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Crystal growth via metal-organic vapor phase epitaxy of quantum-cascade-laser structures composed of multiple alloy compositions

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Abstract: Metal-organic vapor phase epitaxy (MOVPE) is suitable for the growth of superlattice (SL) structures composed of multiple alloy compositions. By taking advantage of this flexibility of MOVPE, we have demonstrated the crystal growth of varying-layer-composition, tapered active-region quantum cascade lasers (TA-QCLs) for which the barriers in the active region gradually increase in height from the injection barrier to the exit barrier, resulting, in turn, in a dramatic suppression of carrier leakage. One stage of the TA-QCL structure consists of seven different alloy compositions. The composition and growth rate of each layer are calibrated by using high-resolution X-ray-diffraction rocking curves. Very narrow mid-infrared absorption peaks (~ 30 meV full width at half-maximum) have been achieved, at room temperature, from 20 periods of $Ga_{0.4}In_{0.6}As/Al_{0.56}Ga_{0.44}As$ SL structures, at the designed wavelength. Transmission-electron-microscope analysis of the QCL structure confirms extremely accurate thickness control and layer uniformity for layers as thin as 1 nm.