Surface segregation in "W"-type quantum well heterostructures revealed by atomic resolution STEM

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III-V semiconductors have a large variety of applications. The formation of quantum well heterostructures (QWHs) is possible by substituting atoms on both sub lattices. "W"-type QWHs ("W"-QWHs) consist of combination of a GaInAs-QW (electron QW), a GaAsSb-QW (hole QW) and a GaInAs-QW (electron QW) grown on GaAs by metal organic vapour phase epitaxy. Due to the shape of the resulting band structure, these "W"-QWHS are a promising candidate for type-II laser application at 1.3m [1] which is an interesting wavelength for telecommunication. Since the recombination of charge carriers takes place across the interfaces of the QWs, these are of special interest for device performance. Generally, a variation of atomic structure and composition influences the optoelectronic properties, especially the bandgap is tuneable. Optimization of device performance is possible by an efficient interplay of theoretical considerations, growth refinement and optical as well as structural characterization. Structural characterization with atomic resolution can be carried out by aberration corrected scanning transmission electron microscopy (STEM).

The investigation of conventionally prepared "W"-QWH samples is realised by high angle annular dark field STEM using a double aberration corrected JEOL JEM 2200FS. A quantitative evaluation to gain atomically resolved information about the composition of the "W"-QWH is accomplished by an intensity comparison to contrast simulations [2]. Contrast simulations are performed using the software package STEMsalabim [3] based on the multi slice method and considering thermal diffuse scattering, geometric aberrations as well as chromatic aberration. The resulting intensity in STEM images is not only influenced by the composition of the "W"-QWHs, but among others surface relaxation and cross scattering give rise to experimental challenges.

Analysing the obtained composition profile of the "W"-QWH, surface segregation was found to play an important role during growth and especially for the formation of interfaces. To model surface segregation in III-V alloys, several models have been proposed before [4, 5] and are used here to describe the surface segregation for "W"-QWHs as well as for separately grown single QWs of GaInAs and GaAsSb grown on GaAs. We find that the surface segregation in the "W"-QWH where QWs are grown on top of each other is different from the one found for single QWs grown on pure GaAs. To gain further understanding of this finding, GaInAs-QWs with systematically varied pre offer of Sb are grown and analysed with respect to the present surface segregation. By this, the influence of already present Sb on the surface segregation is revealed.

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