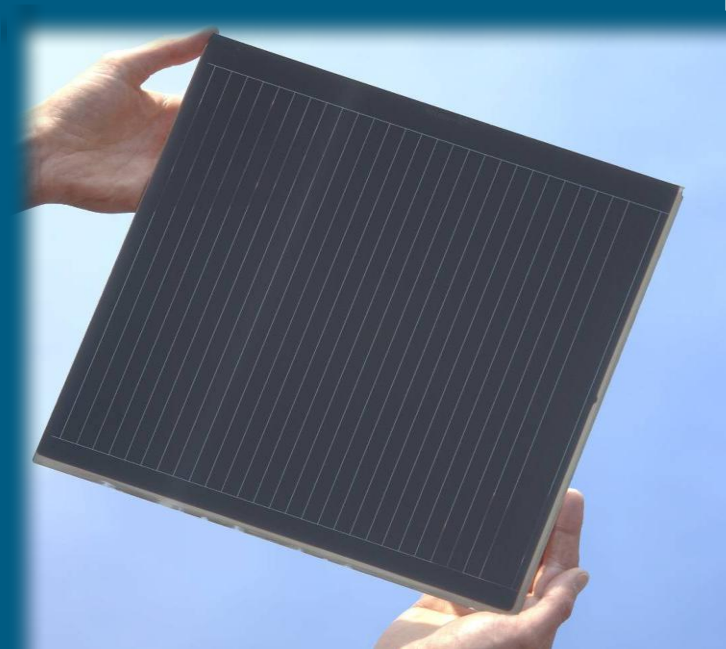
Mitglied der Helmholtz-Gemeinschaft

JÜLICH
FORSCHUNGSZENTRUM

Width optimization of laser patterning

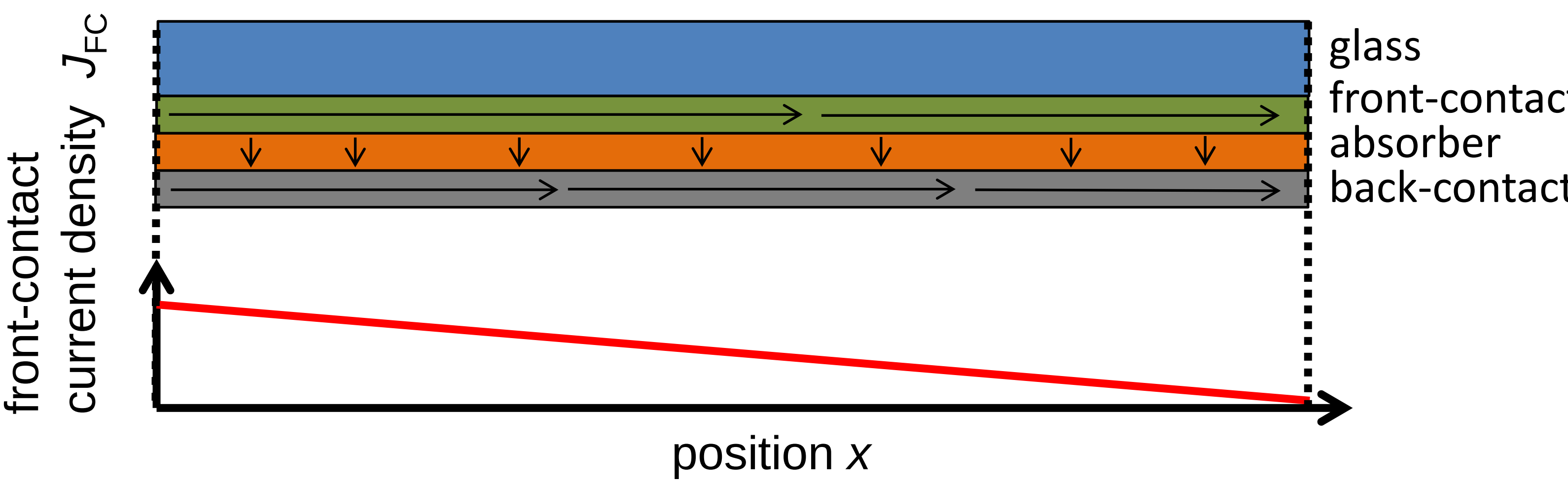


October 18, 2014 | Bugra Turan, Stefan Haas

Motivation

site: wikipedia

site: pv-tech.org



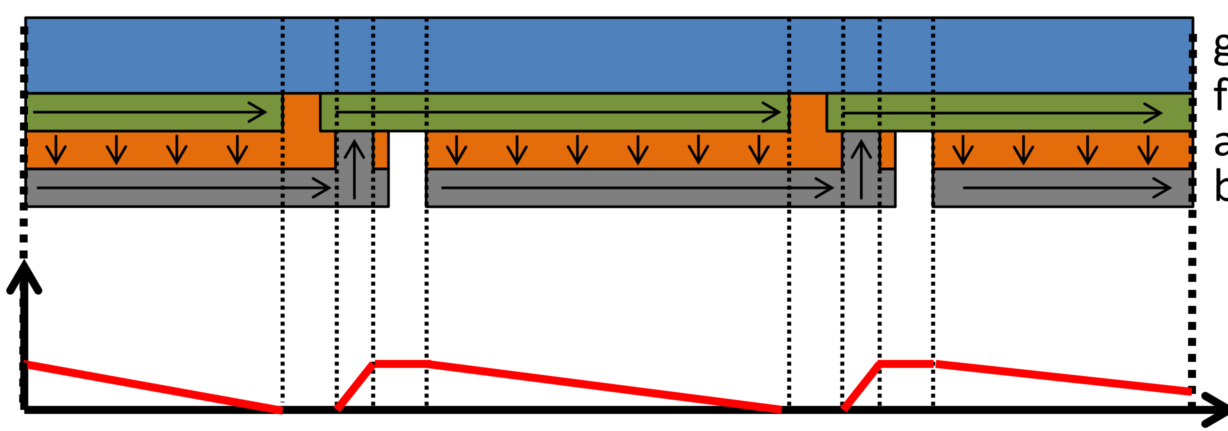
Mitglied der Helmholtz-Gemeinschaft

Motivation

FORSCHUNGSZENTRUM JÜLICH

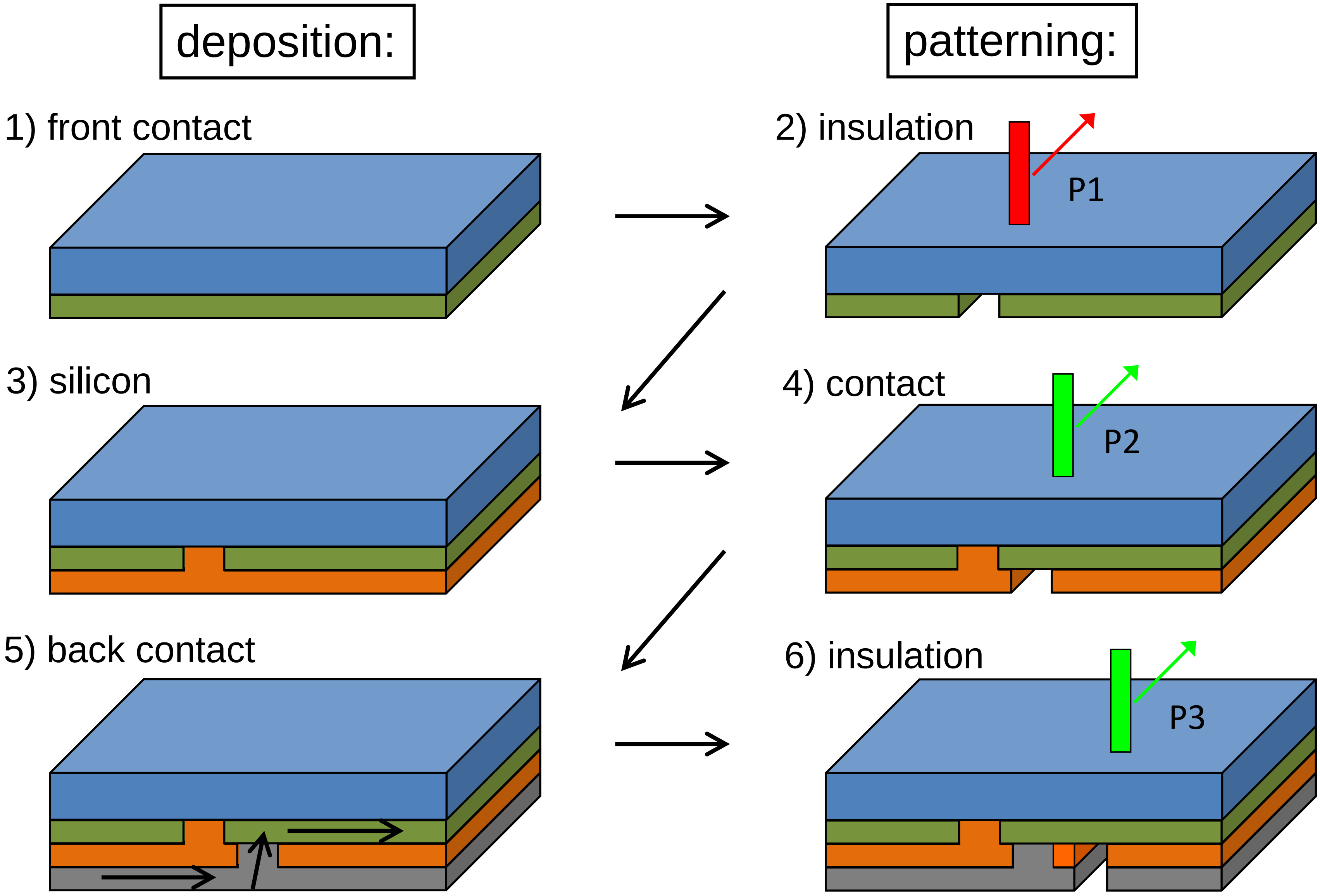
site: wikipedia

site: pv-tech.org



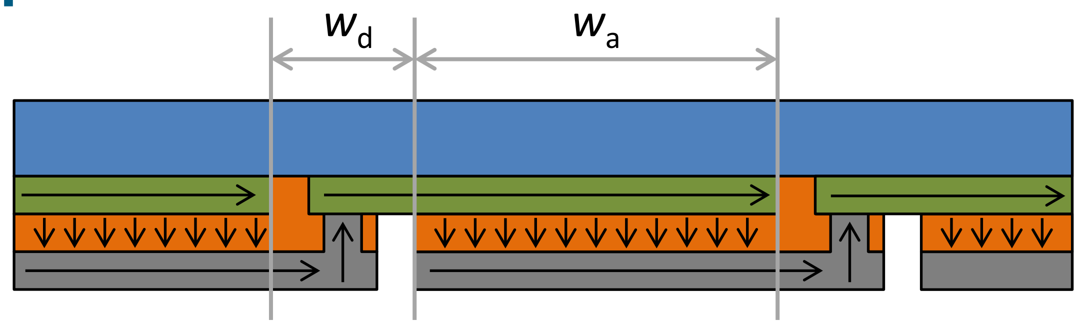
Mitglied der Helmholtz-Gemeinschaft

Fabrication of a series connected module



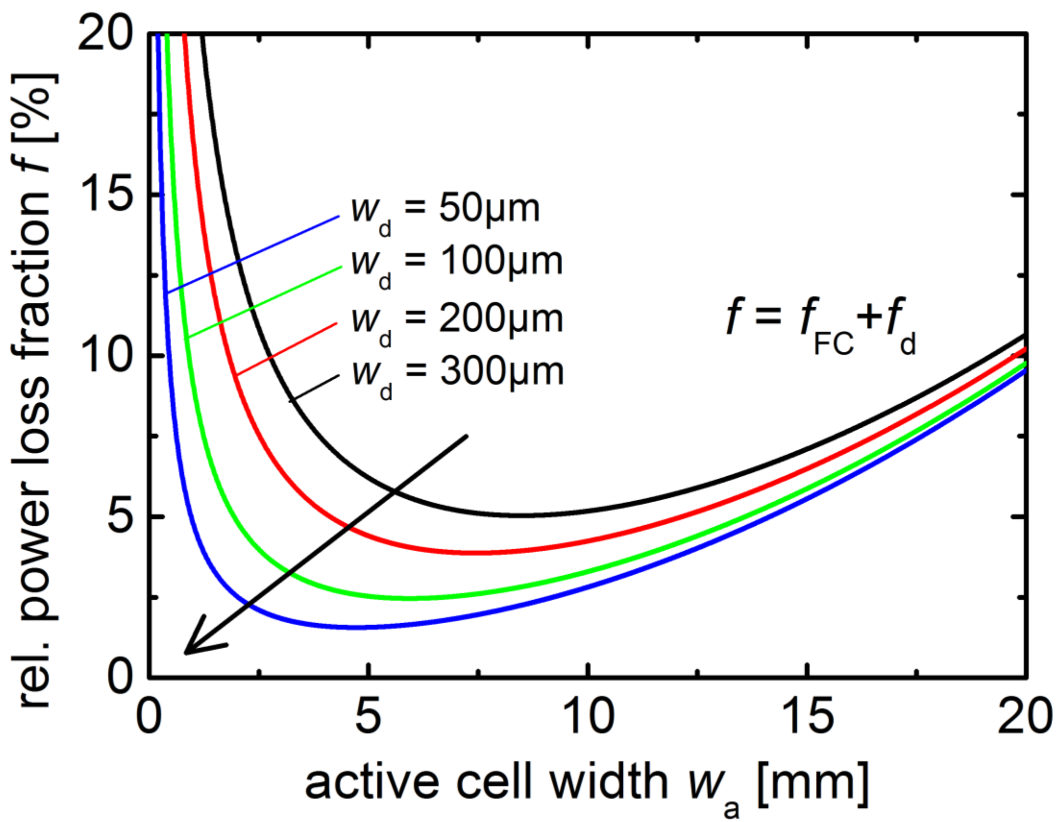
Mitglied der Helmholtz-Gemeinschaft

Motivation



