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Determination of the critical growth rate and growth temperature for group-III elements segregation using two exchanges kinetic model

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High-performance optoelectronic devices such as lasers, light emitting diodes (LED), solar cells, and detectors can be fabricated based on the complex quantum structures of III-V semiconductors. Quantum structures such as quantum wells (QW), quantum dots (QD), and superlattices can be grown with high quality using molecular beam epitaxy (MBE). However, the interface composition abruptness is a challenge due to the surface atom intermixing. The composition asymmetry in the quantum structures leads to the non-abrupt electronic band alignments that change the optoelectronic device properties. For the growth temperature below 600oC, atomic arrangement in the crystal is determined by surface or near-surface processes and atoms cannot rearrange after burial. However, due to the surface mobility, atoms can displace on the growing surface. The increase of the surface mobility leads to the reduction of the growth defects; however, it may cause the so-called "surface segregation" that is the exchange between the sub-layer atoms with the impinging atoms on the growing surface. Surface segregation of atoms is driven by the differences in their binding and elastic energies. Several experimental and theoretical studies indicate that the group III atoms with weaker bond strength segregate to the surface, and therefore, it is expected to see more segregation for In atoms in comparison with Ga Atoms for similar growth conditions. Experimental results on the well known InGaAs/GaAs system show an Indium surface enrichment due to In segregation. A similar behavior has been observed for In atoms surface segregation in InGaAs QDs embedded in GaP matrix. We studied the concentration profile of the group-III atoms for different growth parameters using the two exchanges kinetic model and determined the critical growth temperature and growth rate regions for the growth of structures with less than 10% segregation of group-III atoms. For instance, Figure 1 illustrates the growth rate and the growth temperature regions for InAs/GaAs and GaAs/AlAs heterostructures, in which the segregation rate is less than 10%. The kinetic model results also imply that the growth temperature threshold for segregation of Ga-atoms at the normal interface into the next AlAs layer occurs at higher temperature in comparison with the In-atoms segregation into the adjacent GaAs layer.

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