Growth Habit Control of Epitaxial Lateral Overgrown InP on Si Substrates by MOCVD

Phil Mages, Nick Julian, Chong Zhang, Larry Coldren, Steve Denbaars,
John Bowers *ECE & Material Science Departments, UCSB*

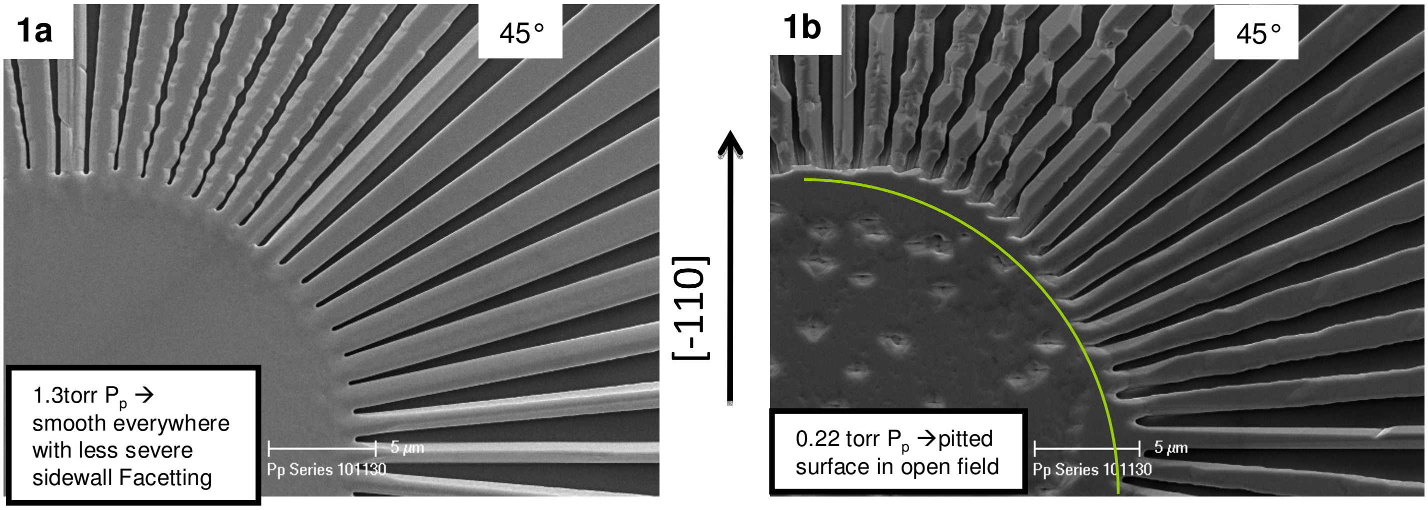
In this work we revisited the oft-attempted idea of Epitaxial Lateral Overgrowth (ELO) of InP on Si. Owing to the large number of failed attempts at this goal in the past, we have refocussed our efforts on a few key growth and geometric relationships that seem to be held in common between InP-on-Si and the more successful c-plane III-Nitrides on sapphire ELO system. In contrast to most past attempts we do not focus initially on the all-important lateral/vertical growth ratio. Instead we consider the creation of an ELO film from the perspective of four key phases: Nucleation within the windows; Cresting of the III-V to the height of the dielectric; steady-state Lateral Propagation; and Film Coalescence. Each phase has different requirements for the sake of reducing defects, propagating laterally and producing a smooth film. Throughout this whole process we focus most closely on the detailed crystal habit of the growing films. We do this because in the past it has been found that lateral growth is easily stalled at some point during attempts to extend growth laterally until coalescence[1]. It has been found that the growth habit or cross-sectional faceting of the ELO material is strongly correlated to the orientation of the stripe opening [2]. We find that both of these results are due to the tendency of certain growth-limiting facets to form and have located parameter windows in which we can control the growth habits of the films during each phase of the ELO process. Namely, we present the results of varying stripe/mask geometry and orientation and discuss the most significant growth condition effects on the morphology of the films prior to and during coalescence. The result is the controllable production of stripes having sidewall geometries ranging from linear and smooth through strongly faceted and weakly roughened. We control profiles showing variation between the natural preference for (111)A and B planes and and mixed plane circumstances of differing value for continued lateral propagation and coalescence. Primarily we show that the cross-sectional growth habit of the ELO material is extremely sensitive to stripe orientation with misalignments as small as 5° being very significant. Secondarily we demonstrate that the effective local overpressure of Phosphorous (TBP) at the lateral growth front is most important to the sidewall formation and faceting at any growth rate or mask geometry.

[1] Zhou J, et.al, MicrElJour **38** (2007) 255-258
[2] Sun YT, et.al, Jour.CrystalGrowth **225** (2001) 9-15

“Growth Habit Control of Epitaxial Lateral Overgrown InP on Si Substrates by MOCVD”

Phil Mages, Nick Julian, Chong Zhang, Steve Denbaars,
Larry Coldren, John Bowers

Figures 1a,b: Wagon wheel patterns showing selectively grown stripes in plan view. A strong transition exists at the 45° [010] line. Facetted/rough sidewalls become very straight.

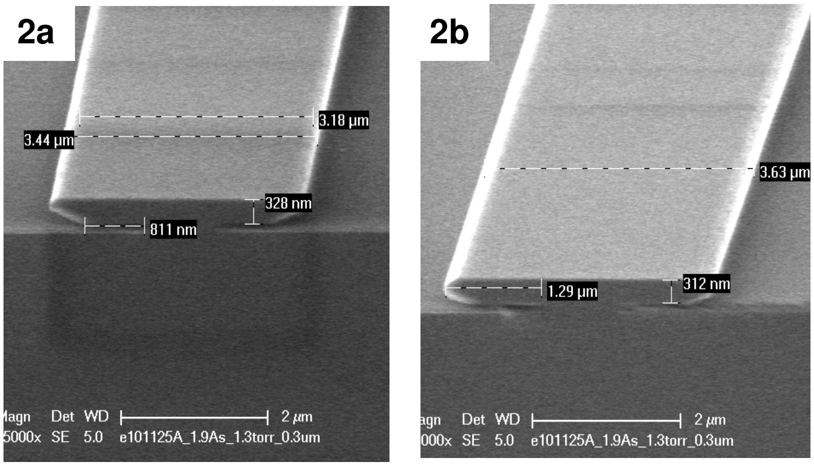


1.3torr P_p → smooth everywhere with less severe sidewall Facetting

0.22 torr P_p →pitted surface in open field

Most clearly in 1a it is seen that the [010] line is strongly pyramidal in cross section while lines between [-110] and [010] have slightly tapering sidewalls leading to a flat top. Lines between [010] and [110] (90°) have very flat tops, which cross section correlates with undercut “dovetail” sidewalls.

Figure 1b: Extremely low phosphorus pressure in figure 1a exaggerates sidewall faceting effects as well as preferential coalescence in directions *not* having the largest lateral growth rates.



Figures 2a,b: “Soft” transition between dovetail growth mode and semi-vertical sidewalls close to the [-110] direction. 2a shows a stripe at ~11° off of [-110] and 2b a stripe ~17° off.