$$f_d = \frac{P_{loss}}{P_{max}} = \boxed{\frac{w_d}{w_a + w_d}}$$ [1]

$$f_{FC} = \boxed{-\frac{J_{MPP}}{U_{MPP}} \frac{R_{\square,FC}}{3} \frac{w_a{}^3}{w_a + w_d}}$$ [1]

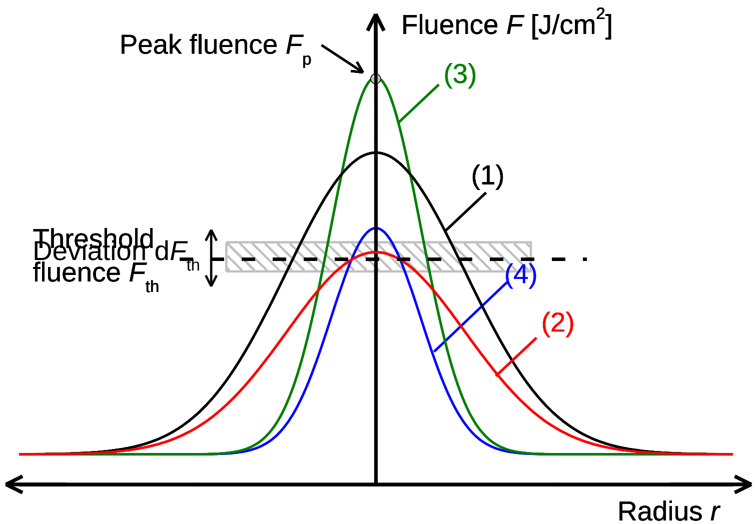


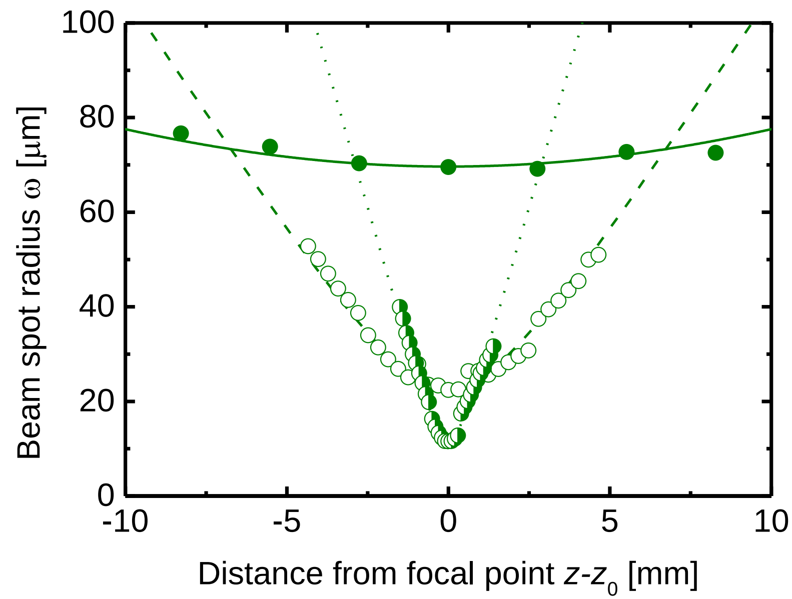
[1] Gupta et al. Proc. 16th PVSC (1982)

Mitglied der Helmholtz-Gemeinschaft

Scribe width minimization

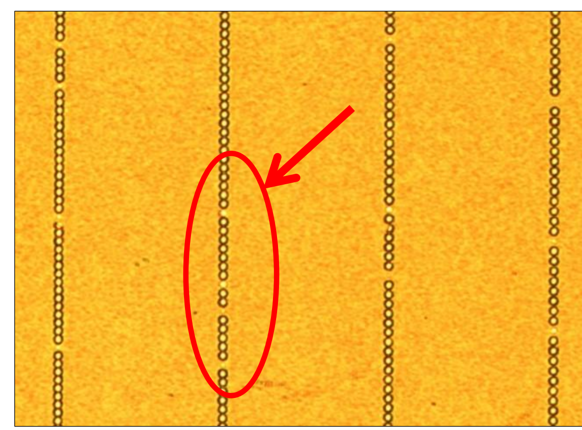
Approach: adaption of peak fluence F_p and beam radius ω_0





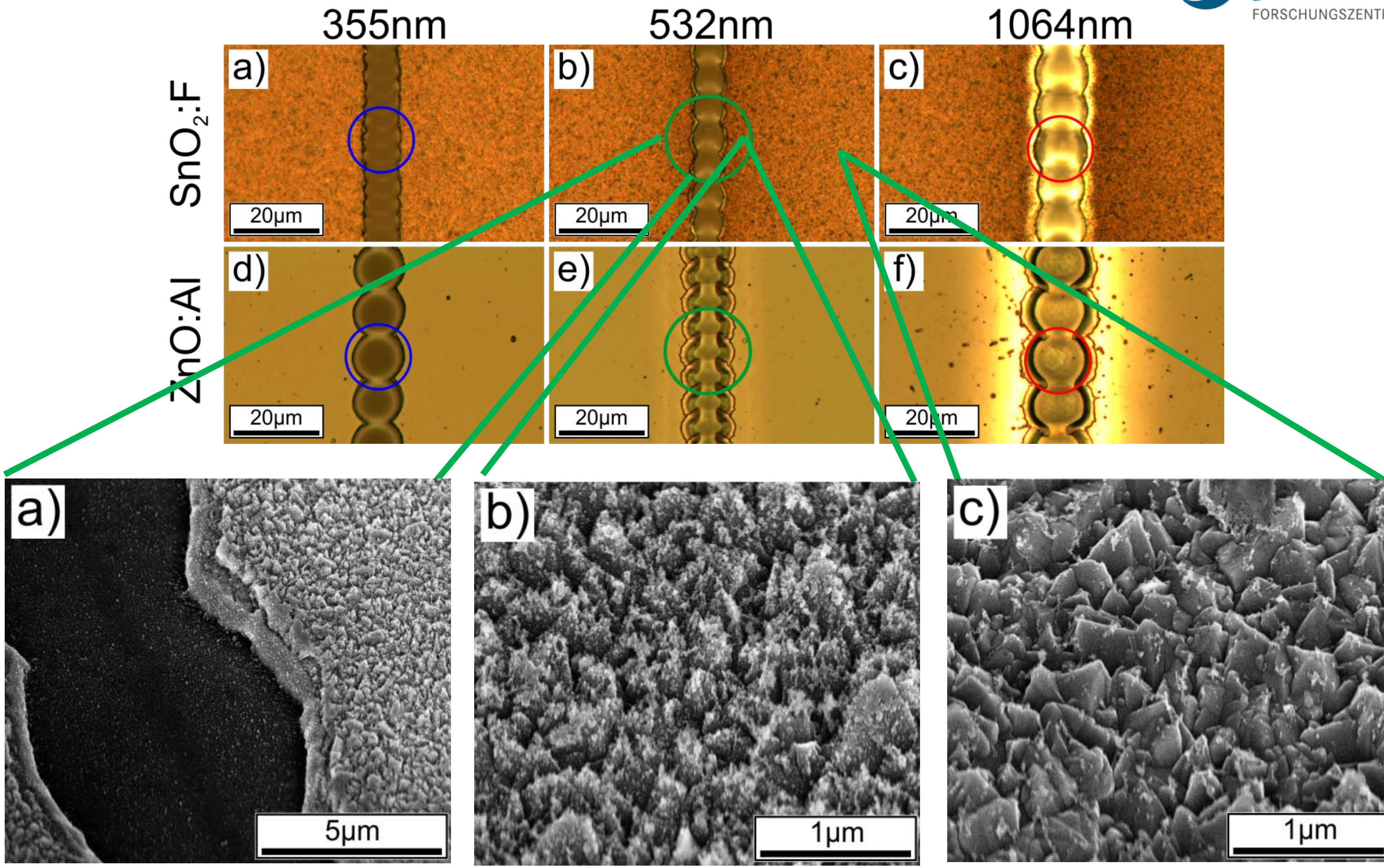
Constraints:

- Deviations of threshold fluence and laser pulse → unstable processing
- Stronger focusing → decreased depth of focus



P1:SnO_2:F

Front contact patterning (P1)

