED array chip width (W_{LED}) and IC driver chip width (W_{IC}). It is difficult to bond wires in wire pitches smaller than 42.3 µm (equivalent to 600 dpi LED array pitch). This is too small to avoid short circuits of high density bonding wires. Therefore bonding wire density restricts LED array density. The LED array area is much smaller than the wire bonding pad area and wiring pattern area between the LED array and the bonding pads (LED area of 20 µm x 20 µm for 600 dpi LED array). Thus, the LED array chip consisting of compound semiconductors that are more expensive than Si is mainly occupied by the bonding pads and the wiring patterns between the LED array and the bonding pads. But the wiring patterns and the bonding pads are not necessarily on the LED array chip. The LED array chip thickness (t_{LED}) is, for example, 350 µm because the LED array is formed on the thick substrate (about 350 µm thick). But we use only very thin compound semiconductor layer (2 µm thick) to form LED arrays.

In order to solve the issues described above, integrating LED arrays and IC driver chips by bonding epitaxial films (epifilm bonding: EFB) [6, 7] is most promising. This paper briefly describes the EFB process and focuses on characteristics of 600 dpi LED arrays integrated with IC drivers and the LED printhead using the LED array chip highlighted.

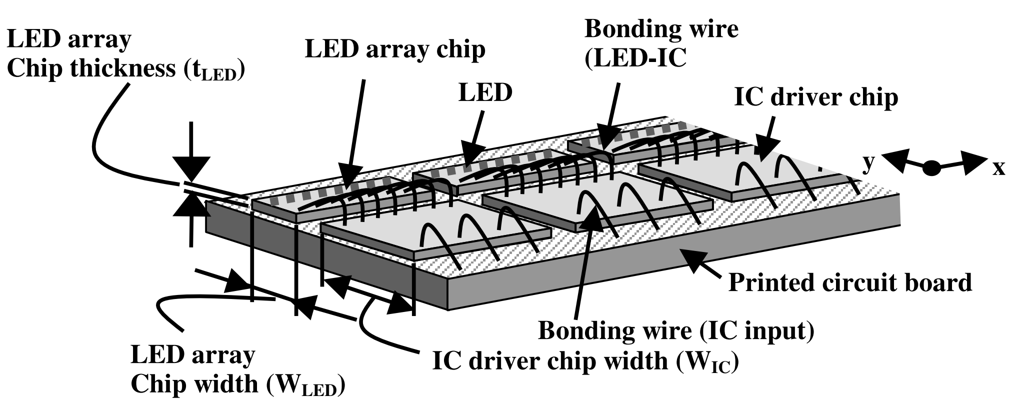

***Figure 1**. Schematic drawing of the conventional type LED array unit.*

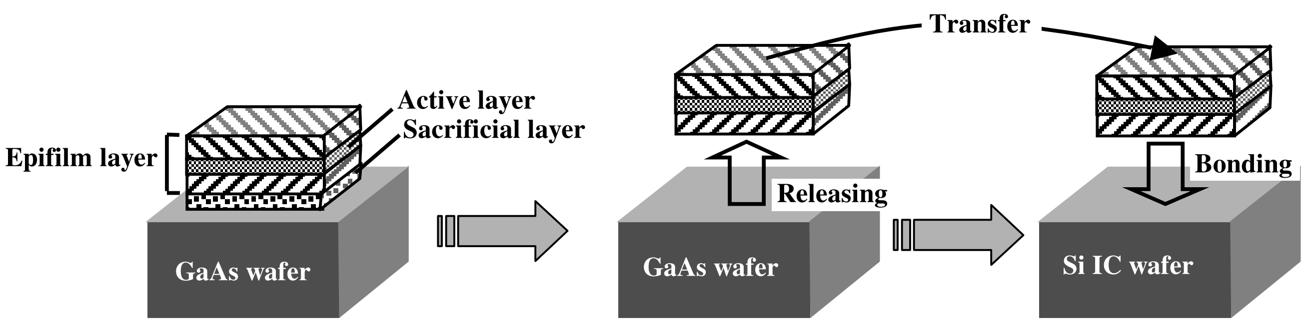

Figure 2. *Schematic drawing of the EFB process.*

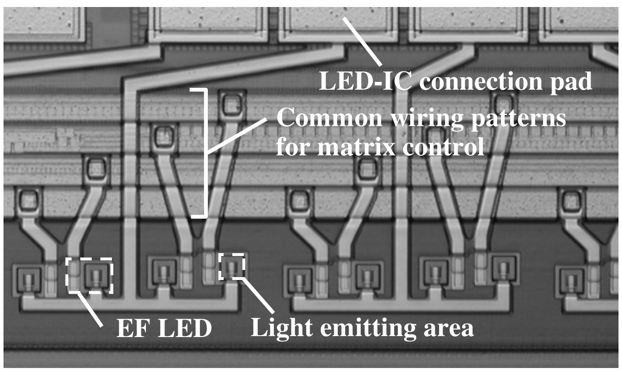

Figure 3. *Microscope photograph of the EF LED array.*

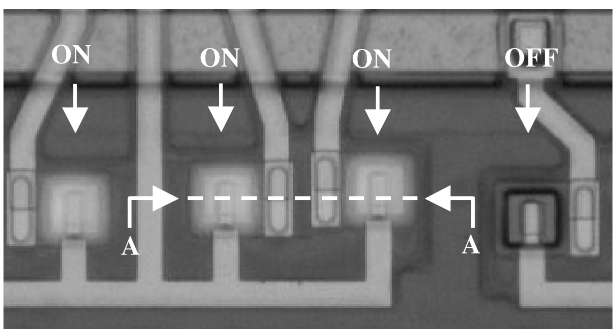

Figure 4. *The EF LED array when some LEDs are switched on.*

EF LED array

Figure 2 shows a brief description of the EFB process in fabricating the epifilm (EF) LED array chips [6, 7]. The EF layer including the active layer that serves as light emitting region is grown on the GaAs wafer using organic metal chemical vapor deposition (OMCVD). The sacrificial layer is formed between the EF layer and the GaAs wafer. The EF layer is released by selectively etching the sacrificial layer [8, 9]. The released EF is pressed and bonded on the Si IC wafer.

