Cost effective low stress float zone silicon feed rods made from Siemens reactor chemical vapor deposition

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Company Facts at a Glance

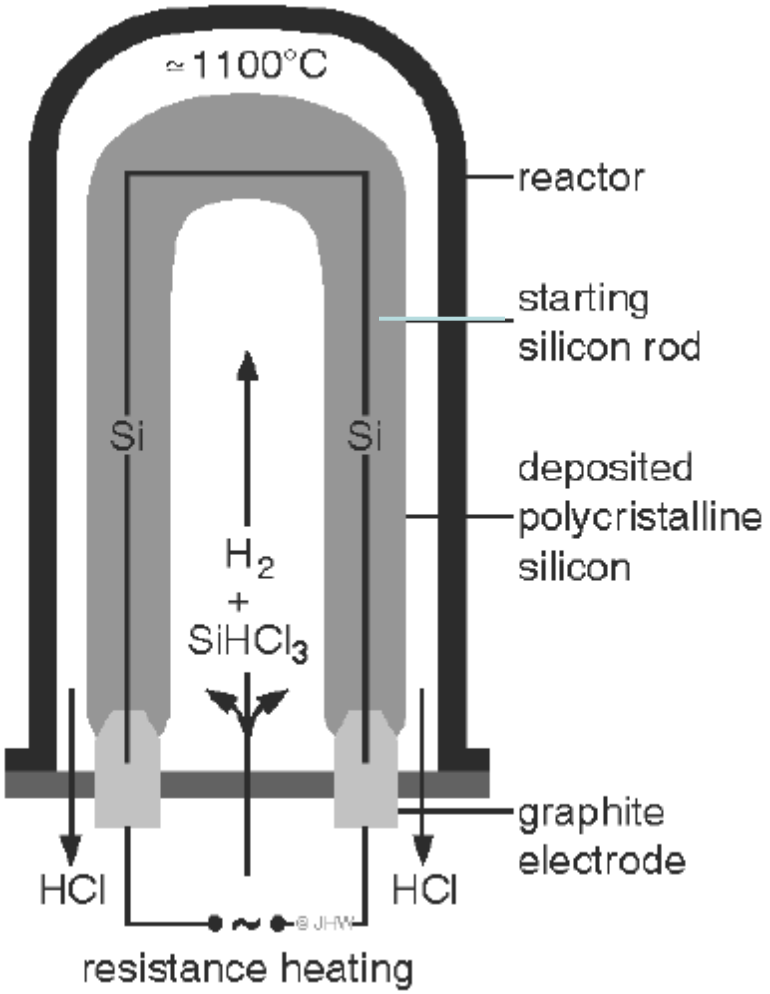
Silicon Products Bitterfeld GmbH & Co. KG

www.silicon-products-gmbh.com

- engineering / consulting
- equipment for Siemens process technology
- silicon / slim rods
- chlorosilanes

Product:	high purity silicon
Output Capacity:	1.800 t/a
Process Technology:	Siemens process
Employees:	ca. 50

