Investigations of C-band InAs/InP Quantum Dots Grown by Molecular Beam Epitaxy Using Indium Flush Technology

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High-quality InAs/InP quantum dots (QDs) emitting at 1550 nm are indispensable to achieve high-performance telecom C-band lasers. In general, a longer emission (>1550 nm) with broad spectral character has been obtained with InAs/InP QDs. Here, we investigate the use of the indium-flush (IF) method to shorten the emission wavelength and improve the optical properties of InAs/InP QDs. By exploiting IF, the full-width at half-maximum of the room-temperature QD photoluminescence spectra was narrowed from 89.2 meV to 47.9 meV, with a blue shift of 300 nm (from 1824 nm to 1522 nm). The scanning transmission electron microscopy and electron energy loss spectroscopy results reveal the atomic-level mechanism of the IF method which uniformly modify the height of InAs/InP QDs in a controlled manner and form distinct Al-rich and In-rich regions. A slight reduction of the strain at the QD/capping layer interface has also been found for the sample with indium flush. Finally, InAs/InP (001) QD lasers with the IF method have been demonstrated with a low threshold current density per QD layer of 106 A/cm^2. We demonstrated both in terms of mechanism model and device performance that the IF method could serve as a robust strategy for the growth of high-performance C-band InAs/InP QD lasers via molecular beam epitaxy.

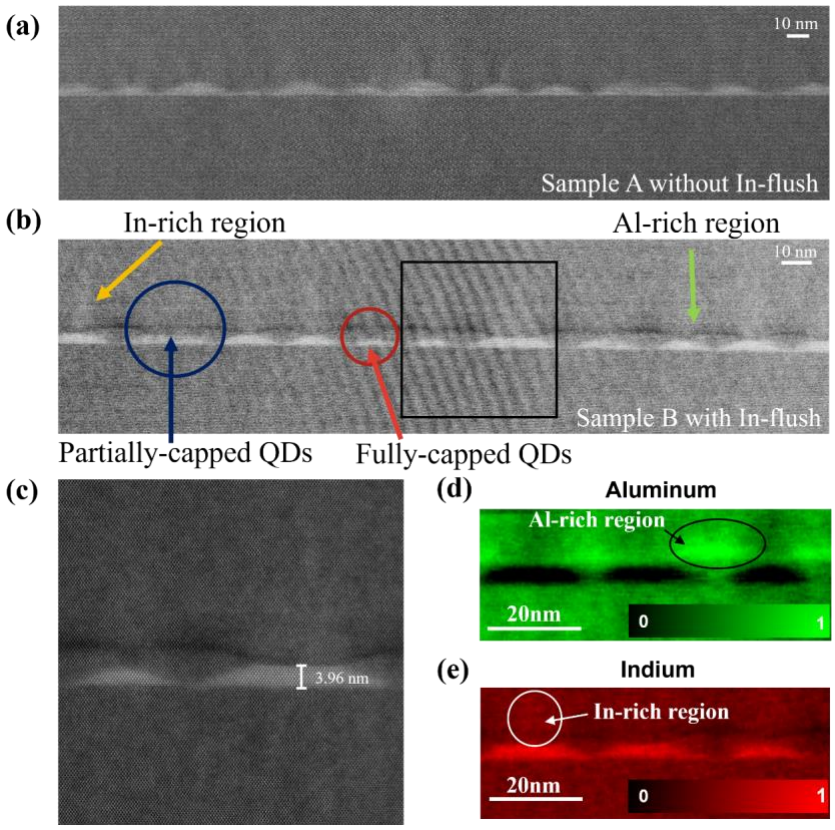

Figure 1. HAADF images of QD morphologies and adjacent layers of the sample A (without IF) in (a) and the sample B (with IF) in (b). (c) High-resolution HAADF image of the area highlighted by a black box in *b*, showing fully-capped and partially-capped QDs. Individual electron energy loss spectroscopy maps of the sample with IF, showing the relative distribution of (d) Al (green intensity channel) and (e) In (red intensity channel).

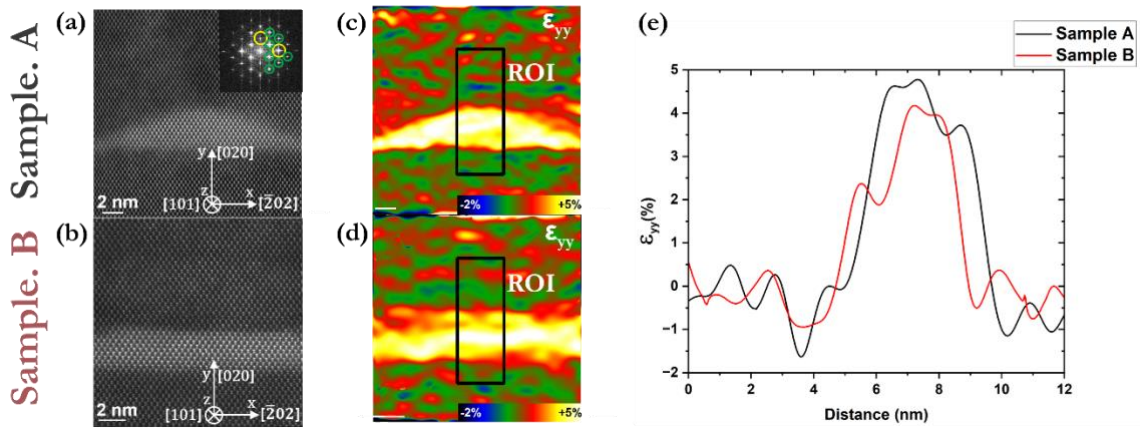

Figure 2. High-resolution high angle annular dark field images of the InAlGaAs/InAs QD/InAlGasAs interface along the [101] axis, as depicted in the Fourier transform (FFT) inset (a), in (a) sample A and (b) sample B. The vertical εyy strain maps calculated using geometrical phase analysis from the FFTs of the experimental images in (c) sample A and (d) sample B (e) The vertical εyy strain profiles for sample A and sample B along the (200) growth direction of the InAs (QD) on the InAlGaAs matrix averaged along the region of interest highlighted by a rectangle box in (c) and (d), respectively.