Figure 3 shows the EF LED array developed in this study. The EF LED and the light emitting area are indicated by the white broken lines. The EF LEDs are bonded in the IC area by Van der Waals force, and any adhesive is not required. EF is about 2 μm thick. The LED pitch is 42.3 μm. This is equivalent to a pitch of 600 dpi. The LED array is of matrix control type. The LEDs are connected to the IC drivers by using thin metal wiring patterns at the LED-IC connecting pad. Using thin EF makes it possible to connect LED arrays to IC drivers using thin metal wiring patterns.

Figure 4 shows the EF LED array when some LEDs in the array are switched on; three LEDs are switched on and one is switched off. A thin metal layer is formed below the LED array area to reflect light that is emitted backward from the EF LED. Light reflected at the thin metal layer is emitted forward. Figure 4 indicates that light emission is observed in the area that is roughly equal to the light emitting area shown in Figure 3.

Figure 5 shows the near field pattern (NFP) of the LED array at line A-A indicated in Figure 4. As shown in Figure 5, two peaks are well separated and no light cross talk between adjacent LEDs. Light spot size estimated at I_P/e^2 is 20 μm, where I_P is the peak intensity and e is the base of natural logarithm (e=2.718...). The estimated light spot size is almost equivalent to the light emitting area indicated in Figure 3 and to a half of the LED array pitch. The NFP in Figure 5 suggests that reflection of light at the thin metal layer below the LED array has no effect on spreading the light spot.

Figure 6 shows I-P characteristics of the EF LED array chip, where I is LED current and P is emitted light power. Figure 6 also shows I-P characteristics of the 600 dpi high power efficiency LED array chip having buried pn junction that is fabricated by using shallow zinc (Zn) diffusion technique [2-5]. As shown in Figure 6, the emitted light power efficiency of the EF LED array is higher than that of the high power efficiency LED array, where emitted light power efficiency means emitted light power per LED current. Reflection of light at the thin metal layer contributes the high emitted light power efficiency of the EF LED array chip.

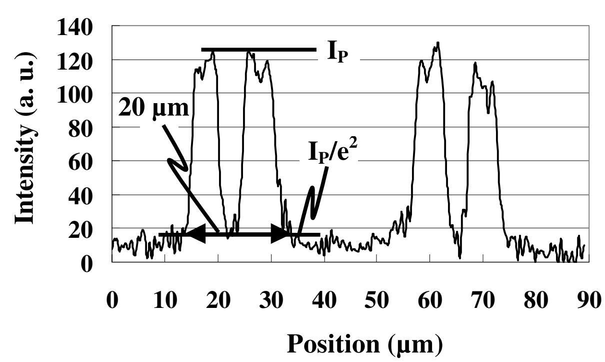

Figure 5. *Near field pattern at line A-A indicated in Figure. 4.*

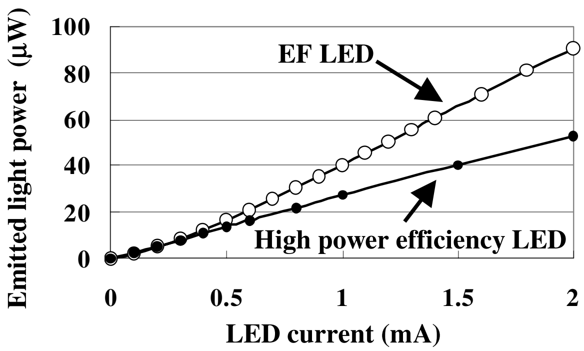

Figure 6. *I-V characteristics of the EF LED array chip and the high power efficiency LED array chip.*

