Strain and composition variations in the (211)B GaAs/InAs quantum dot heterostructure

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InAs QDs grown on high-index GaAs (*h*11) surfaces seem to exhibit superior optical properties compared to the usual QD growth on GaAs (001), due to their sizeable piezoelectric field, which can be efficient in nano-photonics and quantum computing. However, the morphology of the QDs and their strain state and chemical composition, influence the light emission and absorption, the lasing efficiency, and other optoelectronic properties of QD-based devices. To this end, we have explored the nanostructure, the strain properties, and the related chemical composition of buried InAs QDs grown on (211)B GaAs surface employing both quantitative HRTEM techniques and elastic strain field simulations by the Finite Elements Method (FEM).
Local strain measurements by the geometric phase analysis (GPA) method showed that pyramidal buried QDs were pseudomorphically grown on GaAs. Assuming a plane stress state of the QDs, we found a systematic increase of the local GPA strain (decrease of the elastic strain) from the base area to their apex region (Fig. 1). Subsequently, we calculated the chemical composition of the QDs, which exhibited an indium composition gradient along the growth direction, implying gallium segregation inside the dots. While the gradual increase of indium concentration is a common trend for all QDs, various In-content maxima (0.50 to 0.92) were measured at the apex area of different QDs. This variation can be attributed to the corrugated form of the (211) surface, resulting in local compositional fluctuations of the wetting layer at the nucleation sites of the QDs. Therefore, gallium segregation is already involved at the onset of the Stranski-Krastanow QD growth. Photoluminescence (PL) and *μ*-PL experiments, as well as simulations of the QDs' transition energies, showed variations in their emission energy, which comply with the graded In-content along the growth direction revealed by the quantitative HRTEM analysis and FEM simulations.

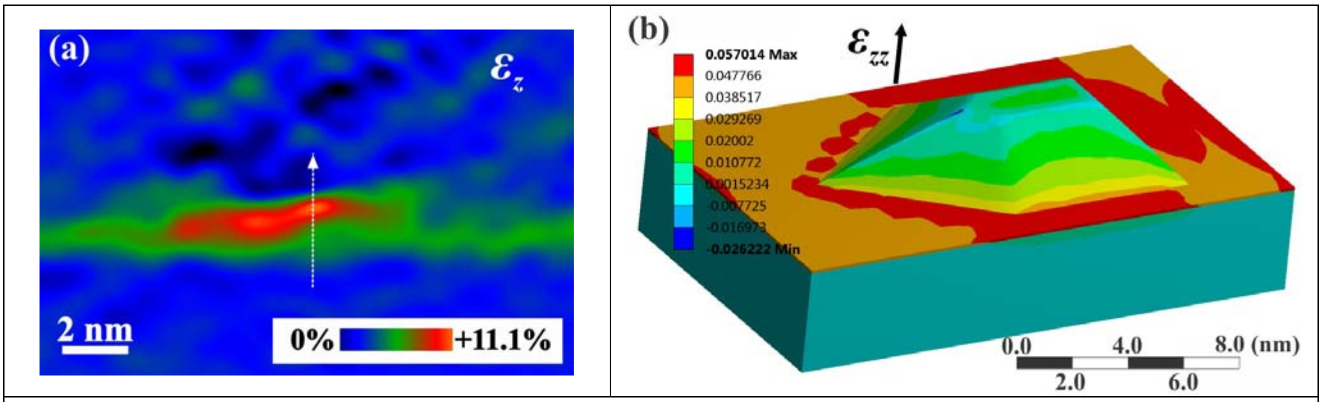

Fig. 1. (a) 2-D GPA strain map along the growth direction, illustrating the gradual increase of the ε_z strain inside an InAs QD with the GaAs lattice taken as the unstrained reference. (b) 3-D FEM simulated ε_{zz} elastic strain in an InAs QD model, showing gradual relaxation from the base toward the apex of the QD.

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