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1200 DPI Light Emitting Diode Array for Optical Printer Print Heads

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We investigated the characteristics of a 1200 dpi LED array developed using solid-phase Zn diffusion. The experimental results showed that the diode characteristics were influenced by the resistance of the shallow Zn diffusion region, but that the sheet resistance of the diffusion region was low enough to obtain good light emission characteristics in spite of a diffusion depth of 1μm. Performance tests showed that the characteristics of the LED array were good enough for use in a 1200 dpi LED print head.

1. INTRODUCTION

Optical printers are widely used because they perform high quality printing. A laser diode (LD) or a light emitting diode (LED) array is used as the light source in an optical printer. From the optics point of view, one would expect that higher quality, higher resolution printing would be achieved with the *LED method* in comparison to the *LD method.* In this respect, there have been strong demands for the development of a 1200 dpi LED array chip. Because the pitch of the LEDs on a 1200 dpi array chip would be very small (21.2μm), a highly-Zn-doped, shallow p-n junction needs to be formed.[1] It seems that the solid-phase Zn diffusion technique is a promising means[2] for achieving this aim. However, the junction depth and Zn diffusion concentration in an LED on a 1200 dpi array fabricated by solid-phase diffusion will be different from those in a conventional LED fabricated by vapor-phase diffusion.[3] Therefore the diode characteristics and light emission characteristics may also be different. In this study, we investigated these characteristics of LEDs in 1200 dpi array chips. Performance tests were also carried out to examine their feasibility for use in LED print heads.

2. 1200 DPI LED ARRAY FABRICATION

A $GaAs_{0.8}P_{0.2}$ epitaxial substrate (GaAsP) was used. Zn was selectively diffused into the GaAsP wafer by solid-phase diffusion using an aluminum nitride (AlN) diffusion mask, a Zn-doped silica film as the Zn source and an AlN or silicon nitride film as the anneal cap. Diffusion temperature was 700℃ and diffusion depth (X_j) was controlled by diffusion time. The Zn diffusion process is described in detail elsewhere.[2]

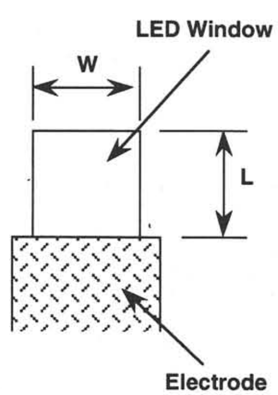

Fig. 1. Schematic drawing of an LED on a 1200 dpi LED array chip.

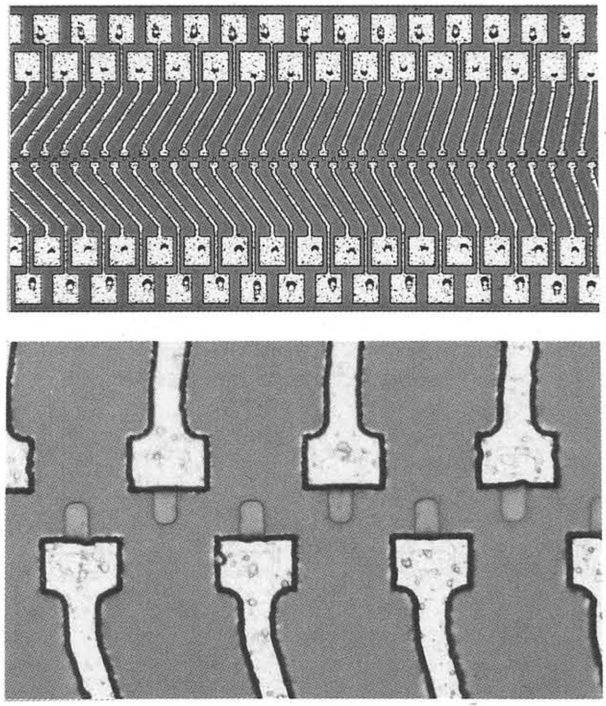

Fig. 2. 1200 dpi LED array.