EF LED array unit

Figure 7 shows the photograph of the 600 dpi EF LED array unit. Figure 8 shows the photograph of the conventional 600 dpi LED array unit. All of the LEDs in Figure 7 are switched on, and every other LED is switched on in Figure 8. In the EF LED array unit, 26 EF LED array chips are mounted on the printed circuit board. One LED array chip contains 192 LEDs. In the conventional LED array unit, 26 LED array chips and 26 IC driver chips are mounted. The LED array chips are connected to the IC driver chips by bonding wires. The LED array chip shown in Figure 8 is of static type. The wires are bonded at every other bonding pad for demonstration, and the bonding wire pitch is 84.6 μm (equivalent to 300 dpi array pitch). As seen in Figure 8, 300 dpi bonding wire pitch is even tight.

In the EF LED array unit, only input pads of the IC drivers are connected to the printed circuit board by bonding wires. Thus, the number of bonding wires in the 600 dpi EF LED array unit is decreased to 1/10 that in the conventional static type 600 dpi LED array unit. Figures 7 and 8 show that the chip width of the EF LED array chip is 1/4 to 1/3 the total chip width of the LED array chip and the IC driver chip in the conventional LED array unit.

EF LED printhead

Figure 9 shows light power distribution of the EF LED printhead when every other LED is switched on. The light spot size is 52 μm when it is estimated at the light power intensity of I_P/e^2, where I_P is the light power intensity at the peak and e is the base of natural logarithm (e=2.718…..). MTF is estimated as MTF= $(I_P-I_B)/(I_P+I_B)$ x 100 (%), where I_B is the light power at the bottom at a position of around 95 μm in Figure 9. The MTF value is 85 %.

