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# Increase of Acceptor Concentration in Nitrogen Doped ZnSe Film Grown on a Tilted GaAs Substrate

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A p-type ZnSe film has been obtained by using MBE with a nitrogen radical doping technique[1]. Since the first report of pulsed operation of ZnCdSe/ZnSe laser diode(LD) at 77 K [2], much progress has occurred in development of lasers for CW operation at room temperature. However, these LDs, in comparison with III-V compound LDs, have a serious problem with high series resistance and high operation voltage. It is expected that new means will be found to improve the p-type doping characteristics. This study shows that the nitrogen doping characteristics in MBE ZnSe growth are improved by using tilted GaAs substrates. These tilted substrates are also effective in lowering the operation voltage of LDs.

Nitrogen doped p-type ZnSe films were grown by using MBE on eleven differently oriented GaAs substrates; nominal (100), tilted 11.4° (711), 15.8° (511), 25.2° (311), 35.3° (211) and 54.7° (111) toward the <111>A and <111>B direction. The growth temperature was 330 °C, the growth rate was 1 μm/h, and the sample thickness was 2 μm. The ZnSe layers were doped with nitrogen from an rf plasma source using $N_2$ gas at a nitrogen flow rate of 0.3 sccm and an RF power of 300 W. The net acceptor concentrations of the samples were evaluated by a Double-Schottky C-V method. Figure 1 shows the relationship between the net acceptor concentration of the p-type ZnSe layer and the tilted angle of GaAs substrates from (100) toward the <111>A and <111>B direction. In this figure, the open squares and filled circles correspond to different growth procedures. The net acceptor concentrations on (711), (511) and (311) substrates are twice as large as that of the ZnSe layer grown on a (100) substrate regardless of the tilt direction. The maximum net acceptor concentration, $8\times10^{17}$ $cm^{-3}$, is obtained on the (511)B substrate. On the other hand, when grown on the (111)A and (111)B oriented substrate, the ZnSe layers show high resistivity.

A laser diode structure was fabricated on a (311)A n-type GaAs substrate. This separate-confinement heterostructure consists of $Zn_{0.8}Cd_{0.2}Se$/ZnSe MQW active layer, ZnSe guiding layers and $ZnS_{0.07}Se_{0.93}$ cladding layers[3]. Here, p-type ZnSe is used as the cap layer. Both p-type and n-type electrodes are Ti/Pt/Au. The injection current is restricted within a 20 μm-wide stripe with $SiO_2$ as the insulator. The cavity length is 900 μm. Both facets are coated with 3 pairs of $TiO_2/SiO_2$ dielectric multilayers which yield 90 % reflectance. Figure 2 shows the voltage versus current characteristics for LDs fabricated on a (311)A and a (100) substrate. The built-in voltage of the LD on the (311)A substrate decreases by 5 V compared with the LD on the (100) substrate. Light output versus current characteristics of the LD on the (311)A substrate are shown in Figure 3.

The measurement temperature range was from -68 °C to 25 °C under pulsed operation with a width of 200 nsec and a repetition rate of 1 kHz. This LD oscillated with a threshold current of 3.1 A at 25 °C and a wavelength of 501 nm.

In summary, tilted substrates have been shown to be effective for high-concentration acceptor doping and lowering the built-in voltage of LDs.


REFERENCES

[1] K. Ohkawa, T. Karasawa and T. Mitsuyu, Jpn. J. Appl. Phys. **30**, L125 (1991).

[2] R. M. Park, M. B. Troffer, and C. M. Rouleau, Appl. Phys. Lett. **57**, 2127 (1990).

[3] Y. Kawaguchi, T. Ohno and T. Matsuoka, Extended Abstracts of the 1992 International Conference on Solid State Devices and Materials, 345 (1992).


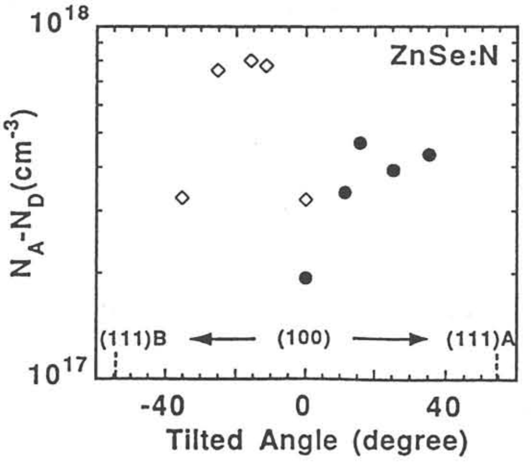


Fig. 1 Dependence of the net acceptor concentration of ZnSe layers on tilted angle of GaAs substrates.

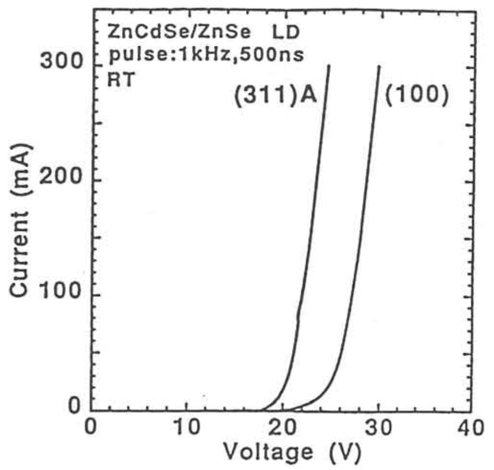


Fig. 2 Voltage-current characteristics of LDs on a (311)A and a (100) substrate.

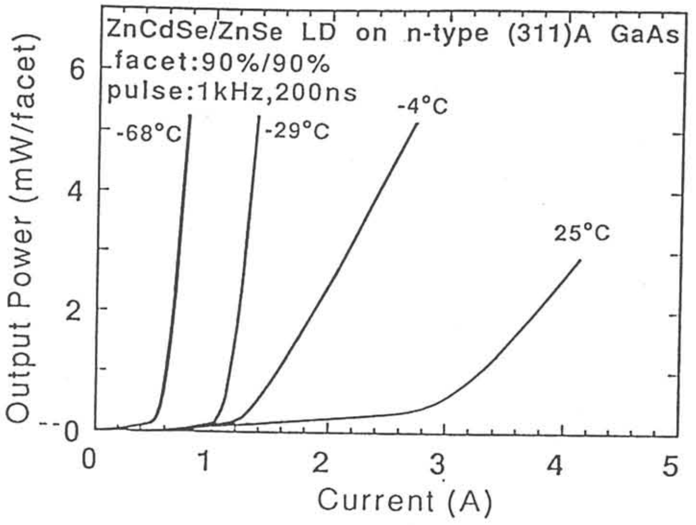


Fig. 3 Light output-current characteristics of an LD on a (311)A substrate.