

1200 DPI LED Printhead for Very High Speed Printing

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Abstract

We have developed 1200 dot-per-inch (dpi) light-emitting-diode (LED) array chips for very-high-speed electrophotographic printheads. The emitted light efficiencies of the 1200 dpi new LED array chips developed in this study were one order of magnitude higher than those of the 1200 dpi conventional GaAsP LED array chips. Temperature increases (ΔT) of the printhead using the 1200 dpi new LED array chips operated at 12 pages per minute (ppm) were very small, while those of the printhead using the 1200 dpi GaAsP LED array chips were 50°C operated at the same printing speed. ΔT of the new LED printhead at 120 ppm was estimated to be 30°C at most. Registering error caused by thermal expansion of the printhead substrate was also estimated, and is small enough for 1200 dpi printing due to small temperature increases when used with the new LED array chips. Performance tests show that the new LED array chips can be used for printhead applications requiring high resolution, high printing speed, and low power consumption. The new LED array chips can be applied for color electrophotographic printheads.

Introduction

High printing speeds are required for digital printing. Electrophotographic printers are most widely used for high-speed printing in offices. Electrophotographic printers using LED array chips seem to be more suitable for higher speed printing than those using a laser diode, because LED array chips can simultaneously expose the printing width on a photoconductive drum.

To increase printing speed, drive current of LEDs should be increased to increase emitted light powers of LEDs. Increasing drive current, however, increases power consumption and temperature on the LED printhead. Special, large cooling systems are used to suppress temperature increases in high-speed printing.[1), 2)] Therefore, it is necessary for high-speed LED printheads to increase emitted light efficiency of LEDs.

We have developed new LED array chips with very high emitted light efficiency for high-speed printheads. This paper focuses on temperature increases in the printhead and registering errors due to printhead temperature increase when the new LED array chips are used for very-high-speed printhead applications.

Emitted Light Characteristics of New LED Array

Figure 1 shows emitted light power versus drive current for the 1200 dpi new LED array chip and the 1200 dpi conventional GaAsP LED array chip.[3)] The emitted light power of the new LED array chips is ten times or more that of the GaAsP LED array chips for the same drive current; the emitted light power of the new LED array chips was 74 µW at a drive current of 3 mA, and that of the GaAsP LED array chips 5 µW at the same drive current. Therefore, exposure time on a photoconductive drum is reduced to one tenth when the new LED array chips are used, enabling the new LED array chips to be used at much higher printing speed than the GaAsP LED array chips.

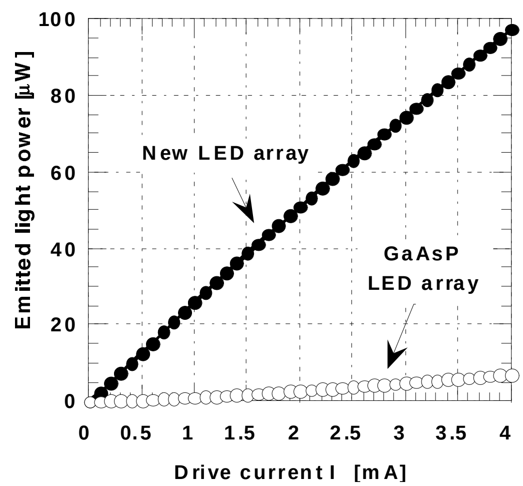

Figure 1. Emitted light power versus drive current for the new LED and the GaAsP LED arrays.

Figure 1 indicates that the drive current for the new LED array chips is much lower than that for the GaAsP LED array chips for the same emitted light power. Thus, power consumption of printheads can be strongly decreased using the new LED array chips.

As shown in Fig. 1, emitted light power from the new LED array chips is well proportional to the drive current in the measured drive current range. The linear relationship between emitted light power and drive current is important, because emitted LED light power on the printhead should be corrected to minimize emitted light power variation. The linear relationship results in appropriate emitted light power correction.

Temperature Increase of LED Printhead

Temperature Increase Measured at 12 ppm

Large printhead temperature increases adversely affect printing quality.[2)] Emitted LED light power should decrease with increasing printhead temperature. Thermal expansion of a printhead substrate due to temperature increases causes registering error. We measured temperature increases of printheads using the new LED array and the GaAsP LED array chips.

To measure the temperature increase (ΔT) in A3 printheads using the new LED array chips, we determined the drive current (I_F (new)) and the strobe time (t_{STB} (new)) to print characters appropriately at 12 pages per minute (ppm), where the strobe time is when LEDs are turned on. When the GaAsP LED array chips were used, we used standard values for the drive current (I_F (GaAsP)) and the strobe time (t_{STB} (GaAsP)) for 12 ppm. When the new LED array chips were used, I_F (new) = I_F (GaAsP) $\times$ 1/6 and t_{STB} (new) = t_{STB} (GaAsP) $\times$ 1/4 were used for 12 ppm. Figure 2 shows samples printed using the new LED array chips and the GaAsP LED array chips. As shown in Fig. 2, character printing quality for the new LED array chips was equivalent to that for the GaAsP LED array chips. From the results shown in Fig. 2, I_F (new) and t_{STB} (new) used in the ΔT measurement for the printhead using the new LED array chips are appropriate for printing characters.

