# Characterization of the electronic and chemical structure at thin film solar cell interfaces

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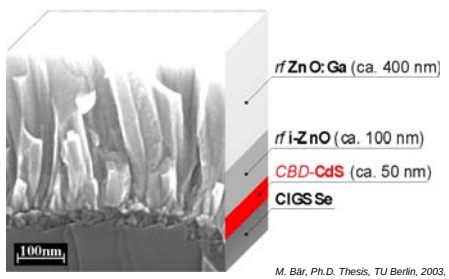
## Objective:

The main objective of this project is to develop an understanding of the status-quo and optimization potential of interfaces in $Cu(In,Ga)(S,Se)_2$ ("CIGSSe") and CdTe thin film solar cells.

The work focuses on
- **(I)** deriving the bench mark picture for world-record cells,
- **(II)** analyze state-of-the-art cells from industrial processes, and
- **(III)** aid in the troubleshooting of cells with substandard performance.

Interfaces to be considered in the upper part of a conventional CIGSSe thin film solar cell




*M. Bär, Ph.D. Thesis, TU Berlin, 2003, http://edocs.tu-berlin.de/diss/2003/baer_marcus.pdf.*

## Approach: Systematic Combination of Spectroscopic Methods

By using a unique combination of spectroscopic methods a comprehensive picture of the electronic (i.e., band alignment) as well as chemical structure can be painted.

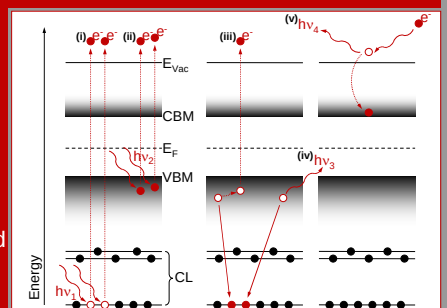
- (i) XPS (X-ray Photoelectron Spectroscopy)
- (ii) UPS (UV Photoelectron Spectroscopy)
- (iii) XAES (X-ray Excited Auger Electron Spectroscopy)
- (iv) XES* (X-ray Emission Spectroscopy)

} Probing Occupied States

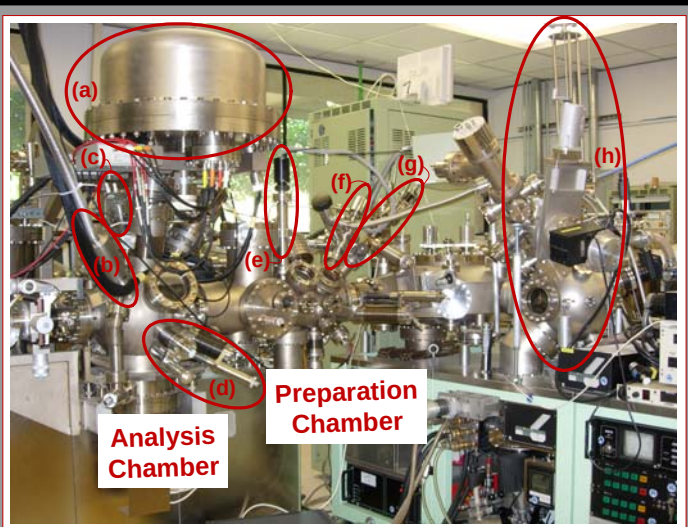
- (v) IPES (Inverse Photoemission Spectroscopy)
- (vi) NEXAFS* (Near-Edge X-ray Absorption Fine Structure)

} Probing Unoccupied States

* performed at the Advanced Light Source, Lawrence Berkeley National Laboratory




## Equipment: The "*Andere ESCA*" at UNLV

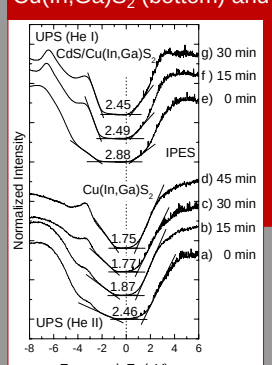



- **(a)** Electron Analyzer
- **(b)** X-ray Source ⇒ **XPS, XAES**
- **(c)** UV-Source ⇒ **UPS**
- **(d)** $e^-$-Gun / Detector ⇒ **IPES**
- **(e)** Mass Spectrom.
- **(f)** $Ar^+$-Ion Gun
- **(g)** Evaporator
- **(h)** ECR Plasma Chamber

## Examples from Previous Work:

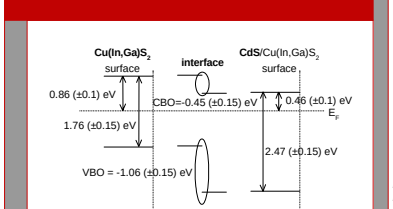
### The $CdS/Cu(In,Ga)S_2$ Interface:

**Left**: Evolution of the electronic surface band gap of a $Cu(In,Ga)S_2$ (bottom) and a CdS (top) thin film as a function of surface cleaning with 50 eV Ar+ ions



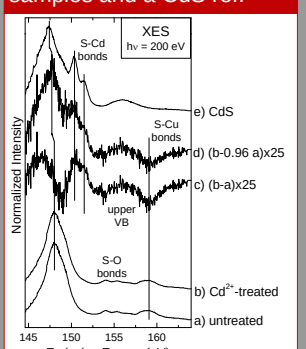

*L.Weinhardt, O.Fuchs, D.Groß, G.Storch, E. Umbach, N.G.Dhere, A.A.Kadam, S.S.Kulkarni and C.Heske, APL **86**, 062109 (2005).*

**Bottom**: Schematic diagram of the band alignment at the CdS/ $Cu(In,Ga)S_2$ interface




### $Cd^{2+}$-treated CIGSSe:

S $L_{2,3}$ XES difference spectra of treated CIGSSe samples and a CdS ref.




*L.Weinhardt, Th.Gleim, O.Fuchs, C.Heske, E.Umbach, M.Bär, H.-J.Muffler, Ch.-H.Fischer, M.C.Lux-Steiner, Y.Zubavichus, T.P.Niesen, F.Karg, APL **82**, 571 (2003).*

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