Investigation of gallium-related defects in III/V epitaxial layers

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III/V materials are among the most common materials for the production of IR detectors. Gallium and indium droplets in MBE grown material are long-time known to be a major cause for decrease in detector operability (percentage of good pixels). In this work we present the investigation of gallium-related defects formed in an InAs/GaSb strained layer superlattice (SLS) structure. The SLS structure allows us to understand, in details, the mechanism in which the defect is formed and evolves.

Based on TEM analysis shown in figure 1 and other results (AFM, SEM, cross-section EDS mapping), we conclude that after a gallium droplet reaches the epilayer, it etches and dissolves several hundreds of nanometers below its landing point. Gallium from the droplet migrates sideways on the surface (at different rates along the [01-1] and [011] directions) for few microns, increasing temporarily the growth rate of the epilayer around the droplet and changing its composition (figure 1c). The incoming fluxes together with the dissolved material enrich the Ga droplet with Sb, As and In. In our growth conditions, the Ga droplet top surface solidifies, forming a GaAs shell [1]. High threading dislocation density is formed in the InAs-GaSb SLS grown on such surface due to the large mismatch between the SLS and the GaAs shell. The InGaAsSb solution inside the droplet separates, at some point, to the thermodynamically stable InSb and GaAs phases. In some parts of the core we see pure gallium that probably solidifies only when the sample is cooled down.

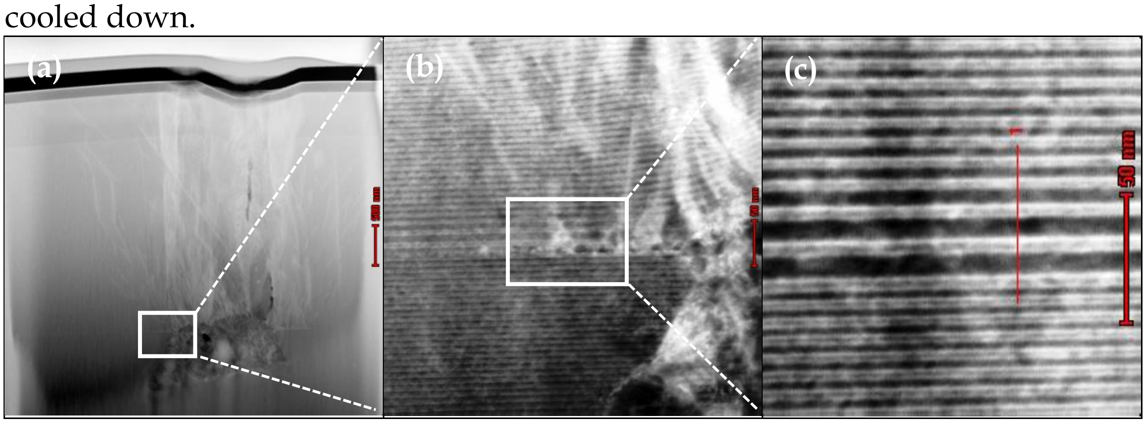

Figure 1. TEM cross section images of the Ga-related defect. (a) Cross section of the entire structure from the bottom of the defect to the epi-layer surface. (b) Higher magnification of the highlighted area in figure 1a showing the details of the growth disruption due to the defect. (c) Higher magnification of the highlighted area in figure 1b showing the abrupt change in the growth rate for several SLS loops.

[1] K. Reyes, Phys. Rev. B **87**, 165406 (2013).