Figure 1 shows a schematic drawing of the LED fabricated in this study. W and L indicated in Fig. 1 are the width and length of the LED window. Figure 2 shows the 1200 dpi LED array. The LED windows were arrayed in a single line, and the electrode pads were arrayed at both sides of the LED array.

3. DIODE CHARACTERISTICS

Figures 3 and 4 show the current-voltage (I-V) and emitted light power-voltage (P-V) curves of the LED. A straight line with a diode factor of n=2 provided a good fit to

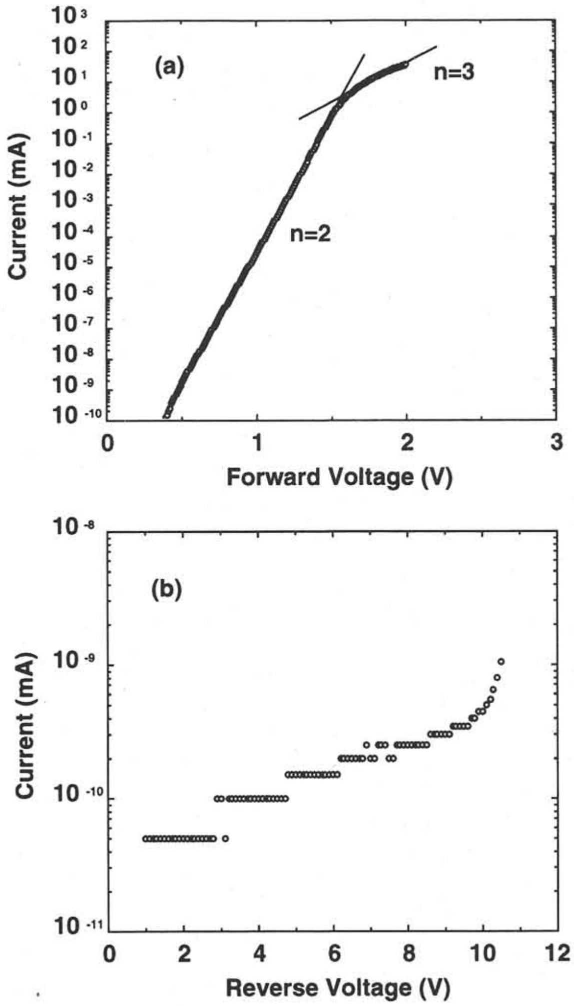

Fig. 3. I-V curve of the LED.

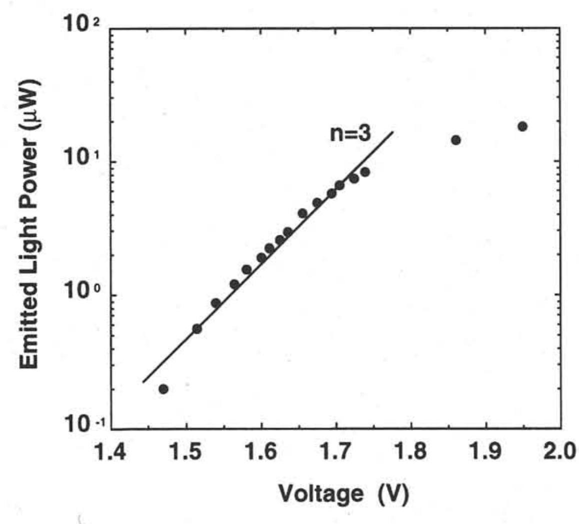

Fig. 4. P-V curve of the LED.

the data in the lower current range; this value of n agrees with the theoretical value found when recombination current is taken into account. The results indicate that the leakage current was negligible. The I-V curve in the reverse voltage range (Fig. 3 (b)) also indicates that the leakage current was very small. Thus it can be said that a good p-n junction was formed even when X_j=1μm. However, the value of n was 3 in the higher current range, where diffusion current may dominate. In the P-V curve, it can also be seen that n=3 but that the data began to deviate from the straight line for n=3 in the higher voltage range. These tendencies in the I-V and the P-V curves differ from those for conventional LEDs fabricated by vapor phase diffusion.[3] The Large deviation of n from a value of 1 in the I-V and the P-V curves in the higher voltage range arises mainly from the series resistance effect; in this voltage range, the value of n should be 1 in the ideal case. This effect seems to arise from the resistance of the shallow Zn diffusion region.

