
HIPIMS-ITO from Cylindrical Cathodes

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Motivation: HIPIMS-ITO

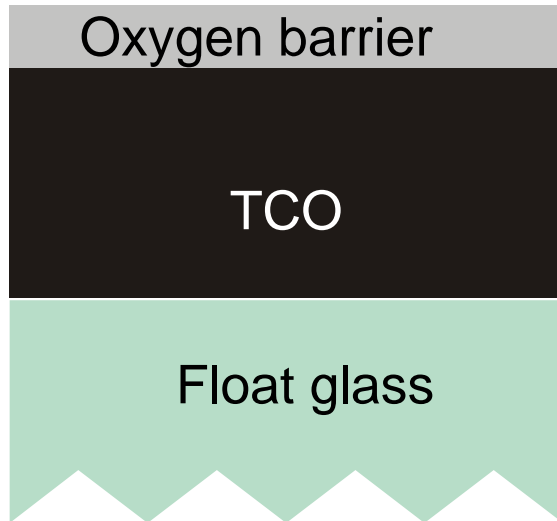
Movie: [ice-free windshield](#)

Outline

- Motivation
- HIPIMS ITO-process
 - Process parameters
 - Resulting properties
 - Which HIPIMS-Power Supply to use?
- Use of cylindrical cathodes
 - Motivation
 - Demand of HIPIMS process
- Potential Applications

Layer stack and design of experiments for ITO HiPIMS

Low-E Stack



← SiO_xN_y : thickness ~ 40 nm

← ITO: thickness ~ 140 nm

Layer stack was annealed at 650°C (10 min / air)

Investigations on:

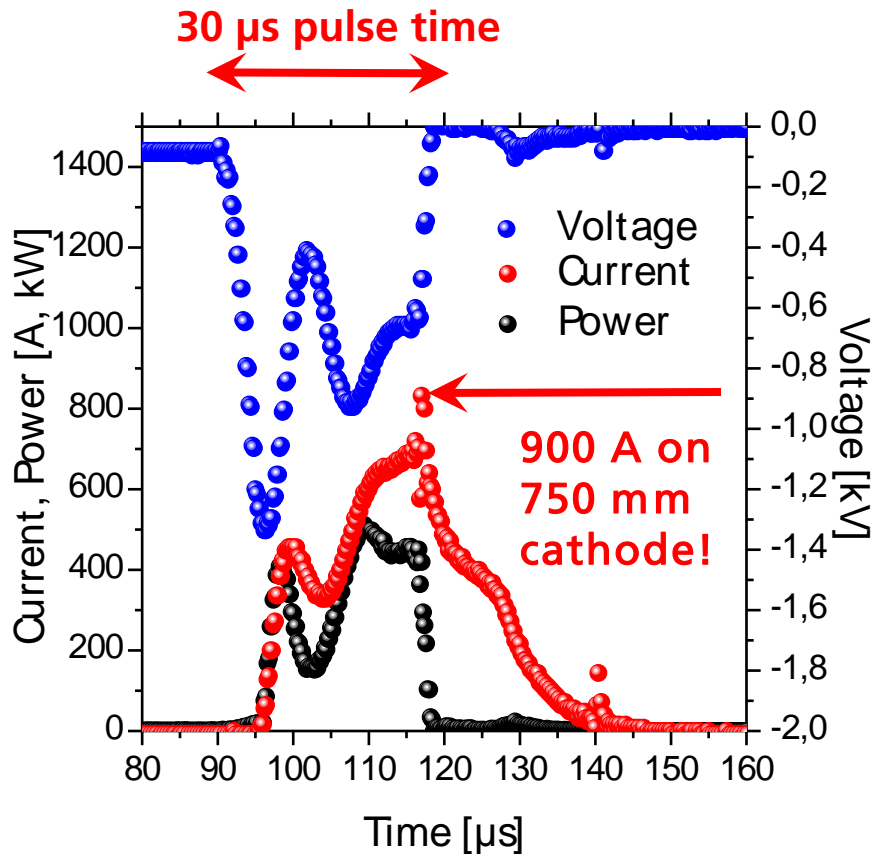
- Charge voltage
- Pulse length (t_{on})
- Arc controlling

Demands:

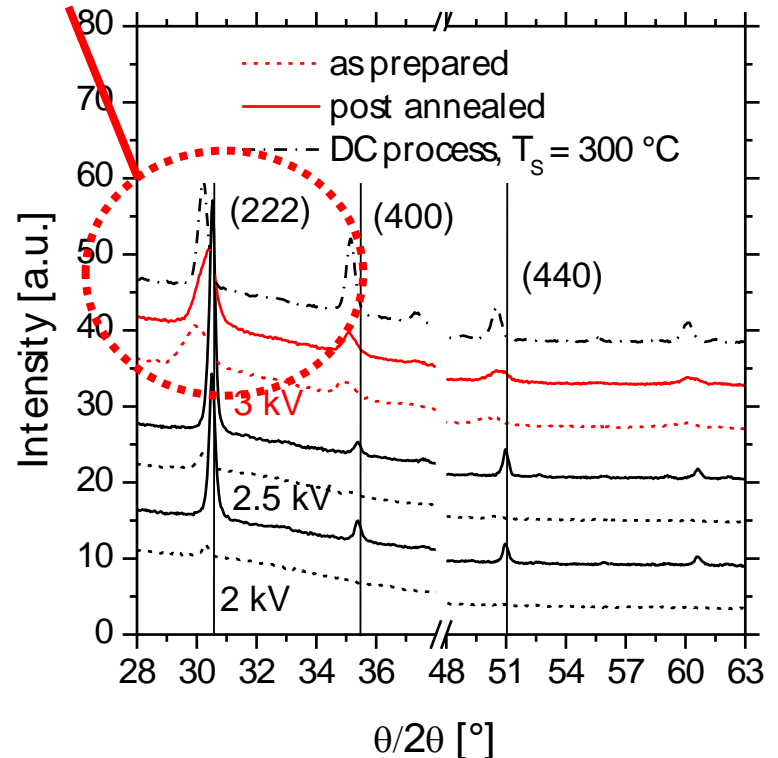
- Mechanical and chemical resistant Low-E coating for pos. 1
- Low-E coating with $\varepsilon < 0.30$
- Visible light transmittance $T_{\text{vis}} > 80$ %

ITO HiPIMS using an experimental power supply #2

Short pulse HiPIMS for nc-ITO with extraordinary stability



Stable nanocrystalline films during annealing at 650 °C / 10 min / air

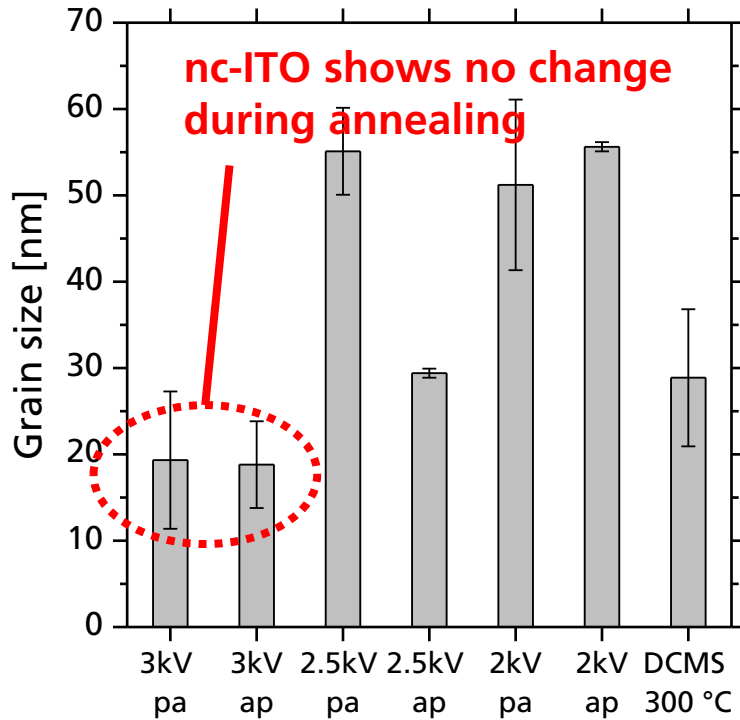


■ Growth of nanocrystalline ITO due to **short pulse HiPIMS at $U_c = 3$ kV**

F. Horstmann et al., *TSF 517 (2009) 3178* | *DE 10 2008 028 140 B3*

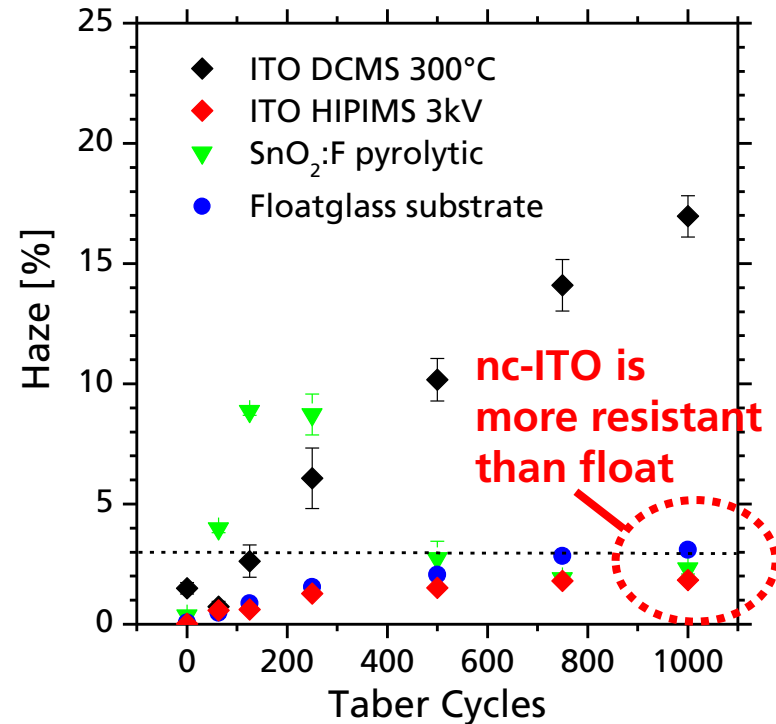
Criteria for the evaluation of ITO HiPIMS coatings