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Supplementary Pages

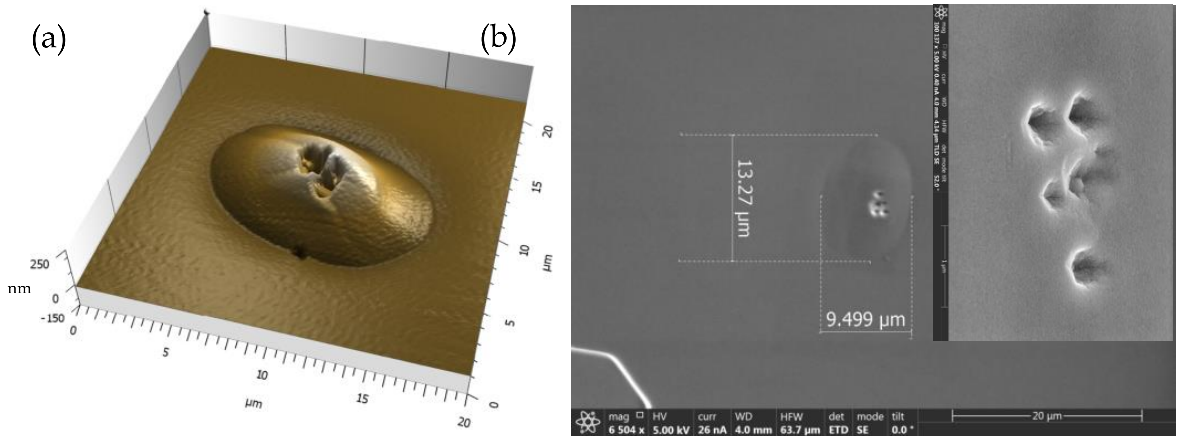

Figure 2. (a) AFM measurement of a typical defect. The length of the defect in the [0-1-1] direction is in the order of 10-15 µm while the length in the perpendicular direction [01-1] is always shorter (probably due to lower ad-atom mobility at this direction in this material) (b) SEM images of the defect shown in figure 1. The pits in the center of the defect are seen also in the TEM cross section.

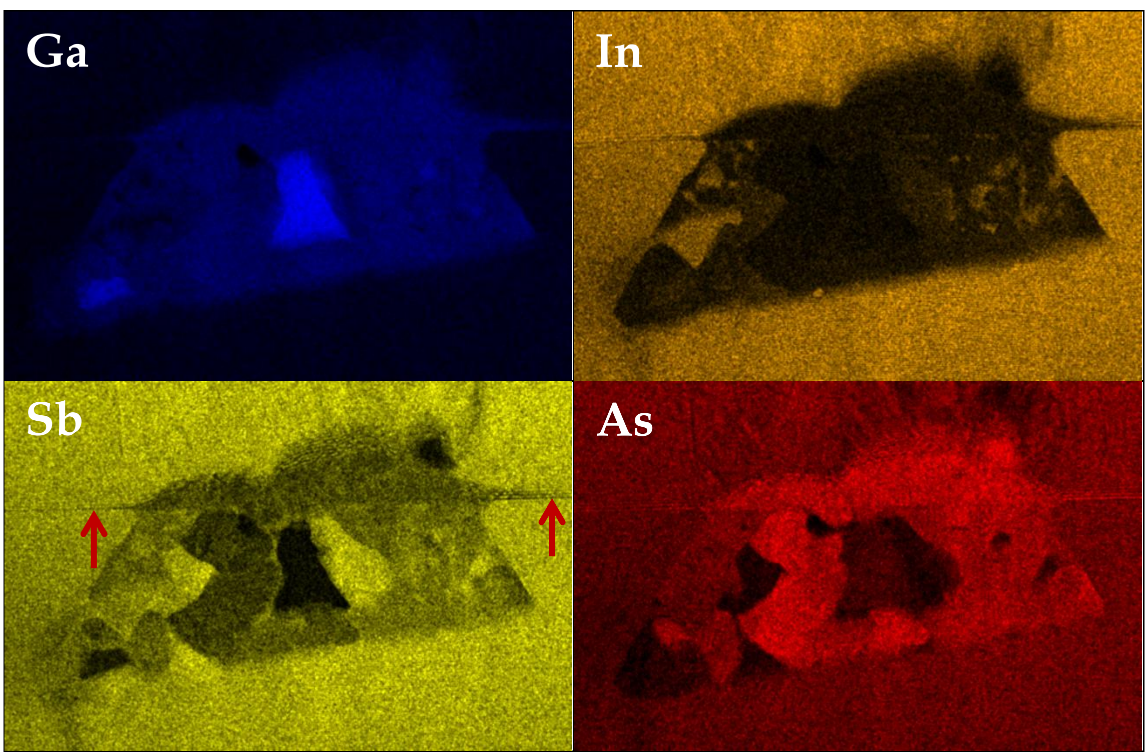

Figure 3. TEM EDS mapping images of the sample shown in figure 1. Note that in the center of the defect there is practically pure Ga and around it we can see mainly GaAs and some InSb although our structure is InAs/GaSb. The two red arrows indicate the growth front at the moment of the Ga droplet landings. The highlighted layer there is Ga rich due to gallium migration from the droplet.