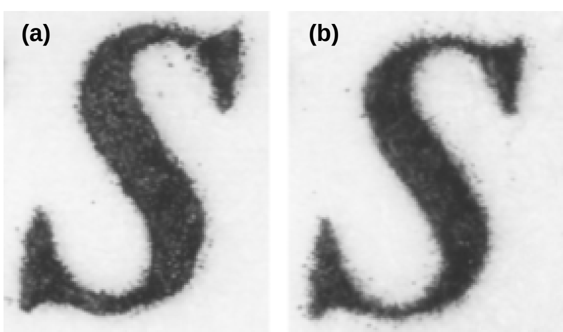

Figure 2. Printed samples: Micrographs of 9-point characters printed using (a) the GaAsP LED array chips and (b) the new LED array chips.

When ΔT was measured, no cooling fins were used. The ambient temperature was 30°C. The temperature on the back of printhead substrates was measured using a thermocouple. During ΔT measurement, all LEDs on the printhead were turned on for each line printing.

Figure 3 indicates ΔT versus time for printheads using the new LED array chips and the GaAsP LED array chips operated at 12 ppm. As seen in Fig. 3, saturated ΔT is only 6°C for the new LED array chips, while that for the GaAsP LED array chips is 50°C.

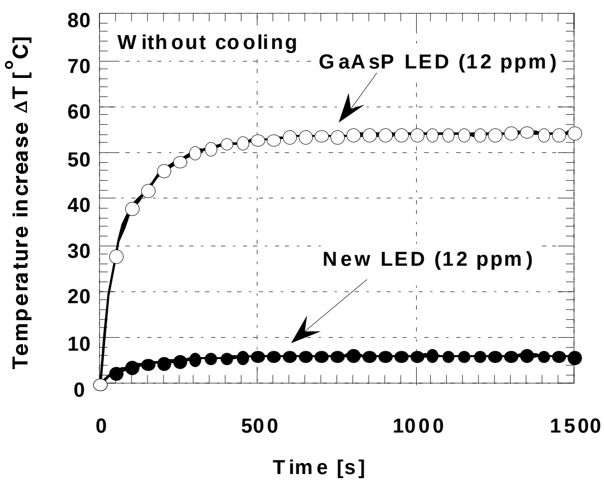

Figure 3. Temperature increase (ΔT) versus time for printheds using the new LED array and the GaAsP LED array chips operated at 12 ppm.

Thus, the power consumption of the printhead using the new LED array chips is low enough for small ΔT. No large cooler is needed when the new LED array chips are used due to low power consumption.

ΔT Simulation at Higher Printing Speed

To simulate ΔT versus time for the printhead using the new LED array chips operated at higher printing speed than 100 ppm, we measured ΔT of the printhead using the new LED array chips under operating conditions roughly equivalent to 120 ppm printing operating conditions. We did this measurement under operating conditions of $I_F = I_F$ (GaAsP) and $t_{STB} = t_{STB}$ (120 ppm) $\times$ 10 every 400 μs, where t_{STB} (120 ppm) is the appropriate strobe time for 120 ppm printing estimated from I_F (new) and t_{STB} (new) at 12 ppm. In this measurement, all LED array chips on the printhead were turned on for t_{STB} (120 ppm) $\times$ 10 every 400 μs. This is roughly equivalent to the operation that all LED array chips on the printhead are turned on for t_{STB} (120 ppm) every 40 μs for line printing speed at 120 ppm.

Figure 4 shows ΔT versus time for the printhead using the new LED array chips in measurement for ΔT simulation at 120 ppm. As indicated in Fig. 4, ΔT was only 30°C with no cooler, smaller than ΔT of the printhead using the GaAsP LED array chips at 12 ppm. ΔT can thus be decreased using the new LED array chips even at very high printing speed, such as 120 ppm. No large cooling system is needed with the new LED array chips at high speed. Note that the GaAsP LED array chips cannot be used in printheads operated at high printing speed, such as 120 ppm, without large cooling systems because of the large drive current.[2)]

Registering Error

Because ΔT of the printhead operated at high printing speed is expected small using the new LED array chips, thermal expansion of the new printhead substrate must be smaller compared to the GaAsP LED printhead when a small cooler is used. Thermal expansion of the printhead substrate due to temperature increase causes light spot registering error on a photoconductive drum, where highly accurate light spot registering is required, especially in color electrophotographic printers.[1), 4)] Registering error of the 1200 dpi printhead substrate should be restricted within a pitch of LED array of 21.2 μm. In Fig. 5, straight line indicates the calculated registering errors versus ΔT for the A4 1200 dpi LED printheads when no coolers for printheads are used; the circle indicates the calculated registering error of the new LED printhead operated at 12 ppm, the diamond that at 120 ppm, and the square that of the GaAsP LED printhead at 12 ppm. ΔT of the printheads deduced from Figs. 3 and 4 were used to calculate registering error in Fig. 5. The hatched area indicates the permissible registering error range, within 21.2 μm.

