Solar-blind AlGaN PIN Hetero Junction Photodiode

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UV photo-sensor which selectively detects the flame luminescence within range from 250 to 280nm is capable of detecting flames against the strong background of sun-light or room-light. In fact, photo-tube with optical-electronic plane (UV photo-tube) is applied to industrial-use or larger boilers. The reason why conventional Si or GaP-based photo-sensors coupled with UV transmission filters cannot be used as flame detector is mainly due to their poor wavelength selectivity. Therefore, the materials of which bandgap is larger than 4.4 eV (280nm) at the high end of solar light is indispensable for the flame detector applications. The required specification as the flame detector is :

i) Sensitive to the light of which wavelength is shorter than 280 nm to be solar blind.

ii) Detectable to low-intensity light of $1nW/cm^2$ at 250-280nm.

Group III nitride is thought to be one of the best promising candidate among wide bandgap materials(1) for this purpose. (Al, Ga)N based p-i-n diode(2) with cutoff wavelength at 285 nm fabricated on laterally epitaxially overgrown (LEO) GaN was reported. Unfortunately, LEO technique is not so suitable to get a large detection area which is indispensable for the low-intensity light detection. Furthermore, composition and thickness of AlGaN directly growth on LEO-GaN is limited by the crack-generation.

In this study, low temperature deposited AlN interlayer (LT-AlN IL) technique(3) was applied to grow crack-free and high-quality AlGaN(4). We will report on the performance of the AlGaN-based p-i-n photodiode grown by MOVPE using LT-AlN IL technique.

Photodiode which consists of p-GaN:Mg (100 nm)/i-$Al_{0.44}Ga_{0.56}N$/n-$Al_{0.44}Ga_{0.56}N$:Si was fabricated on the LT-AlN interlayer. Reactive ion etching was performed to form n-type electrode. Ti/Al bi-layer n-electrode and Ni/Au mesh p-electrode was deposited and annealed at 700℃ for 40 sec. The layer structure is schematically shown in Fig. 1.

The spectral responsivity was measured at 0V bias for the 2mmϕ diode. The result is shown in Fig. 2. Constant light power of $500nW/cm^2$ (HWHM 6nm) was used from 220nm to 400nm and a sharp-cutoff at 270nm was observed. The peak responsivity of 12mW/A was recorded at 270nm. This responsivity corresponds to the internal quantum efficiency of 50%, assuming an absorption coefficient of $2x10^5$ at p-layer and the surface reflection loss of 19%. Even at this weak incidence, rejection ratio of three orders is obtained between 270nm and 300nm and this satisfies critical rejection ratio of the flame detector in this region (5). Almost all the p-i-n diodes showed the reverse current of $4-35pA/mm^2$ under –5V bias, which is comparable to the best result of GaN homo-junction diode(6). However, this value is still too large for the flame detector application, because the signal output without gain would be around 10-20pA/mm^2, and the further improvement should be necessary.

Consequently, from the critical point of view, within our best knowledge, the first solar blind p-i-n detector has been demonstrated. Its performance satisfies the rejection ratio at 280-300nm for the flame detector application, however; its low reverse current is not enough to detect 1nW/cm^2 on biased condition and the rejection at 300-360nm should be improved by 2 orders.

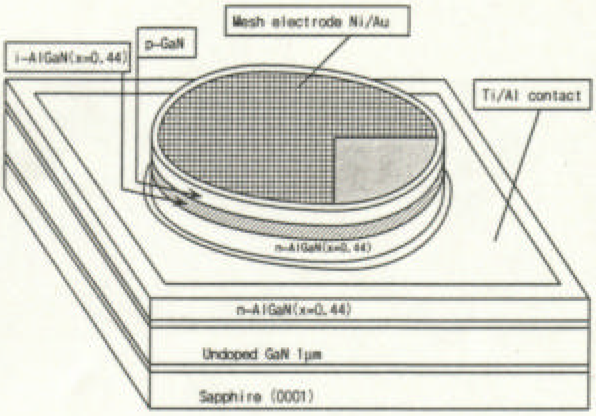

Fig. 1 Schematic structure of the p-i-n photodiode.

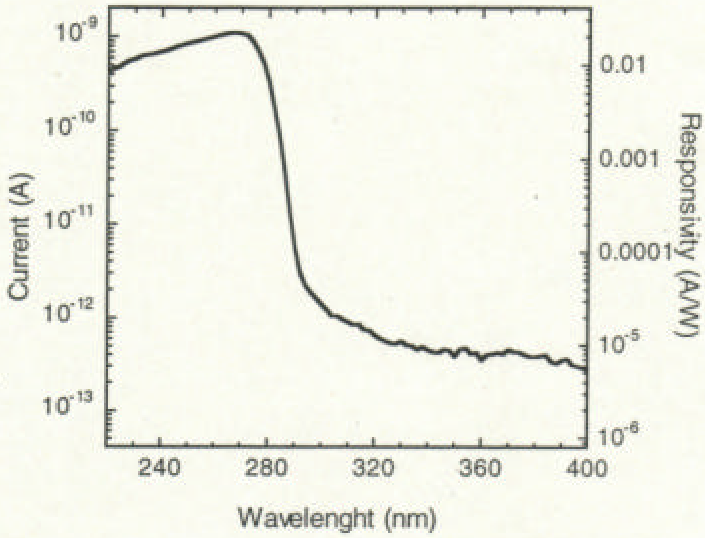

Fig. 2 Wavelength responsivity at 0V bias.

References

1) A. Hirano and C. Pernot: Oyo butsuri 68 (1999) 805 [in Japanese]

2) G. Parish, S. Keller, P. Kozodoy, J. P. Ibbetson, H. Marchand, P. T. Fini, S. B. Fleischer, S. P. Denbaars, U. K. Mishra and E. J. Tarsa: Appl. Phys. Lett. 75 (1999) 247

3) M. Iwaya, T. Takeuchi, S. Yamaguchi, C. Witzel, H. Amano and I. Akasaki: Jpn. J. Appl. Phys. 37(1998)L316

4) C. Pernot, A. Hirano, M. Iwaya, T. Detchprohm, H. Amano and I. Akasaki: Jpn. J. Appl. Phys. 38 (1999)L487

5) A. Hirano, C. Pernot, M. Iwaya, T. Detchprohm, H. Amano and I. Akasaki: in proceedings of Photonics West (SPIE) 2000, San Jose, Jan. 27 (2000)

6) J. C. Carrano, T. Li, P. A. Grudowski, C. J. Eiting, D. Lambert, J. D. Schaub, R. D. Dupuis and J. C. Cambell: Electron. Lett. 34 (1999)692