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Rapid thermal annealing of GaAsBi/(Al,Ga)As multiple-quantum-well structures

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Thermal annealing is widely used to tune the optical and structural properties of epitaxially grown III-V heterostructures. However, the response of GaAsBi multiple-quantum-well (MQW) systems to rapid thermal annealing (RTA) remains insufficiently understood, largely due to the complex interplay between Bi redistribution, interface intermixing, and defect evolution. In this work, we systematically investigate the effects of RTA in the 550 - 750 °C range on GaAsBi/GaAs and GaAsBi/AlGaAs MQWs with varying barrier thicknesses and compositions, enabling a direct comparison of design-dependent annealing behaviour.

Our results reveal that the impact of RTA is strongly governed by barrier design. GaAsBi MQWs structures incorporating narrow 7 nm GaAs barriers exhibit a degradation of room-temperature photoluminescence (PL) across all annealing temperatures. Although atomic force microscopy and X-ray diffraction measurements show preserved surface morphology and structural periodicity, the PL intensity decreases significantly, consistent with Bi redistribution that reduces the barrier thickness and weakens carrier confinement. In contrast, GaAsBi MQW with wider GaAs or AlGaAs barriers exhibit a qualitatively different response. For these structures, annealing up to 700 °C leads to a clear enhancement of room temperature PL intensity and reduced thermal quenching, attributed to a redistribution-driven reduction of alloy disorder and decreased density of point defects after RTA.

For all investigated structures, annealing at higher temperatures leads to the disappearance of the topmost QW and the formation of Bi quantum dots (QDs), as confirmed by transmission electron microscopy. Low-temperature cathodoluminescence measurements reveal sharp QD-like emission features; however, no corresponding PL signal is observed in the 4 - 300 K range, likely due to the low QD density or inefficient carrier capture into these states.

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