a) Grain size analysis by Scherrer



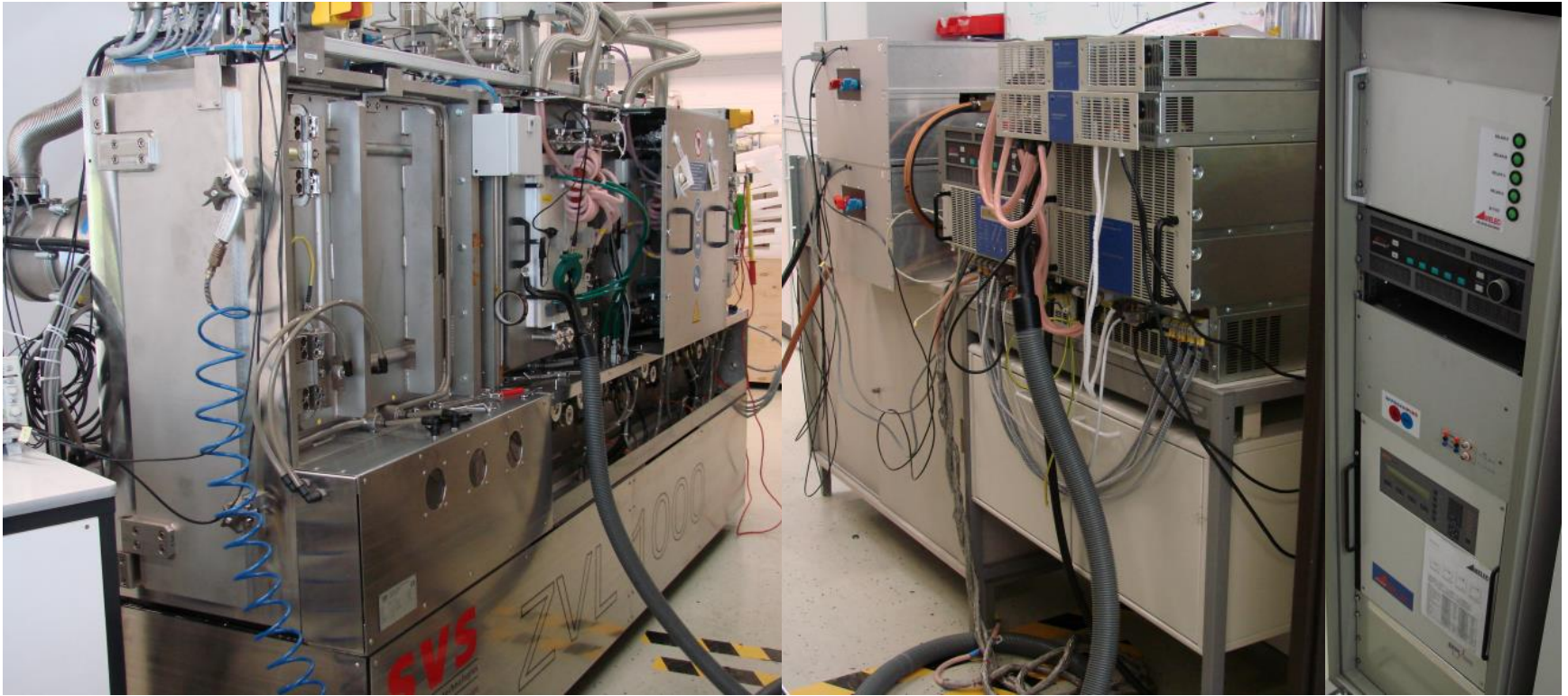
- Phase stability correlates with haze post annealed

