Competitive tandem structures for highly efficient solar energy conversion – direct bandgap III/V compounds on Si

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1. Introduction

Epitaxial integration of direct bandgap III/V compounds on Si may use GaAsP graded buffers to bridge the lattice constant towards GaAs/Ge[1]. In a new GaAsP/Si dual-junction solar cell concept utilizing strain-balanced multi-quantum wells, solar energy conversion efficiencies above 40% are feasible and GaAsP grading to only 50% of As is required [2], see Fig.1. Si(001) substrate preparation as well as low-defect pseudomorphic GaP nucleation on Si(001) have been established [3] as ideal starting point for GaAsP grading, which we study here in situ with reflection anisotropy spectroscopy (RAS).

2. Discussion

We find that the growth surface exhibits optical fingerprints of a well-ordered, group-V rich surface reconstruction (Fig. 2, left pannel). With increasing As supply, a characteristic feature in the RA spectrum—which is assigned to surface-modified optical bulk transitions close to the E_1 critical point energy—shifts towards lower photon energies. Within a simplified empirical model, this shift depends approximately linearly on the As content in the GaAsP layer (obtained by ex situ high-resolution X-ray diffraction) and it can be described in analogy to the shift of E_1 from GaP to GaAs (Fig. 2, right pannel). The shift is well observable at growth temperature and for a broad range of As concentrations since both the P-rich GaP(001) surface and the As-rich GaAs(001) surface exhibit characteristic peaks at E_1. The evaluation of the shift is further eased by strong absorption suppressing interference modulations.

3. Conclusion

The As/P content of individual GaAsP layers can be quantified in situ during growth, which is beneficial for process control and optimization.

References

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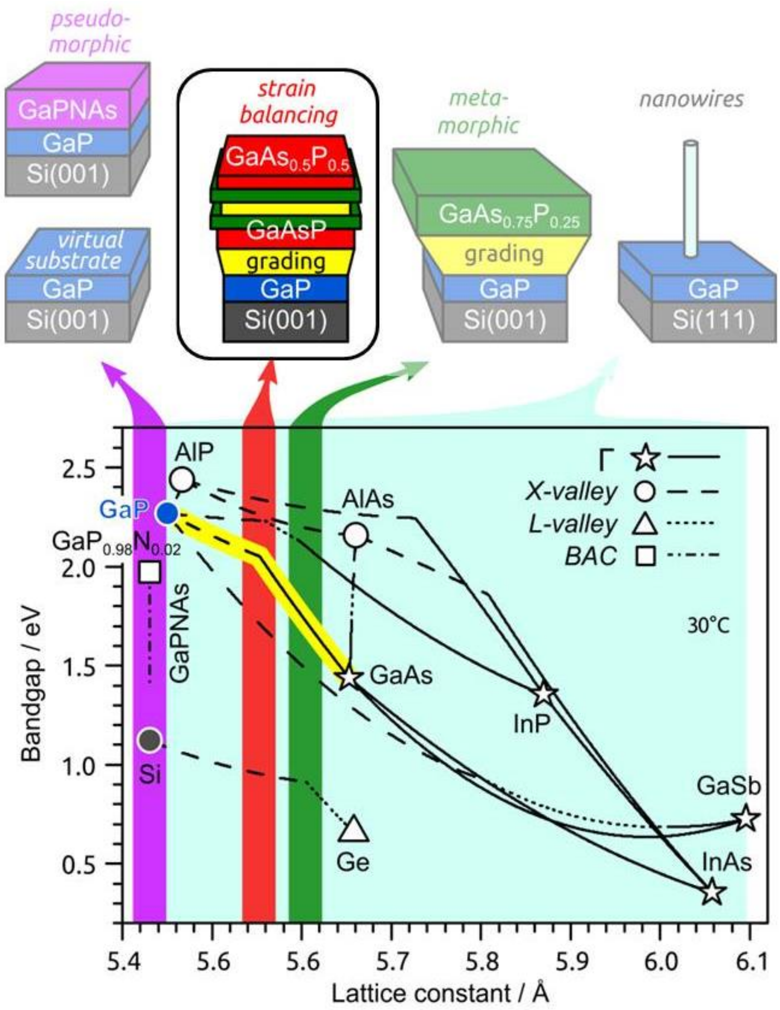

Figure 1: Bandgap as a function of the lattice constant for III–V semiconductors, Si, and Ge at room temperature. Sketches on top show possible realizations of epitaxially grown III–V-on-Si device structures.

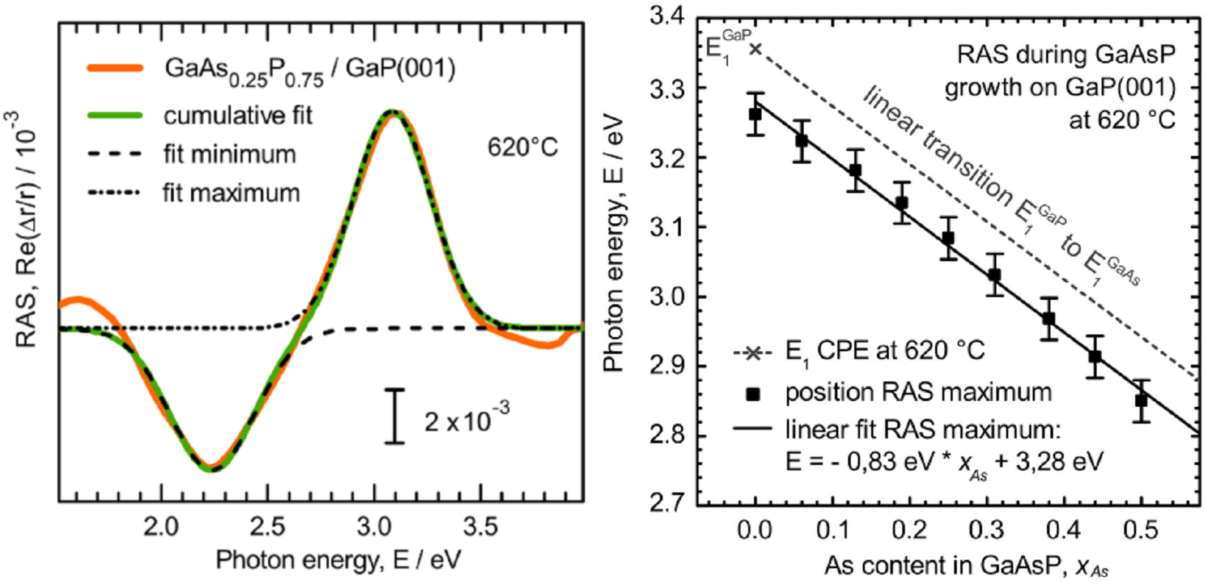

Figure 2, left pannel: RA spectrum of GaAs0.25P0.75 measured at 620 °C (orange) and fit (green) consisting of two contributions (black) to obtain the peak positions.

Fig.2 , right pannel: Position of the maximum in the RA spectra of GaAsP vs. As content (squares) and a linear fit.