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# Double-Function Light-Emitting-Diode Array

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The development of a double-function light-emitting-diode (DFLED) is reported for the first time. A DFLED is a pn junction which works as a light-emitting-diode (LED) and works as a photosensor as well. The DFLED has a shallow junction (~ 0.8$\mu$m) region and a deep junction (~ 5$\mu$m) region. In this work, it is found out that the use of an aluminum oxide ($Al_2O_3$) thin film is essential to fabricate the shallow junction region. It has been confirmed that the DFLED has the superior performances as both of a photosensor and a LED.

## 1. INTRODUCTION

A light-emitting-diode (LED) array is often used as a light source for an optical printer.[1, 2] Recently it is strongly desired to produce a compact multi-functional machine which has functions of a printer, a copier, a facsimile and a scanner. If the LED has a high sensitivity to a light detection, the LED array can be also used as the photosensor array of a scanner in stead of a charge coupled device array. Such LED array must be a promising device applied for a read-write head.[3] The junction depth of LED used in the optical printing head is usually deep (~ 5$\mu$m), because a high intensity light is emitted from the deep pn junction. However, the deep pn junction cannot be used as a photosensor. The ratio of signal to noise (S/N) is considerably small in the case of using the deep pn junction as a photosensor. The S/N ratio is required to be larger than 20 dB at least for the use of a photosensor in the scanner. The typical S/N ratio for the deep pn junction has been found out to be 15 dB at most. On the contrary, a shallow pn junction can have a high sensitivity to a light detection,[4] although a large intensity of light cannot be emitted.

From this point of view, a pn junction that has both a shallow junction region and a deep junction region has been developed. This pn junction is named a double-function light-emitting- diode (DFLED) in the sense that this pn junction has a superior performance as a photosensor as well as a LED.

In this paper, fabrication and performance tests of the DFLED is reported.

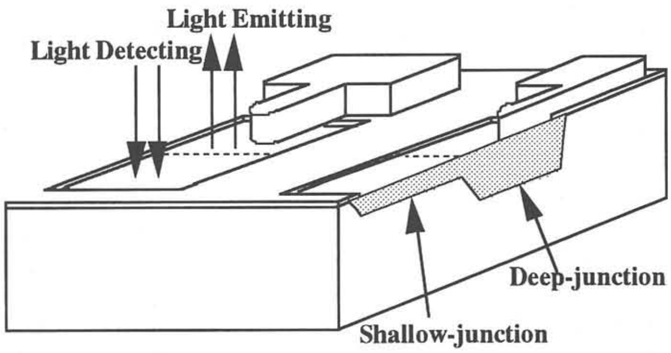


**Fig.1 Schematic drawing of a part of the DFLED array.**

## 2. JUNCTION DESIGN

The DFLEDs were fabricated by close-tube zinc (Zn) diffusions in $GaAs_{0.8}P_{0.2}$. First of all, photocurrent ($I_{ph}$) from the LED was measured as a function of the diffusion depth (Xj), in order to optimize the Xj value of shallow junction region in the DFLED. The LEDs were irradiated by a light of 100lux under an applied reverse bias voltage of 5V in these measurements. $I_{ph}$ increased with decreasing Xj and became maximum at Xj ~ 0.8$\mu$m. Based on this result, Xj in the shallow junction region of the DFLED was determined to be ~ 0.8$\mu$m.

Figure 1 shows the schematic drawing of a part of the DFLED array developed in this study. As shown in Fig. 1, the cross section of the Zn diffused layer is shaped like a step; there exist the junction regions ofÅ Xj ~ 0.8$\mu$m and Xj ~ 5$\mu$m. Note that this junction structure is essential to fabricate a high quality DFLED array.

## 3. FABRICATION PROCESS

In general, it is difficult to form the step-like-sharped junction indicated in Fig.1 due to lateral Zn diffusion. A length of lateral Zn diffusion strongly depends on material of a diffusion barrier film that is used to control Xj.

Figure 2 shows Xj as a function of the film thickness for $Al_2O_3$, PSG and SiN. As seen in Fig. 2, the thick film should be deposited on $GaAs_{0.8}P_{0.2}$ in the case of using the PSG film and the SiN film to form the shallow junction. However, It is found out that thick diffusion barrier films of PSG and SiN cause abnormally large lateral Zn diffusion for selective masked Zn diffusions. Therefore it is concluded that the PSG film and the SiN film are not suitable for the diffusion barrier film to form the shallow junction. As indicated in Fig. 2, the shallow junction of Xj ~ 0.8$\mu$m can be formed with the $Al_2O_3$ film of 200Å. Furthermore in the case of using the $Al_2O_3$ film, no large lateral diffusions were observed in selective masked Zn diffusions. Thus it can be said that the $Al_2O_3$ film is suitable for the diffusion barrier film as well as the diffusion mask film to fabricate the pn junction structure of the DFLED.