Production of FZ Feedstock via Siemens Process



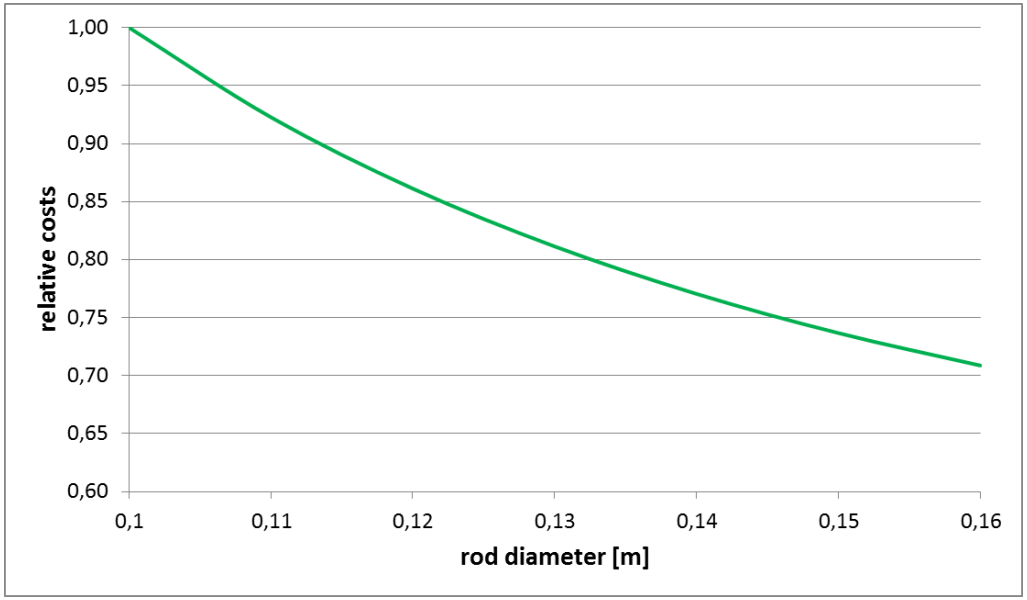

Top view of a opened 12 pair reactor at Silicon Products Bitterfeld GmbH&Co.KG

Main Challenges

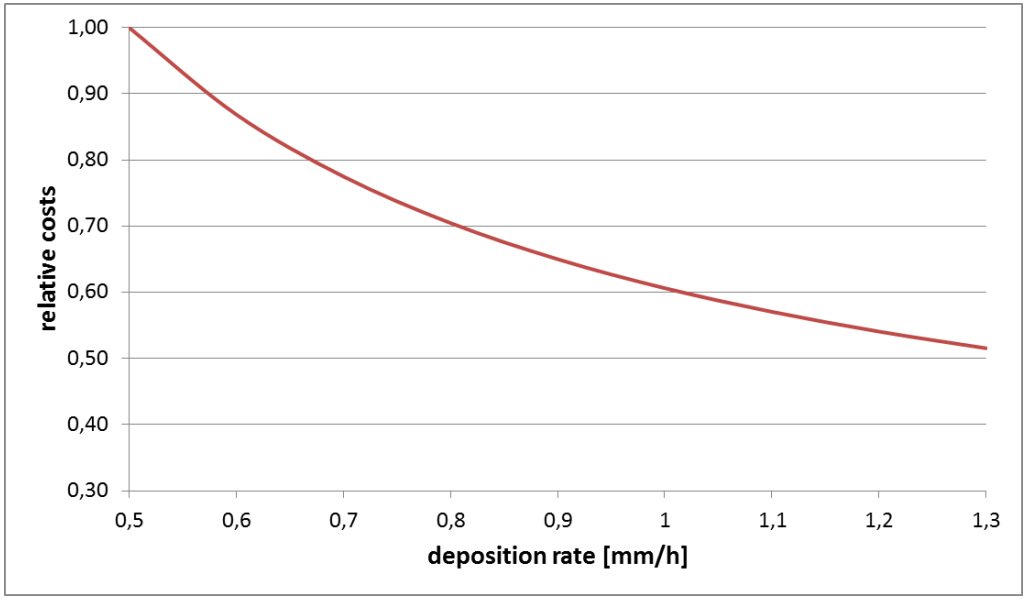
- **purity (dopants, metals, non-metals, particles)**
  → crystal yield
- **low stress silicon**
  → mass yield

Cost Influence Parameters for Silicon FZ - Feedstock – “Process Engineer ´s View”

