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Ohmic Contact of p-Type ZnSe Using Heavily Alkaline Doped p^+-ZnSe by Excimer Laser Doping Technique

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1. Introduction

Blue emitted semiconductor laser diodes(LDs) are needed as the next generation for higher density disk system as the shorter wavelength allows the higher recording density. Red-green-blue (RGB) full-color all-solid-state light-sources are also required. Recently, wide band gap II-VI semiconductors have intensively been investigated for their potential applications in the blue laser diodes. Up to now, ZnSe based blue-green laser diodes which have lifetime of 100 hours in room temperature with continuous wave operation[1]. However, for the extension of lifetime, much efforts have been devoted to fabricate a prefect device which has defect free and close lattice match in the crystal.

In the practical devices, nitrogen doped p+ type ZnSe has been used for the ohmic contact to metal electrode with a hole carrier concentration of $\sim 10^{18}cm^{-3}$. However, the carrier is not enough to contact with the metal electrode. It is required $10^{19}cm^{-3}$ carrier concentration for the well contact between semiconductor and metal[2,3].

In this paper, an excimer laser doping technique for the heavily doped p+-ZnSe layer was studied.

2. Experimental

Two types of samples were used in this experiments. One type of samples as shown in Fig.1 is for nitrogen doped ZnSe film grown on semi-insulating GaAs substrate for the investigation of a treatment of excimer laser doping (type-I). The anther type of samples is for double hetero(DH) structured light emitting diode(LED) (type-II).

In the type-I case, epitaxial ZnSe films used in this study were grown on the insulating GaAs by a remote plasma assisted metal organic chemical vapor deposition (MOCVD)[4]. The prepared ZnSe films were with nitrogen doping of $10^{16}cm^{-3}$ by the nitrogen radical assisted method[5]. Crystallinity of this ZnSe film was about 200 arcsec in FWHM of X-ray diffraction[6]. A evaporated gold was used as contact metal electrode for p-type ZnSe. Figure 1 shows the procedure for the excimer laser doping.

In the first step, a thin layer 50 nm thick containing dopant atom is evaporated on the surface of the ZnSe on GaAs using one of the compound materials containing alkaline metal atoms such as Na_2S, K_2S, Na_2Se, K_2Se, Na_3P, K_3P, etc.. In this experiments, K_2S and Na_2Se were used and compared. In the second step, impurity diffusion processes are carried out. One method is a thermal diffusion by heating in the N_2 ambient at the temperature of 550°C for 10 min., and the other is an excimer laser radiation(KrF : 248 nm, 300 mJ/shot, 20 ns/shot) followed by the thermal diffusion. The second process is also done in the ambient of nitrogen. As a third step, 2 mm diameter gold electrodes were deposited at the corners of 1 cm square sample in order to measure the electrical characteristics by means of the Hall measurement.

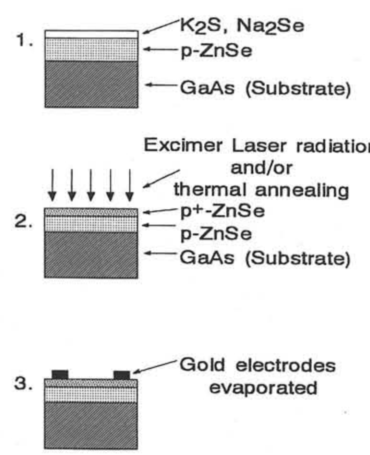

Fig. 1 Treatment process of excimer laser doping for type-I

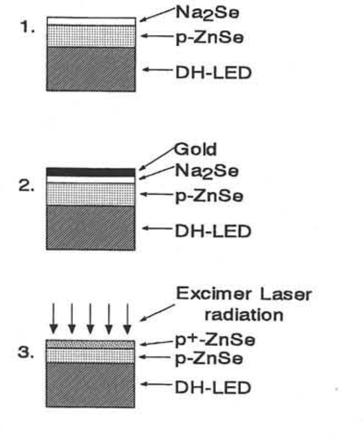

Fig. 2 Treatment process of excimer laser doping for type-II

In type-II case, the DH-LEDs are consist of an well constructed and complicated layers with super lattices. It was considered that the thermal annealing process is too severe to protect the fine active construction from the alkaline atom diffusion. Only laser annealing were adapted to the type II samples without the thermal annealing. Figure 2 shows the procedure for excimer laser doping for these samples. A thin Na_2Se layer of thickness 20 nm was evaporated and 300 nm of gold was also evaporated on alkaline layer. These samples were exposed to excimer laser radiation in the next step..