b) Taber test and stray light



- Taber test post annealed & haze measurement

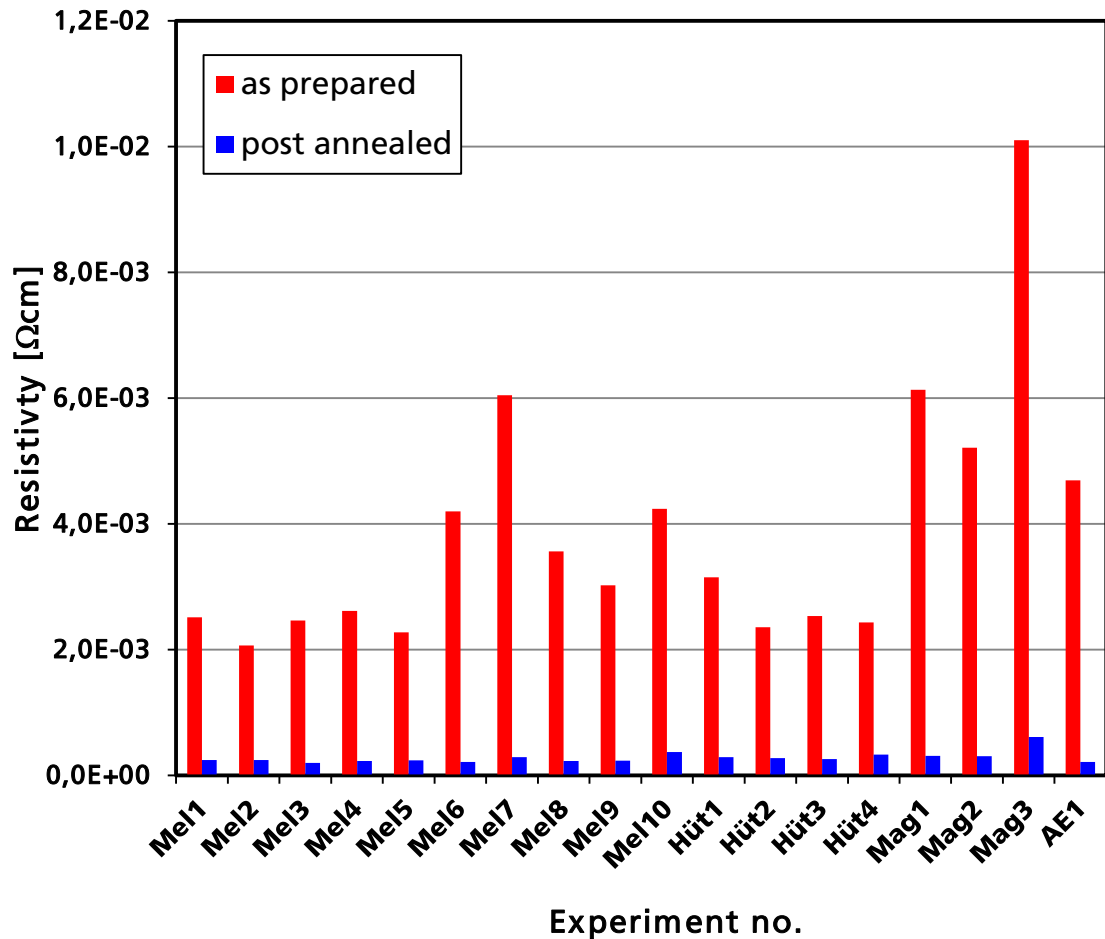
Arrangement of HIPIMS power supplies



- Magpuls prototype
- Hüttinger TruPlasma Highpulse 4008

- MELEC SIPP
- Advanced Energy prototype (at Leybold A700V)

Sheet resistance (four point and eddy current)



- Resistivity as prepared:
 $\rho = (2.1 \dots 10) \times 10^{-3} \Omega\text{cm}$
- Resistivity post annealed:
 $\rho = (2.0 \dots 6.1) \times 10^{-4} \Omega\text{cm}$
- Best p.a. samples:
■ $2.0 \times 10^{-4} \Omega\text{cm}$

Influence of HIPIMS Power Supply

- Short pulse HiPIMS
 - Pulse length in the order of 30 μs can be reached by all power supplies investigated.
 - Proper arc handling at high power conditions is the crucial point.
- ITO film properties
 - ITO films for coat & bend processes can be realized with commercially available HIPIMS power supplies.
 - Arc quenching is different and might be the reason for differences in film quality.
 - Fine tuning of parameter range is necessary.
 - Successful solutions with all HIPIMS power supplies possible.

Use of Cylindrical Cathodes

Planar vs. Rotatable

- Higher average power possible
- Higher utilization (same thickness)

Planar	Cylindrical
Width: 150 mm	Ø: 150 mm $d \cdot \pi = 470 \text{ mm}$
Utilization: 30-40%	80-90%
Lifetime	6x Planar

Especially when using expensive materials more cost efficient (than reclaim: time consuming; costly)

