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Elimination of ErAs luminescence-quenching complexes from Er-doped AlGaAs native oxides

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Rare-earth-doped materials have been extensively studied as a means of realizing atomic-transition-based optical amplifiers that offer several advantages over direct semiconductor band-to-band transitions, including broader gain bandwidths, lower channel crosstalk, higher data rates, lower amplifier noise, and greater temperature insensitivity. We have previously shown[1] that wet thermal native oxides of AlGaAs offer a potentially viable host for optically-active Er^{3+} with advantages for monolithic integration with pump and signal lasers and the possibility for creating an oxide heterostructure waveguide[2] amplifier.

During wet oxidation of AlGaAs, when most As leaves the crystal, the probable formation of ErAs complexes in Er-implanted before oxidation (EIBO) samples creates non-optically active Er and "As quenching" of the photoluminescence (PL).[1] In this study, we demonstrate that this limitation is largely overcome in Er-implantation *after* oxidation (EIAO) samples. A 2 μm $Al_{0.3}Ga_{0.7}As$ layer capped by ~ 50 nm GaAs is grown by MOCVD. After cap removal, a 400 nm oxide is grown (450°C, 6 h). For EIBO samples, the cap is thinned to ~20 nm before implantation such that >99% of the total Er dose reaches the AlGaAs layer. Both EIAO and EIBO samples are implanted with 300 keV Er ions at a dose of 10^{15} cm^{-2}, giving a peak Er concentration of 0.22 at.% in the

oxide and 0.34 at.% in the semiconductor, respectively, as simulated by TRIM'98. Post-annealing is done via rapid thermal processing.

Pumped with an Ar^+ ion laser (488 nm, 280mW), the 300 K continuous wave PL signal intensity and lifetime of the EIAO sample are ~3.3X and ~5X larger, respectively, than measured for the comparison EIBO samples. The PL spectrum shows a peak at 1.531 μm with broadband emission of 50 nm FWHM. A lifetime as long as 7 ms is obtained from the EIAO sample annealed at 650°C for 2 min. The annealing temperature dependence of both PL intensity and lifetime will be presented. Er-Er pair ("concentration") quenching, which causes multi-exponential PL decay with $\tau<1.5$ ms for 10^{15} cm^{-2} dose EIBO samples, is virtually eliminated for 10^{15} cm^{-2} dose EIAO samples, indicating that still higher peak doping concentrations are feasible. By using multiple high-energy (≤2 MeV) implants to increase the dose while maintaining acceptable peak concentration levels to avoid Er-Er quenching,[1] calculations show that a practical Er-doped AlGaAs native oxide waveguide amplifier with monolithically integrated optical pumping may be achievable.

[1] L. Kou, D. C. Hall, C. Strohhofer, A. Polman, T. Zhang, R. M. Kolbas, R. D. Heller and R. D. Dupuis, IEEE J. Sel. Top. Quantum Electron. **8**, 880 (2002).

[2] Y. Luo, D. C. Hall, L. Kou, L. Steingart, J. H. Jackson, O. Blum and H. Hou, Appl. Phys. Lett. **75**, 3078 (1999).