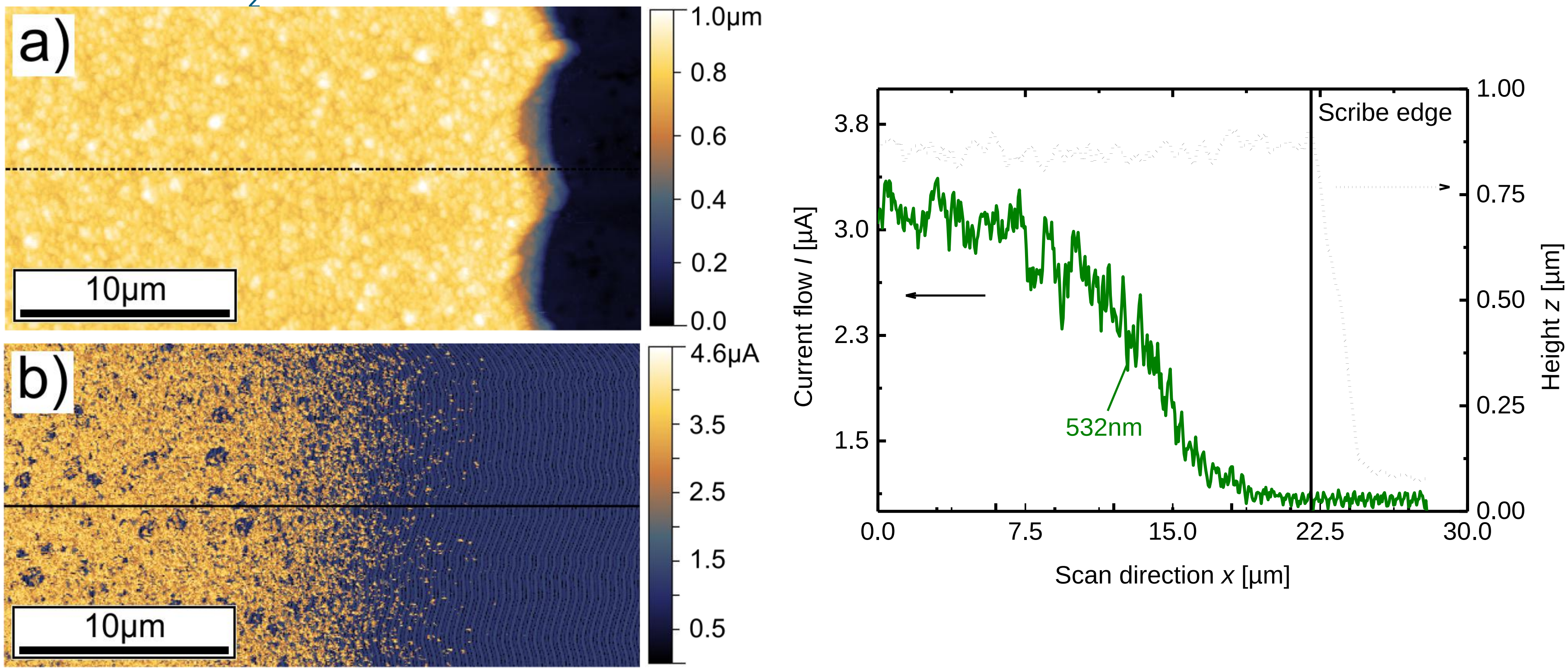


- Thin scribes possible, but large amount of debris and/or HAZ

Electrical width of front contact separation

Detection of electrical properties by spatially resolved measurements

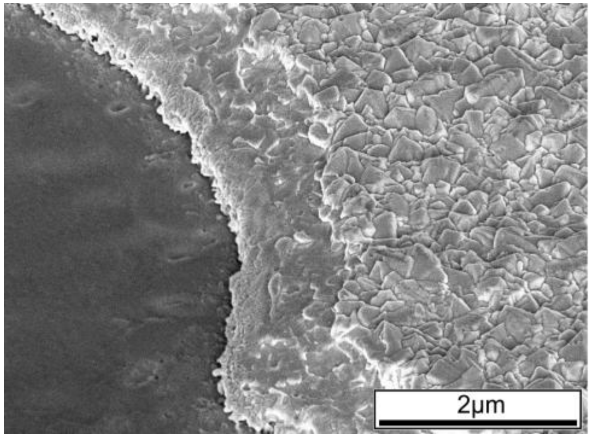
c-AFM: SnO_2:F

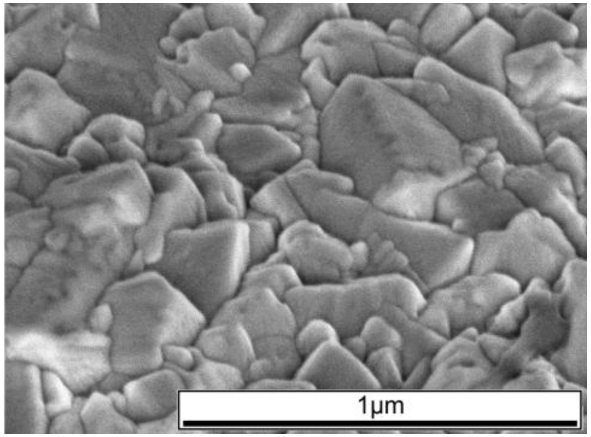


- Strong decrease of current flow, influence on active solar cell
  → Electrical width >> geometrical width
  → counterproductive for width minimization

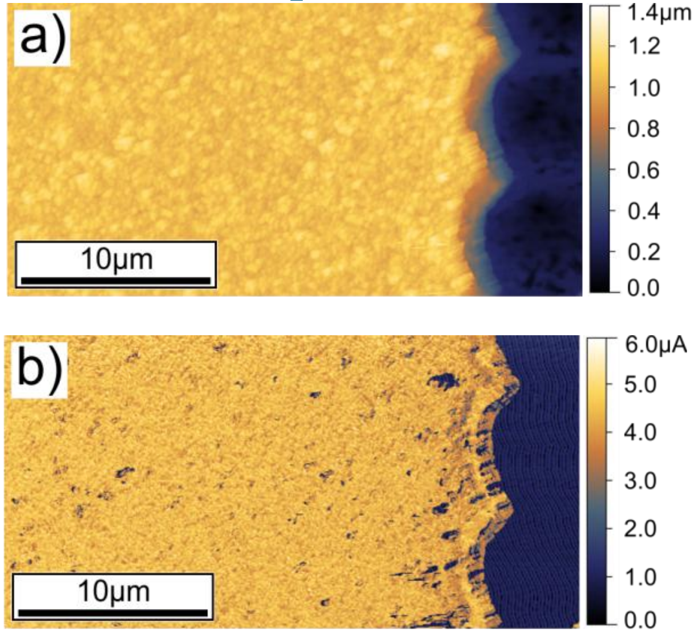
Heat affected zone or barrier layer formation