3. Result and Discussion

Figure 3 shows the resistivity of ZnSe obtained from thermal and laser annealing in type-I sample. When K_2S was used as an alkaline source material, average resistivity of the ZnSe film decreased to 4 Ωcm for thermal annealing and 2×10^{-1} Ωcm for laser and thermal annealing. In case of Na_2Se, resistivity as low as 3×10^{-2} Ωcm could be obtained using laser and thermal annealing. Corresponding values of carrier concentration and hole mobility were $9.1\times10^{17}cm^{-3}$ and $4.8\times10^{19}cm^{-3}$ and 34.2 $cm^2V^{-1}s^{-1}$ and 8.17 $cm^2V^{-1}s^{-1}$, respectively for K_2S and Na_2Se treated samples.

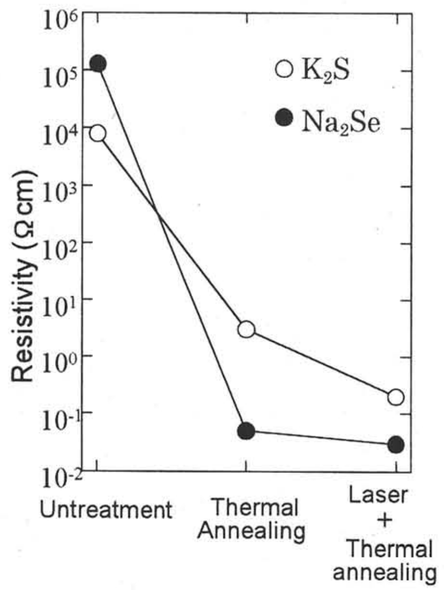

Fig. 3 Resistivity characteristics on the laser doping for the type-I sample.

Figure 4 shows I-V characteristics of type-II samples in various shots of excimer laser radiation. The threshold voltage is decrease with increasing number of shots. Furthermore, the blue-green luminescence of this LED treated excimer laser doping was stable. For the application of excimer laser doping techniques to fabricate LED or LD, the influences of alkaline material at the diode junction must be investigated. However, this result shows that a excimer laser radiation is not damaged by alkaline materials at the junction. It is consider that the excimer laser radiation can penetrate only few tens nanometers from the surface.

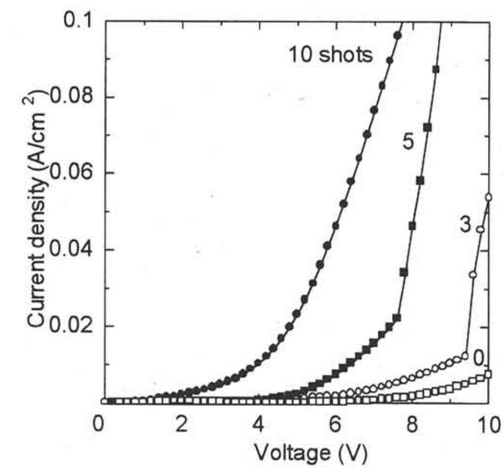

Fig. 4 I-V characteristics for various shots of excimer laser radiations (type-II sample).

4. Conclusion

Heavily doped p-type ZnSe films were formed by an excimer laser doping technique. The alkaline impurity such as K_2S or Na_2Se was diffused by heating and excimer laser radiation. Carrier concentration and hole mobility were $9.1\times10^{17}cm^{-3}$ and $4.8\times10^{19}cm^{-3}$ respectively using Na_2Se diffusion with excimer laser radiation in addition to heating. In the case of LED, only laser annealing was adapted for the doping process. The threshold voltage of LED was decreased with increasing shots number of excimer laser. It was resulted that LEDs were not damaged by excimer laser radiation and alkaline diffusion.

This technique has quite high potential for making ohmic contact to wide gap materials and hence device fabrications.

References

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