- final rod thickness and rod length



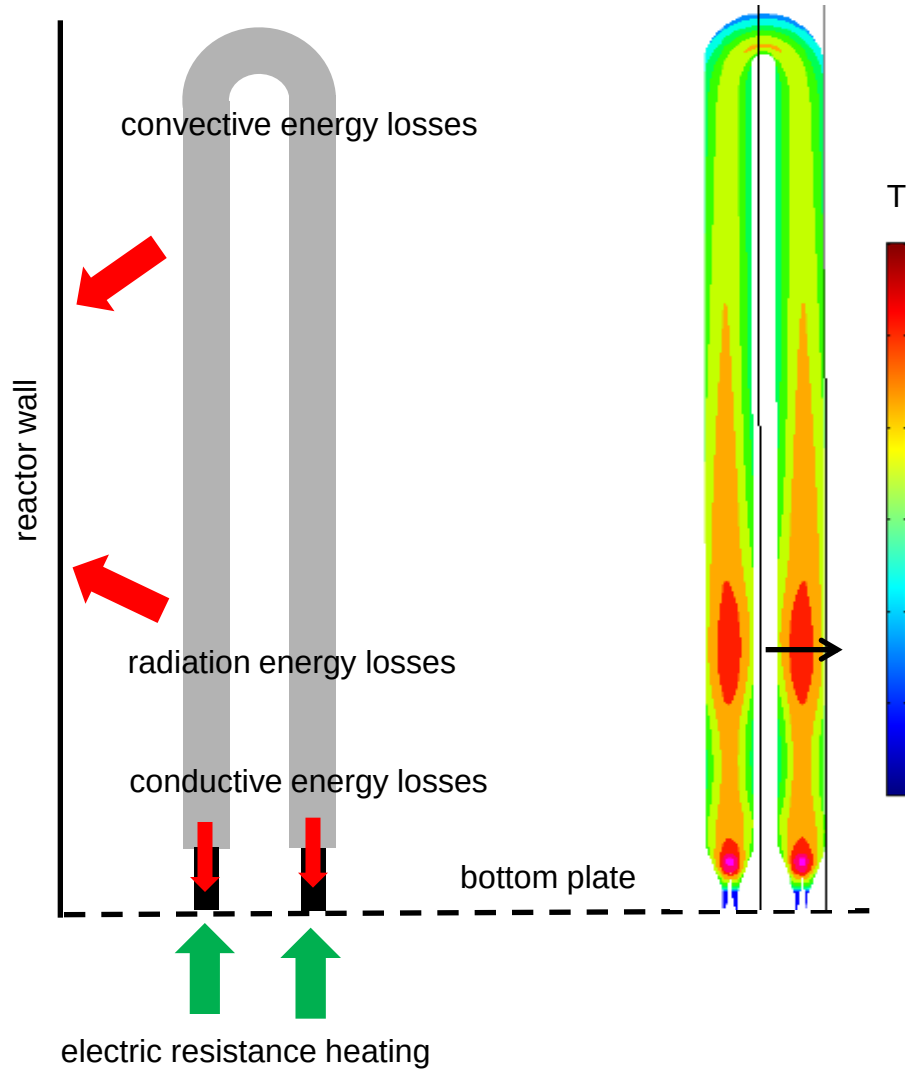
- deposition rate

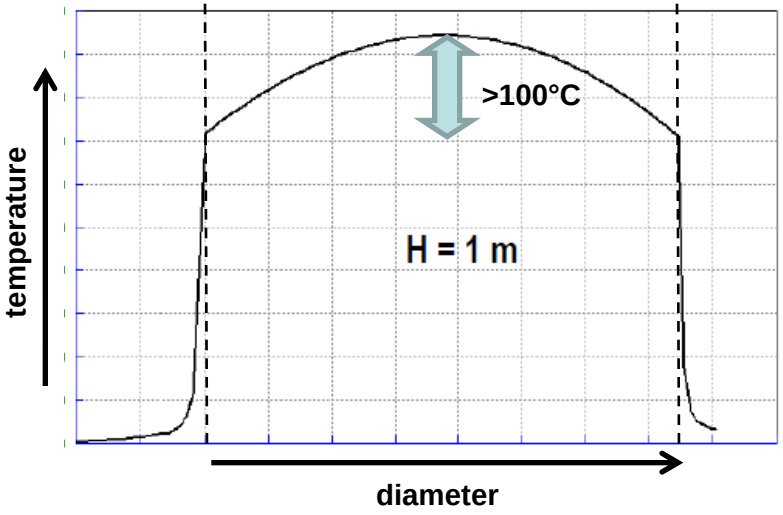


Motivation: control and reduction of rod stresses

How is Thermo-Mechanical Stress Formed?

