The quest for $Cu(In,Ga)S_2$/Si Tandem Solar Cells: Epitaxial $Cu(In,Ga)S_2$ Thin Film Growth on GaP/Si(001) Pseudo-Substrate

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Pure-sulfide $Cu(In,Ga)S_2$ (CIGS) attracts much attention as its bandgap may be tuned from 1.54eV (for $CuInS_2$) to 2.43eV (for $CuGaS_2$) [1], making it a suitable top cell partner for crystalline Si (c-Si) bottom tandem solar cells. However, CIGS solar cells still suffer from a low output voltage compared to their selenide counterparts. One improvement pathway to increase minority carrier lifetime consists in eliminating extended crystalline defects, like grain boundaries, where chemical fluctuations may introduce recombination centers [2].

$CuIn_{0.75}Ga_{0.25}S_2$ displays a nearly ideal bandgap of 1.7eV for a top cell absorber and shares crucial similarities with GaP and Si in terms of crystal structure and lattice parameters (as shown in Figure 1). In this work, we study the use of a thin epitaxial GaP layer between the CIGS and Si to (i) promote the growth of a high-quality and adherent epi-CIGS film on Si, (ii) impede the diffusion of Cu from the CIGS into the Si, and (iii) form a selective contact for holes at the rear side of the CIGS top cell.

In particular, we evaluate the microstructure and extended defects in epi-CIGS grown on GaP/Si(001) by means of high-resolution transmission electron microscopy. We observe defects in the cation-sublattice that, to the best of our knowledge, had not been detected in CIGS. Furthermore, we evaluate the applicability of GaP as a diffusion barrier for Cu by means of atom probe tomography. In parallel, we study the performance of GaP/Si(p+) as a back contact for ZnO:Al/ZnO/CdS/CIGS monojunction solar cells to pave the way for the fabrication of a 2T CIGS/Si tandem device.

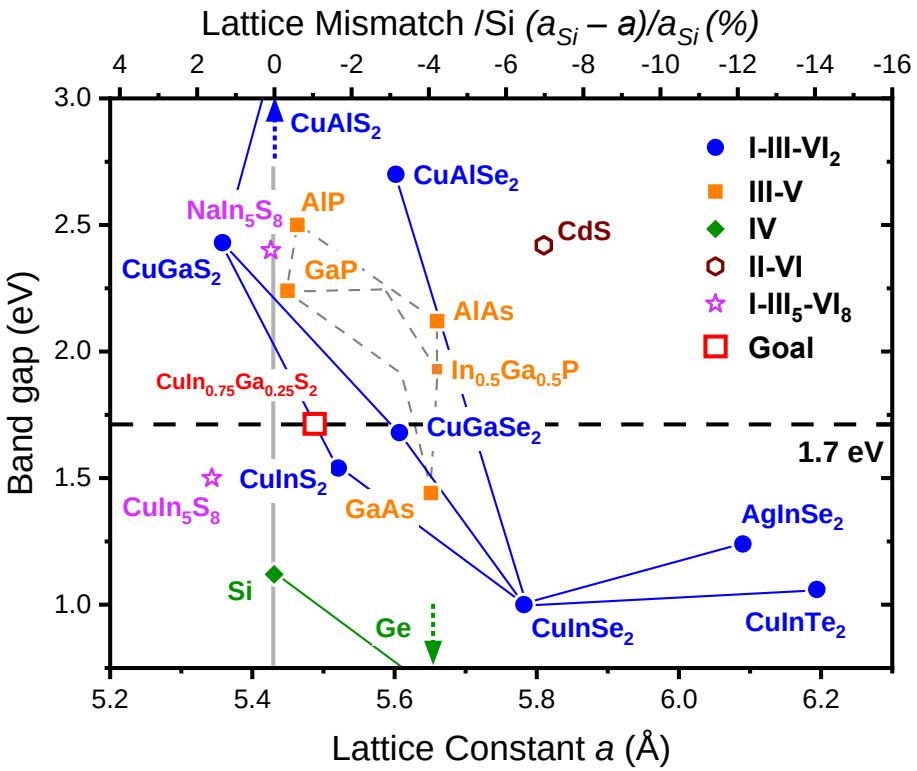

Figure 1: Band gap vs lattice mismatch for chalcopyrite I-III-VI$_2$, group IV, II-VI and III-V semiconductors, whose crystal structures share important similarities. Gallium phosphide GaP is quasi lattice matched with Si. Alloys with the approximate composition $CuIn_{0.75}Ga_{0.25}S_2$ have near ideal band gap for top cell applications and suitable lattice parameter for epitaxial growth on Si and GaP. Lattice mismatch relative to Si, is represented on the top x-axis scale.

References :

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