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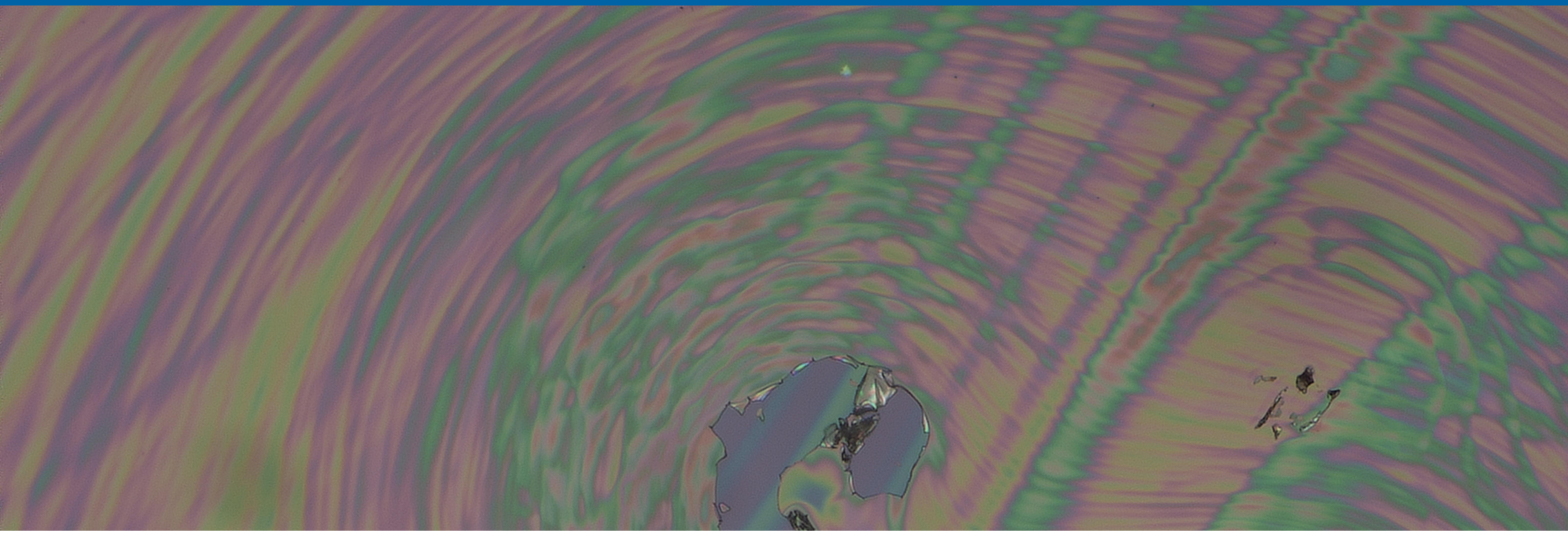
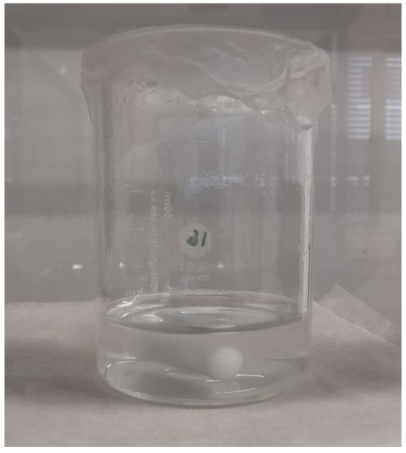
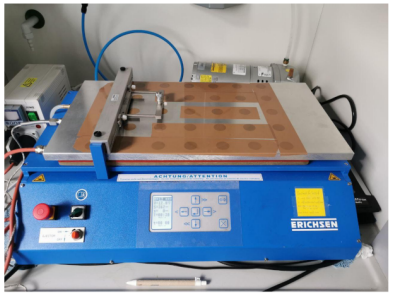
Particle Swarm Optimization for Electrical Passivation of Steel Substrate Using Zirconium Oxide

PSO for Steel Passivation with ZrO



Johann Dorn

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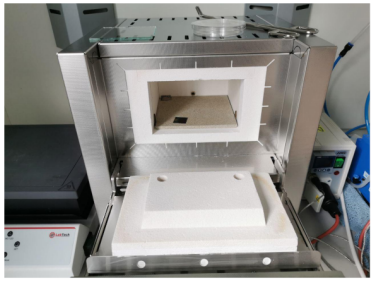

