III-V materials grown directly on V-groove Si for Solar Cells

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III-V solar cells offer superior performance to other technologies, reaching light conversion efficiencies above 40% [1]. However, their high cost has limited their use to space applications, with the GaAs or Ge substrate contributing a large portion of the overall cost [2]. The direct growth of III-Vs on Si is a compelling strategy to combine the high performance of III-V solar cells with the low cost of Si substrates. Nanopatterned V-groove Si offers both additional cost savings through its compatibility with low-cost wafer polishing and an ideal crystallographic surface for preventing the formation of antiphase domains that typically plague III-V on Si growth. In this work, we demonstrate the growth of low-dislocation-density GaAs on GaP grown via metalorganic vapor phase epitaxy (MOVPE) on V-groove Si substrates.

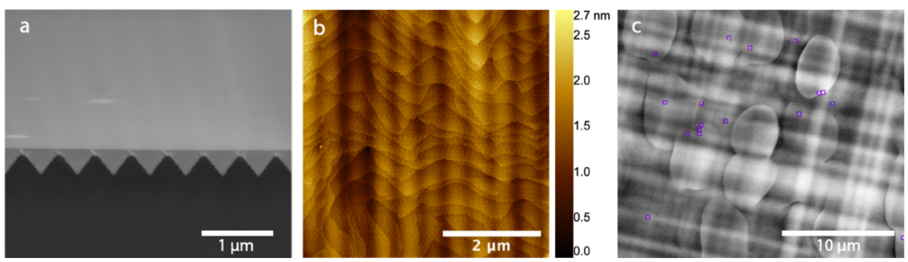

Fig. 1: a) SEM cross-sectional image of coalesced GaP on V-groove Si. b) AFM of the coalesced GaP with a R_q of 0.2 nm. c) ECCI image of GaAs on GaP on V-groove Si after TCA and DFLs showing a TDD of $3{\times}10^6$ cm^{-2}.

We studied a number of MOVPE nucleation conditions for GaP on V-groove Si and found that a high V/III ratio and growth temperature produces uniform nucleation at the bottom of the grooves that later coalescences into a thin film as shown by cross-sectional scanning electron microscopy (SEM, Fig. 3a) [3], with the exact geometry of the nanopatterns also playing an important role in coalescence. The coalesced GaP was very smooth, with a RMS roughness (R_q) of 0.2 nm measured by atomic force microscopy (AFM, Fig. 3b). However, with a threading dislocation density (TDD) of $5{\times}10^7$ cm^{-2} as measured by electron channeling contrast imaging (ECCI, Fig. 3c), the defects in this GaP on Si template would be limiting for solar cells applications. To decrease the TDD, we grew GaAs on the GaP/Si templates and employed thermal cycle annealing combined with a dislocation filter like the one described in Ref. 4. This resulted in relaxed GaAs with a TDD of $3{\times}10^6$ cm^{-2} as measured by ECCI, achieving a low TDD in a material with a bandgap suitable for solar cells. We will present solar cell results and discuss the materials science consideration involved in achieving smooth and high-quality III-V growth on V-groove Si.

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