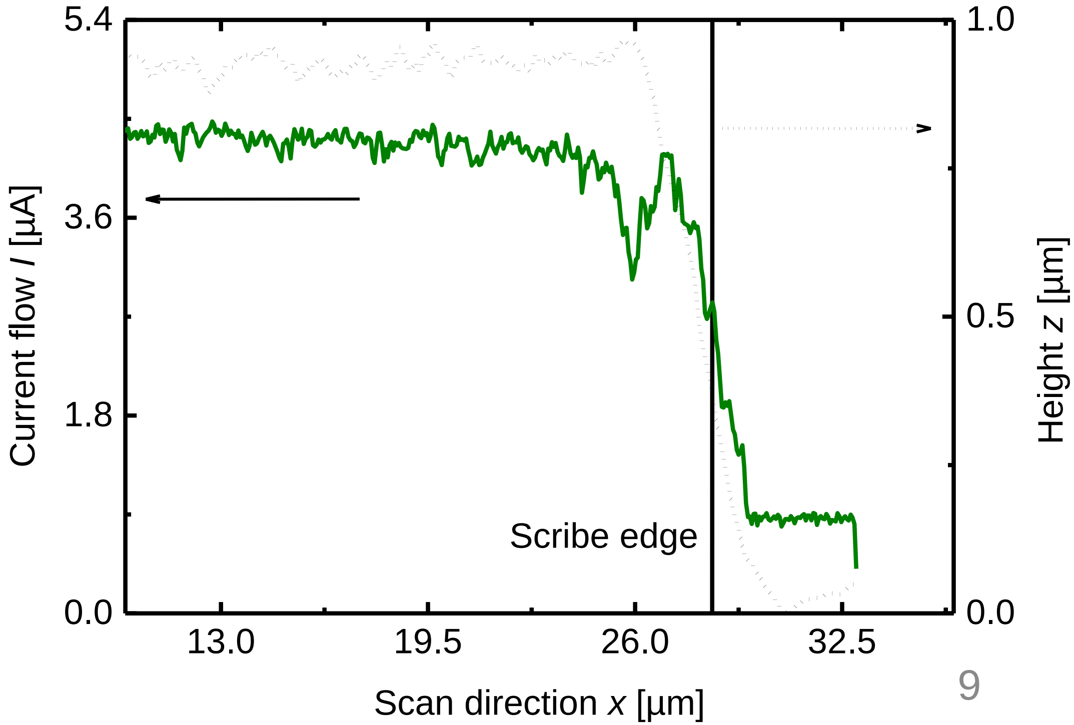
Wet chemical post treatment





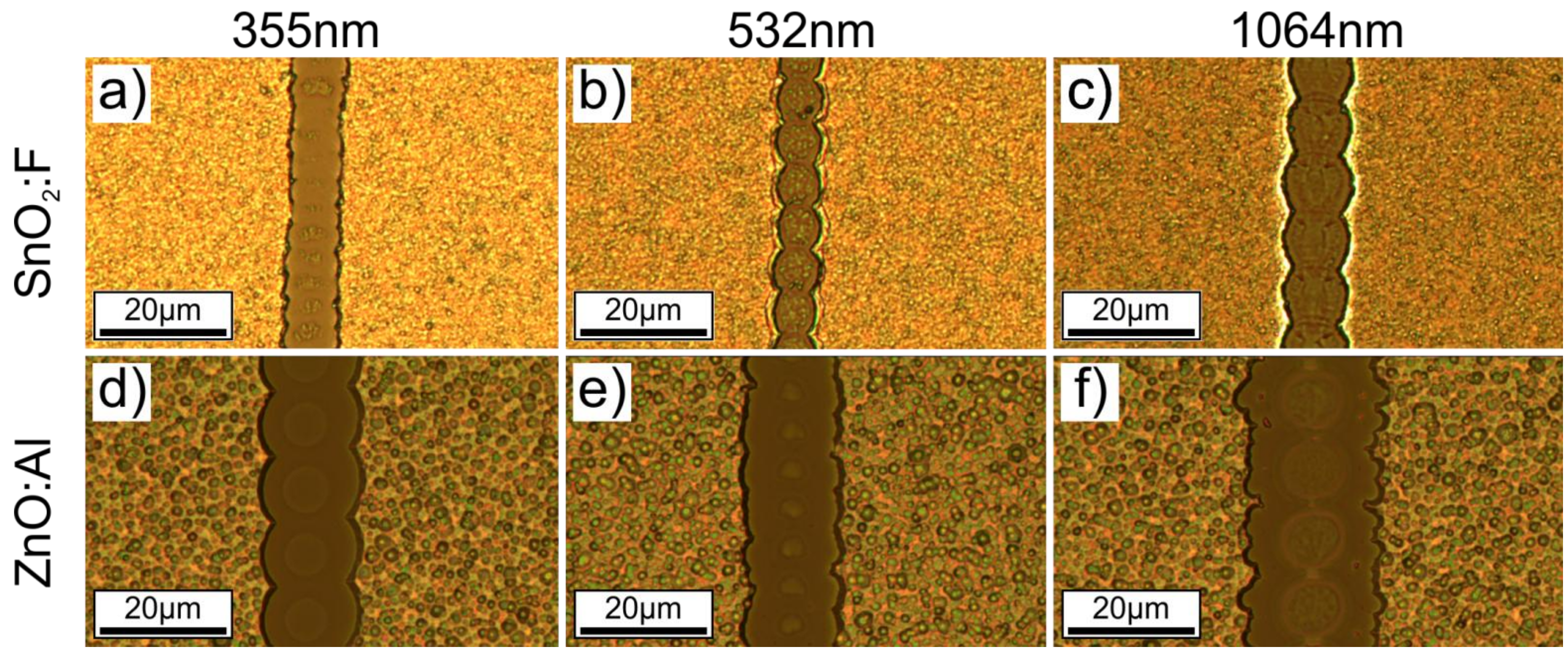
c-AFM: SnO_2:F





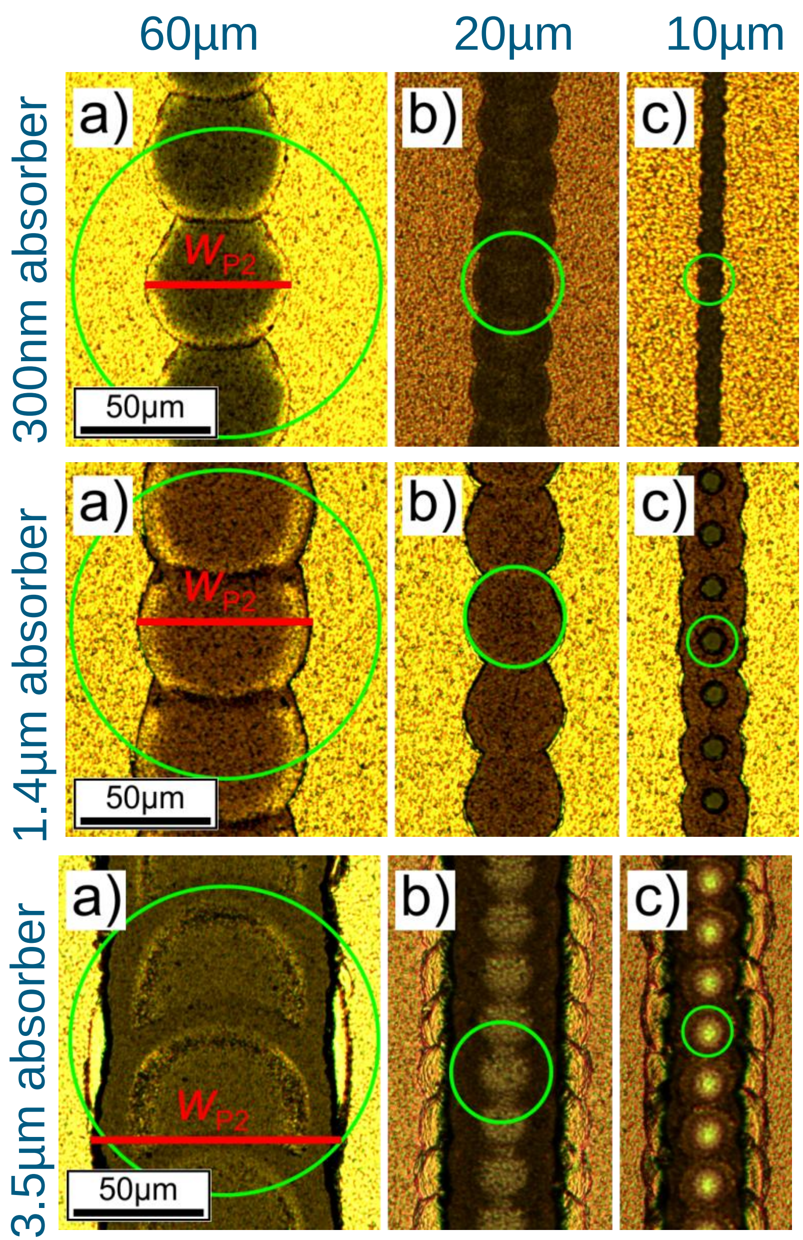
Front contact patterning (P1)

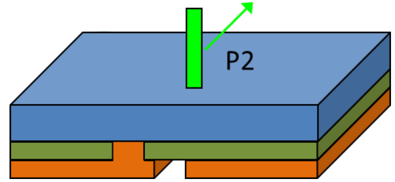
Summary after wet chemical treatment



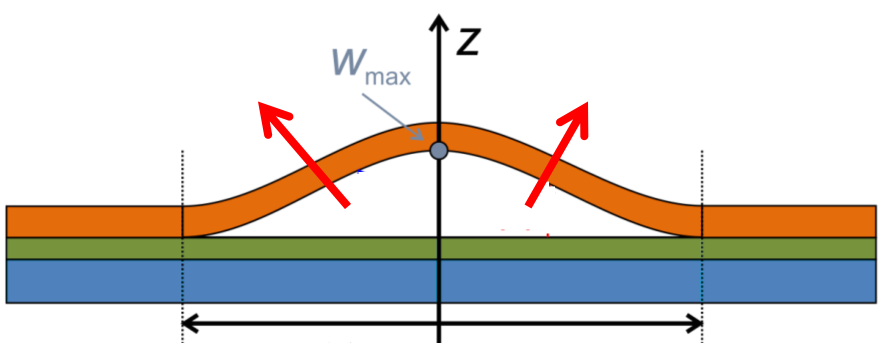
- Thin scribes possible for both materials with good electrical quality
- For etched ZnO:Al width slightly increased
- Isolation of TCO in MΩ-range also after solar cell deposition

Absorber patterning (P2)



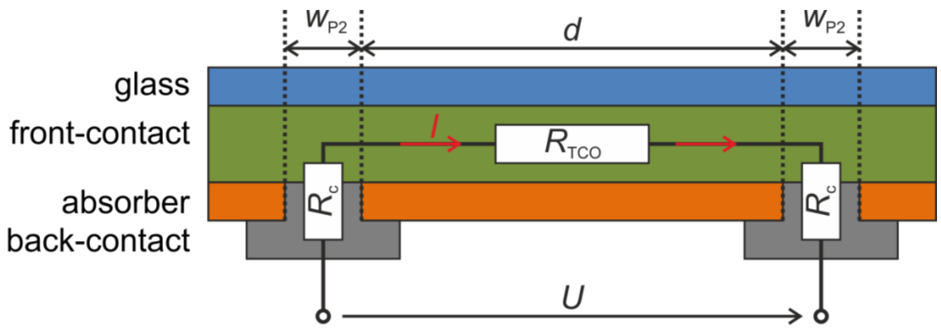


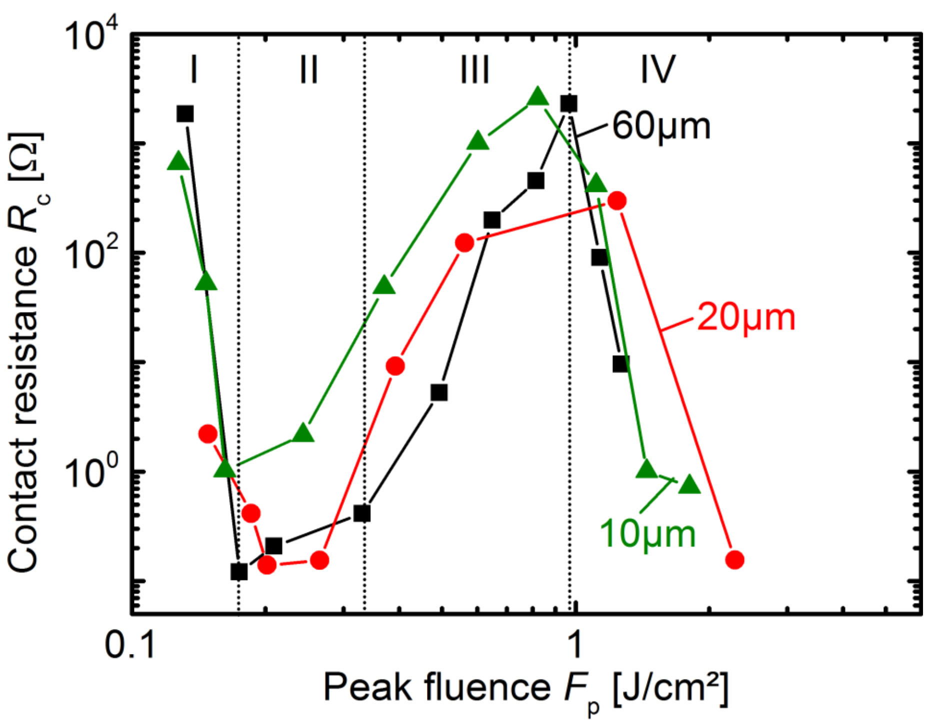
- Thin scribes possible for 300nm thickness
- For 1.4µm thick absorber – scribe width limit above laser beam diameter
- Mechanical properties most probably responsible for thickness/radius dependence