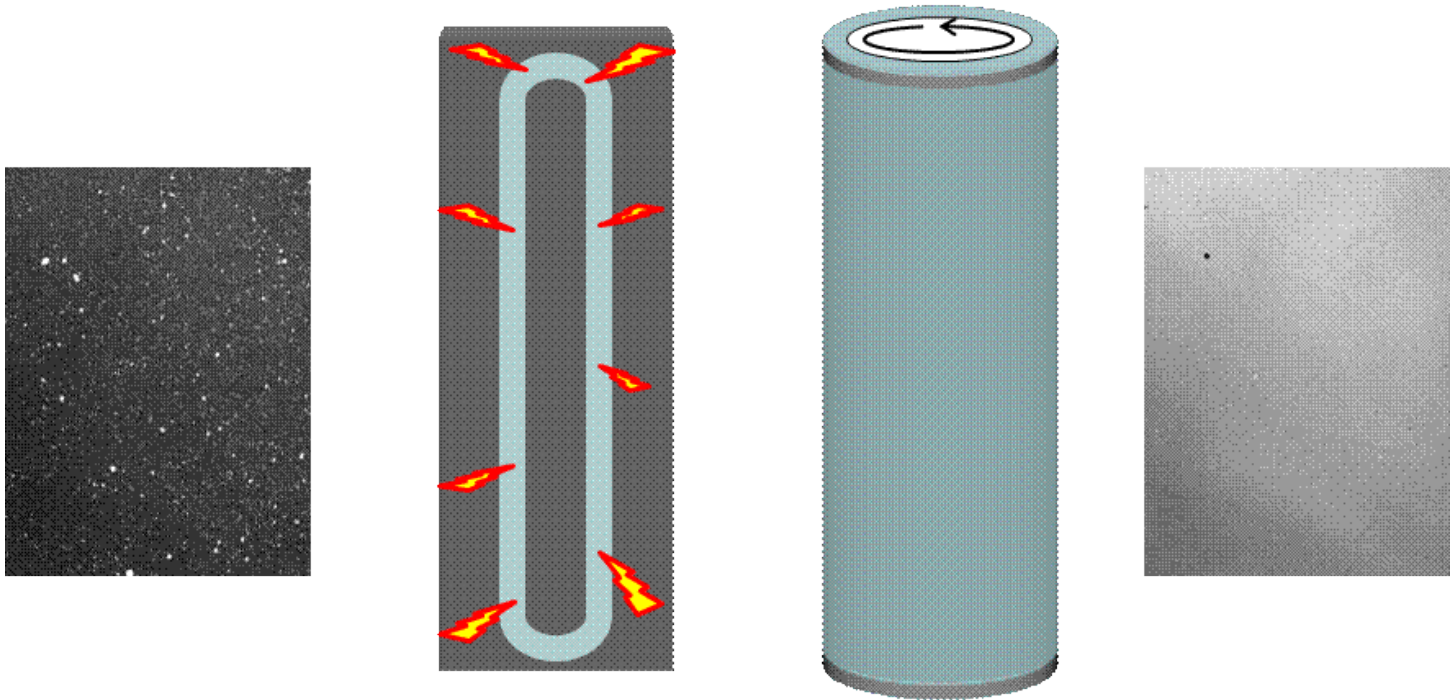


Source: Angstrom Sciences

Use of Cylindrical Cathodes

Planar vs. Rotatable

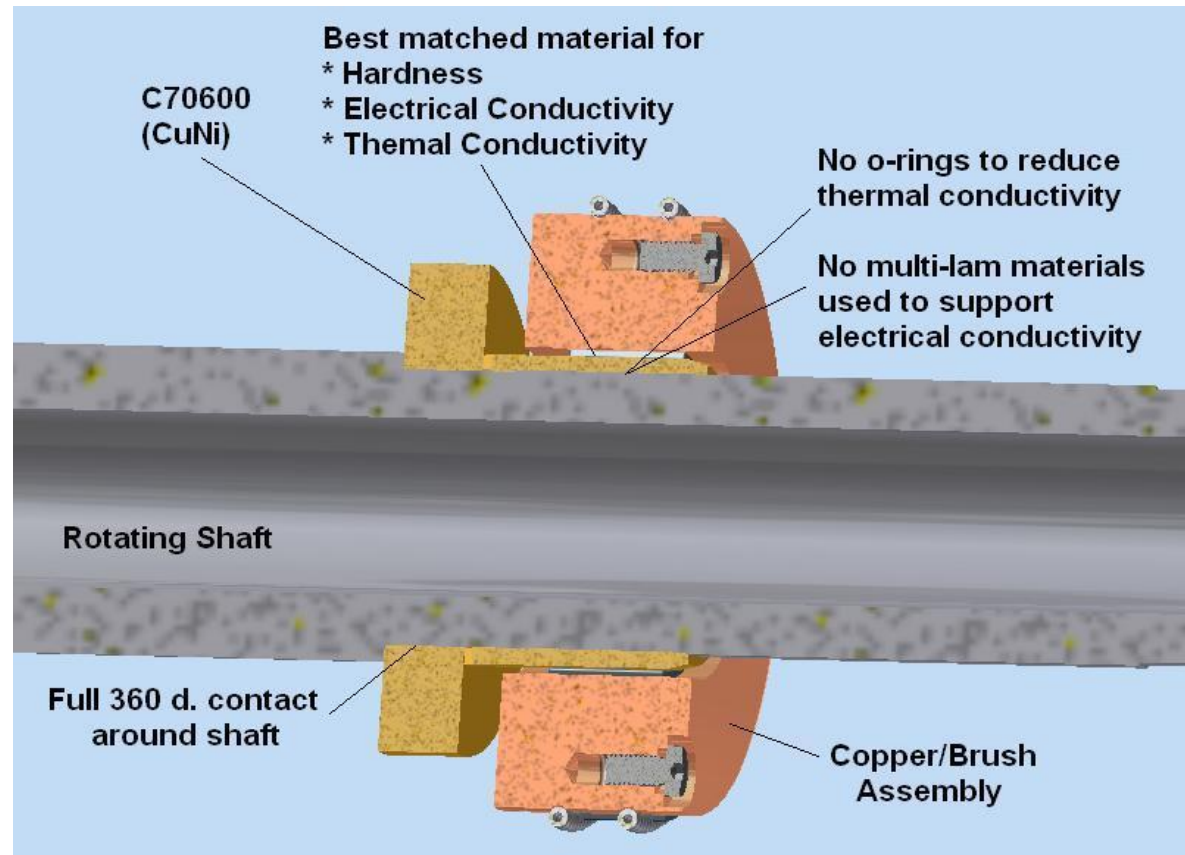
- Reduced arcing
 - nearly no re-deposition zones
 - reduced nodule growth



