

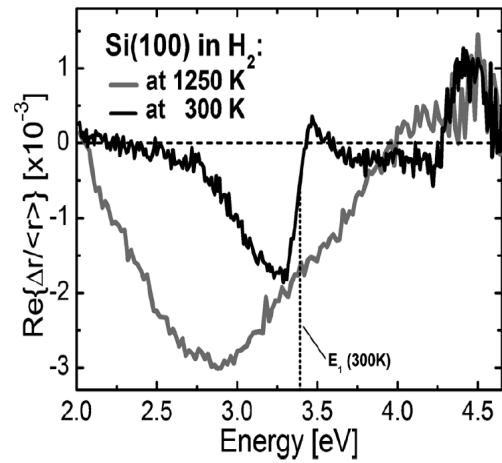
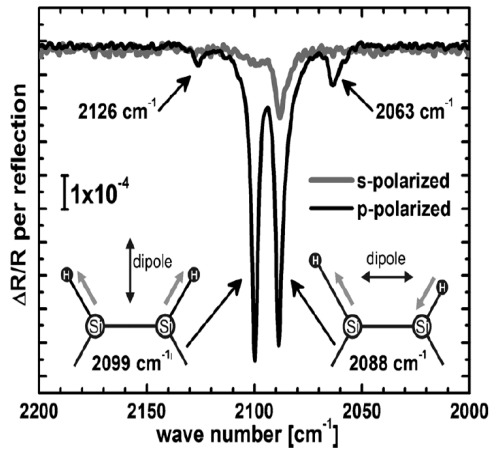
Combining high performance III-V solar cells and silicon

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The technological interest in the superior electronic and opto-electronic properties of III-V semiconductors drives the research for their heteroepitaxial integration on cheaper standard substrates such as silicon and germanium. Triple junction solar cells with ultimate performance grown III-V compound semiconductors with metal organic chemical vapour deposition (MOVPE), which are today's most efficient photovoltaic devices with conversion efficiencies exceeding 40%, are based on germanium substrates. A next generation multijunction cell with four or more junctions and optimized band gaps is expected to break the present record efficiency surpassing the 50% mark and a great challenge for solar cell-relevant breakthrough technologies is the merge of silicon and III-V technologies. Metal-organic vapour phase epitaxy (MOVPE) is technologically well-established for III-V growth, but there is less experience in the preparation of qualified Si(100) as well as Ge(100) surfaces via MOVPE. In our work, the above mentioned topics have been tackled and the delicate MOCVD preparation of critical interfaces was monitored on the atomic scale with optical in-situ spectroscopy and, associated to these signals, sophisticated analytic tools. Subsequent III-V deposition requires the complete removal of intrinsic silicon oxides and the generation of a suitable atomic surface structure. In particular, the reduction of undesirable anti-phase disorder necessitates the formation of double layer steps instead of the typical two-domain (2x1)/(1x2) surface reconstruction of Si(100) associated to single layer steps [1].

We studied the atomic surface properties of Si(100) during preparation in a (metal-organic) vapour phase epitaxy (VPE) reactor and the impact of the hydrogen ambient. Absorption lines in Fourier-transform infrared spectra were identified as stretch modes of coupled Si-H monohydrides [1], in agreement with Si-dimers observed by scanning tunneling microscopy (STM). The polarization dependence of the antisymmetric stretch mode distinguished different dimer orientations and verified a clear preference for one of the (2x1) / (1x2) surface reconstruction domains. Tip-induced H-desorption proved the complete saturation of dangling bonds after VPE-preparation. In situ reflectance anisotropy spectroscopy (RAS) showed the absence of Si-H bonds at elevated annealing temperature. In addition, we applied reflection anisotropy (RA) spectroscopy in our MOVPE reactor to in situ characterize and control the preparation of Si(100). A dedicated contamination free sample transfer system from MOVPE environment to UHV enabled us to benchmark the RA spectra with results from various surfaces science instruments. X-ray photoelectron spectroscopy (XPS) provided direct observation of the oxide removal under various specific process parameters. Our RA spectra measured in the MOVPE environment were consistent with results reported in the literature that were derived from UHV studies. Benchmarking of the RAS signals enabled us to observe the reconstruction [2] and the atomic structure of the surface in situ by transient RAS measurements [3].



- [1] H.Döscher, A. Dobrich, S. Brückner, P. Kleinschmidt, T. Hannappel, Appl. Phys. Lett. 97, 151905 (2010)
- [2] H. Döscher, P. Kleinschmidt, T. Hannappel, Appl. Surf. Sci. 257 (2010) 574
- [3] S. Brückner, H. Döscher, P. Kleinschmidt, T. Hannappel, in prep.