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Morphological and compositional interface stability of metastable ternary and quaternary (Ga,In)(As,Sb) quantum wells

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(Ga,In)(As,Sb) semiconductor alloys have attracted interest as active materials in optoelectronic devices operating in the 2-3 μm wavelength range. Requirements for high performances in laser diodes are perfect two-dimensionally grown quantum well structures with low interface roughness and intermixing. Recently, we have proposed a refined method for reliable and systematic characterization of semiconductor interfaces: a phenomenological model based on sigmoidal functions is established describing quantitatively the interface profiles in combination with detailed analysis of (002) dark-field and high-resolution TEM images. The width L of the interface, which is deduced from the best fit of the experimental contrast with calculated profiles, describes the chemical sharpness of the transition [1,2].

In the first part of the talk, we present results on the influence of epitaxial stresses on the interface stability by comparing almost lattice-matched InAs/GaSb layer structures [3] with (highly) strained (In,Ga)As/GaSb quantum wells. The role of tensile strain character will be emphasized that is totally different to the (In,Ga)As/GaAs case under compressive strain. Additionally, the quantum well thicknesses are varied to identify the critical layer thickness as the morphological instability limit [4,5]

In the second part, non-equilibrium quaternary (In,Ga)(As,Sb) alloys are introduced to discuss the effect of the miscibility gap and phase separation on the interface structure. In spite of the thermodynamic metastable condition, a homogenous alloy composition along the quantum wells as well as smooth and sharp interface morphologies are obtained as indicated by small L values of interface profiles of the individual elements. Remarkably, a sharpening of the interface profiles is detected after annealing instead of an expected broadening due to diffusive intermixing. These results are explained in conjunction with the miscibility gap, which acts to maintain the compositional discontinuity and thus to support the interface stability. Furthermore, we discuss this interface phenomenon in comparison with a similar behavior that we found in the non-equilibrium dilute (In,Ga)(N,As) system.

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