On the Origin of Hillock Formation during the Growth of InGaAs/InAlAs on InP(111) Substrate

I. Sadeghi,[a] A. Pofelski,[b] G. A. Botton,[b] Z. R. Wasilewski [a,c-e]

[a] Department of Electrical and Computer Engineering, [c] Department of Physics and Astronomy, [d] Waterloo Institute for Nanotechnology, [e] Institute for Quantum Computing, University of Waterloo, Waterloo, ON, Canada
[b] Department of Material Science and Engineering, McMaster University, Hamilton, ON, Canada,

InAlAs/InGaAs growth on polar InP(111) wafers offers physical properties of interest for optoelectronic devices. For instance, strain-induced internal piezoelectric field in the [111] orientated heterostructures can be useful for applications operating at the 1.55 µm wavelength [1]. However, growth on (111) substrates is much less understood than that on the conventional (001) substrates. Strong surface roughening with high density of hillocks and pits is the primary challenge for growth on (111) substrates.

Previous studies mainly focused on the surface morphology of the structures grown in [111] direction with less attention on the underpinning of the hillock formation [2]. In this study, scanning transmission electron microscopy (STEM) was used to elucidate the origin of the hillocks and surface roughening on singular and vicinal (111) surfaces. STEM analysis showed that the hillocks on singular (111) surfaces are formed due to the underlying stacking faults and twins. Observed strong suppression of twins and consequently hillocks on vicinal (111) surfaces (Fig. 1) is believed to result from minimizing (111) island formation through step flow promotion, as discussed in Ref. [3]. Since stacking faults and twins are caused by the local insertion of one monolayer of wurtzite (W) phase between two zinc blende (ZB) phases, suppression of phase instability between ZB and W structures is the most important challenge to overcome. Compared to the near lattice-matched growth of AlGaAs on GaAs(111) substrates [4], the difficulty is further compounded for (In,Al,Ga)As growth on InP(111) substrates due to the large bond length differences between InAs, AlAs, GaAs and InP.

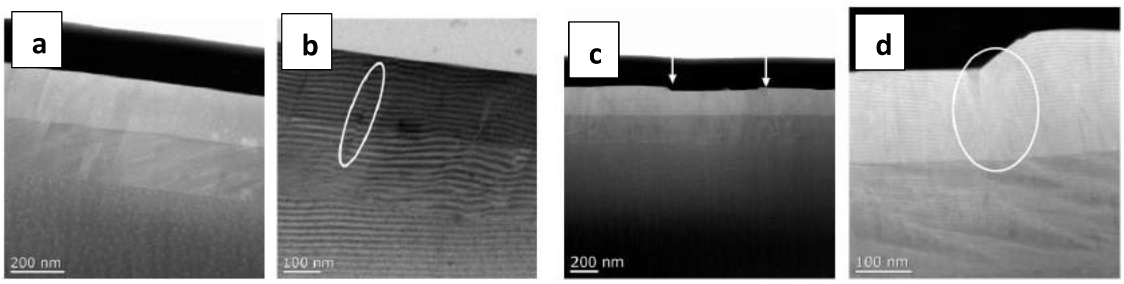

Fig.1: STEM images of the InGaAs/InAlAs structures grown at 460°C on a) and b) vicinal and c) and b) singular (111) surface. The striations in Fig. b are the Moire fringes which are indicative of strain variations in InGaAs due to compositional nonuniformities. A stacking fault and a twin are circled in Fig. b and d, respectively. Arrows in Fig. c show hillocks on the surface.

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+ Author for correspondence: zwasilewski@uwaterloo.ca