InAlAs/InGaAs Growth on InP(111)A and InP(111)B Substrates with Varying Substrate Offcut Angle

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InAlAs/InGaAs growth on polar InP(111) wafers offers physical properties of interest for optoelectronic and spintronic applications. However, growth on the (111) wafers is much less understood than that on conventional (001) substrates. Strong surface roughening with high density of hillocks and pits is the primary challenge for the growth on (111) substrates. Growth on offcut substrates may promote step-flow growth mode and avoid hillock formation [1]. Although growth on such substrates have been reported, the systematic study on the optimization of such offcut angle is lacking.

In this work the influence of substrate misorientation on the surface morphology of InGaAs/InAlAs on InP(111) was studied. We grew on wafers with rounded by chemo-mechanical polishing edges. Such surface bowing at the wafer edge exposes vicinal surfaces with monotonically varying effective offcut angle and the entire range of atomic step crystallographic orientations. The epitaxial structures consisted of InAlAs buffer layer followed by InGaAs layer. Grown wafers were analyzed using Nomarski DIC microscopy, atomic force microscopy and surface profilometry. The optimum As overpressure for the growth on (111)B and (111)A was found to be $6\times P_{min}$ and $12\times P_{min}$, respectively. Here P_{min} stands for minimum As overpressure ensuring As stable surface reconstruction during GaAs growth on (001)GaAs substrate at 580°C, using equivalent group III flux. It was also found that for growth on (111)B the optimum growth rate can be higher than that for the growth on (111)A; 1 Å/s compared to 0.5 Å/s. There is a range of surface orientations, particularly well-defined for (111)B (Fig. 1), which promotes smooth surface morphology. The width of such smooth region depends on the azimuth around the wafer. At its widest, this smooth region corresponds to a range of surface offcuts of 4.5°-12.5°. A much smoother surface was obtained on (111)B substrate.

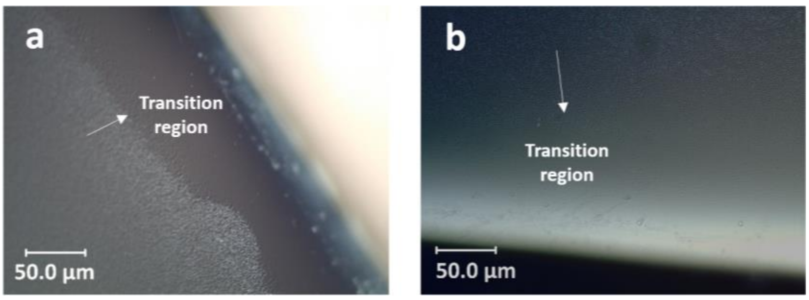

Fig. 1: Representative Nomarski images of the grown layers on a) (111)B and b) (111)A substrates at optimum growth conditions taken at the wafer edge.

[1] C.D. Yerino, B. Liang, D.L. Huffaker, P.J. Simmonds, M.L. Lee, J. Vac. Sci. Technol.B 35(1), 2017.

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Supplementary Page

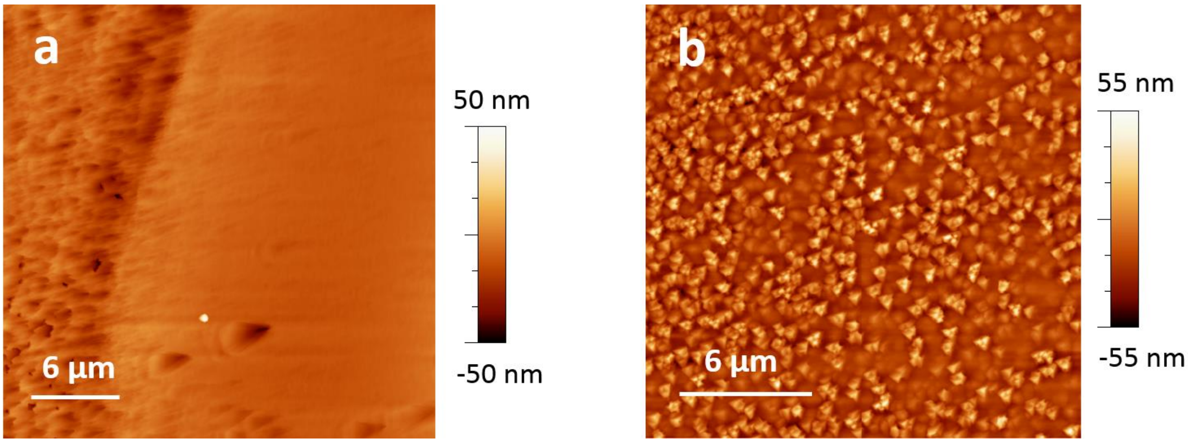

Fig. S.1: AFM height mode images of the grown epilayers on the exact a) (111)B and b) (111)A. The panel (a) shows the transition between the rough and smooth regions.

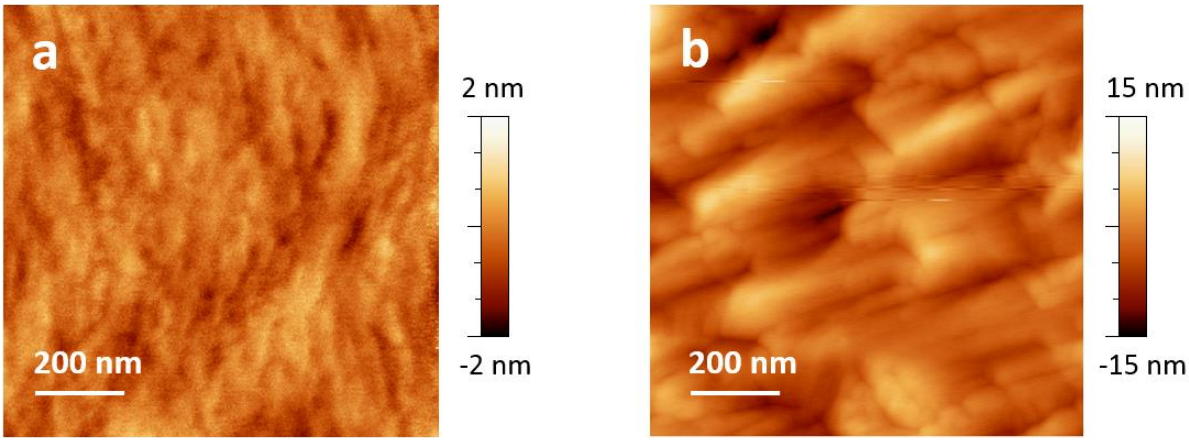

Fig.S.2: AFM height mode images of the grown epilayers of a) (111)B and b) (111)A. Images are taken at the optimum vicinal surfaces region.