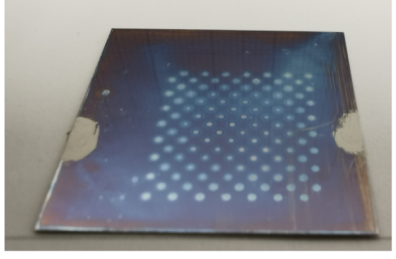

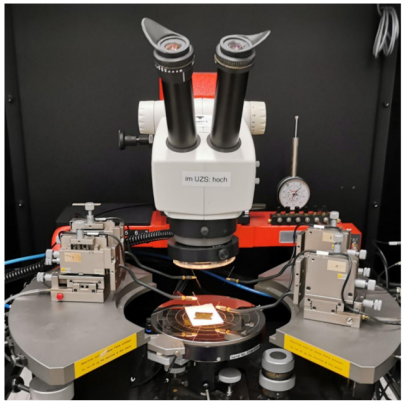
im UZS: hoch

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Thin-Film Photovoltaics: CIGS modules

- high absorption coefficient
- connected in series
- substrate:
  - must be insulating
  - mostly glass

Adaption of Precursor Solutions Recipe

Ceramics International 42 (2016) 16867–16871

Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

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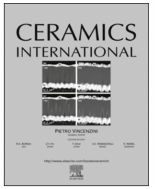

A new sol-gel route to prepare dense Al_2O_3 thin films

Baofu Hu *, Erguang Jia, Baoli Du, Yuehong Yin *

recipe	original	adapted
solvent	EtOEt	BuOH
precusor	$Al(OPr^i)_3$	$Zr(OPr)_4$
chelating agent	AcAc	AcAc
stabilzing agent	AcOH	iPrOH/AcOH

Different Precusor Concentrations

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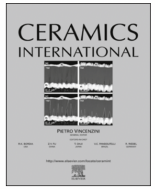


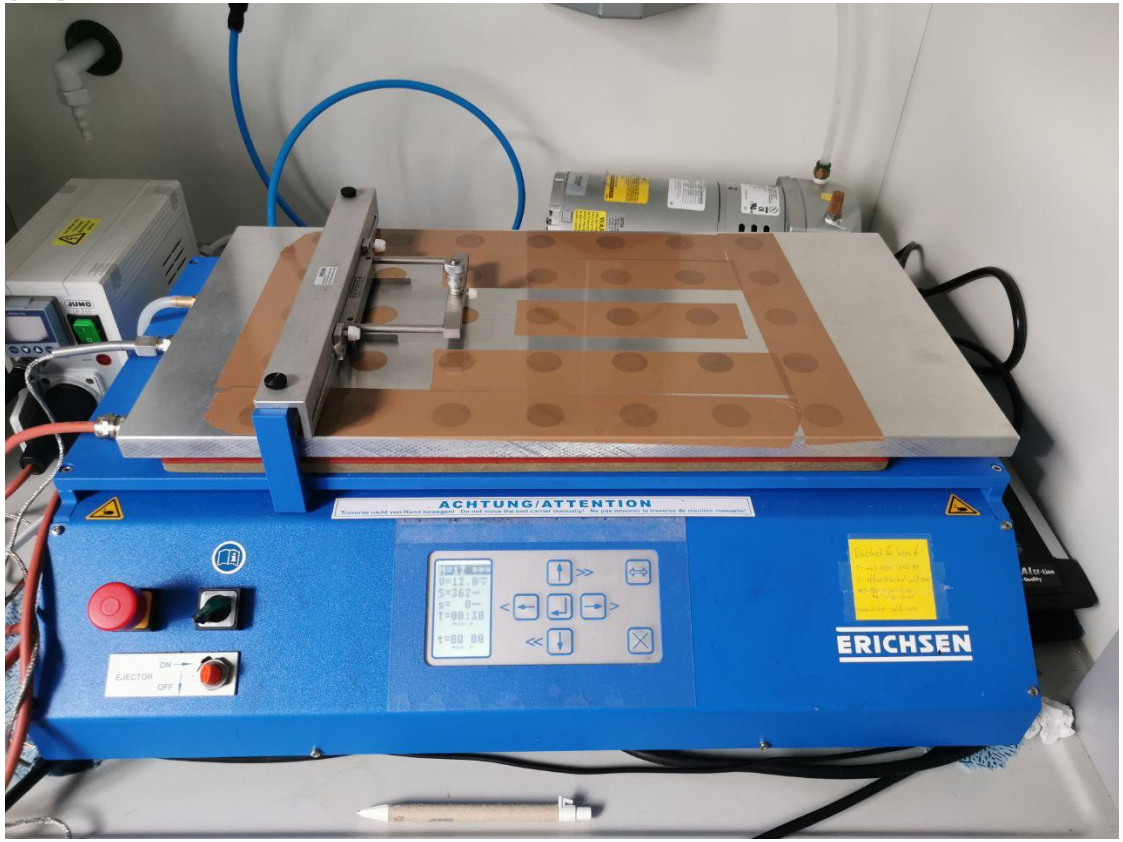
A new sol-gel route to prepare dense Al_2O_3 thin films

