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B—3—8 Degradation Characteristics of $Ga_{1-x}Al_xAs$ Visible Diode Lasers

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$Ga_{1-x}Al_xAs$ visible diode lasers[1-5] are attracting a great deal of attention as light sources for optical information processing devices. Room temperature cw operation down to a wavelength of 714nm has been achieved.[3] Laser transverse mode has been stabilized using a channeled substrate planar (CSP) structure.[3] However, little work has been done on laser reliability[4-5], which is the most concern in practical use. In this paper, we report on the reliability and degradation mechanisms of these visible lasers.

Lasers with a CSP structure and a conventional planar stripe structure were used. A double heterostructure was formed by growing an n-$Ga_{0.4}Al_{0.6}As$ layer (Te-doped), a $Ga_{1-x}Al_xAs$ active layer (x=0-0.35), a p-$Ga_{0.4}Al_{0.6}As$ layer (Zn-doped), and a GaAs cap layer successively on a GaAs substrate. Life tests were performed under constant current cw operation at an initial light output power of 3mW/face.

Laser lives are plotted as a function of wavelength in Fig.1. The solid line is the envelope of the life data for facet uncoated lasers with an undoped active layer. A marked dependence of life on wavelength was found. The degradation proceeded faster for the shorter wavelength lasers.

A deteriorated laser facet is shown in Fig.2, with the oxygen Auger signal in the direction perpendicular to the junction superimposed on the electron-beam absorption image. The laser emitted at 744nm and was aged for 70hours. It was found that facet oxidation proceeded very rapidly in visible lasers compared with infra-red $Ga_{1-x}Al_xAs$ lasers[6]. This enhanced facet oxidation can be attributed to the high AlAs mole fractions in the composite layers and to the high photon energy emitted from the active layer.

Laser facets were coated with SiO_2 films in order to suppress facet oxidation. Special care was taken to avoid facet oxidation before and during the coating processes. The extrapolated lives obtained for the coated lasers are shown in Fig.1 by the dotted line. The lifetime of lasers with wavelength longer than 740nm were much improved by the facet coating. This shows that the lives of lasers in this wavelength region were dominated by the enhanced facet oxidation. On the other hand, no prominent improvement of laser lives was obtained for lasers in the 720-730nm wavelength region. This fact suggests that these shorter wavelength lasers deteriorate by other mechanisms which cause more rapid degradation.

Electron-beam induced current images of a laser before and after degradation are shown in Fig.3. The laser emitted at 720nm. Irregular shaped dark regions appeared after degradation. The irregular dark regions and/or well known dark line defects parallel to the <110> stripe edges appeared without exception after degradation in lasers in the below 730nm wavelength region. Pinning of the defects by appropriate impurity doping[7] may provide longer lives for this shorter wavelength lasers. Lasers with a Te-doped active layer were fabricated. A notable improvement in laser lives was obtained, as shown in Fig.1.

In conclusion, realization of long life visible lasers will be made possible by careful facet coating and by taking some measures, including doping in the active layer, to overcome degradation due to the formation of the macroscopic defects.

References

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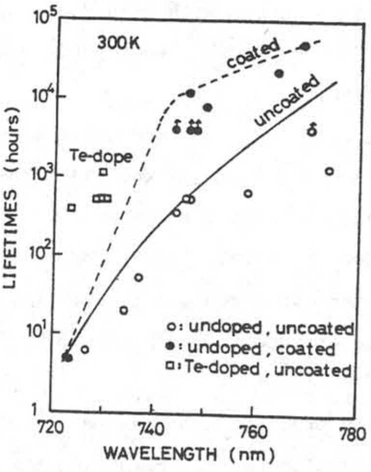

Fig.1. Relation between laser wavelength and lifetime. The arrows indicate lasers still operating. The solid line and dotted line show the envelope of uncoated laser lives and of coated laser extrapolated lives. The active layers of these lasers were not intentionally doped. The squares indicate uncoated lasers with Te-doped active layer.

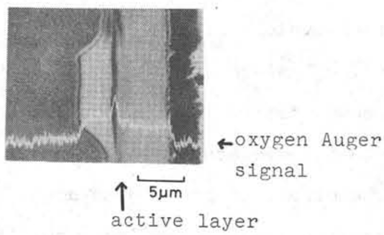

Fig.2. Deteriorated laser facet. The observation was made after sputter etching of the facet down to 99nm.

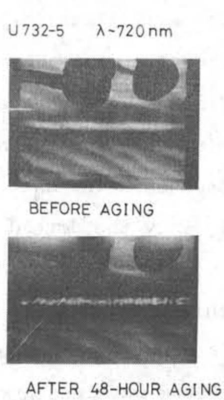

Fig.3. EBIC images of a laser before and after aging.