U-shaped polysilicon rod in the CVD reactor





non-linear temperature gradients during deposition and cool down

⇩

thermo-mechanical stress after cool down

⇩

breakage

Approach of Residual Stress Simulation

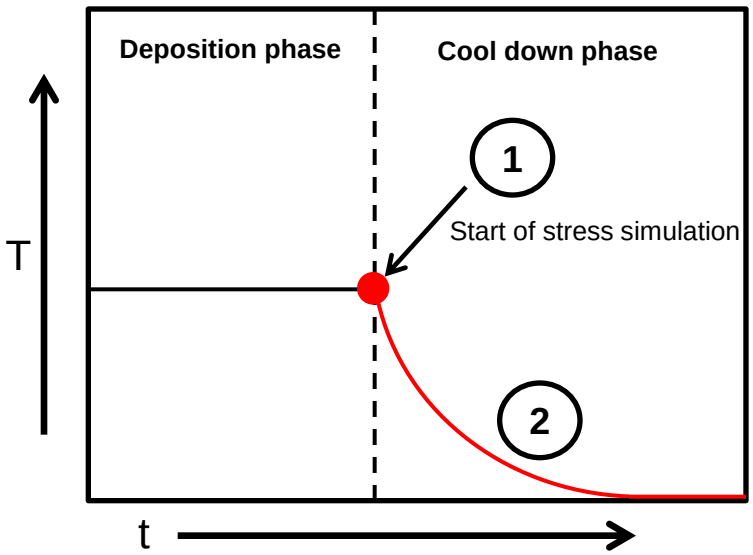
Aim

- build up of an 2D model for stress calculation (FE)
  - calculation temperature distribution -> strain field -> stress field

Basic Assumption

- stress is created during cool down phase.
- stress due to temperature gradients during deposition can mainly be released by plastic deformation.
  - T>1000°C

temperature curve of the rod surface

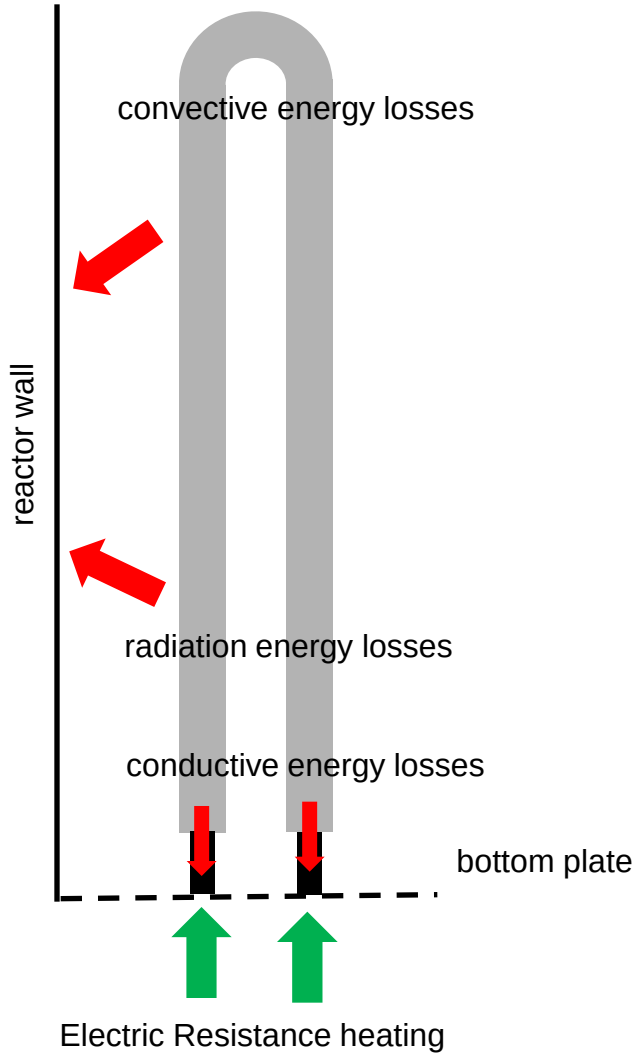


1 **temperature field constant – stationary process condition**
constant gas flow, constant voltage and current, constant rod thickness

2 **temperature field changes**
time dependent stress evolution

What Can We Do to Reduce Thermo-Mechanical Stress?