The series resistance was estimated to be about 10 Ω, based on the difference between the ideal case and the experimental data. The resistivity of the Zn diffusion region was measured and found to be 2×10^{-3} Ω · cm.[4] Therefore, a resistance of 10 Ω would be approximately equivalent to a Zn diffusion region 10 μm wide and 5 μm long with X_j=1 μm. This is comparable to the size of the diffusion region below the LED window on the 1200 dpi array.

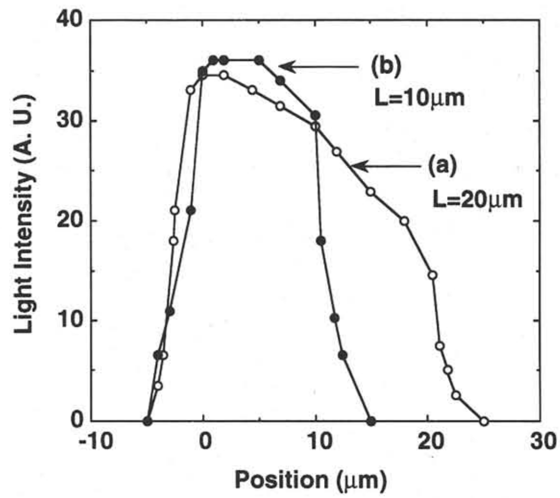

Fig. 5. Near-field pattern of the LEDs .

4. LIGHT EMISSION CHARACTERISTICS

The resistance of the Zn diffusion region may exert an influence on the light intensity distribution in the LED window.[1] Figure 5 shows near-field patterns of an LED on the array chip ; L=20 μm (a) and L=10 μm (b) with a constant W, measured at 3 mA. As shown in Fig. 5, the light intensity decreased by about 50 % at L=20 μm, but by about only 15 % at L=10 μm; this decrease is due to the resistance of the diffusion region. In Fig. 5, the peak intensity of (b) was larger than that of (a), and the shape of pattern (b) also differed from that of pattern (a). This increase in the light intensity of pattern (b) may be due to an increase in current density.

Figure 6 shows the luminous efficiency (I_e) of the LED as a function of current density I/S; I_e is defined as P/(S · I), where P is emitted light power, S is the area of the LED window and I is current. L was in the range of 5 - 30 μm with the LEDs measured for Fig. 6, and W was constant. As shown in Fig. 6, I_e was approximately proportional to I/S in the measured range of L. From this result, P should be expected to be independent of L. Figure 7 shows P as a function of L. As seen in Fig. 7, P was roughly constant in the measured range of L. This implies that sufficient emitted light power can be obtained even if the size of the LED window is made small enough for a 1200 dpi array. Thus it can be said that the sheet resistance of the diffusion region with X_j=1μm should be low enough to obtain good light emission characteristics. Here, it must be noted that in a LED fabricated by vapor-phase diffusion, the sheet resistance of a Zn diffusion region with X_j=1 μm will be too high to obtain sufficient emitted light power.[1]

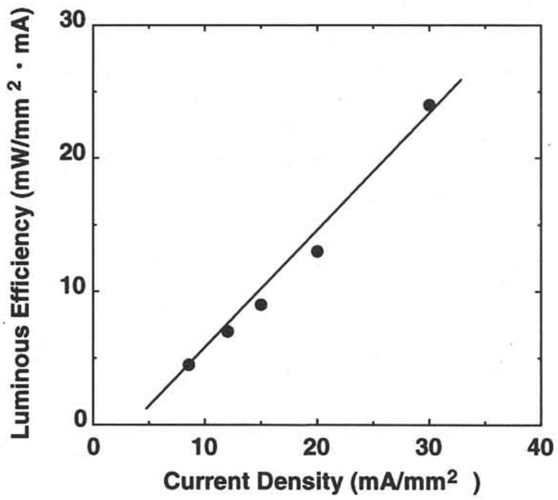

Fig. 6. Luminous efficiency of the LED.