Baofu Hu *, Erguang Jia, Baoli Du, Yuehong Yin *

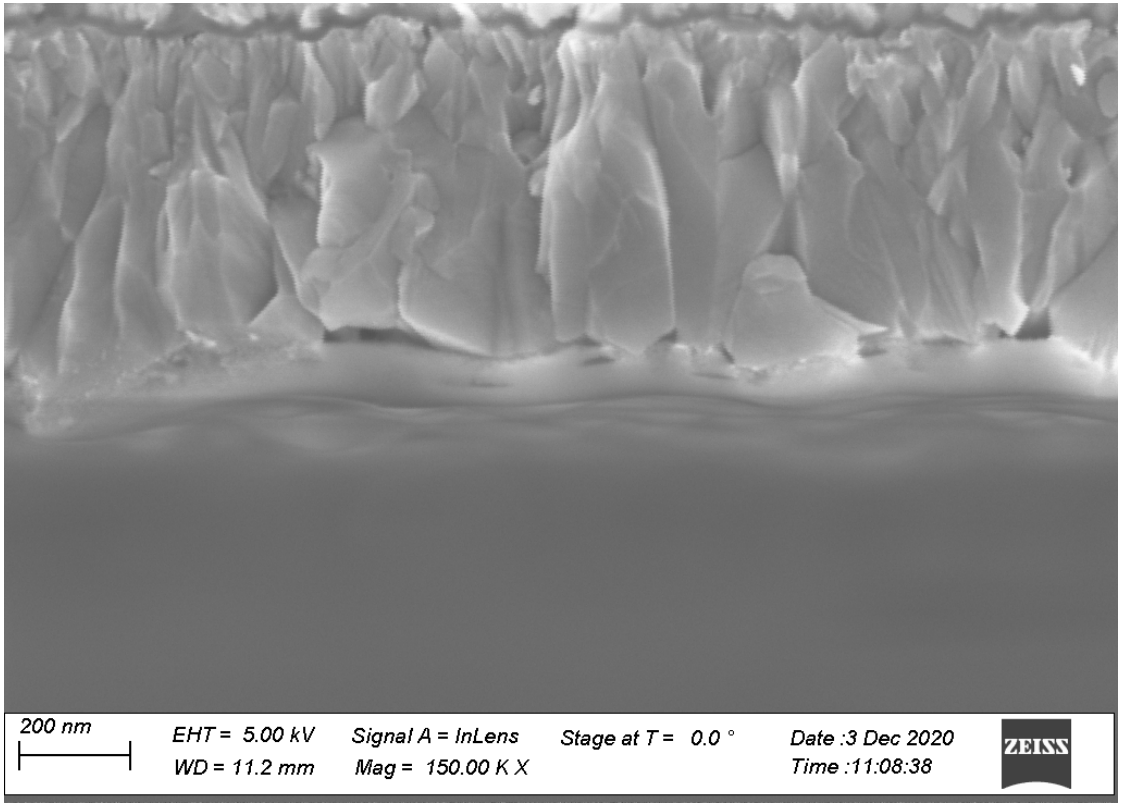
	1x	2x	3x	4x	5x
BuOH [ml]	4.95	4.9	4.85	4.8	4.75
ZrPro [ml]	0.05	0.1	0.15	0.2	0.25
AcAc [ml]	0.0125	0.025	0.0375	0.05	0.0625
IPO/AcOH [ml]	2	2	2	2	2

Tape Casting and Calcination

- Tape Casting
  - temperature: 40-80°C
  - blade speed: 10-20mm/s
- Calcination
  - temperature: 300-500°C
  - heating rate: 2-18°C/min



Cross Section of ZrO_2



- Scanning Electron Microscope
- substrate: FTO (Fluorine Doped Tin Oxide)
- single layer of ZrO_2

