Master's Thesis Engineering Technology

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Optimization of the optoelectrical properties and induced damage of ITO and ZnO layers on CIGS solar cells

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Introduction

Solar power is essential for the **energy transition** and to counteract climate change. Energyville performs research into **Thin Film Photovoltaics** (TFPV) can:

- save costs because less material is used
- be manufactured on flexible substrates (see Fig. 1)

One of these TFPV types is **CIGS**-based, which stands for Copper Indium Gallium Selenide. This is the **absorber material** and usually has a **bandgap** of 1.2 eV. CIGS can also be used in **tandem** applications. The CIGS solar cell consists of several layers, as shown in Fig. 2. Ongoing efforts are trying to improve the conversion efficiency and stability.

The upper two layers are the window layers **indium tin oxide (ITO)** and **zinc oxide (ZnO)**

Main research objectives:

- Optimize **optoelectrical properties** (resistivity and transmittance)
- Reduce the induced **sputter damage**

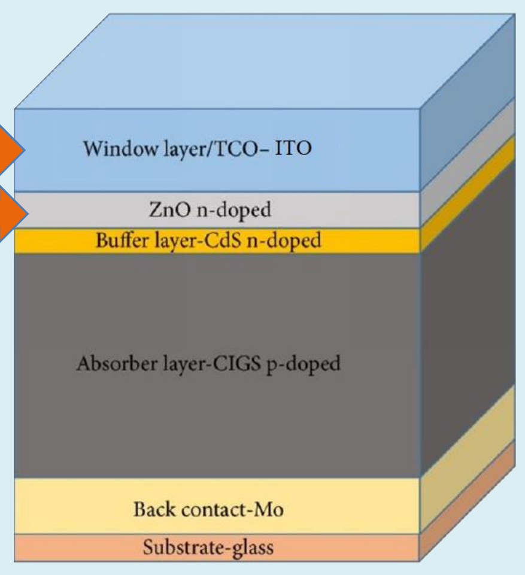

Fig. 2: Layer composition of CIGS solar cells [2]

Sputtering

ITO and ZnO were deposited with **RF linear sputtering** (Fig.3), suitable for large area depositions.

The sputter process is complex but contains **four key steps** :

1. Strong **magnetic field** is applied and gasses are introduced **2.** Argon atoms are **ionized. 3.** Ions sputter off **target particles 4.** Particles are deposited on **substrate**.

Sputtering parameters

- Working pressure
- Carrier speed
- Gas mixture
- Sputtering power
- Target-substrate distance
- Substrate temperature

*The investigated parameters are colored in orange.

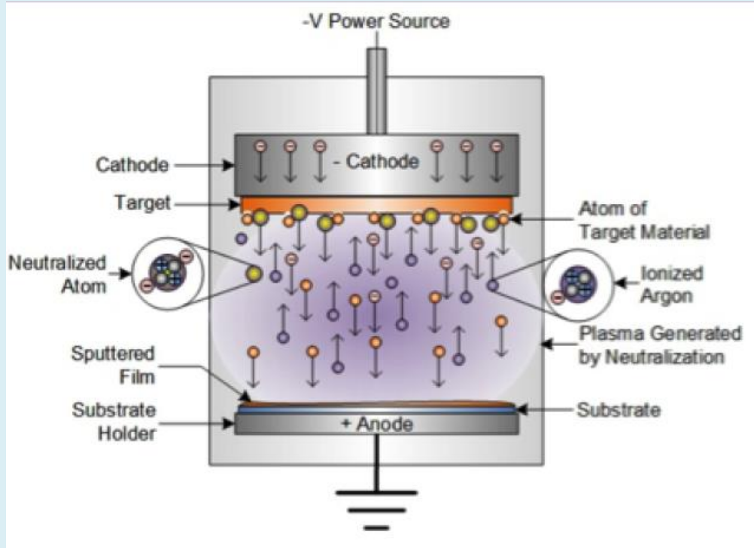

Fig. 3: RF sputtering mechanism [3]

Fig. 1: CIGS on flexible substrate [1]

On Soda Lime Glass

Integration into solar cell

Characterization

Several methods were used to characterize the **properties** of both the ITO and ZnO and the solar cell **performance.**