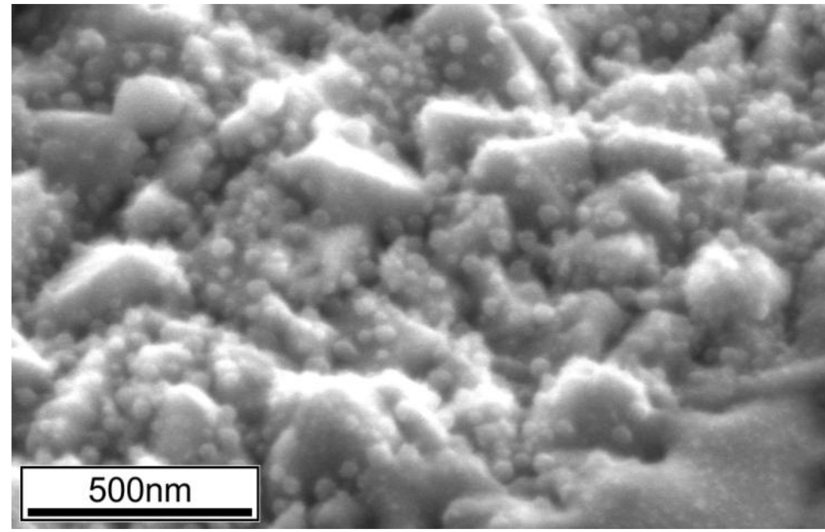


Electrical properties

Contact resistance: TLM setup

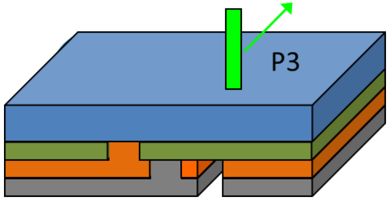


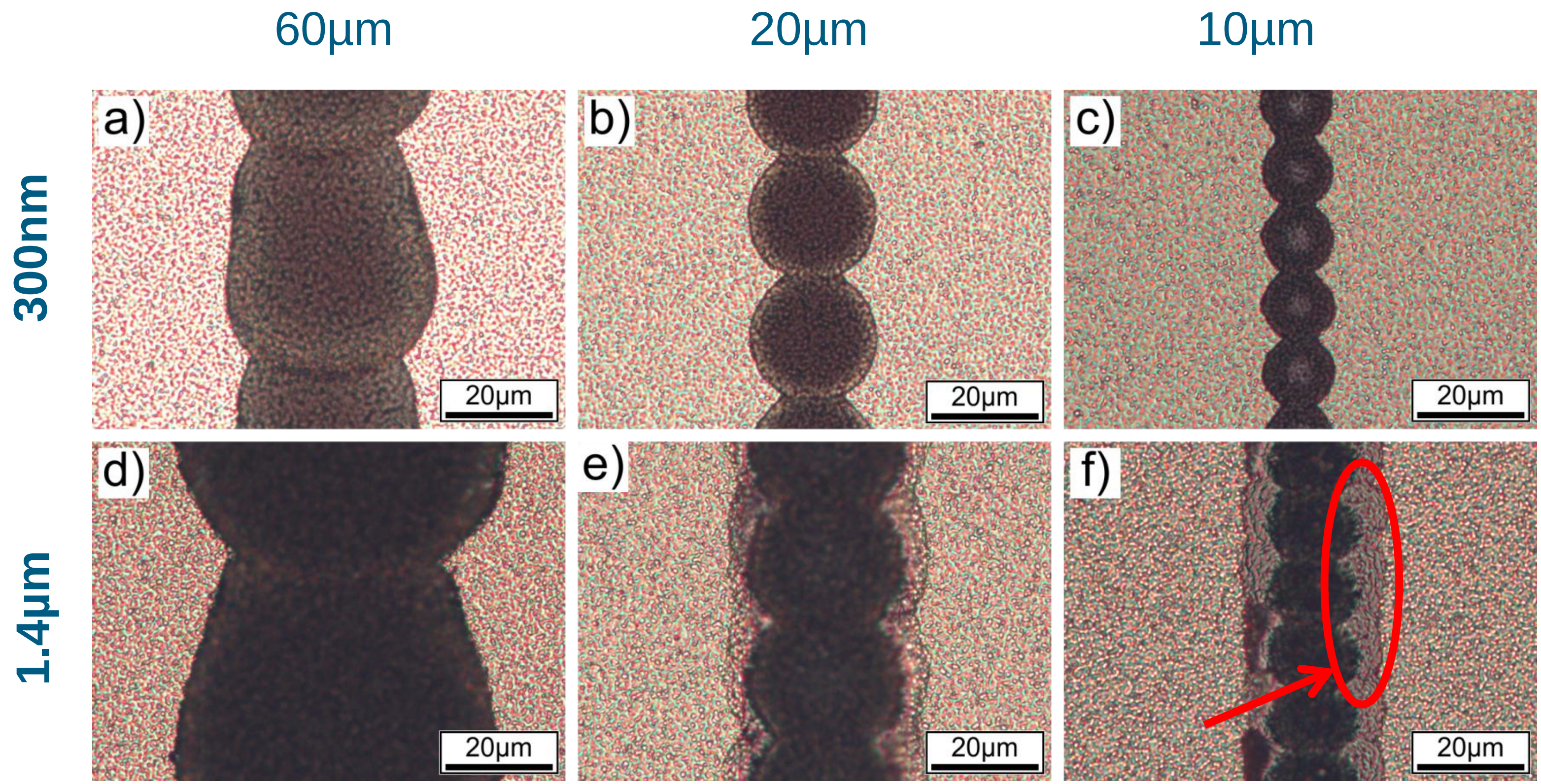




- Gupta calculations: 10µm radius (R_c~1Ω) counterproductive
- Change of specific contact properties?
- SEM: increased debris redeposition on TCO

Back contact patterning (P3)

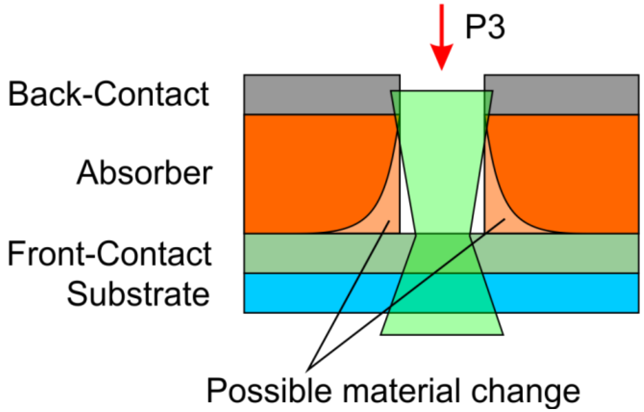


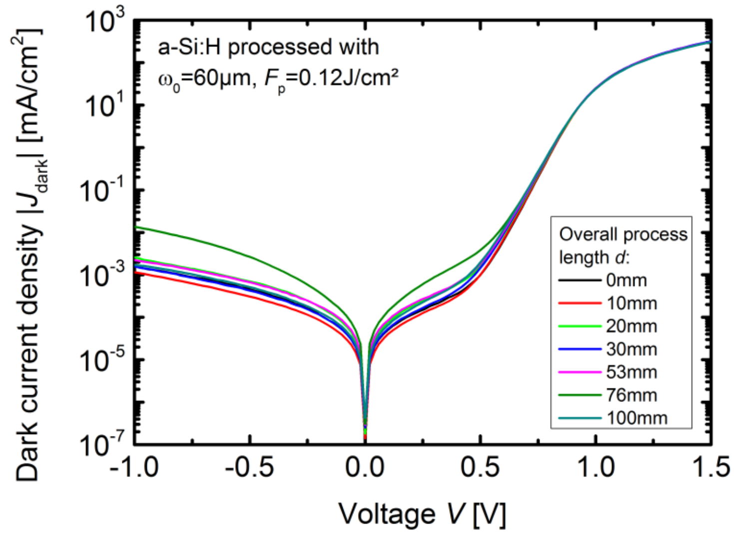


- Even stronger mechanical constraints with additional back contact
- Large irregularities at scribe etch, tilted silver layer

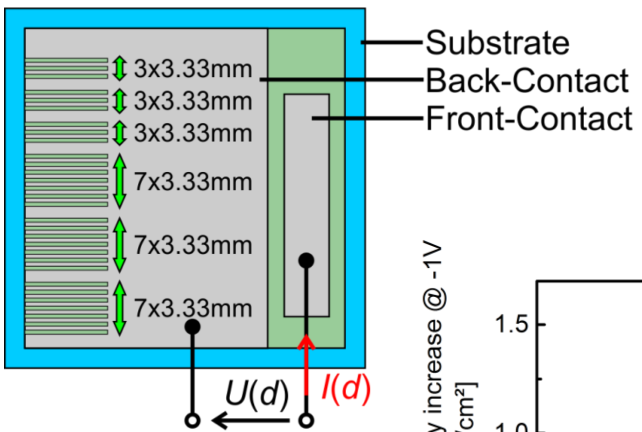
Electrical properties

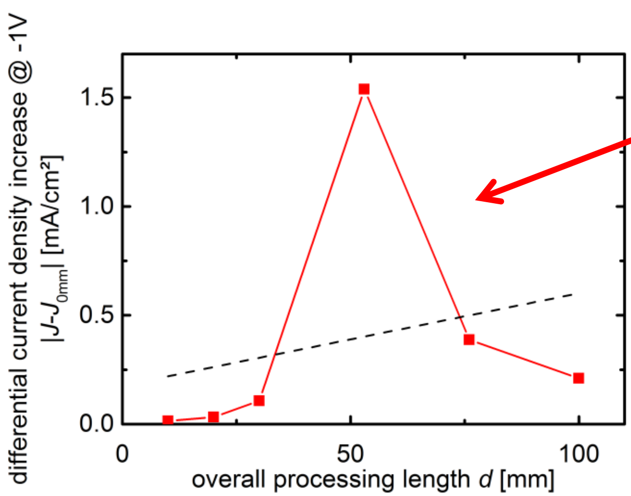
Parasitic shunt due to sub threshold energy

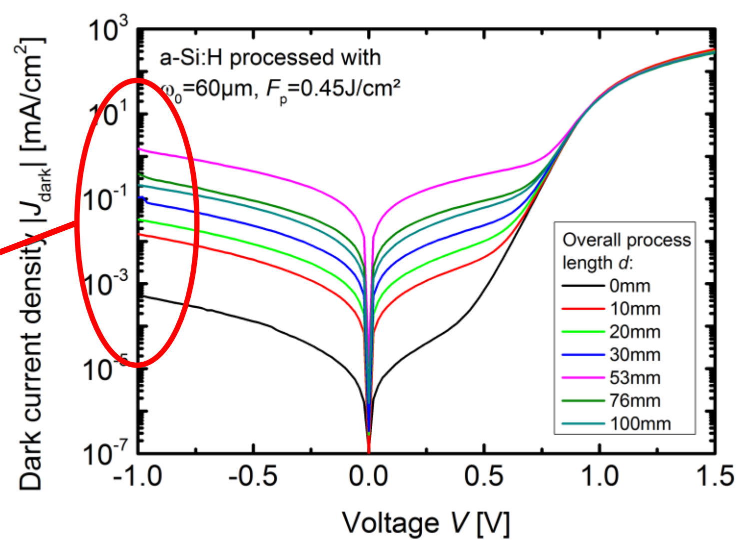




Test sample:



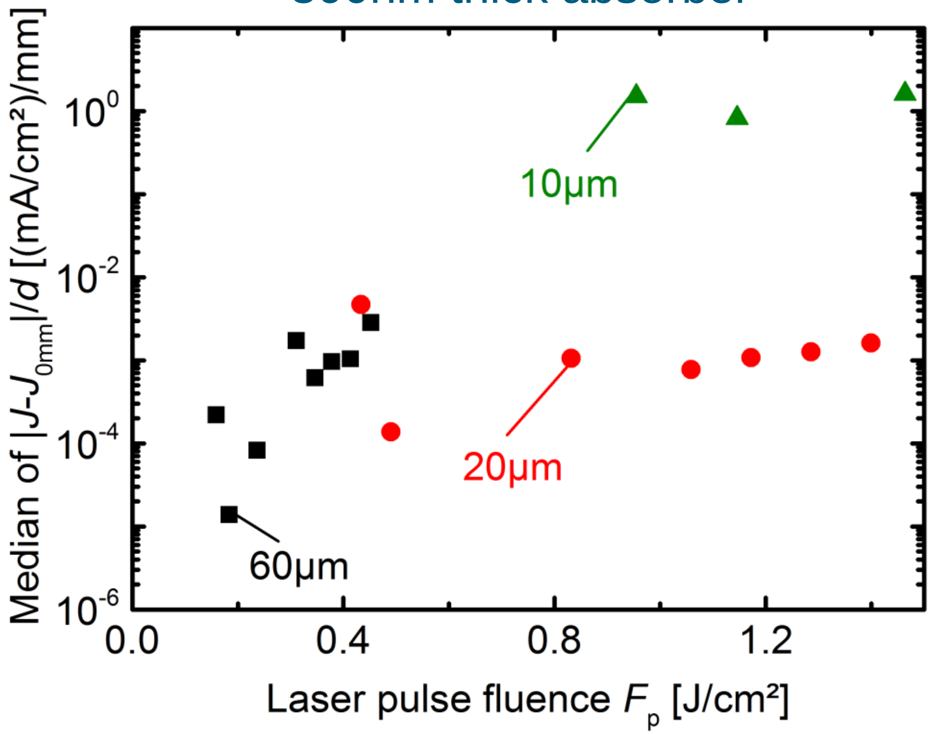


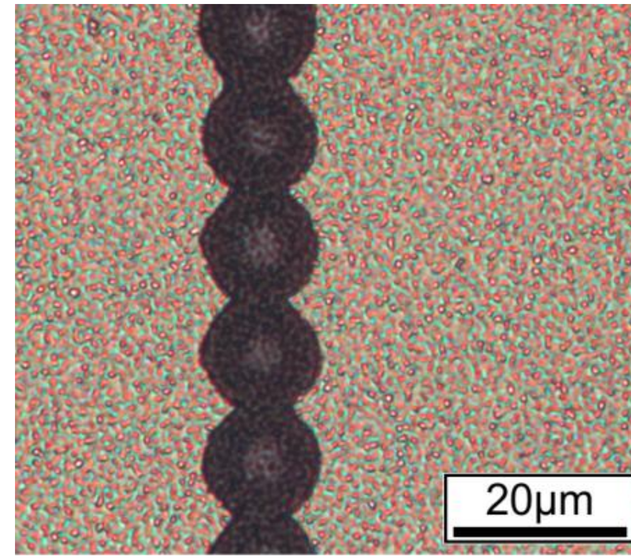


Electrical properties

Current increase taken at -1 V

300nm thick absorber



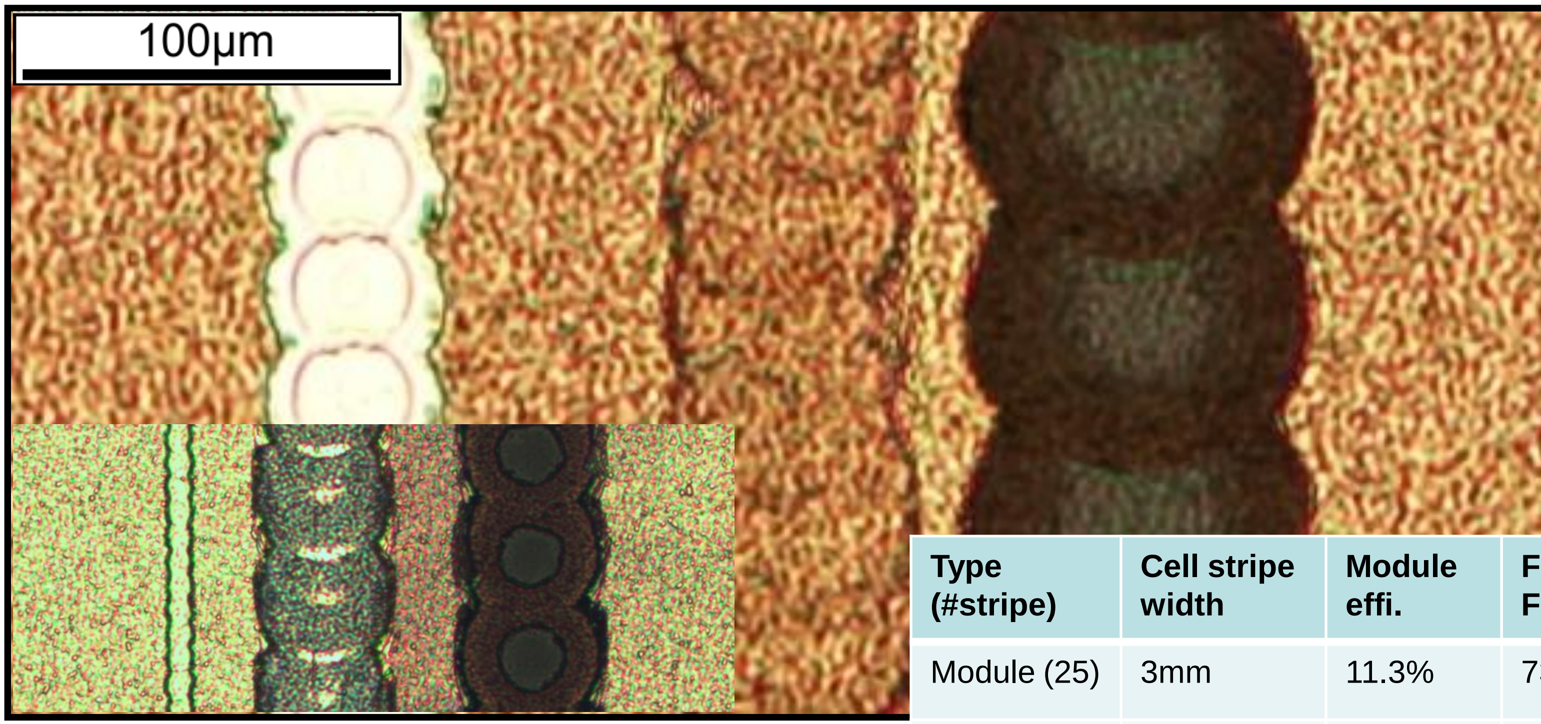


- Rather constant behavior as function of F_p
- For 10µm radius always leads to highest shunting
- Similar behavior for 60µm and 20µm

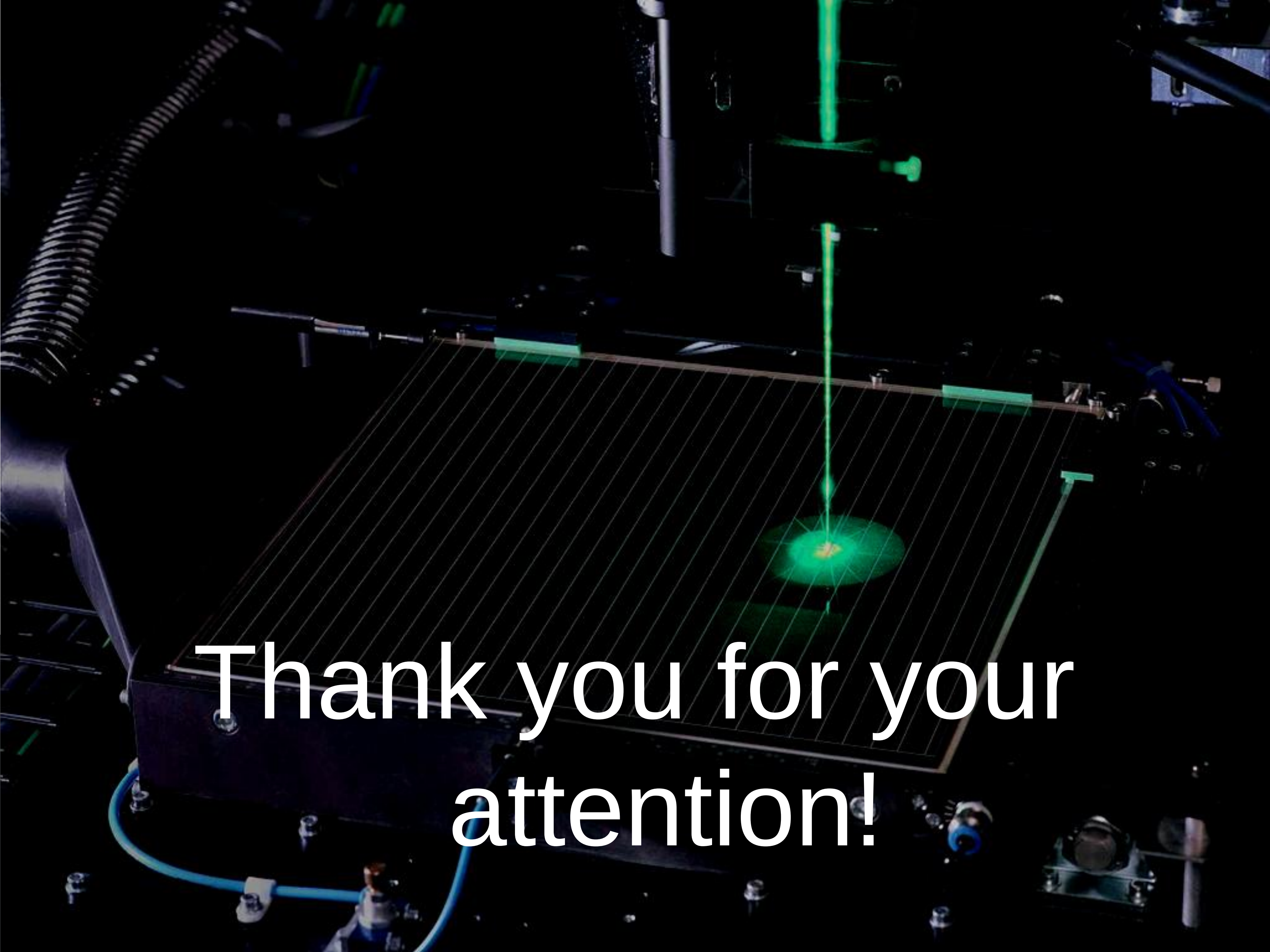
  → Just like for P2 usage of 10µm counterproductive with detrimental impact!

Conclusion

- **P1:** scribe width mainly limited by depth of focus
  → Post treatment removes redepositions
- **P2/P3:** ablation mech. sets strong constraints on the width minimization
  → Thin scribes only possible for thin layers
- Electrical properties of are strongly influenced by scribe width
  → Thinner lines lead to worse electrical properties

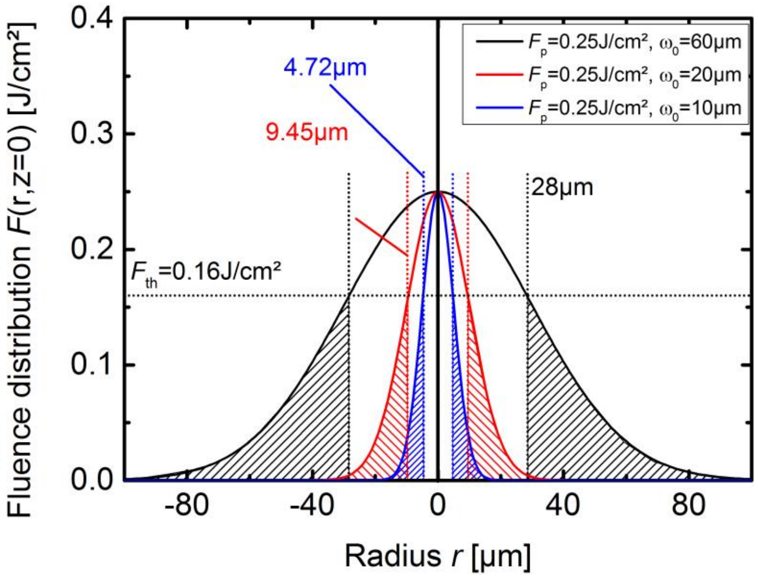


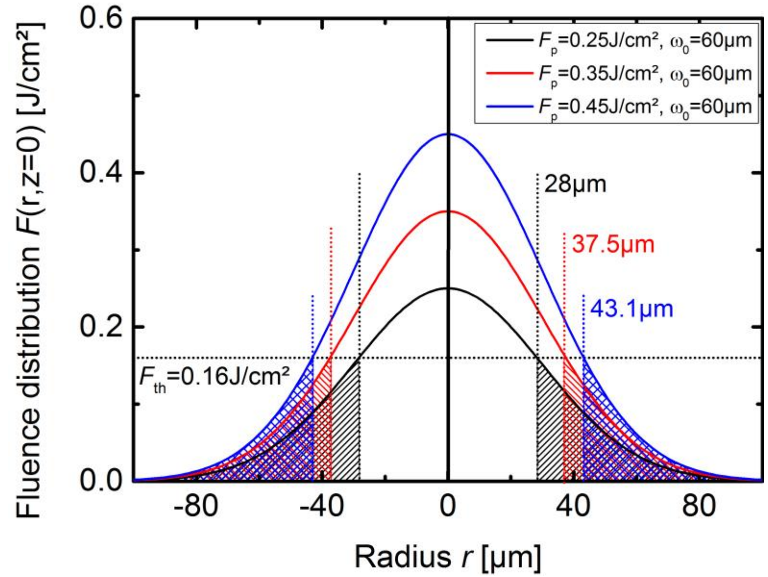
Type (#stripe)	Cell stripe width	Module effi.	Fill-Factor
Module (25)	3mm	11.3%	73.9%
Single cell	10mm	11.2%	74.2%

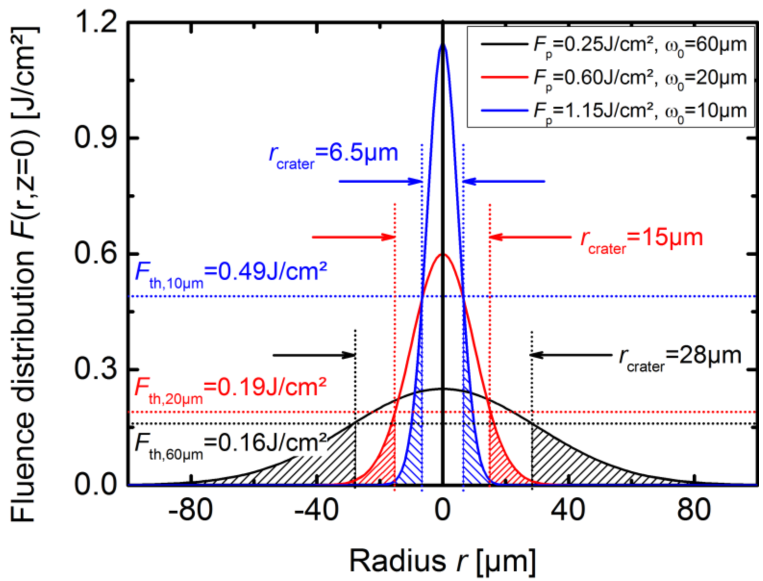


Thank you for your attention!