Use of Cylindrical Cathodes

Demand for HIPIMS

- High peak current required



Source: Angstrom Sciences

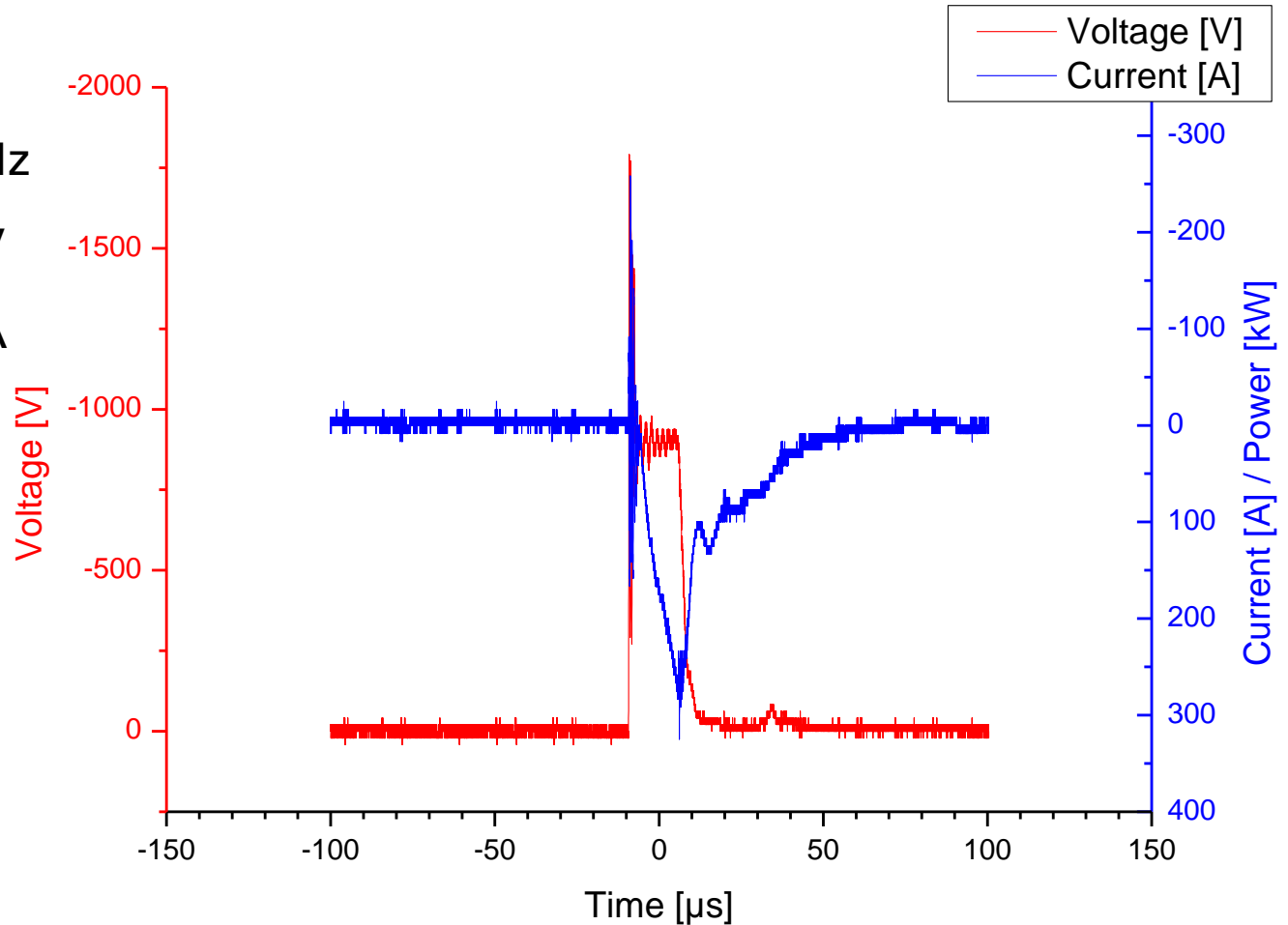
Voltage – Current Behavior Cylindrical Cathodes

