The Effects of Selenium Doping on Performances of MOVPE Grown Compressively Strained (Al)GaInP Lasers

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Visible light source (Al)GaInP laser is finding applications in many fields such as optical data storage, barcode scanning, low-cost data transmission via plastic optical fiber, laser printers[1]-[4] and optical pumping of tunale Cr^{3+}-doped solid state lasers (hosts are alexandrite or LiSAF), but, to be well used in such fields, low threshold current densities of visible (Al)GaInP laser diodes are critically required due to the poor thermal-transport characteristic of AlGaInP. Because of the smaller conduction band offset of AlGaInP material system compared to that of AlGaAs, the electron leakage through heterobarrier in p-side was well known to take a big part of the total current leakage[5]. Both higher doping level in p-side and multi-quantum-barrier (MQB) structure are suggested to suppress the electron leakage[5]. In addition, laser structures with graded index (GRIN) barrier layers proved to be effective to confine carriers in active layers[6]. In this letter, we report the effecs of selenium doping in n-type cladding layers on the performances of compressively strained (Al)GaInP lasers.

Our laser wafers were grown by low pressure metal organic vapor phase epitaxy (LP-MOVPE). The substrates used were GaAs:Si (100), deliberately mis-oriented 6° toward the (111)A crystallographyic direction. SeH_2 and DMZn were respectively used as n-type and p-type dopants. In our work, except for the selenium-doping level (R, which is defined as the dilution level of SeH_2 by hydrogen before flowing into the reactor) in n-cladding layers, all orther parameters were kept constant. The details are as follows. The active region of laser structure consisted of a compressively strained 6-nm thick $Ga_{0.4}InP$ quantum well, sandwiched between two undoped 80-nm $(Al_xGa_{1-x})_{0.5}InP$ confinement layers. The cladding layers were made of $(Al_yGa_{1-y})_{0.5}InP$, each 1-μm thick and doped to a level of $0.1\text{-}1.0\times10^{18}$ cm^{-3}. On the top of the p-type cladding layer, a 80-nm p^+-$Ga_{0.5}InP$ barrier reduction layer and a 200-nm p^+-GaAs metal-contact layer were grown.

Several such laser wafers have been grown, which were selenium-doped to different levels in n-type cladding layer. We performed low temperature (4.2 K) photoluminescence (PL) measurements on all these wafers. The samples were excited by an Ar ion laser (wavelength: 514 nm) and the PL was spectrally resolved and detected by a monochromator with a cooled Ge detector and convententional lock-in electrical system. Fig.1 is the photoluminescence results. From fig.1, a narrow window of selenium doping level was obviously ditinguished in the range of 0.1 and 0.2, where the laser wafers show stronger PL intensities, narrower PL linewidths (FWHM).

64 μm wide broad area gain guided (GG) lasers based on these laser wafers have also been fabricated. For each R, by measurements of P-I curves of several GG lasers with different cavity lengths, we got the a minimum threshold current density (J_{thmin}) which experimentally corresponds to the threshold current density of a GG laser with cavity length over 1200 μm long. Fig.2 is the R-dependence of the minimun threshold current densities. Obviously, when R is inside the same window as shown in fig.1, the GG lasers have much smaller values of J_{thmin}. By [7], we also calculated the relation of peak gain and injection current for each R, which are shown in fig.3. It is seen the highest peak gain appears for R=0.15 which is inside the window mentioned above. We also found that the intrinsic optical loss is increased linearily with R as shown in fig.4, which seems within our expection.

It should be pointed out that these effects of selenium doping are repeatable (that means, the laser wafers with the same R showed the same performances, even if they were grown by our MOVPE system at different time) and so the existence of this window should be treated as intrinsic. The similar phenomenon was not founded for MOVPE grown tensibly strained (Al)GaInP lasers[8]. Based on this founding of the

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window described above, we have achieved high quality 670 nm (Al)GaInP SQW lasers, which have ultra low threshold current density of 238 A/cm^2, high characteristic temperature of 150 K, high quantum efficiency of 95.5%, record high output power of 3.11 W.

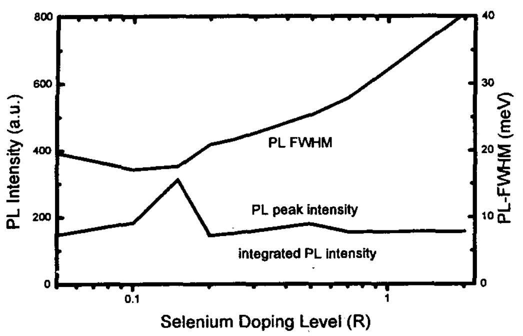

Fig.1 4.2K photoluminescence measurement

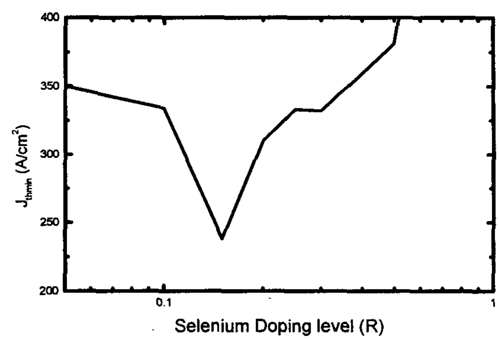

fig.2 R-dependece of the minimum threshold current density

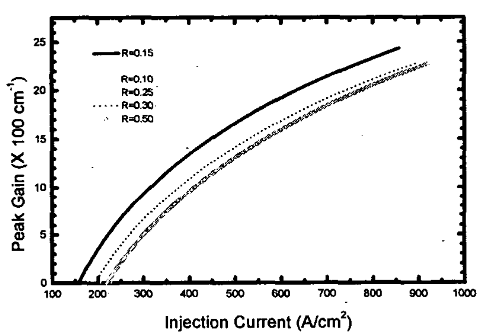

Fig.3 the peak gain for GG lasers with different R

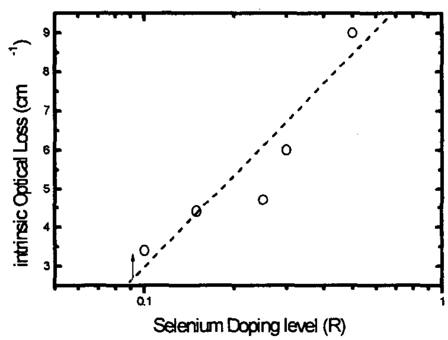

fig.4 the R-dependence of intrinsic optical loss of GG lasers

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