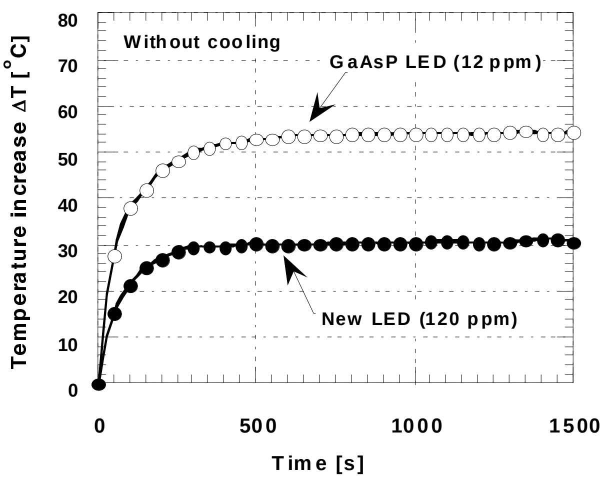

Figure 4. Temperature increase (ΔT) simulation for printhead using the new LED array chips at 120 ppm.

On the printhead substrate, LED array chips are appropriately spaced between each other. In calculation for registering error of the printhead, we assume that the space between LED array chips expands with the thermal expansion coefficient of the printhead substrate and the regions under LED array chips expand with the thermal expansion coefficient of the LED array chips.[5)] As shown in Fig. 5, for the new LED printhead, registering error is negligible for a printing speed of 12 ppm, and is roughly equal to the limitation of the permissible range for 120 ppm. From registering error estimation in Fig. 5, we conclude that printhead registering error using the new LED array chips is small enough for 1200 dpi printing even if no large coolers are used. Although the estimated registering error for the printhead using the GaAsP LED array chips at 12 ppm is not far from the limitation of the permissible range, a small cooler is not sufficient for cooling the printhead to obtain smaller registering error when the GaAsP LED array chips are used.

In color electrophotographic printers, the tandem configuration is advantageous to high-speed printing.[4)] It is necessary to use four printheads for the tandem configuration. Because printheads coolers can be very small when the new LED array chips are used, the new LED array chips are expected to reduce color printers size.

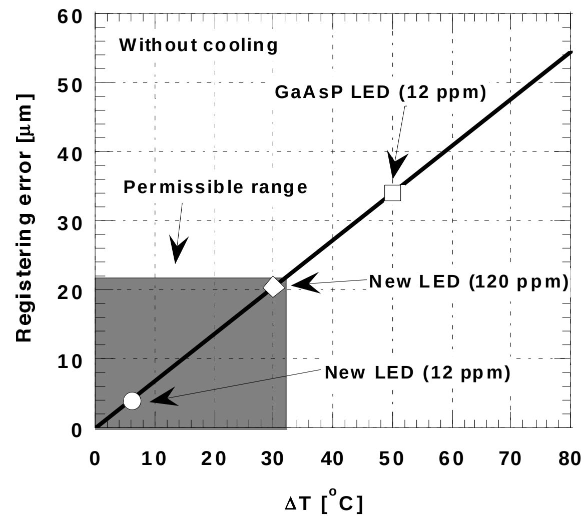

Figure 5. Simulation for registering error versus ΔT caused by thermal expansion of printhead substrate.

Conclusion

We have developed the 1200 dpi new LED array chips whose emitted light efficiency is ten times or more that of the 1200 dpi conventional GaAsP LED array chips. The new LED array chips can be used in very-high-speed printheads. Printhead temperature increases are much smaller using the new LED array chips than using the conventional GaAsP LED array chips due to much lower power consumption. Registering error caused by thermal expansion of printhead substrates will be very small using the new LED array chips even when no large cooler is used at high printing speed.

For high printing speed, low power consumption, and high resolution, we conclude that the new LED array chips are highly promising for color electrophotographic printhead applications.

References

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5. The thermal expansion coefficient for the printhead substrate was assumed to be 1.4×10^{-5} [K^{-1}] and for the LED array chips 6.9×10^{-6} [K^{-1}].

Biography

Hiroshi Hamano received his B. Eng. degree in 1988 and M. Eng. degree in 1990, from Tohoku University, Japan. In 1990, he went to work for the Research and Development Group, Oki Electric Industry, Co., Ltd., Japan. Since 1996, he has been working on LED printheads R & D for high-resolution, high-speed printers. He belongs to the Japan Society of Applied Physics.

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