Properties of Gaussian beams (P3)

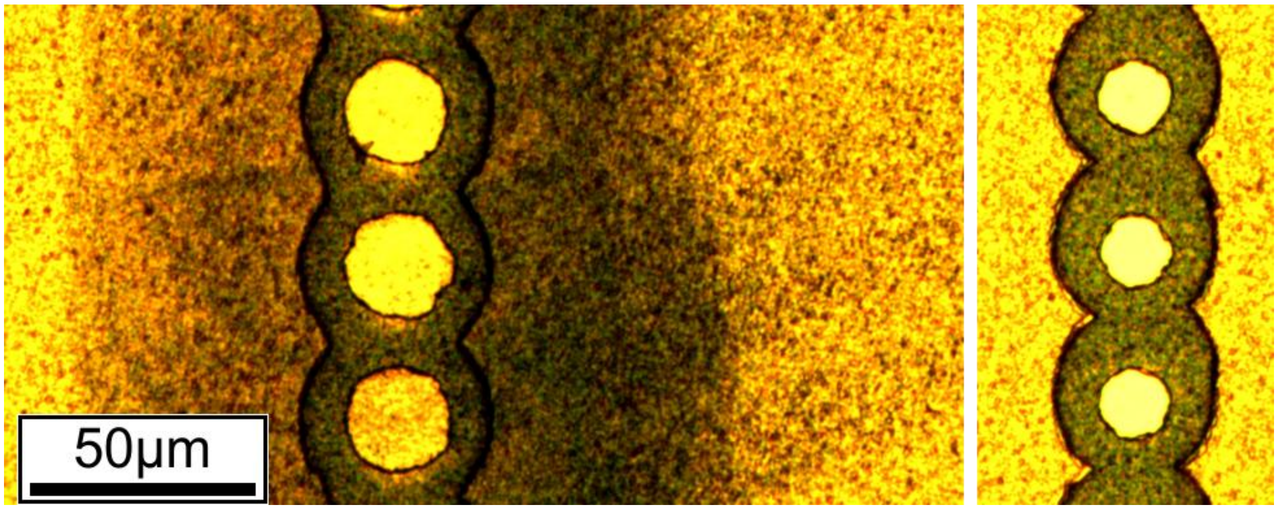


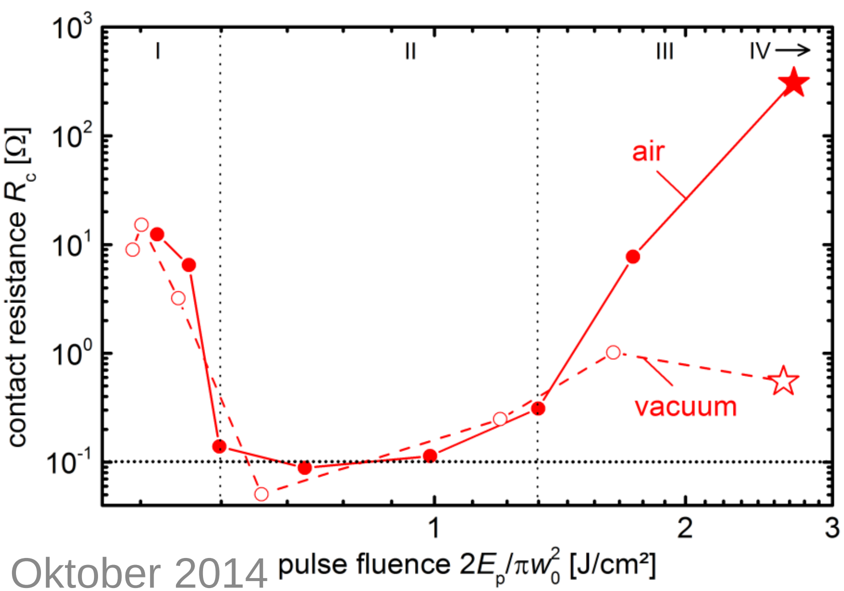




Influence of ambient pressure

air **vacuum**





Vacuum:

→ **lower particle deposition on surface**

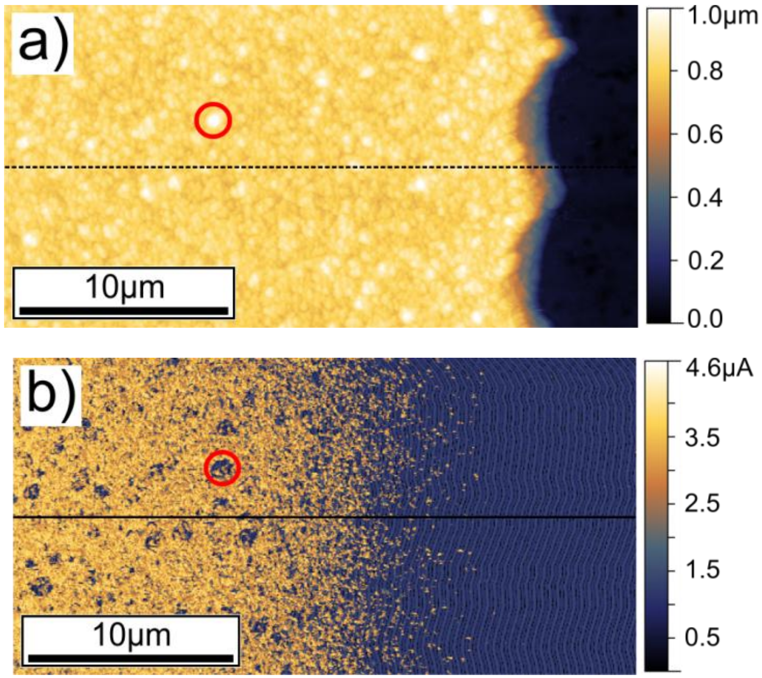
→ **decreased contact resistance**

Electrical width of front contact separation

Detection of electrical properties by spatially resolved measurements

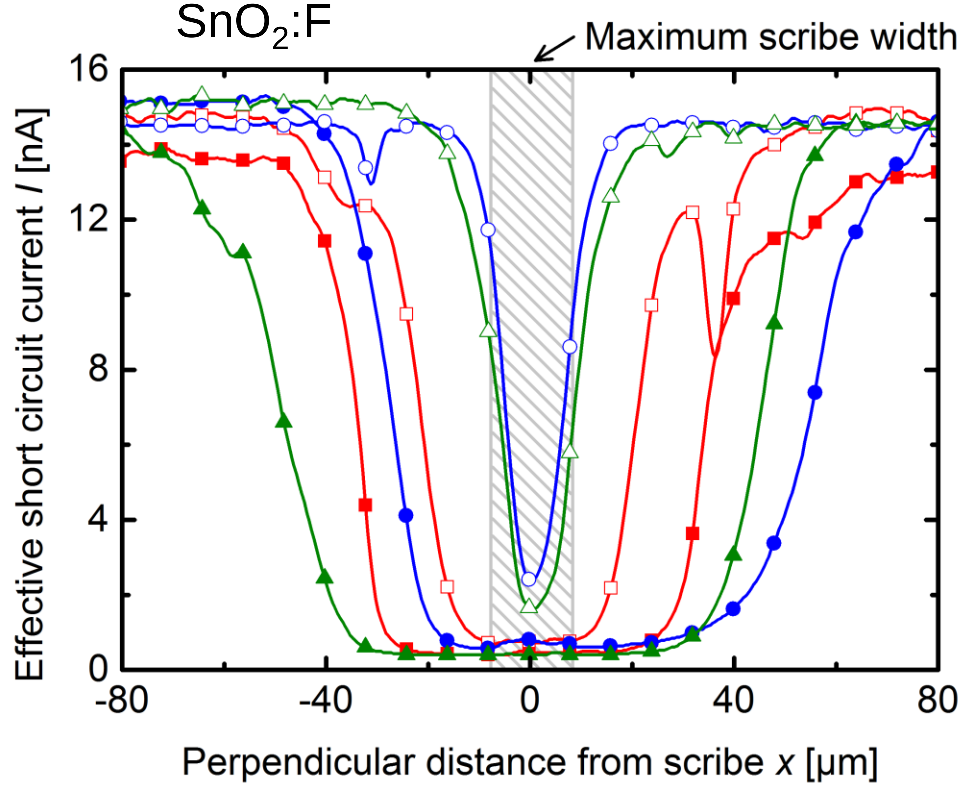
c-AFM:

SnO_2:F



LBIC:

SnO_2:F

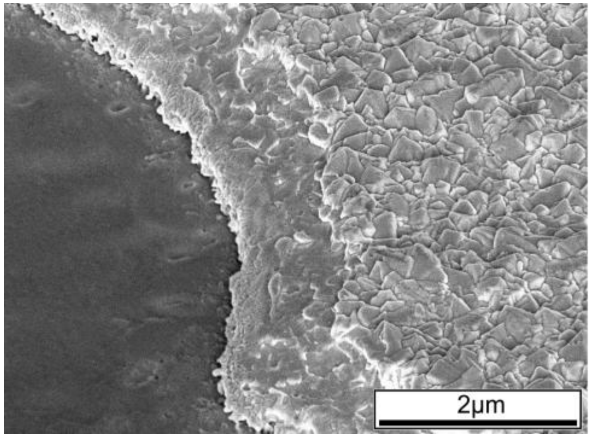


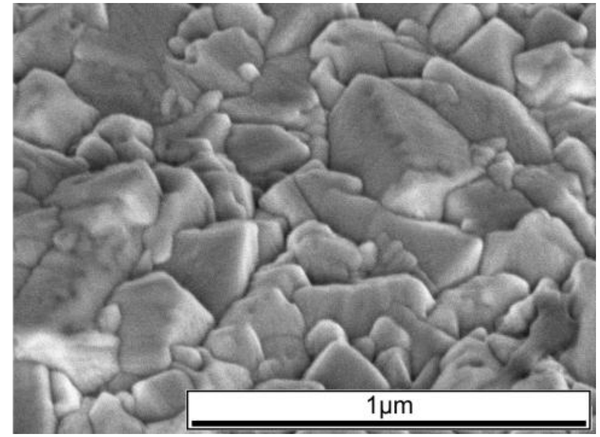
Strong decrease of current conduction and current generation

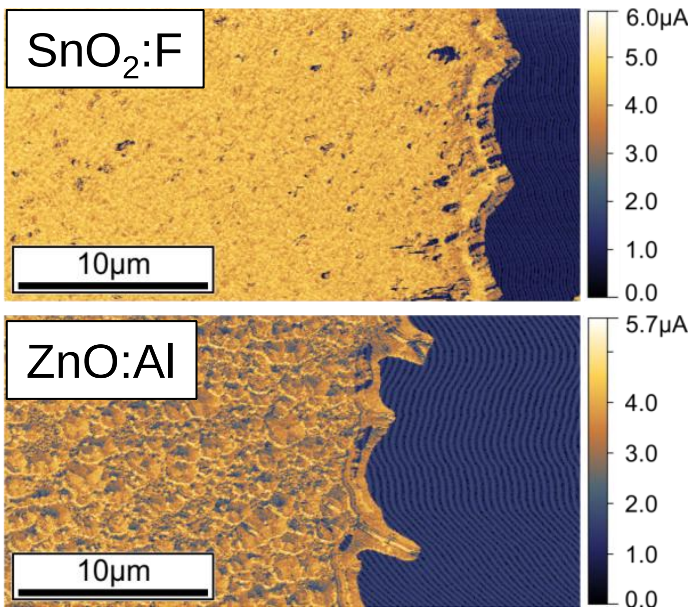
→ counterproductive for width minimization

