펄스 레이저 증착 방식으로 GaAs 기판에 성장된 ZnO의 As 확산에 의한 전기적 특성

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Effect of As diffusion on the electrical property of ZnO grown on GaAs substrate by pused laser deposition

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bstract - In order to form a p-type ZnO thin film, ZnO thin film is eposited by pulsed laser deposition(PLD) on GaAs substrate followed by ermal treatment that ensures the diffusion of As atoms from the GaAs ubstrate to the ZnO thin films. Photoluminescence (PL) measurement eveals that the improved quality of ZnO thin films is acquired at the rowth temperature of 400 ℃. It is ZnO film grown at 100 ℃ that shows e change from n-type to p-type by the thermal treatment. Measured arrier concentration in the film is changed from -5.70×10^{13} to 9.09×10^{18}.

1. Introduction

ZnO has attracted significant attention for its potential to make lectronic and optoelectronic devices. The advantages include uitable band gap (~3.37 eV), large exciton binding energy (~60 eV) at room temperature, and the availability of large-area ZnO ubstrates. However, the preparation of p-type ZnO remains as one f the major problems for practical applications of ZnO-based evices [1]. Even though the p-type ZnO has been studied in many esearch groups [2,3], it is still very difficult to achieve the p-type oping in wide-band-gap semiconductors, and no reproducible igh-quality p-type layers are available yet. In this reason, to find he mechanism of p-type doping of ZnO thin films is the key point f realizing the ZnO electronic and optoelectronic devices.

To obtain p-type ZnO, group V elements have been used as opants. Although the possibility of p-type doping with larger adius group V materials such as arsenic and phosphorous has also een explored, it is found that Nitrogen is suitable than any other roup V materials because nitrogen radius is similar to that of xygen. It is easily expected that a group V elements must ubstitute the oxygen atom to generate holes in ZnO structure. Iowever, many researcher suggest that complex model can explain he electrical and/or optical behavior of the thin film more ffectively [4,5]. For example of the complex model, As substitutes n the Zn site forming a donor, then it induces two Zn-vacancy cceptors.

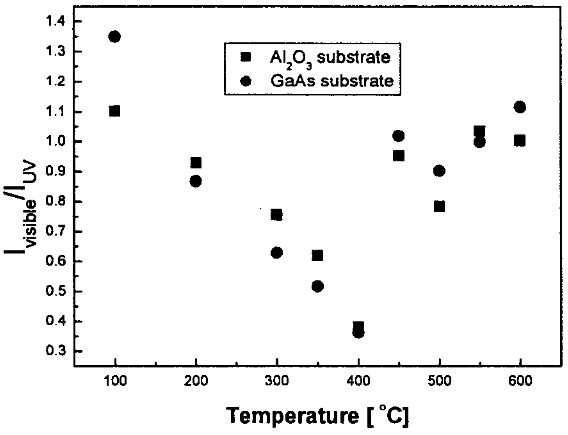
In this research, ZnO thin films have been fabricated on Al_2O_3 by LD. In order to investigate doping characteristics of doped ZnO hin films, PL and Hall measurement have been performed. This esult is very important to suggest how to prepare the p-type ZnO o implement ZnO electric and optoelectronic devices.

2. Experiment and results

ZnO thin films were grown on GaAs and Al_2O_3 substrate to make p-type nO thin film by PLD. 3 wt% As doped ZnO target was used for a source f ZnO to increase the doping effect of As. 355 nm ND:YAG laser was sed for the laser system. The energy density at the target was 1.4 J/cm^2 nd target to substrate distance was 5 cm. Oxygen gas was used as an mbient gas at the pressure of 350 mTorr. The growth temperature was aried from 100 ℃ to 700 ℃, and for details, 350 ℃, 450 ℃, 550 ℃ onditions also performed. The annealing process was also performed to iffuse As. The annealing temperature was 450 ℃ and ambient oxygen gas ressure was 350 mTorr. Hall measurement and PL measurement were erformed to confirm the quality of grown ZnO thin films at room mperature before and after annealing, respectively.

The PL spectrum of ZnO is consisted of two part, UV part around 380 m and visible region part. Actually, ideal ZnO has strong UV peak ntensity compared to visible region PL peak intensity, cause the visible PL eak is occurred by various defects in ZnO. We can estimate the quality of ZnO thin film from the intensity ratio of UV peak intensity and visible region peak intensity as shown in Fig. 1.

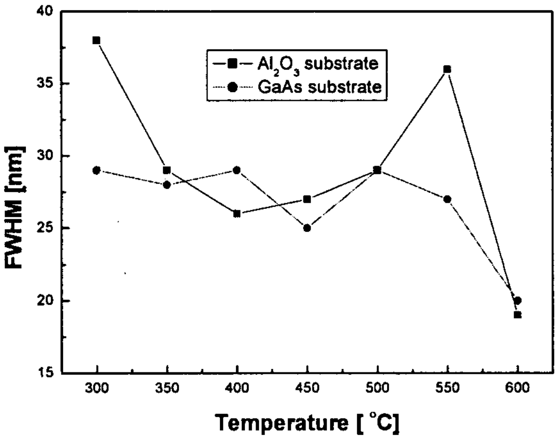
Fig. 1. Ratio of visible peak intensity to UV peak intensity



depending on growth temperature

The minimum value of visible peak and UV peak ratio is 0.38 in Al_2O_3 substrate and 0.362 in GaAs substrate when the growth temperature was 400 ℃. The ratio at 450 ℃ is much bigger than 350 ℃, the appropriate temperature is around 400 ℃close to 350 ℃. We can also estimate the quality of ZnO thin film by calculate the FWHM of UV peaks.

Fig. 2. Variation of FWHM of UV peak depending on growth



temperature

Fig. 2 shows the variation of FWHM of UV peak depending on growth temperature. The FWHM is decreasing when the temperature is increased.

Hall measurement result is shown in table 1. The ZnO thin film grown at 00 ℃ was changed n-type to p-type, after annealing treatment. Before nnealing, the ZnO thin film grown at 100℃ was n-type and, bulk oncentration, resistivity and mobility was -5.7×10^{13} cm^{-3}, 2.13×10^{3} Ωcm, 4.7 cm^2/Vs, respectively. After thermal treatment process, the parameters ,ere changed to 9.09×10^{18} cm^{-3}, 1.24×10^{-1} Ωcm, 8.05 cm^2/Vs, and showed -type characteristics.

Table 1> Electrical property of ZnO films on GaAs depending n before and after annealing treatment.

Growth temp. = 100℃	Bulk concentration (cm^{-3})	Resistivity (Ωcm)	Mobility (cm^2/Vs)	Conductivity
ZnO on GaAs before annealing	$-5.7X10^{13}$	$2.13X10^{3}$	54.7	n type
ZnO on GaAs after annealing	$9.09X10^{18}$	$1.24X10^{-1}$	8.05	p type

3. Conclusion

In this paper, we made ZnO thin film on GaAs substrate to make p-type nO thin film. By the PL measurement, UV peak and visible region peak ,as observed at room temperature. The crystal quality of ZnO is best round growth temperature of 400 ℃ and FWHM of UV peak was ecreased as increasing growth temperature. The ZnO thin film grown at 00 ℃ was changed n-type to p-type, after annealing. It can be explained y complex model of ZnO doping.

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