INVESTIGATION OF THE SELENIUM TO METAL EVAPORATION RATIO WITH RESPECT TO ABSORBER STRUCTURE AND ELECTRICAL PROPERTIES OF Cu(In,Ga)Se$_2$ THIN FILM SOLAR CELLS

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Objectives

- Investigation of SLG/Mo/ Cu(In,Ga)Se$_2$/CdS/ZnO solar cells (GGI=0.36), with absorber layers prepared by means of a three-stage co-evaporation process with varying Se/Me flux ratios (7.7:1, 6.3:1, 5:1, 3:9:1, 2:1:1) and two different first stage substrate temperatures (400°C, 490°C)

- Orientation changes from strongly (112) to (220)/(204) with increasing Selenium pressure

Absorber layer characterisation

- XRD-patterns for $T_s$=400°C under different Selenium pressures
  - Se/Me=3.9 only reflexes of the chalcopyrite structure
  - Se/Me=2.1 (112)-peak is shifted to larger angles, existence of Cu$_2$Se

- Orientation change from strongly (112) to (220)/(204) with increasing Selenium pressure

- Na concentration shows a strong maximum at 1/3 layer thickness from the front contact
- SEM cross-section view shows grain boundary (red line) at 1/3 layer thickness

Electrical properties

- Larger GGI slightly increases $V_{OC}$, but strongly decreases $J_{SC}$ compared to our reference solar cell (GGI=0.24)
- Maximum EQE at Se/Me=5, for both first stage substrate temperatures, it is decreased for smaller as well as higher Se/Me-ratios
- Decreased EQE especially at long wavelengths in comparison to the reference cell, due to the large GGI

- Solar cell parameters show a maximum at Se/Me=5
- But fill factor ($T_s$=490°C) and $V_{OC}$ ($T_s$=400°C) seems to increase after passing Se/Me=6
  - Preparation of absorber layers with higher Se/Me-ratios is necessary to study this behavior
- Solar cells with Se/Me=2.1 did not show any photovoltaic action, probably due to Cu$_2$Se formation

Conclusions

- Se/Me flux ratio strongly influences the preferred orientation
- From (112) to (220)/(204) with increasing Selenium pressure
- Crystal size generally independent from the Se/Me-ratio
- Clear maximum for solar cell parameters at Se/Me=5

- A main problem is the high sodium concentration located to the grain boundary inside the absorber layer