Influence of CIGS Surface Conditioning on GDOES Depth Profile Measurement Results

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CIGS

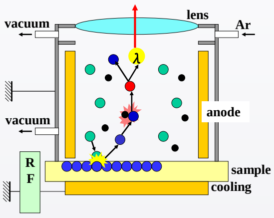
Why CIGS?

- CIGS ($Cu(In,Ga)Se_2$) is the most promising thin-film solar cell material. Cell efficiencies up to 21.7 % for single cell (0,5 cm^2) and 16.5 % on module could be demonstrated. A further increase of cell efficiency to higher values is possible.
- Total cell thickness around 3 to 4 µm CIGS enables use in flexible solar cells with stainless steel or polyimide substrates.

Structure of CIGS

- A 500 nm thick Mo layer is sputtered as the back contact on soda lime glass.
- Semiconductor consists of coevaporated CIGS (2 µm) and chemical bath deposited CdS (60 nm) layers.
- Front contact is sputtered i-ZnO+AZO (1 µm). Small cells are coated with a Ni/Al/Ni grid. For modules a monolithic design is used.

GDOES



schematic diagram of method

Why GDOES?

- Fast depth profiling; no waiting time for sample transfer; depth profile comparable with SNMS and SIMS

Important Values for CIGS depth profiling

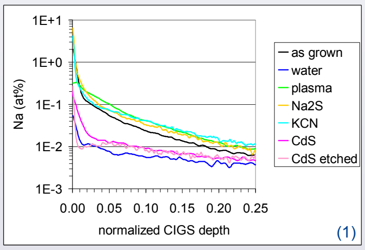
- GGI: Ga/(Ga+In) ratio corresponds to band alignment and band gap E_g
- CGI: Cu/(Ga+In) ratio is related to stoichiometry of CIGS composition; $CuSe_2$ decreases cell efficiency
- Na content in CIGS: strong influence on cell efficiency; reason for efficiency improvement is still under discussion

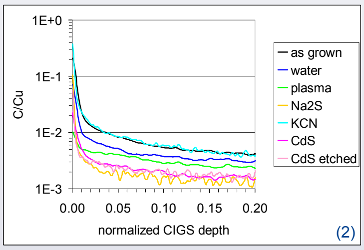
GDOES-Profiler Horiba Jobin Yvon

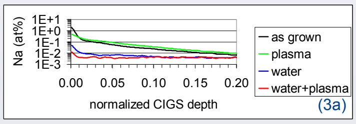
Treatment

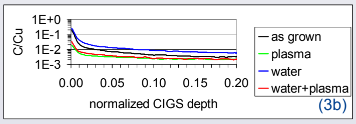
Treatment	Effect		
		as grown:	sample after CIGS coevaporation step
water rinse:	normally used for removing particles	Plasma cleaning:	removing of surface contamination, application of GDOES profiler
Na_2S etching:	removing of oxidized CIGS surface layer	KCN etching:	removing of Cu_2Se
CdS bath deposition:	protection against surface oxidization	CdS etched:	removing of CdS by hydrocloric acid

Surface



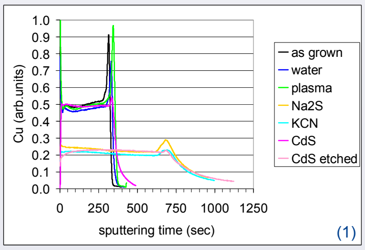


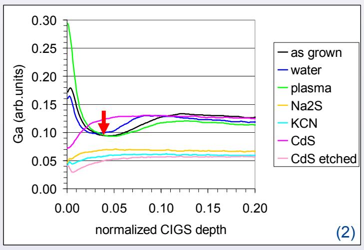


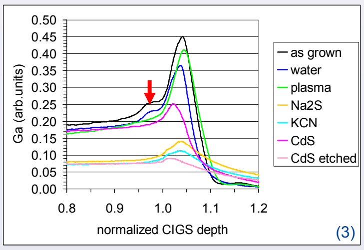


Water and CdS remove Na totally from CIGS surface (1), confirmed by XPS and SIMS measurements (not shown). CdS, Na_2S and plasma are the best choices for removing C from CIGS surface (2). Water sometimes increases C amount at surface (3b, also confirmed by XPS). A combination of treatment methods could improve surface cleaning properties for each method. For instance, water removes Na (3a) and plasma C (3b). The order of treatment is thus important.

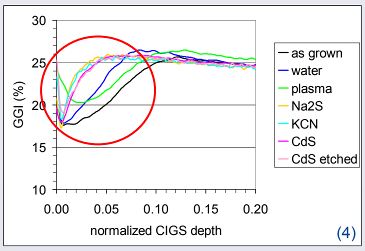
Influence on sputter rate

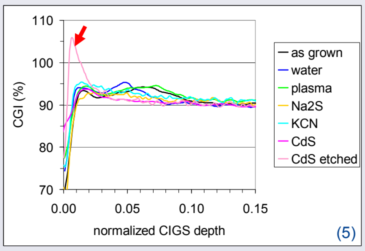


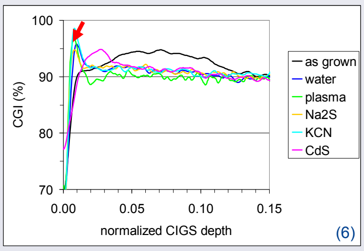




Some surface treatments (Na_2S, KCN, CdS etched) have a diminishing effect on sputter rate (1). A lower sputter rate generates a smaller Ga depletion in the measurement signal near surface (≤ 0.10 normalized CIGS depth) (2) and a corresponding enrichment towards the Mo back contact (0.95-1.0 normalized CIGS depth) (3). But in contrast fast sputter rate leads to a decreased signal intensity and significantly reduced depth resolution.







Ga depletion could also be detected in GGI ratio (4). This effect is not observable for CGI. But sometimes a Cu peak is apparent near the surface (0.01-0.02 of normalized CIGS depth) (5). This effect is not related to surface conditioning and can be observed for all treatment methods and sputter rates (6).

Summary

- Best cleaning effect with CdS treatment, but cleaning effect could also be achieved by combinations of other methods.
- Surface conditioning influences sputter rate and sputter rate influences Ga distribution during measurement
- Best measurements obtained with CdS-coated samples → constant surface conditioning of CIGS sample.
- Appearing of a Cu peak at surface is not correlating to surface conditioning

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