■ t_{on} : 15 μ s

■ f : 128 Hz

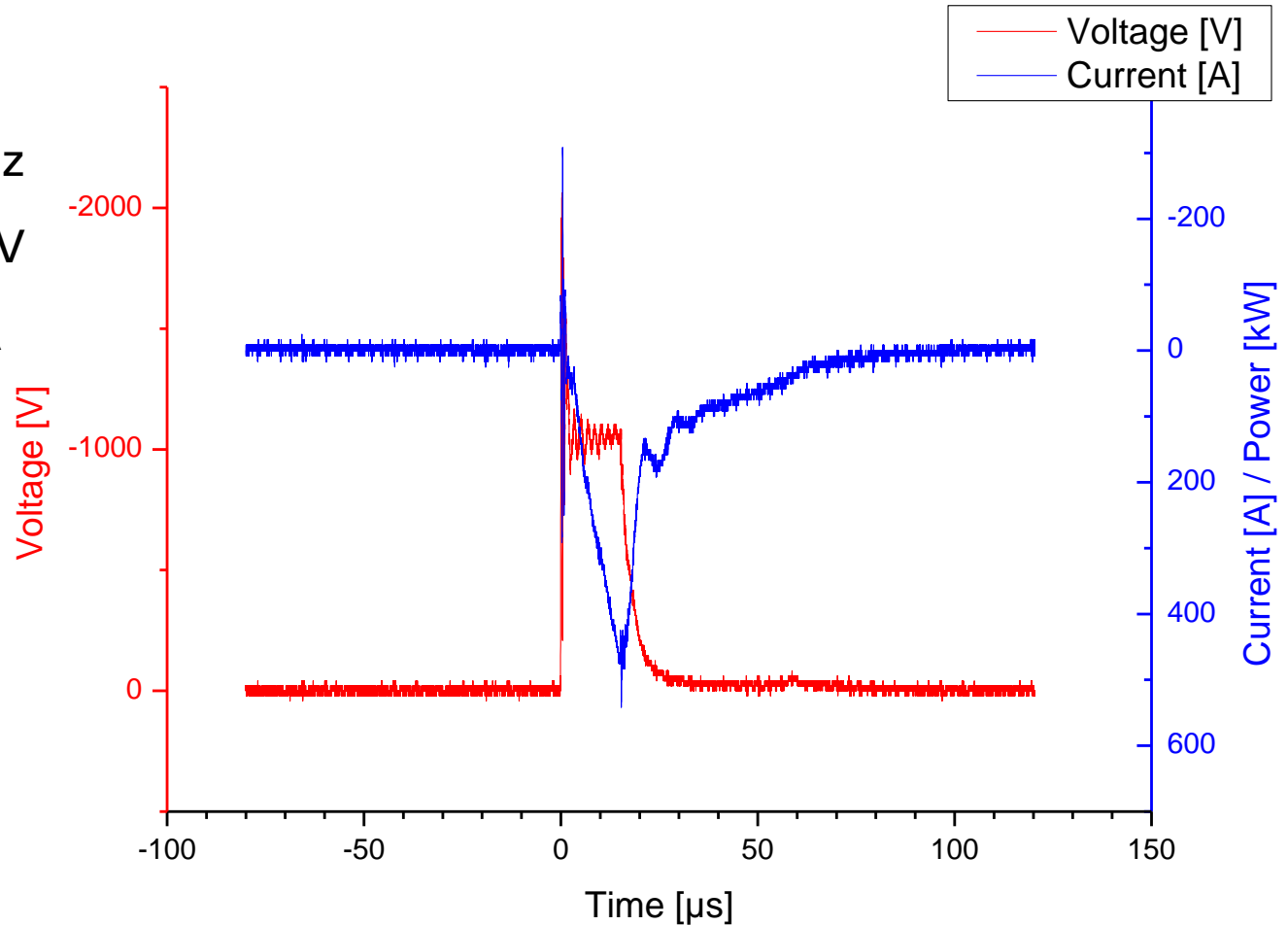
■ U_{Charge} : 900 V

■ I_{peak} : 300 A



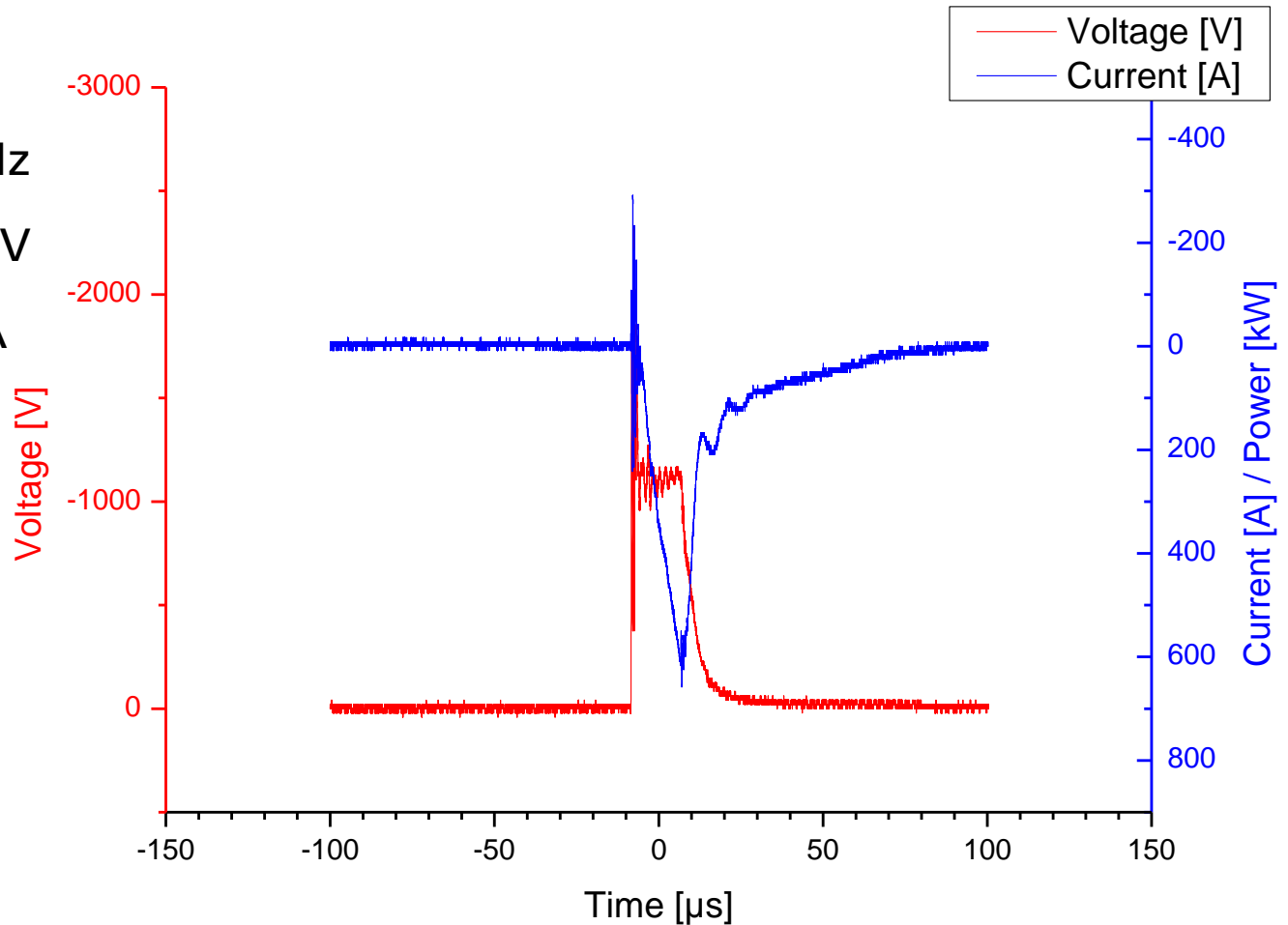
Voltage – Current Behavior Cylindrical Cathodes

- t_{on} : 15 μ s
- f : 320 Hz
- U_{Charge} : 1050 V
- I_{peak} : 500 A



Voltage – Current Behavior Cylindrical Cathodes

- t_{on} : 15 μ s
- f : 208 Hz
