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Extended Defects in II-VI Blue Green Laser Diodes

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Early blue/green laser diodes based on ZnSe exhibited room temperature lifetimes of the order of a minute. Similar to the history of (Al,Ga)As lasers, the source of the degradation was the presence of extended crystalline defects. The early room temperature cw lasers exhibited defect densities, originating at the ZnSe/GaAs heterovalent nucleation event, of the order of $10^6 cm^{-2}$. Currently, laser diodes with CW lifetimes between 1 to 3 hours are reported to generally have a defect density of between $5x10^4$ to $1x10^5$ cm^{-2}. Plan-view TEM imaging of the degraded lasers identified the degradation as originating from patches of dislocation networks developed at the quantum-well region during lasing. The dislocation networks appeared to be nucleated at threading dislocations originated from stacking faults. Complexes of defects consisting of stacking faults, which are nucleated at or near the II-VI/GaAs interface, and associated threading dislocations, are the most commonly observed extended defects present throughout the separate confinement heterostructure (SCH) laser structures. Migration enhanced epitaxy (MEE) is effective in enforcing a 2-D layer-by-layer growth mode for GaAs; it was thus proposed that the 2-D growth mode of ZnSe on GaAs could be further facilitated by the use of the MEE technique (Gaines et al., 1993), and this technique was used as one step to achieve the defect reduction described in this paper. The growth of ZnSe-based SCH laser diodes begins with a 200Å thick (strained) ZnSe layer nucleated on the n-GaAs buffer. The next layer is 1500Å of ZnSSe, lattice matched to GaAs. Since extensive TEM studies have shown the extended defects to be nucleated at or near the ZnSe/GaAs interface, a systematic study of test structures consisting of a ZnSe nucleation followed by a 1 or 2 microns of ZnSSe were used to explore means to minimize extended defects. The same nucleation techniques were then employed for the growth of laser structures. For the test structures, the density of structural defects soon moved below the ability to use plan view TEM imaging, and etch pit counts became the primary evaluation procedure. Here we report an investigation of ZnSe/GaAs heterovalent nucleation, and describe the means for a consistent reduction in the density of the extended defects into the mid to low 10^3 cm^{-2} range over a significant portion of a 3 inch wafer. Etch pit counts, cathodoluminescence, and x-ray topography are used to evalutate the extended defects.

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