U-shaped polysilicon rod in the CVD reactor

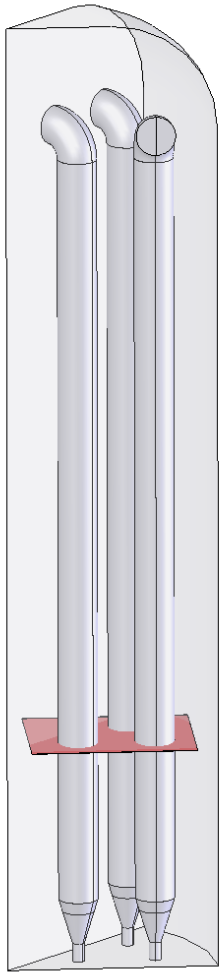


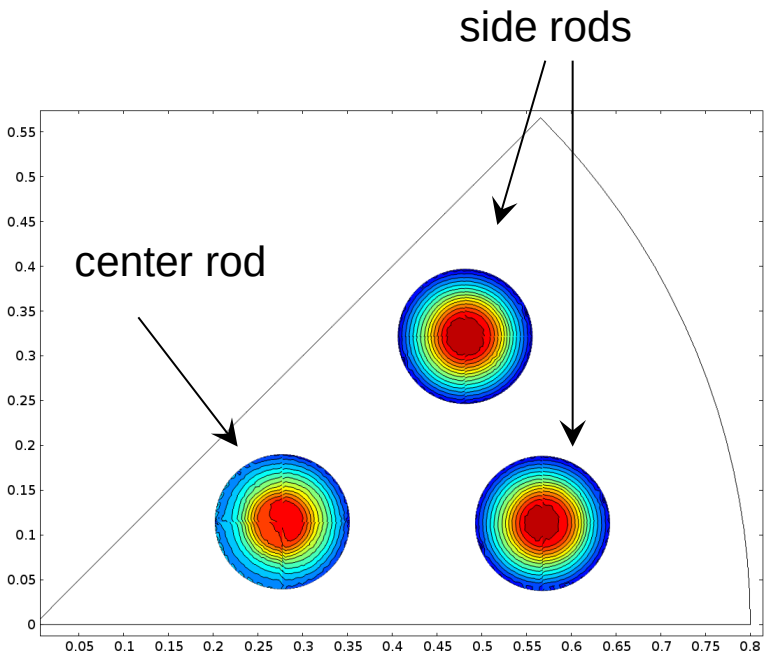
- very low temperature gradients by very low cooling rates
  - reduction of convective energy losses
  - reduction of radiation energy losses

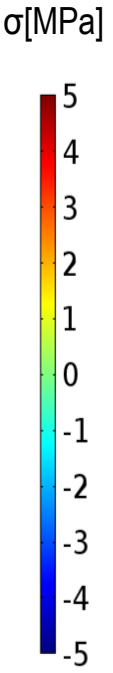
alternatively:

  - external rod heating
  - rise temperature before cool down
    Tokuyama DE19780520B4

- calculated 2D stress field in a horizontal cut plane

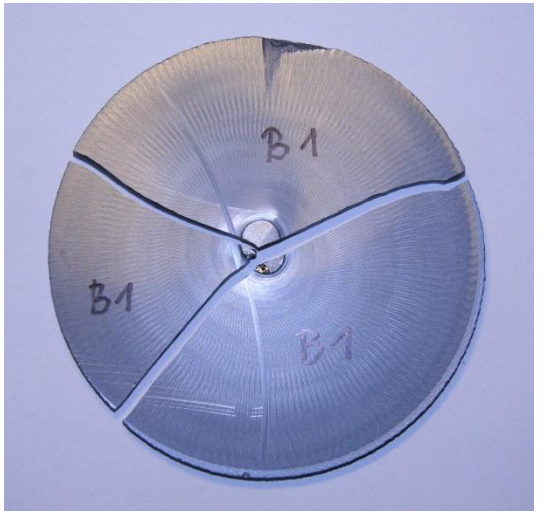






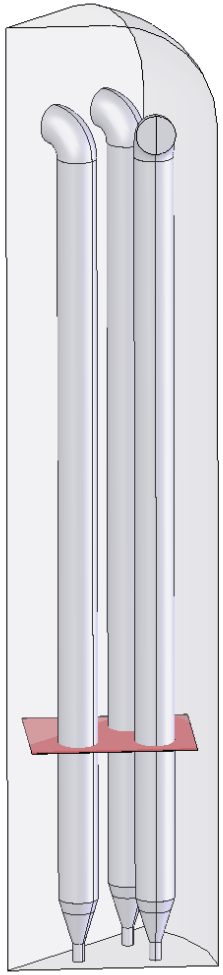
H_2 atmosphere benchmark during cool down (diameter = 150mm, 7 bars, temperature before cool down ~1100°C)

