HIGH Q LASER®
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Application Note

Structuring of CIS/CIGS thin-film solar cells with picosecond laser ablation

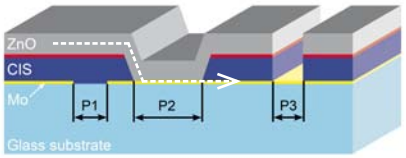
Thin film solar cells have shown a big potential to decrease cost of manufacturing for photovoltaic power generation. Despite of all research attempts to optimize materials and efficiency the mass production of thin film solar cells is still employing some mechanical steps of structuring, where thin films with a thickness of approximately 1 µm are selectively separated for the monolithic serial interconnection.
Structuring CIS ($CuInSe_2$)/CIGS thin films solar cells by picosecond laser ablation shows high potential. A new method called "directly induced laser ablation" can increase process speed for the scribing of a Mo-film on glass.
P1, P2 and P3 can be structured with low thermal effects and high resolution by using ps-laser pulses.

CIS solar cell in-line production steps

1. Mo sputtering
2. Pattern 1 (Laser)
3. Na-compound and Cu(Ga)/In/Se
4. RTP-CIGS formation
5. CdS-Dip
6. Pattern 2 by mechanical scribing
7. ZnO sputtering
8. Pattern 3 by mechanical scribing
9. Dice
10. Contact
11. Encaps

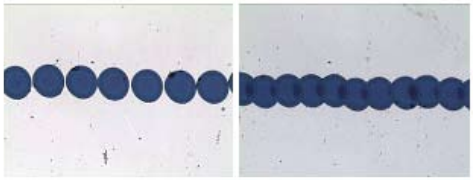
Integrated monolithic serial connection

Structuring processes from pattern 1 (P1) to pattern 3 (P3) form an integrated monolithic serial connection!

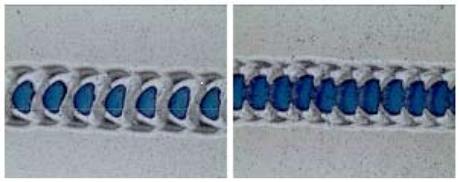


- Glass substrate, 4 mm thickness
- Mo-layer (yellow), 500 nm
- CIS-layer (blue), 2 – 3 µm, p-type semiconductor
- CdS-buffer-layer (red), 100 nm
- ZnO-layer, 1 – 2 µm, n-type semiconductor and front electrode
- Integrated monolithic serial connection: White arrow --> Electron flow

P1 ps-ablation from the back and front side (optical microscope images)



Back side ablation: 0.5 J/cm² with 30 % (left) and 50 % overlap (right)

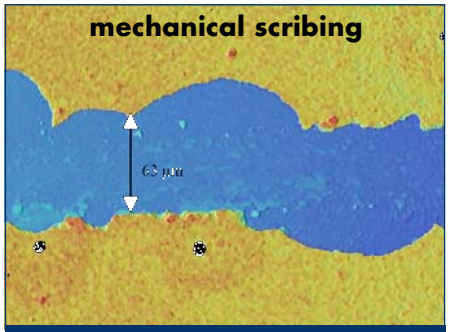


Front side ablation: 7.2 J/cm² with 30 % (left) and 50 % overlap (right)

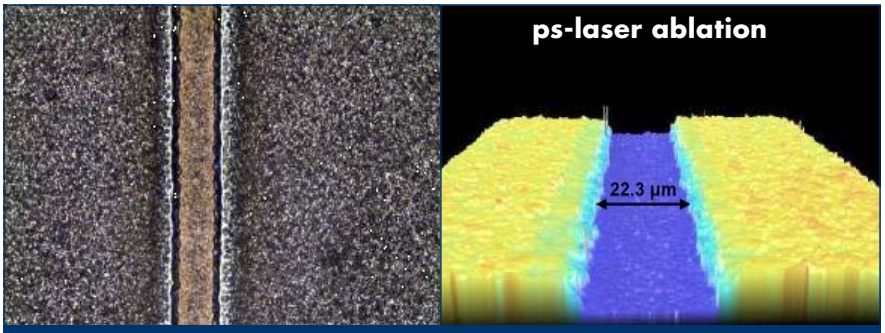
Back side
Mo extrusion below threshold
Mo separation starting with Φ_0>0.4J/cm²
Color change in center indicating barrier-layer ablation from Φ_0>1.0J/cm²

Front side
Mo separation starting with Φ_0>8.0J/cm²
Barrier-layer ablation from Φ_0>10J/cm²

Pattern 2 line structures, mechanical scribing vs. ps-laser ablation



Topography of a P2 structure performed by mechanical scribing

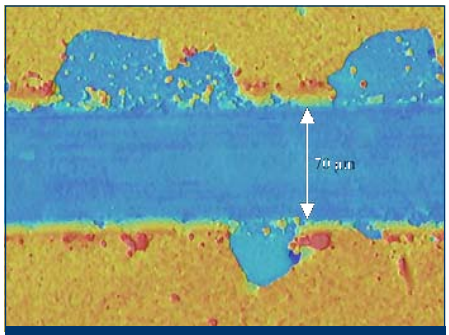


Topography of a P2 structure performed by picosecond laser ablation

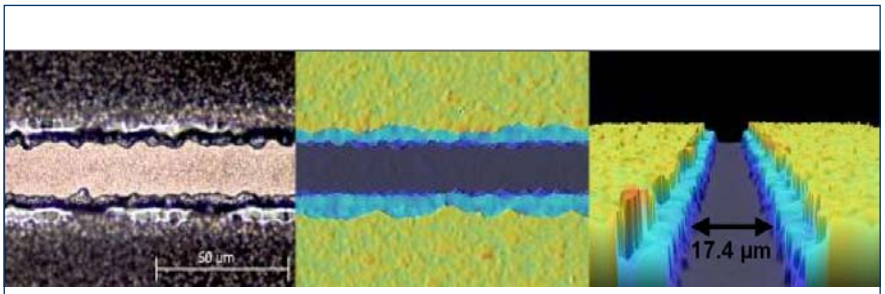
- Random lift offs and chipping of the CIS layer
- Turquoise spots in the groove are indicating residual material, which enhance contact resistance
- Effective Scribe width >100 µm --> loss of active solar cell area (100 lines, ca. 150 cm2)
- Scribing speed is ca. 50 mm/s

- Repetition rate 20 kHz, process speed 20 mm/s
- Groove depth 2.4 µm, width ca. 22 mm
- Complete separation of the CIS-film (brown), minor residual material on top of the Mo-layer (blue)
- CIS shows clean edges by CIP and optical microscope

Pattern 3 line structures, mechanical scribing vs. ps-laser ablation



P3 structure by mechanical scribing



P3 structure by picosecond ablation

- ZnO-CIS-film on a Mo-layer, line width of > 70 µm, ca. 50 mm/s
- Lift-offs and chipping
- Stripe-like residual material in the groove
- Remaining material at the chip-off locations
- Effective Scribe width >100 µm --> loss of active solar cell area (100 lines, ca. 150 cm^2)

- Repetition rate 20 kHz, speed 30 mm/s
- Groove depth of 3.6 µm --> Complete separation of the ZnO-CIS-film
- ZnO-layer (green) is chipped-off without thermal influence and micro cracks
- CIS-film (turquoise) exhibits faint rims on both sides of the groove
- Mo-surface (blue) is free of CIS
- Functionality has still to be validated

Acknowledgements

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