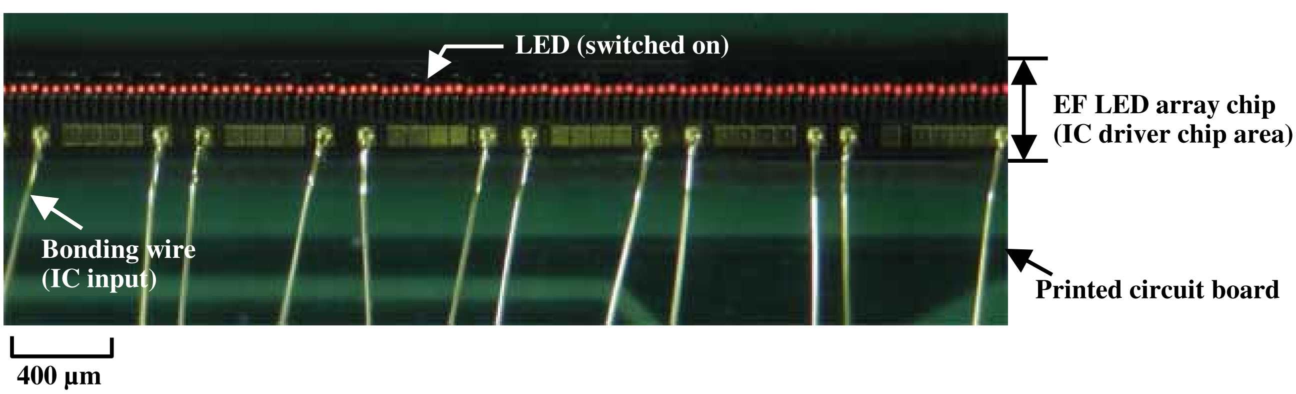

Figure 7. *Photograph of the 600 dpi EF LED array unit.*

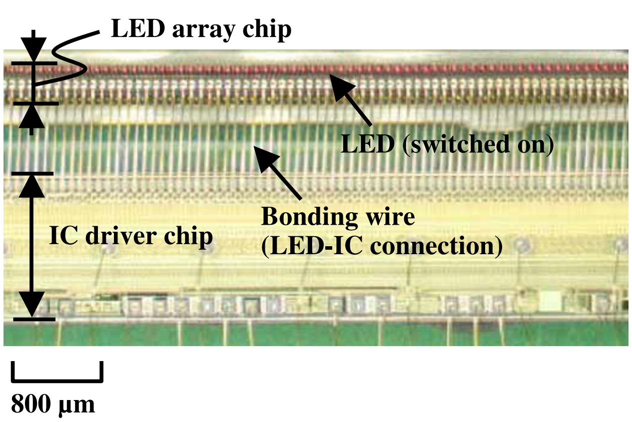

Figure 8. *Photograph of the conventional type LED array unit.*

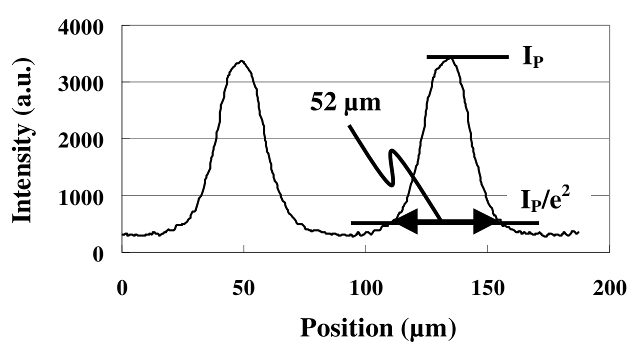

Figure 9. *Light power distribution of the EF LED printhead when every other LED is switched on.*

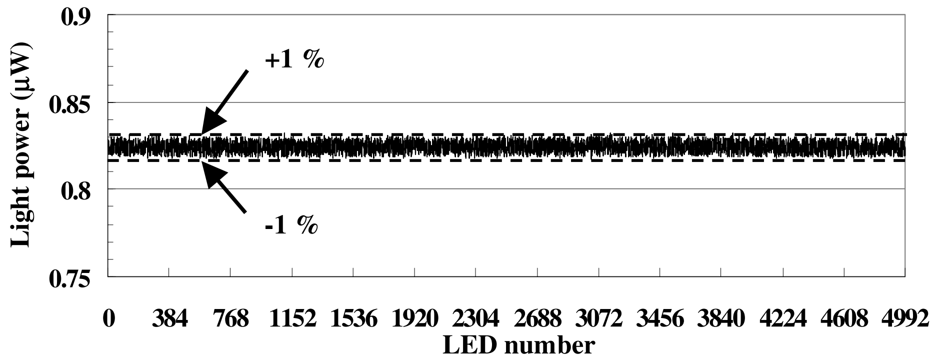

Figure 10. *Light power distribution of the EF LED printhead.*

The light spot size and the MTF value indicate that the light spot is well resolved. The data shown in Figure 9 shows that the EF LED printhead is suitable for high resolution printings.

Figure 10 shows the light power distribution of the EF LED printhead. The average light power is about 0.83 μW and the light power variations are within the range from –1 % to 1 % after the IC drivers correct the light powers. The light power of the EF LED printhead is high enough to provide higher printing speeds [4, 5].

Table 1 lists outline of the EF LED printhead specifications. The EF LED printhead is decreased to 1/2 the conventional EF LED printhead in volume.

Table 1: Outline of the EF LED printhead specifications

Printhead dimensions	212.12 mm (L) x 11.5 mm (H) x 10 mm (W)
Number of LEDs	4992 (A4 printhead)
LED array density	600 dpi (Array pitch = 42.3 μm)
Light emitting area	16 μm x 16 μm
LED control	Matrix control

Conclusions

The new LED printhead (EF LED printhead) has been developed by using the EF LED array chips. We have developed the EF LED array chips by bonding EFs on the IC drivers. Using thin metal layers has formed all the wiring patterns connecting the LED arrays to IC drivers. This leads to significantly decreased chip size and number of bonding wires. The "EF LED array chip" provides better characteristics, such as emitted light power efficiency higher than that of the conventional "high power efficiency LED array chip". The EF LED printheads provide good enough performance to use the printheads in high printing resolution and high printing speed LED printers.

The data proves that integrating the LED arrays and IC drivers by EFB can solve the issues in the conventional LED printheads. The EF LED printhead will achieve breakthrough for much higher printing resolutions, higher printing speeds and more compact design and, for saving semiconductor materials and simplifying fabrication process of the LED printhead.

Acknowledgement

A part of this work was carried out at Research Center for Nanodevices and Systems, Hiroshima University supported by "Nanotechnology Support Project" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

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Author Biography

Mitsuhiko Ogihara received a Doctor of Science degree from University of Tsukuba in 1988. He joined Oki Electric Industry (Oki) in 1989 and Oki Digital Imaging Corporation in 1999. After he studied high-Tc superconducting thin film growth by MBE for 4 years in Oki, he has worked developing novel LED arrays to use in LED printheads for higher printing resolutions and higher printing speeds. He is a member of the Japan Society of Applied Physics and the Physical Society of Japan.