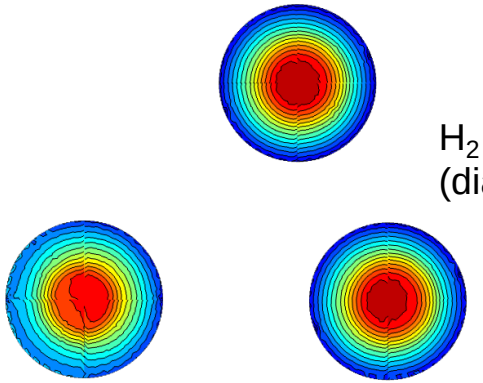
- compressive stresses (blue) near surface
- tensile stress (red) in rod center which leads to breakage



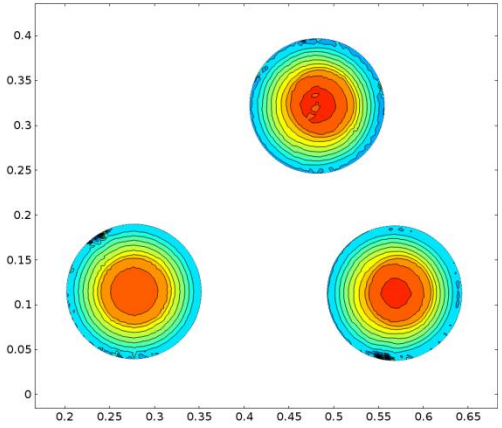
- inner rods have lower stress on surface and in the center

- calculated 2D stress field in a horizontal cut plane

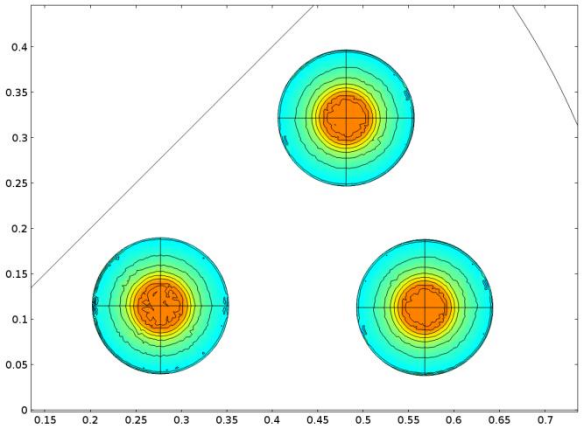




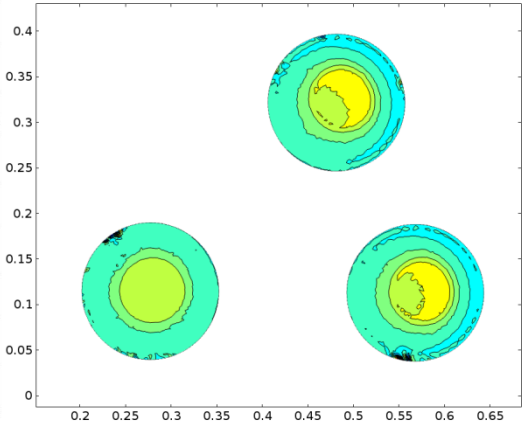
H_2 atmosphere during cool down
(diameter = 150mm)