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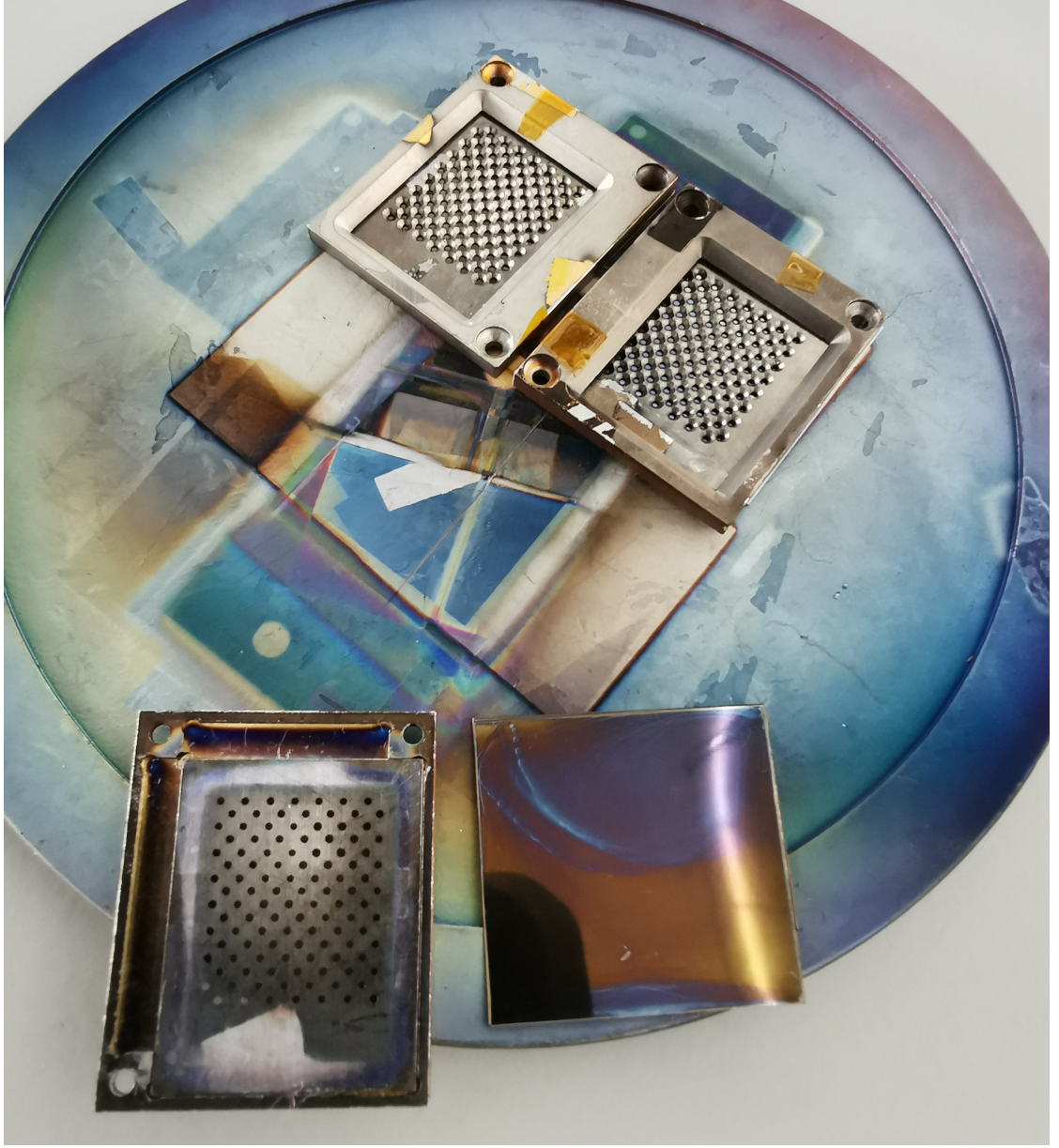
Application of Contacts

- Bottom left: Shadow mask
- Bottom right: Steel substrate ZrO_2 layer
- Top: samples with mask attached



