Fabrication and Characteristics of High Speed Implant-Confined, Index-Guided, Lateral-Current Injected, 850 nm Vertical Cavity Surface Emitting Lasers

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Tremendous progress has been achieved in development of vertical cavity surface emitting lasers (VCSELs) for high speed optical interconnects in high bit rate data transmission systems. Most of the devices are based on an oxide-confined structure, which has proven to provide low thresholds, good thermal resistance and good optical confinement. The oxide-aperture VCSEL design contains only one hetero-interface for current to pass through, lowering the p-contact resistance and reducing the lasing threshold voltage. The oxide also serves to electrically isolate the devices from each other. In this design, the oxide formed acts as an index guide having a different refractive index from that of the active layer. This serves to create laser emission with greater model coherence.

Although the selectively oxidized VCSELs have excellent device performance, there are still issues of control of oxidation rate and therefore of device reproducibility in situations requiring high process yields. The lateral oxidation rate depends on material and processing parameters, introducing variations into the final aperture size. For example, to illustrate the sensitivity of $Al_xGa_{1-x}As$ wet-oxidation rate to material composition, orders of magnitude variation in oxidation rate was observed for $0.84<x<1$. Variations in feature size will lead to difficulty in meeting stringent specifications required by envisioned VCSEL applications such as integration into CMOS circuits. Apertures formed by ion implantation have produced VCSELs with comparable device dc performance to oxide-confined apertures. The implant-apertured VCSEL offers the potential for a highly reproducible process, since the aperture feature is defined by photolithography. Historically, implant apertured VCSELs have had worse modal coherence than oxide-confined structures, due to the simultaneous optical and confinemental in the latter. However the addition of an index guide formed external to the active layer of implant apertured VCSELs can improve model coherence.

The structures were grown by low-pressure metalorganic chemical vapor deposition. Arsine, phosphine, trimethylgallium, trimethylindium, and trimethylaluminum were used as the precursors. Carbon tetrabromide and disilane were utilized as the p- and n- dopant precursors, respectively. The majority of the structure was grown at 760 ^{o}C except for the p lateral current injection, etch stop InGaP, and index guide layers, which were grown at reduced temperature in order to enhance the carbon doping in the p-LCI layers. Perfectly smooth morphology was obtained and there was excellent agreement between the calculated and experimental reflectivity spectrum. Secondary ion mass spectroscopy measurements confirmed the intended doping concentrations and demonstrated the low oxygen concentration in the AlGaAs layers despite the low growth temperature.

In this talk, we report the process integration and optimization of high-speed implant-apertured, index-guide, lateral-current-injection, dielectric-mirror GaAs quantum well vertical cavity surface emitting lasers has been demonstrated. Oxygen and helium implantation were used for aperture definition and extrinsic capacitance reduction, respectively. A negative resist lift-off and SF_6 based dry etch process were developed to pattern the SiO_2/TiO_2 dielectric mirrors. AuBe/Pt/Au and Pd/Ge/Pt/Au were employed for p- and n-ohmic contacts, respectively. The contact resistivities of mid-10^{-6} ohm-cm^2 were obtained for both contacts. GaAs/AlGaAs based 850 nm VCSELs fabricated with the optimal integrations exhibited small signal modulation bandwidths up to 11.5 Gb/s and an eye diagram generated at 12 Gb/s by a pseudorandom bit sequence (PRBS) of 2^{31}-1 was achieved with this process integration.

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