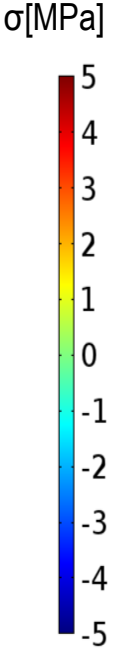
reduction of H_2 flow
by 2/3



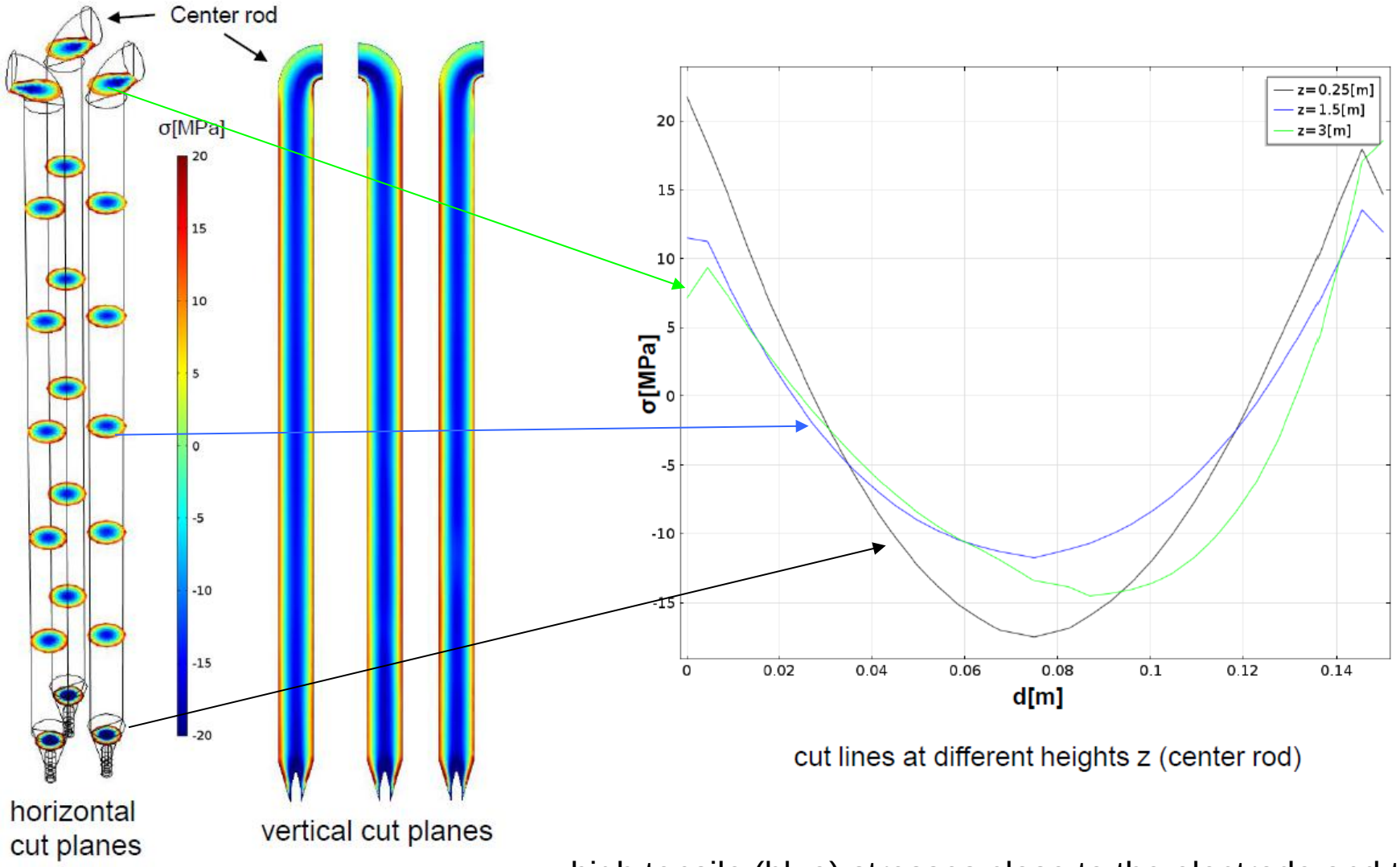
$T_{initial}$+100°C



N_2 atmosphere during
cool down



Results - 3D Residual Stress Consideration



cut lines at different heights z (center rod)

– high tensile (blue) stresses close to the electrode and the bridge

Summary

- Main operation cost factors are final rod thickness, rod length, growth rate and rod stress.
- Development of an 2D model for simulation of residual rod stress was carried out.
- Rod stress can strongly be reduced by reducing conductive losses.

- The inner ring is expected to have lower rod stresses.
- The electrode and bridge regions are most critical for stresses and cracks.

Thanks to…

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