Overgrowth study of back-bonded III-V semiconductor membranes

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In the last decade, freestanding semiconductor nanomembranes have been established as promising novel class of two-dimensional semiconductor structures. Such structures have been used to form hybrid nanomaterials, constructing devices for optical applications as well as flexible electronics.

In this work, we investigate the overgrowth behavior of a virtual substrate based on a completely released, wrinkled and in-place bonded GaAs/InGaAs/GaAs membranes. The virtual substrate was obtained by molecular beam epitaxy (MBE) growth of the heterostructure on an AlAs sacrificial layer over a GaAs (001) substrate. In a second fabrication step, the heterostructure structure is release by selectively removing the AlAs sacrificial layer, cleaned and re-introduced into the MBE, where it serves as template for growth. After atomic hydrogen cleaning, we deposited 10-nm thick $In_xGa_{1-x}As$ layers varying the Indium content from x=0.05 to x=1.

Samples are characterized using atomic force microscopy, scanning electron microscopy, 3D reciprocal space mapping obtained by gracing incident x-ray diffraction and photoluminescence measurements.

Results from microscopy show a flat InGaAs layer growth up to x=0.4 on the membranes, whereas layers on GaAs already show island and dislocation formation at x>0.3. Furthermore, we observe the formation of bubbles in the membrane for higher Indium content as well as preferred material migration and accumulation on top of wrinkles. The shift in the critical thickness for island formation is associate to the change in the lattice parameter of virtual substrate compared to bulk GaAs. Furthermore, the membrane acts as compliant substrates This assumption is strongly supported by the x-ray diffraction experiments indicating coherent crystal growth up to x=0.4.

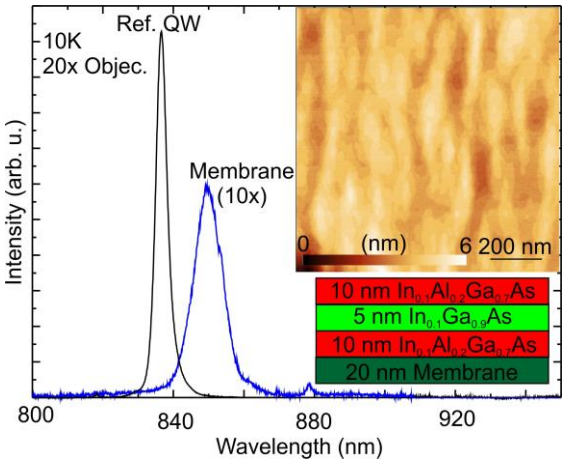

Fig. 1: Photoluminescence spectrum obtained from an InAlGaAs/InGaAs/InAlGaAs quantum well grown on a released and relaxed membrane or a GaAs (001) substrate as reference. The upper inset shows the AFM topography of the quantum well on the membrane, the lower the grown structure.

To demonstrate the ability to grow optical or electric active structures on membranes, we deposited a nominally unstrained InAlGaAs/InGaAs/InAlGaAs quantum well on top of a released wrinkled membrane. From the observed red shift photoluminescence signal (see Fig. 1) from this quantum well compared to a reference grown on GaAs (001) wafers, we conclude that the quantum well on the membrane is less or not strained compared to structures grown on bulk GaAs substrates.

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