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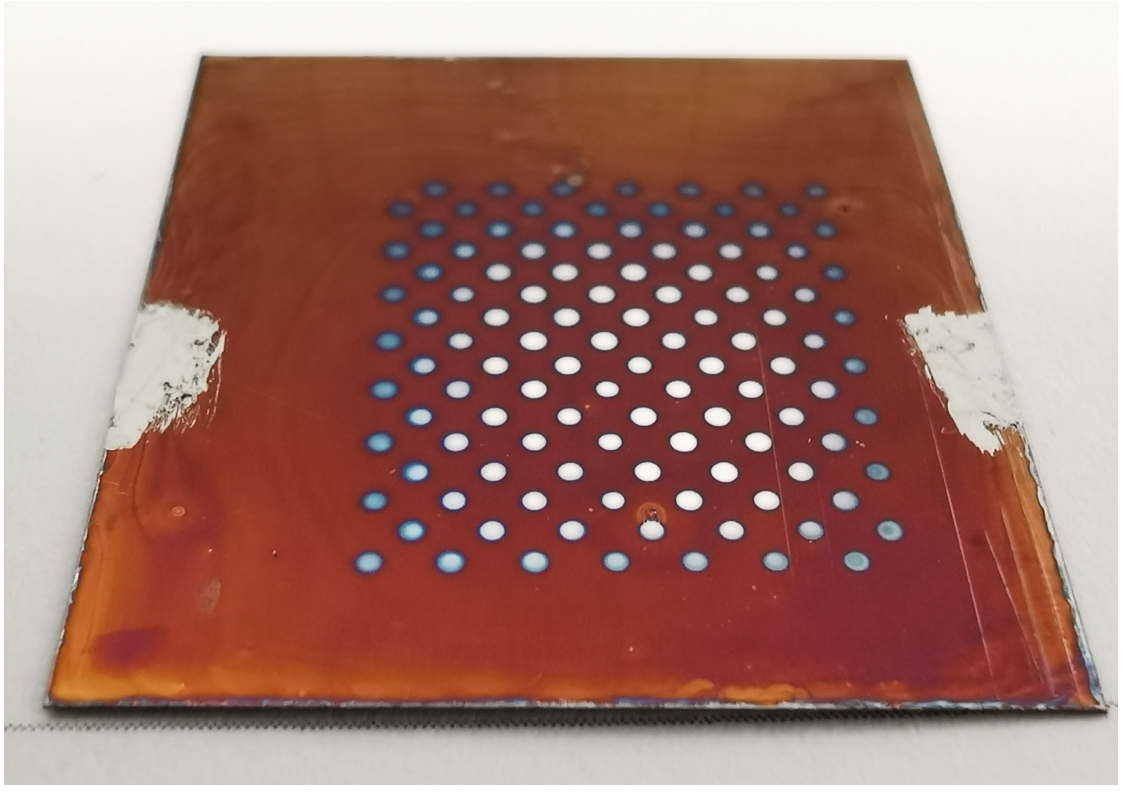
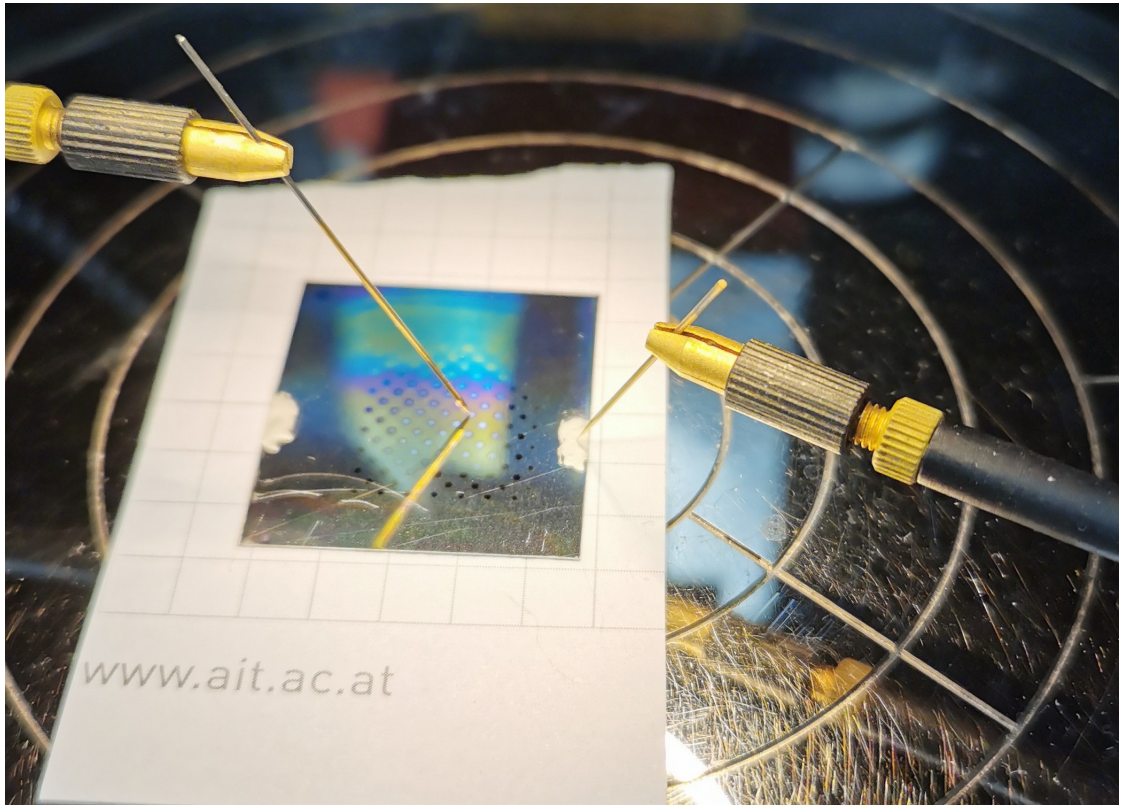
Applied Contacts