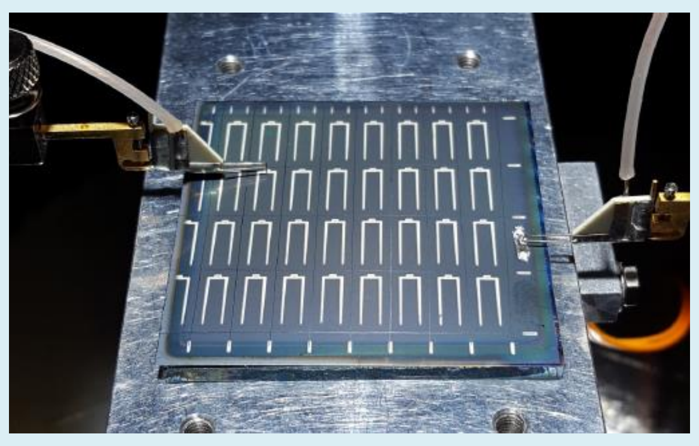

Fig. 4: IV setup

Measurements

- Profilometer for thickness (nm)
- Four point probe for resistivity ($\Omega\ cm$)
- Hall-effect setup for mobility ($m^2/(Vs)$) and carrier concentration ($/m^2$)
- Spectrometer for transmittance, reflectance and absorbance (%)

Performance of solar cell

- Measured with IV-curves, setup is shown on Fig. 4.
- Information about conversion efficiency, fill factor, short circuit current density, open circuit voltage, series- and shunt resistance.

Results

1) Pressure changes

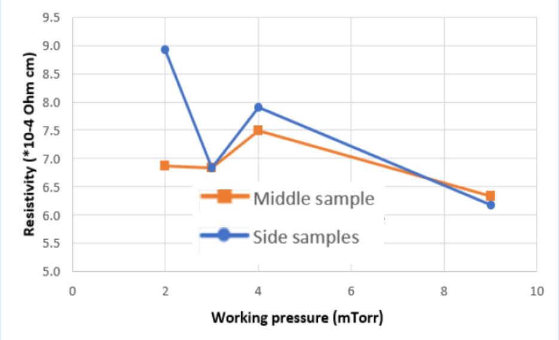

Fig. 5: resistivity of ITO

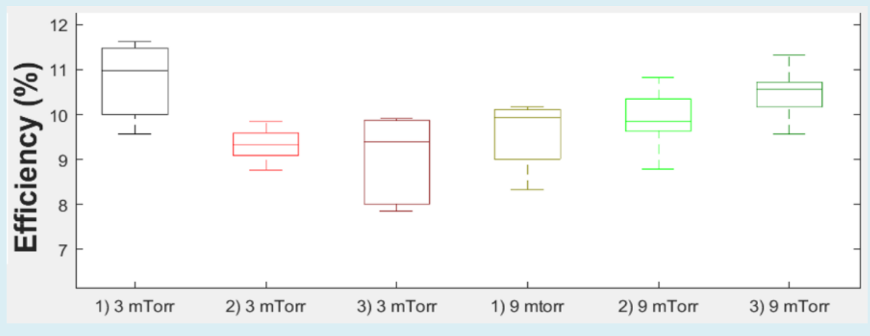

Fig. 7: efficiencies after deposition, two weeks, one month

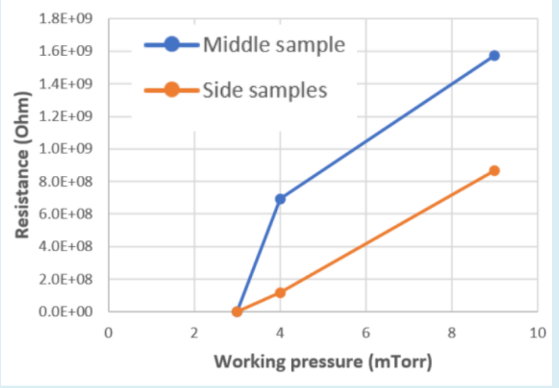

Fig. 6: resistivity of ZnO

Increasing the pressure **decreases** the resistivity of ITO slightly, while for ZnO it **surges by 3 orders**, which are both beneficial. An increased pressure results in a **more stable** solar cel with a remarkably low short-term degradation.

2) Carrier speed changes

- Changing speed from 10 to 2 mm/s had **no effect** on resistivity or transmittance.
- **Worsening** of the solar cell performance.