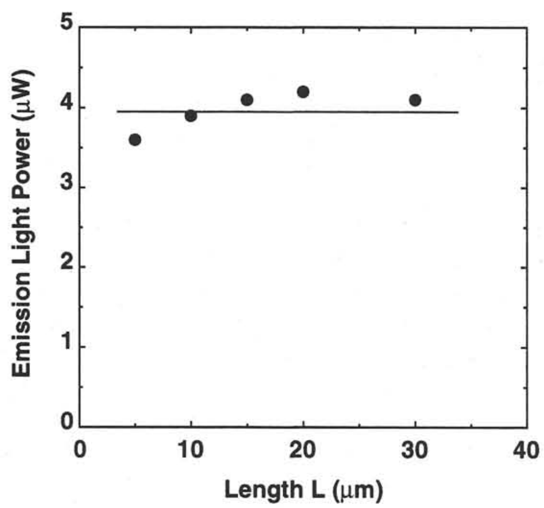

Fig. 7. Emitted light intensity as a function of L.

5. LIFE EXPECTANCY OF THE LEDS

High Zn concentration diffusion may exert some degree of influence on the life expectancy of the LEDs, due to defects induced by the Zn diffusion. A life measurement test was carried out by measurement of time-dependent emitted light power in applying a forward current to the LEDs for 500 hours. A forward current of 6 mA was used, which is twice as large as the recommend current.

Figure 8 shows the results of life measurement; that is, time-dependent light power deterioration η, which is

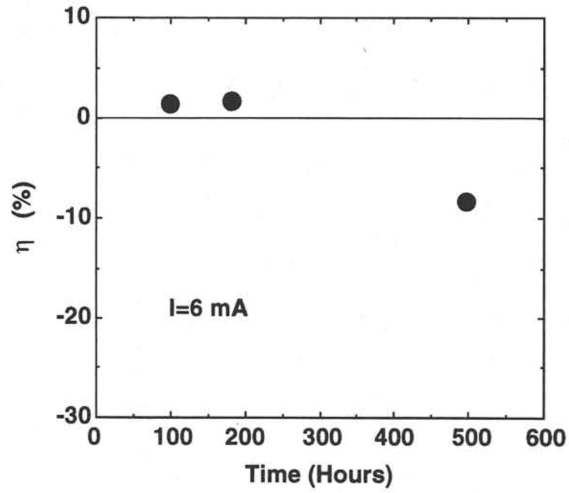

Fig. 8. Time-dependent emitted light power of LEDs on a 1200 dpi LED array chip.

defined as $\eta=[P(t)-P_0]/P_0$, where P_0 and P(t) are the emitted light power at time = 0 and time=t, respectively. As shown in Fig. 8, the value of η was negligible up to 168 hours and was still only about -10 % at 500 hours. From the viewpoint of application in print heads, this is a sufficiently long life expectancy. Thus it can be concluded that highly doped Zn should not have a serious influence on the life expectancy of the LEDs in a 1200 dpi array chip.

6. CONCLUSION

We investigated the diode- and light-emission characteristics of LEDs in a 1200 dpi LED array developed using solid-phase Zn diffusion. The diode characteristics were influenced by the series resistance due to the shallow Zn diffusion. However, it can be concluded that the sheet resistance of the Zn diffusion region will be low enough to obtain good light-emission characteristics. It can be also said that these good light emission characteristics are essentially owing to a highly doped shallow p-n junction formed by the solid-phase Zn diffusion. Furthermore the LEDs have sufficiently long life expectancy in spite of high-concentration diffusion. Thus the results showed that the characteristics of this 1200 dpi LED array are good enough for use in an optical printer print head. Considerably high quality, high resolution printing could be achieved[5] with an LED print head using such a 1200 dpi LED array.

References

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