- passivated sample with array of contacts
- contacts to steel on edges

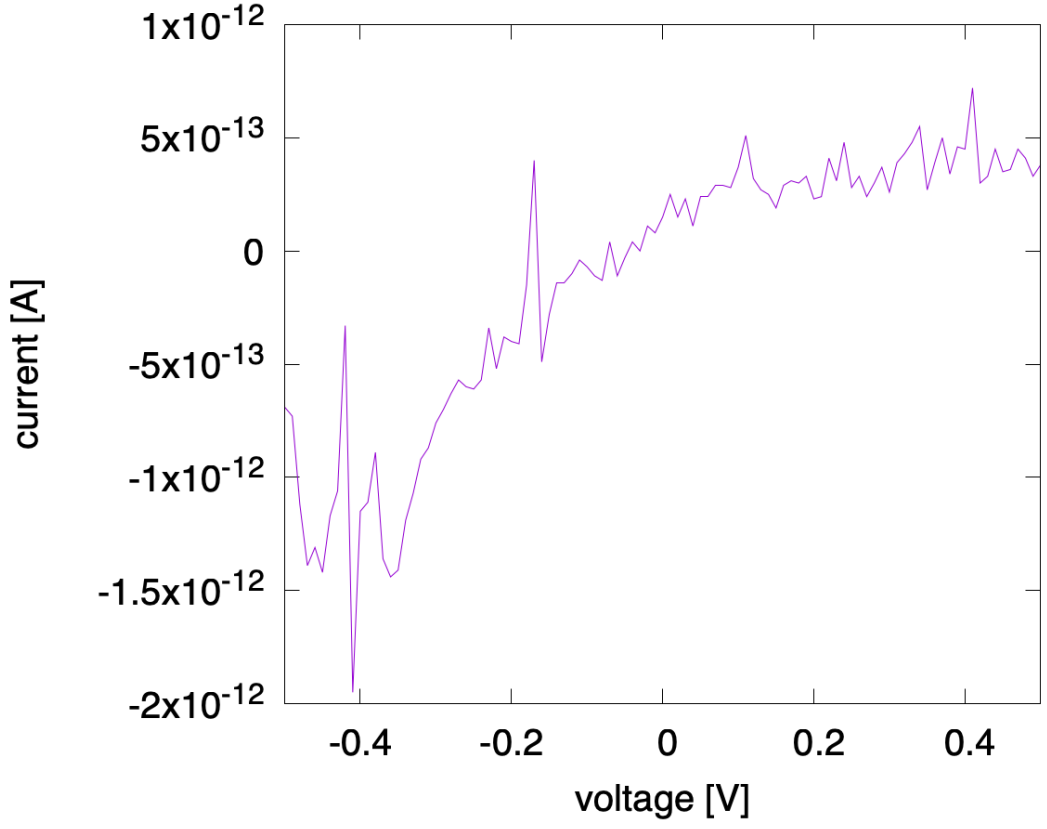
Measuring Current Voltage Characteristics

- left needle touches top contact (ZrO_2)
- right needle touches bottom contact (steel)



