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Characterization of laser structures in photovoltaic Cu(In, Ga)Se_2 thin film systems

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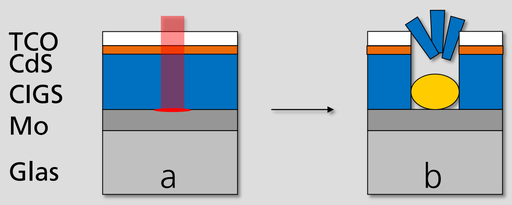
Motivation

- In CIGS photovoltaics laser processes for implementing the monolithic series connection still did not reach industrial level.
- Currently there are two methods used for laser structuring CIGS on laboratory scale, the ablation by ps [I] and fs pulses and ablation by a brittle fracture process [II]
- Both processes result in different kind of defects like melting or left residuals depending on the CIGS material and CIGS/Mo interface properties
- An extensive characterization of the scribe and sample system itself is the basis for understanding and optimizing these laser processes.

Samples and preparation

Scribing

- the samples contained the complete layer stack glass/Mo/CIGS/CdS/ZnO
- Scribing was done using a process similar to that one depicted in [II]



[Fig. 1] ns scribe process schematically, a) energy deposition at CIGS/Mo Interface, b) explosive lift off

- Energy is deposited at the CIGS/Mo-Interface (Fig. 1a)
- Evaporation of Se leads to brittle fracture of the CIGS layer and explosive lift off of the CIGS layer (Fig. 1b)
- Successful scribing causes no melting of the CIGS layer, no residuals on the bottom and clean, sharp scribe edges

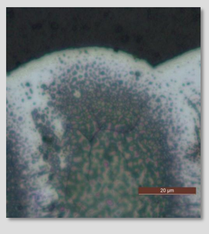
Analysis

- Scribes were investigated using optical microscopy and stylus profilometry
- For TEM analysis cross sections of the layers were prepared
- Compositional analysis was done using ToF-SIMS depth profiling

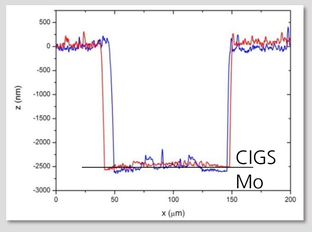
Results

- The results included both the successful ablation and the melting of the CIGS
- Fig. 2 shows no melting at the scribe edges, the scribe walls are sharp and nearly vertical (Fig. 3)
- In Fig. 4 the CIGS was just molten, no ablation was possible

brittle fraction

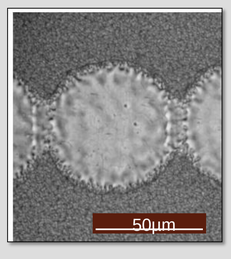


[Fig. 2] process sucessful, no melting at the scribe edge but some residuals on the scribe bottom

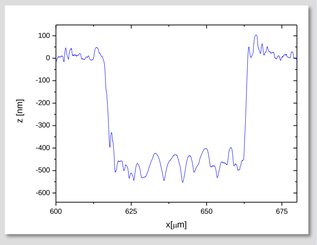


[Fig. 3] Profilometry shows sharp and vertical scribe edges

no brittle fraction



[Fig. 4] melting of the CIGS-Layer, Process was not successful

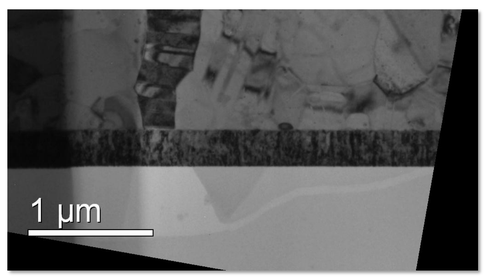


[Fig. 5] Profilometry, CIGS was not ablated completely (layer thickness 1,5 µm)

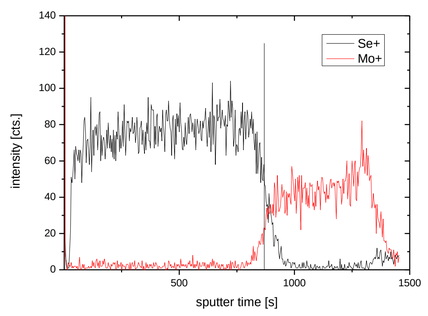
Results

- It is assumed that the successful ablation of the CIGS utilizing a brittle fracture process depends on the existence of a $MoSe_2$ layer [III].
- In our case experiments show the opposite behavior.
- On a sample without a $MoSe_2$ layer a the brittle fracture process could be applied successfully, on sample B (with $MoSe_2$) no ablation was possible (see fig. 4).

Sample A, brittle fraction

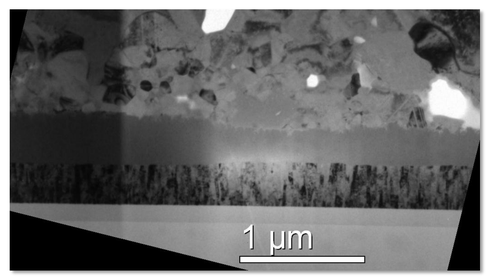


[Fig. 6] crossection of the CIGS/Mo layer stack

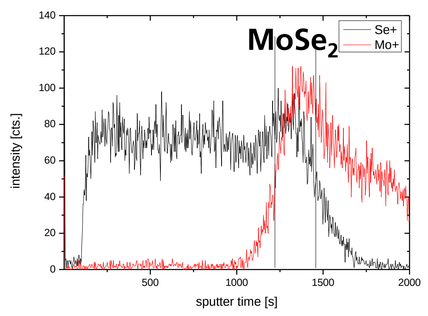


[Fig. 8] ToF-SIMS depth profile, an $MoSe_2$ layer is not visible

Sample B, no brittle fraction



[Fig. 7] cross section of CIGS/$MoSe_2$/Mo layer stack



[Fig. 9] ToF-SIMS depth profile, an $MoSe_2$ layer is visible

- The $MoSe_2$-layer can also be seen in the cross sections of the CIGS/Mo interface. The $MoSe_2$ is about 500µm thick (Fig. 6 and Fig. 7)
- Fig. 8 and Fig 9 show ToF-SIMS depth profiles without and with an $MoSe_2$ layer at the Mo/CIGS interface
- We assume, that either the $MoSe_2$ layer is not crucial for successful ablation or the layer has to be below a certain thickness.
- Furthermore, optical und structural properties of CIGS layer itself may prevent successful ablation.

Summary

- Since the exact role of the $MoSe_2$ layer during the scribe process is not fully known, both the characterization of interfaces and the CIGS layer itself is crucial for optimizing the laser based structuring process
- Structural and compositional characterization by ToF-SIMS and TEM provide necessary information of CIGS/Mo interface properties
- Characteristics of the CIGS layer itself (depth dependent composition, sodium content) may also make an influence to the laser process.

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