JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. 6 No 3, 03002(2pp) (2014) ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том 6 № 3, 03002(2cc) (2014)

Impurity Influence on Nitride LEDs

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(Received 19 May 2014; revised manuscript received 01 July 2014; published online 15 July 2014)

Light emitting diodes (LEDs) are widely used nowadays. They are used in major parts of our life. But it is still necessary to improve their characteristics. In this paper the impurity and Indium atoms influence on the LEDs characteristics is investigated by computer simulation. Simulation was carried out in Sim Windows. The program was improved for this purpose by creating new files for AlGaInN heterostructure and devices including more than 25 basic parameters. It was found that characteristics depend on impurity and indium atoms changes a lot. The optimum impurity concentration for doping barriers between quantum wells was achieved. By varying impurity and Indium concentration the distribution in AlGaInN heterostructure LEDs characteristics could be improved.

Keywords: Light emitting diode, AlGaInN, Simulation, Quantum efficiency.

PACS numbers: 07.05.Tp, 85.60.Jb

1. INTRODUCTION

The optoelectronics started at the beginning of the XX-century and its progress was so dynamic that it can be compared with the modern scientific and technological revolution.

Last time the usage of the software for simulation semiconductor devices increases noticeably. Device simulations play an important role in device research [1-5]. The equations that govern device physics are complicated and not easy to solve except for very simple devices using crude approximations.

In spite of so optimistic expectations there are still problems in the main using devices − light emitting diodes (LEDs). Different factors influence upon their degradation. Here the Indium and impurity concentrations influence upon LEDs characteristics are investigated by simulation in Sim Windows [1].

2. EXPERIMENTAL PROCEDURES

The LED structure in files for simulation was common – Indium atoms in quantum active region was $X = 0.05$-0.35 with a 0.05 step; there were 4 quantum wells (QWs), and the QW width was 2 nm with the thickness of the GaN barriers – 3 nm; the QWs and barriers in the active region had the n – type conductivity, the concentration of donors in the QW was $N_d = 10^{18}\ \mathrm{cm}^{-3}$ and in the barriers – $N_d = 10^{18}\ \mathrm{cm}^{-3}$; the concentration of donors in the Si-doped n-GaN emitter was $N_d = 10^{18}\ \mathrm{cm}^{-3}$; the p-type region was consisted of the GaN contact layer and $Al_{0.2}Ga_{0.8}N$ emitter 80 nm thick, both p-type layers were Mg-doped with the concentration $N_a = 10^{19}\ \mathrm{cm}^{-3}$; in simulation the temperature was assumed to be $T = 300\ K$.

3. RESULTS AND DISCUSSION

At first the Indium concentration influence on the nonideality factor (n) vs. the current density reveals the following (fig. 1).

In the absence of the QW ($X = 0$), the nonideality factor $n > 1$, which is associated with a substantial effect of electrons and holes recombination in the space charge region on the current value; then the overbarrier injection of charge carriers current starts to increasingly prevail; in this case, $n \to 1$ at a low injection level (j = 1-20 A/cm^2) and $n \to 2$ upon increasing the injection level (j = 20-500 A/cm^2). The presence of the QWs starts to influence on n even at the values $X = 0.05$-0.1, especially in the range $X = 0.1$-0.35. At $X > 0.1$, the value of n gradually increases over the whole range $j = 0.1$-500 A/cm^2 and attains the values $n > 2$ and even $n >> 2$ at $X >> 0.15$. At low Indium contents, $X = 0.05$-0.1, as the current increases, the electrons and holes concentrations in the QWs increase, too, while the nonuniformity of their distributions over the QWs decreases.

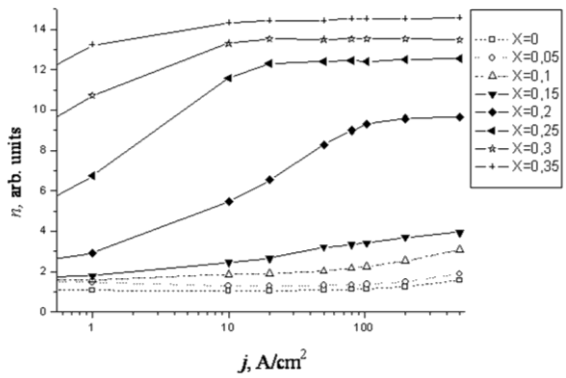
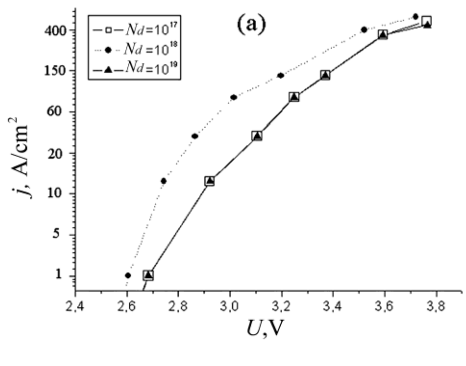


Fig. 1 – Dependence of the value of nonideality factor n of the I-V characteristics on the current density at various contents X of Indium in the QWs



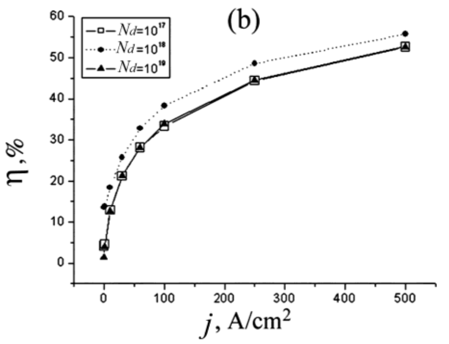


Fig. 2 – *I-V* (a) & quantum efficiency (b) vs. different doping in barriers between QW

The next step was to investigate the impurity influence upon *I-V*. It was detected that the optimum impurity concentration in barriers between QWs is $N_d = 10^{18}$ cm^{-3} (for blue LEDs). This doping shifts *I-V* to less voltage and increase quantum efficiency (fig. 2).

4. SUMMARY

This effect is due to reducing potential barrier (additional carriers injection) between QW and barriers among them so j increases at the constant voltage.

By varying Indium and doping concentrations in AlGaInN heterostructure active region it is possible to increase quantum efficiency at the same voltage at j = 0.1-500 A/cm^2.

ACKNOWLEDGE:

The investigation was carried out according the State project for NUST MISiS.

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