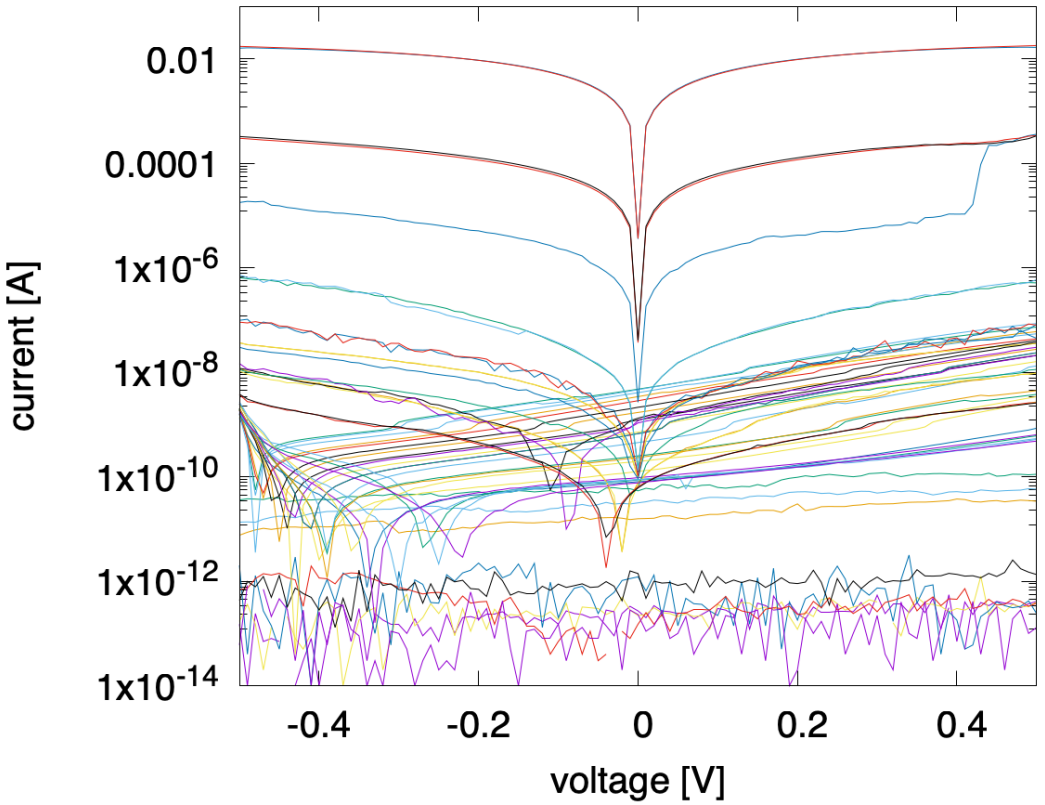
Current-Voltage characteristics

- voltage sweep
- 10mV steps
- very low current
- low conductivity
- high resistance



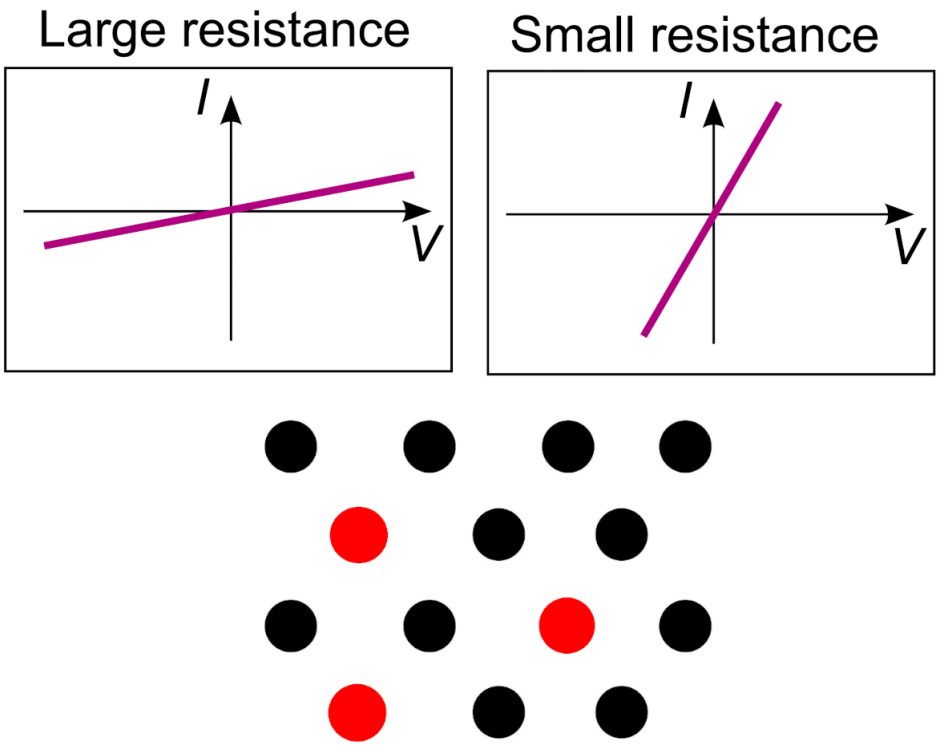
Current-Voltage characteristics II

- all measurements of single sample
- huge range
- low current
- high current



Pin Hole Density and Leakage Current

- Conductivity
  - $g = \frac{\mathrm{d}I}{\mathrm{d}V}\Big|_{V=0}$
- Pin Hole Density
  - $s_i = \begin{cases} 1 & \text{if} \quad g_i < 10^{-5} \\ 0 & \text{if} \quad g_i \geq 10^{-5} \end{cases}$
  - $\rho = \sum_i^N \frac{s_i}{N}$
- Leakage Current
  - $\gamma = \sum_i^N \frac{(-log_{10}(g_i)-13)^2}{N}$