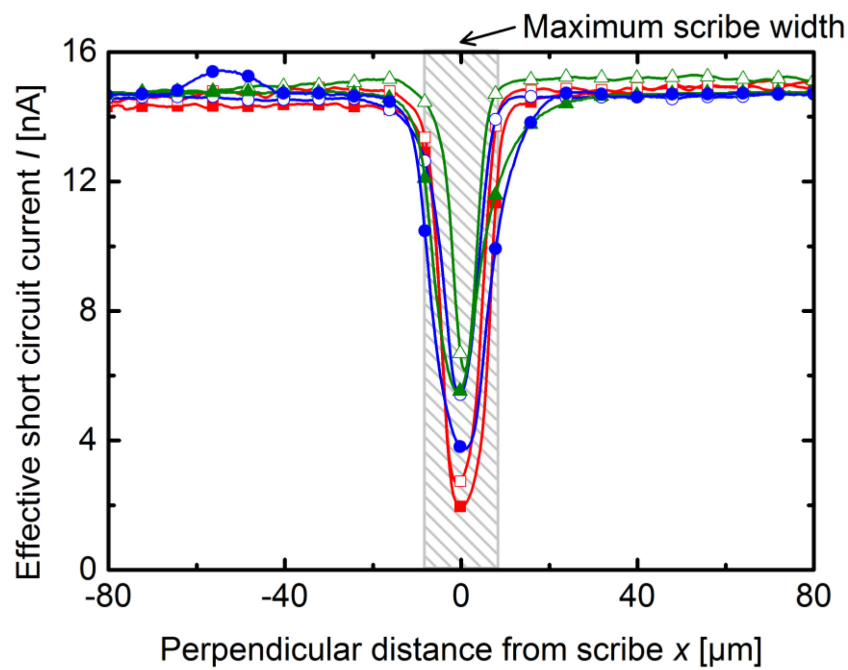
Heat affected zone or barrier layer formation

Wet chemical post treatment

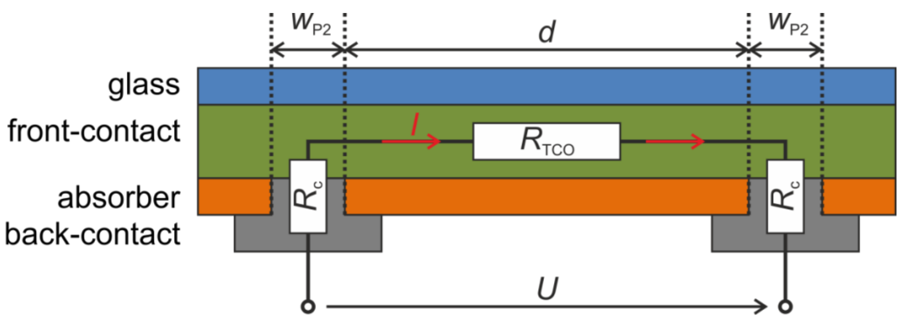


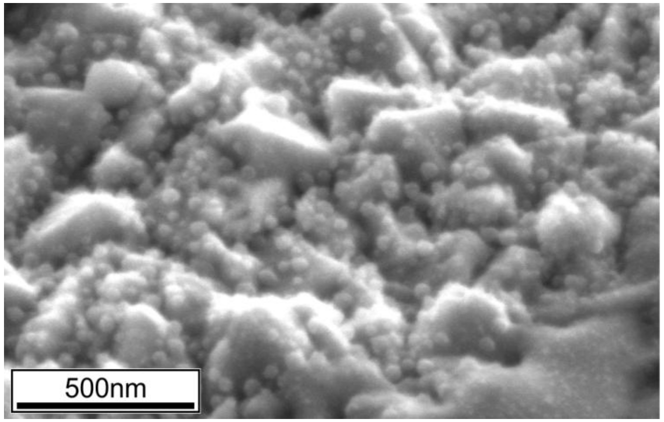


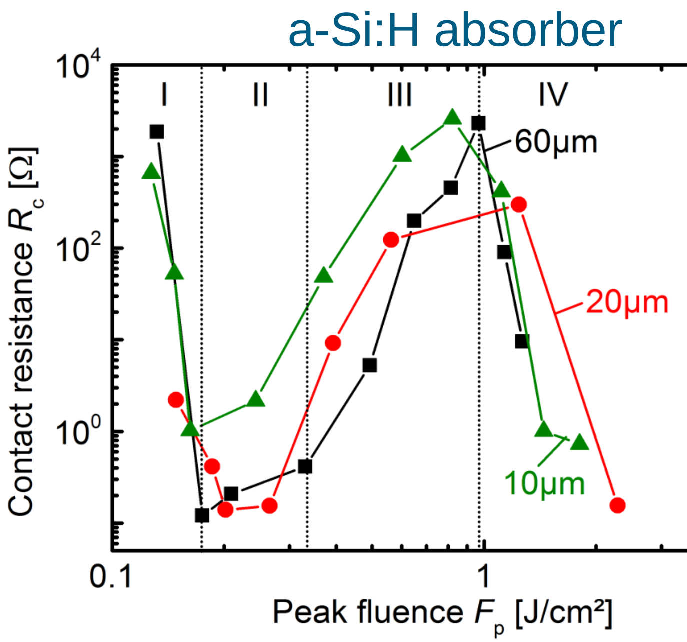


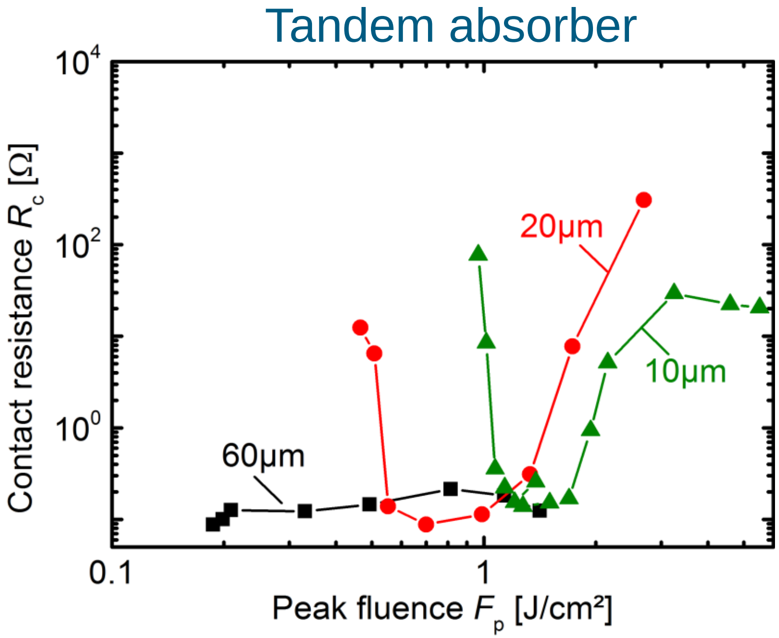


Electrical properties







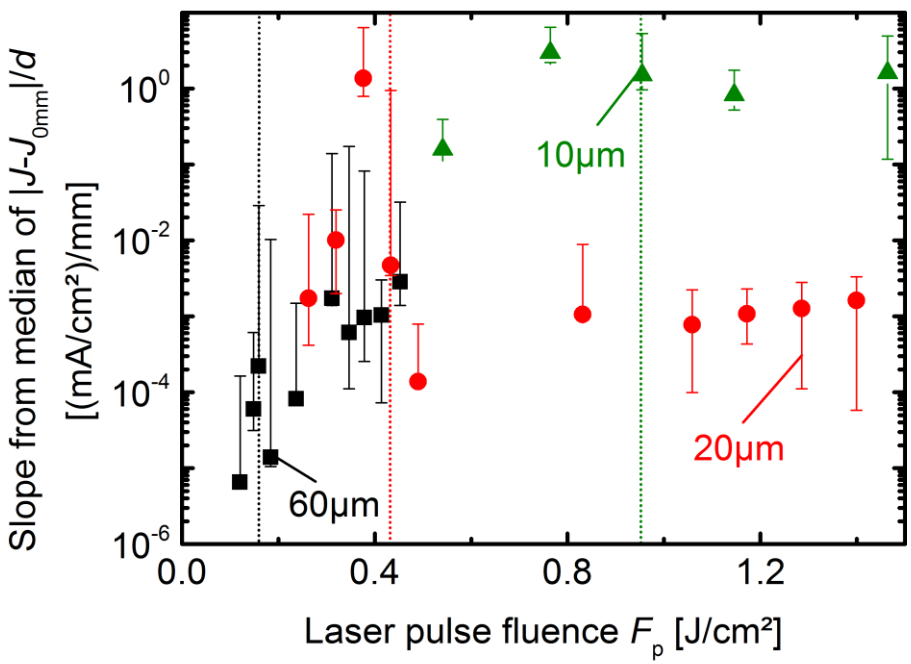


Gupta calculations: 10µm radius counterproductive for a-Si:H

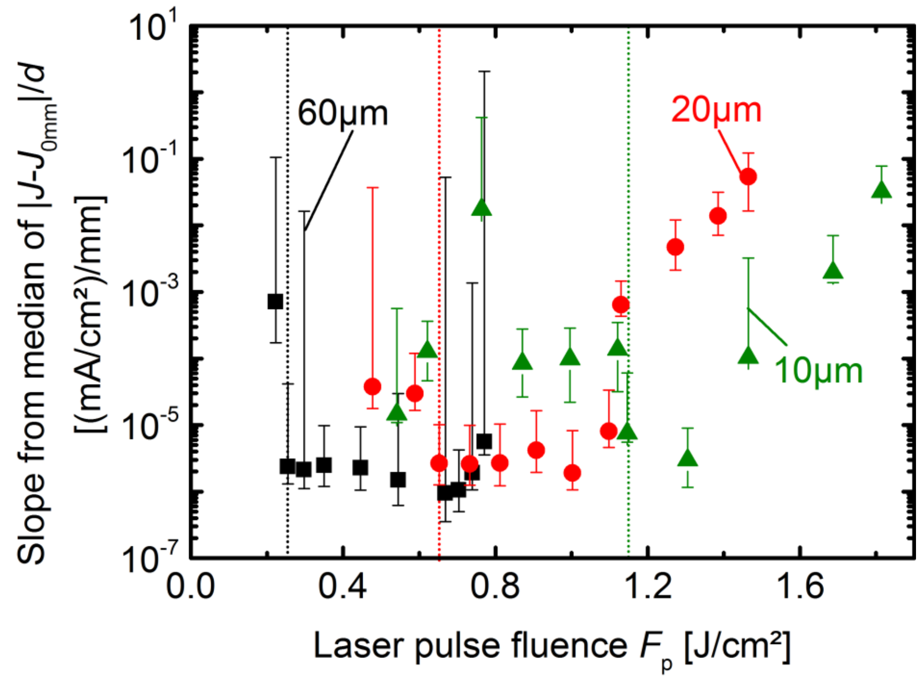
Electrical properties

Current increase taken at -1 V

a-Si:H single junction



tandem



- Strong fluctuations detected
- Above onset fluence (dashed line) almost constant for a-Si:H
- 10µm radius always leads to highest shunting
- Tandem shunting always lower than a-Si:H