ADVANCED METHODS FOR STRAIN MEASUREMENT IN CRYSTALLINE NANOMATERIALS: APPLICATION TO MULTILAYER INALGAP QUANTUM DOTS FORMED ON HIGH-INDEX (11L)GAAS SUBSTRATES

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A complex integration of multiple strained heterostructures within the devices is the continuous trend in the modern semiconductor technology. The need for a control over their strain properties promoted the development of several methods based on transmission electron microscopy (TEM). These include dark-field electron holography (DFEH) and moiré-based technique by specimen design (MoSD) that have some specific advantages with respect to the other methods.

DFEH is a technique based on the interference of two parts of the diffracted electron wave, one of which crosses an area of interest and the other a reference area. The quantitative analysis of the interference fringe distance variation allows strain mapping in the area of interest. In a HR mode, a distance between the fringes can be adjusted to 1-2 Å that ensures a subnanometer spatial resolution. HR-DFEH requires a simple geometry of the specimen with a constant thickness over 200 nm large area and the use of two biprisms.

MoSD is a technique which applies a judicious design of specimen geometry while experiments can be carried out on the most basic electron microscope and in the usual imaging modes. The sample is prepared of two superimposed lamellas rotated one with respect to the other that allow the formation of controlled moiré patterns for general monocrystalline structures in cross-section and at specific sites. One lamella is prepared of known undistorted material which serves as a reference. By applying moiré image analysis, strain is measured and mapped with respect to such well-defined reference that ensures high accuracy. MoSD allows a nanometer resolution, \(10^{-4}\) precision and over µm-large field of view.

Here, we apply these methods for the strain analysis within the laser-diode structures grown on high–index (118), (223) and (112) GaAs substrates by metal–organic vapor phase epitaxy. The active medium of the structures contains multiple tensile strained \(\text{In}_x\text{Ga}_{1-x}\text{P}\) quantum wells and \(\text{In}_x\text{Al}_{y}\text{Ga}_{1-x-y}\text{P}\) barriers which are sandwiched between several µm-thick GaAs-matched InAlGaP layers. We will make evident the formation of islands (quantum dots) within the active medium and discuss the impact of the substrate orientation on their parameters.

\textbf{Keywords:} electron holography, moiré by specimen design, strain measurement

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