Alternative−precursor growth of InGaAs/GaAs quantum dots for laser applications

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Tertiarybutylarsine (TBAs), an alternative arsenic precursor for the growth of compound semiconductor based optoelectronic devices, is of increasing importance due to its efficient pyrolysis and low hazardous potential. Growth of laser structures based on self−organized In(Ga)As/GaAs quantum dots (QDs), however, has not been studied in detail by now using TBAs. Here we demonstrate self−organized growth of coherent, monodispersed QDs with excellent optical and structural quality, being comparable to QDs grown with conventional arsine. Conclusive evidence of the high quality is provided by the first demonstration of TBAs−grown QD laser diodes with ultralow optical losses and threshold current densities.

Use of the comparatively temperature−stable AsH_3 for QD growth at typical temperatures around 500°C leads to a strong dependence of the effective V/III ratio on deposition temperature due to a pronounced variation of the AsH_3 decomposition. In contrast, due to the efficient pyrolysis of TBAs at low temperatures, V/III ratio and growth temperature can be varied independently. Moreover, using TBAs a wide range of V/III ratios can be covered without changing the monodispersive character of the QD size distribution. When using arsine, an undesirable change between monodispersed and bimodal size distribution is observed upon variation of the V/III ratio, leading to a reduction of peak gain and deterioration of the laser parameters.

The interesting wavelength for optoelectronic datacom devices is around 1.3 µm. Experiments were therefore conducted to tune the QD emission wavelength from initially 1.1−1.2 µm to larger values by overgrowing InGaAs QDs with Ga−rich InGaAs quantum wells previous to top barrier growth. The wavelength shift was found to scale with the In content of the overgrown InGaAs quantum well. The observations comply with simulations based on 8−band k·p theory. If TBAs is used in these experiments instead of arsine, a reduced tendency to defect formation in the highly strained QD layers is observed.