3) Waiting time after CdS

Depositing the window layers directly (vacuum sealed) after the CdS reaction ➔ 1% **increase in efficiency.** Degradation trough **oxidation of CIGS.**

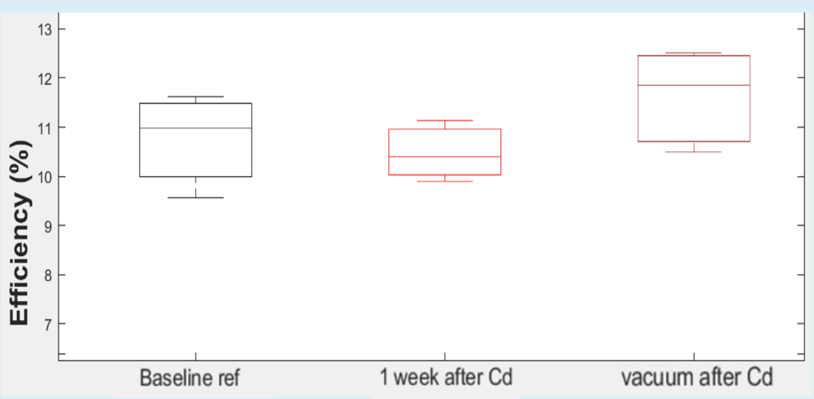

Fig. 8: efficiencies of reference, waiting one week and vacuum after Cds

4) Effect of anneal

Annealing **reduces** the resistivity by factor 3 (on average).
O2 annealing is a little more effective.

Fig. 9: resistivity drop after O2 and N2 anneal

5) Power changes

Initial ZnO layer functions as short circuit barrier, as shown in Fig. 10. Decreasing the power from 25% (base) to 10% and then 6%. The loss in deposition rate has to be compensated with extra passes.

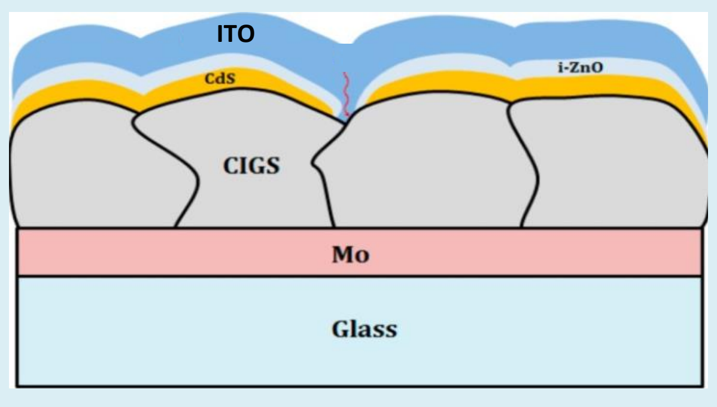

Fig. 10: ZnO as short circuit barrier [4]

➔ up to 2.2% **increase in efficiency**, as shown in Fig 11.

Higher power results in more dislocated atoms ➔ **defects**

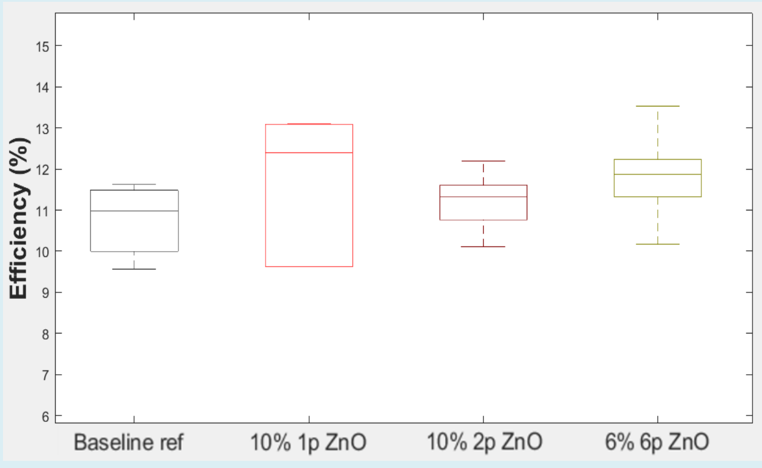

Fig. 11: effect of lower power ZnO sputtering

Combination of **higher pressure** and **lower power** for initial ZnO layers can be integrated into the baseline to manufacture CIGS solar cells that are more performant and stable.

Supervisors / Co-supervisors / Advisors

Bart Vermang, Guy Brammertz and Jeroen Lievens

References

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