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Particle Swarm Optimisation

- inspired by fish schools
- iterative process
- particles:
  - input vars: position
  - velocity
- next times step
- R package `emma`

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Input Variables for Optimisation

- precursor solution concentration
- number of layers
- coating temperature
- blade speed
- calcination temperature
- calcination heating rate

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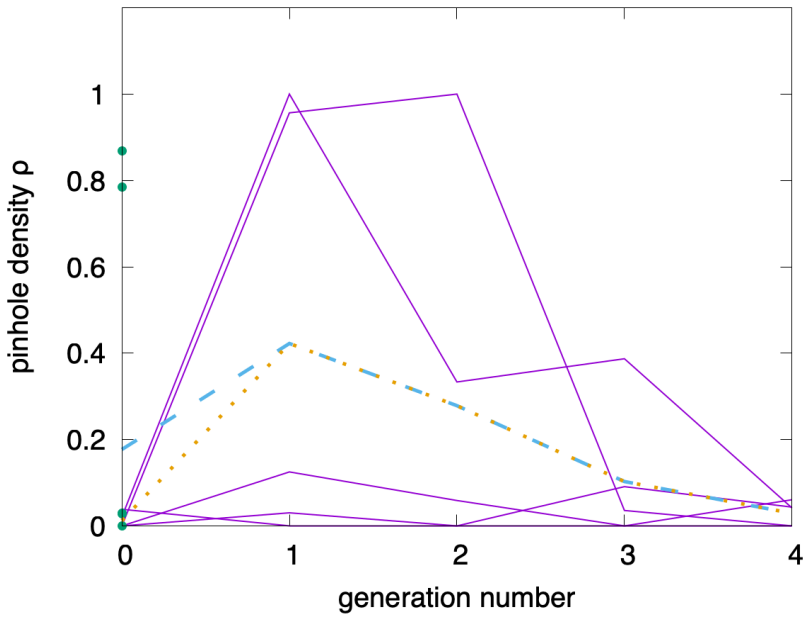
Input Variables for Optimisation

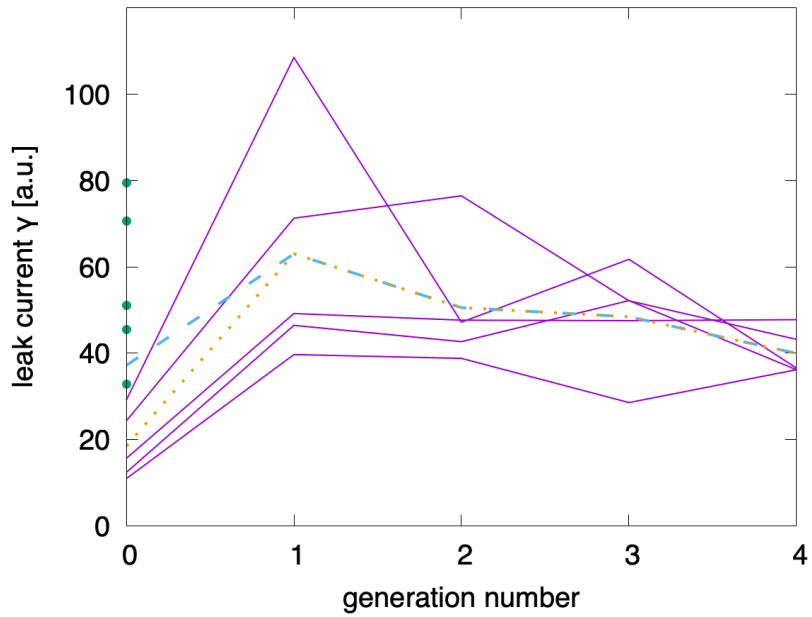
c_{zr} [22mmol/L]	n_L	T_C[°C]	v_C[mm/s]	T_{cal}[°C]	v_{cal}[°C/min]
2	4	40	10	300	2
3	6	50	12	400	6
4	8	60	14	500	10
5	10	70	16		14
	12	80	18		18
			20		

Table: Discrete levels of each input parameter

Particle Swarm Optimisation Iterations

- metrics are reduced per generation
- model learned to represent data





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Summary

- found recipe for dense ZrO_2 via sol-gel
- prepared insulating ZrO_2 layers
- optimization chose correct input variables