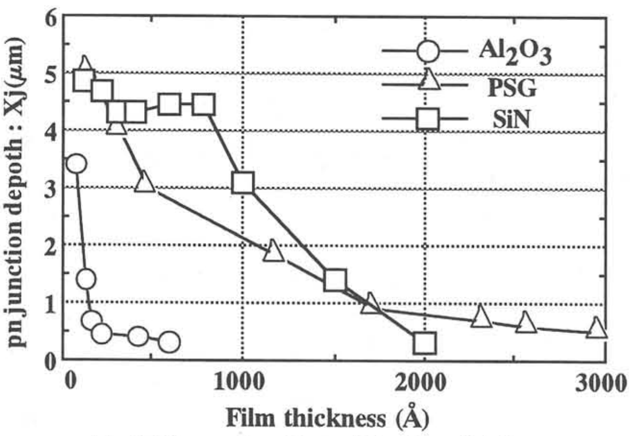

**Fig.2 Xj as a function of the film thickness for $Al_2O_3$, PSG and SiN.**

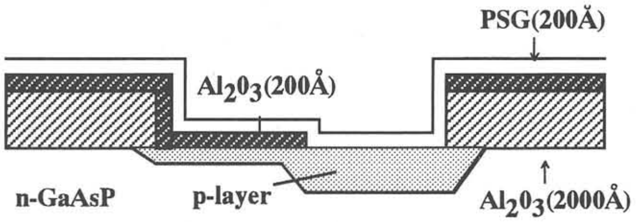

**Fig.3 Schematic drawing of the cross section of the DFLED at the Zn diffsion step .**

Fig. 3 shows a schematic drawing of the cross section of the DFLED at the Zn diffusion step. The $Al_2O_3$ film of 2000Å was used as a diffusion mask.[5] The $Al_2O_3$ diffusion barrier film of 200Å was deposited and was etched to remove the $Al_2O_3$ film only on the deep junction region. The PSG diffusion barrier film of 200Å was deposited. Then closed-tube Zn diffusion was carried out.

Figure 4 shows the optical micrograph of a cleaved and preferentially etched section of the DFLED. As clearly seen in Fig. 4, the shallow and deep junction regions are formed in shape as designed. As shown in Fig. 4, the length of lateral Zn diffusion in the deep junction region is equivalent to Xj ~ 0.8$\mu$m. Note that the shallow junction region could never be formed due to large lateral Zn diffusion in the case of using the diffusion barrier film of PSG or SiN on the shallow junction region.

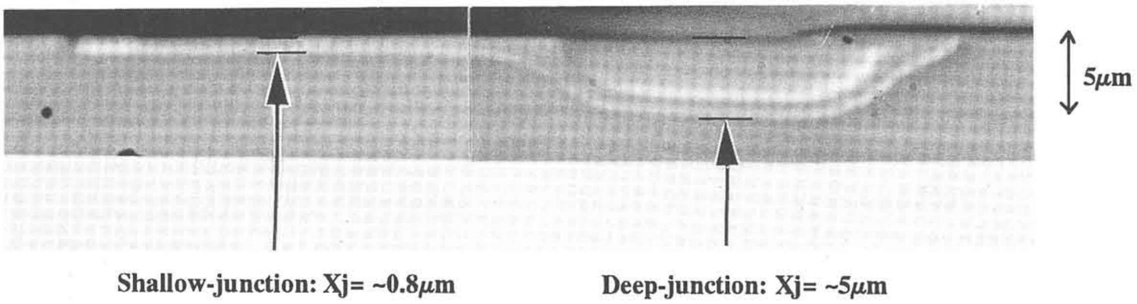

**Fig.4 The optical micrograph of a cleaved and preferentially etched section of the DFLED.**

## 4. CHARACTERISTICS

Figures 5(a) and 5(b) indicate a representative position-dependent-photocurrent ($I_{ph}$) profile and a typical near-field pattern along the line A-A'. The $I_{ph}$ profile was measured at an applied reverse bias voltage of 5V under irradiation of a slit-light of 550nm. As shown in Fig. 5(a), large $I_{ph}$ is obtained only when the shallow junction region is irradiated by the slit-light. The S/N ratio of $I_{ph}$ is much improved compared to the LED of Xj ~ $5\mu m$. The S/N ratio of 30dB for $I_{ph}$ from the DFLED is obtained. This suggests that the DFLED array can be used as the photosensor array head of the scanner.

The near-field pattern was measured at a forward current of 5 mA. As indicated in Fig.5(b), a high intensity light is emitted only from the deep junction region. Therefore it can be said that the shallow junction region has no influence on the light emitting characteristics of the DFLED.

From these results, it is concluded that the shallow junction region works mainly as a photosensor and the deep junction region works mainly as a light-emitter in the DFLED. This characteristic is really desirable for the practical use of the DFLED array.

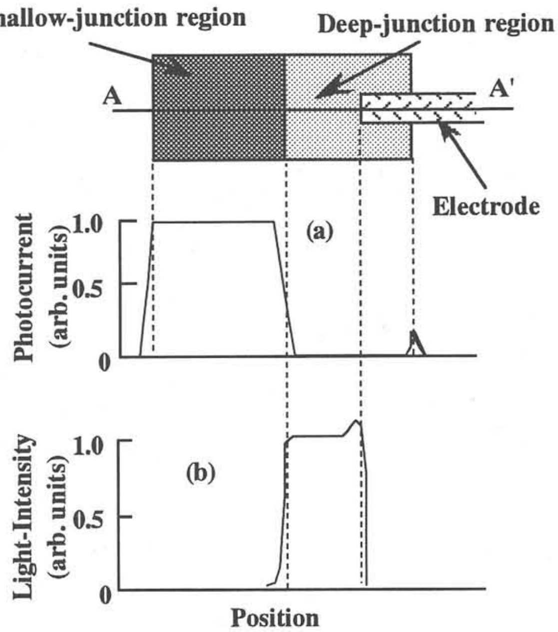


**Fig.5 (a) Photocurrent profile and (b) Near-field pattern .**

## 5. CONCLUSION

The DFLED has been developed in this study for the first time. It has been confirmed that the DFLED can be applied to the photosensor as well as the LED. In this report, it can be said that the DFLED array is the promising device for the scanner head as well as the optical printing head. It way be possible to develop a compact multi-functional machine using the DFLED array developed in this investigation.

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