p-type and *n*-type doping of ZnSe-based alloys for Light Emitting Diodes

Hong-Chan Lee+·Yongho Choi[1]·Sang-Tae Lee[2]·Jiho Chang[2]·Koshi Ando[3]

High-brightness blue, green, and white light emitting diodes (LEDs) are highly desirable for numerous practical applications such as multicolor LED indicators, automotive interior lighting, traffic signals, backlights for TV and cell phone displays, general-purpose indicator and display applications. Wide band-gap II-VI semiconductor compounds have been regarded as very promising materials for the fabrication of both LEDs and laser diodes (LDs) for the wavelength region described above. In order to obtain an efficient ZnSe-based light-emitting devices, we present the fabrication techniques of undoped-ZnSe, *n*-type, and *p*-type ZnSe epilayers.

1. High quality undoped-ZnSe epitaxial films : High-quality *p*-type ZnSe alloy is the most important requirement in order to achieve to high-efficient blue or/and green LEDs. There have been some attempts to grow *p*-ZnSe by using an N-atom ion implantation technique [1] or epitaxial growth techniques [2]. In general, to obtain high-quality *p*-ZnSe alloys with high effective carrier concentration is difficult. This is because undoped ZnSe contains both electrically active impurities and native defects, so that *p*-type dopant impurities were compensated. It is highly desirable to establish growth technique for high-quality undoped ZnSe thin films.

2. *n*-type doping of ZnSe-based alloys : Chlorine has been fairly well investigated in the context of *n*-type doping of ZnSe using the conventional MBE technique and was found to be an effective shallow *n*-type dopant for ZnSe, as well as for wider bandgap (Zn,Mg)(S,Se) materials [3,4]. In this study, an effusion source of solid anhydrous $ZnCl_2$ (6N) was used to achieve and effect *n*-type doping of ZnSe, ZnSSe, and ZnMgSSe. It is found that the carrier concentration (N_D-N_A) can be widely controlled by the $ZnCl_2$ effusion cell temperature (T_{cl}). At T_{cl}=180℃ the carrier concentration attains 2.2×10^{19}cm^{-3}. The N_D-N_A value obtained shows marked improvements (by one order of magnitude or more) in comparison with Al-doped ZnSe or Ga-doped ZnSe layers previously reported [5,6]. It seems that the maximum value of the carrier concentration is high enough for n^+contacting layers in device applications. The Hall mobility is found to be as high as 240 cm^2/Vs at a lighter doping level, suggesting good crystallinity.

3. *p*-type doping of ZnSe-based alloys : The controversial subject as to the exact species (nitrogen ions, excited molecules, or atomic nitrogen) responsible for the *p*-type doping of ZnSe was mostly resolved by Vaudo *et al.* [7] where the N_2 plasma emission spectrum was analyzed and correlated with the doping concentration. We can see that under optical conditions (under RF power 300W, 0.2 sccm, and 230℃), the net acceptor concentration up to 5.0×10^{17} cm^{-3} in *p*-type ZnSe has been obtained, while still growing ZnSe a lower temperatures ($T_{sub.}$<250℃). These results show that N-doping *p*-type ZnSe is of sufficient quality for fabricating practical ZnSe *p-n* junction devices by molecular beam epitaxy (MBE).

References

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+ 이홍찬 (중원대학교 에너지자원공학부), E-mail: leehc@jwu.ac.kr, Tel: 043)830-8623
1 최용호 중원대학교
2 이상태 한국해양대학교
2 장지호 한국해양대학교
3 Koshi Ando Tottori University, Japan