- U_{Charge} : 1100 V
- I_{peak} : 700 A



Applications

Functional films - ITO

HIPIMS-ITO

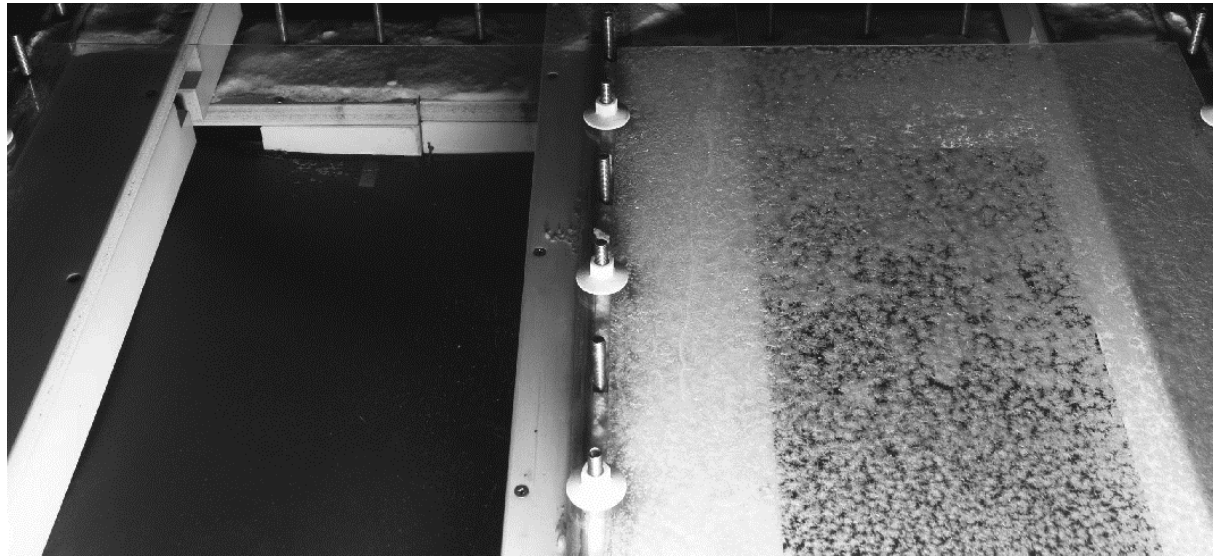
- Room temperature process
 - Excellent properties on complex shaped parts
 - Improved scratch resistance (pos. 1 application)
-
- ➔ Displays, Touch panels
 - ➔ Solar cells (e. g. nano carpets)
 - ➔ Architectural glazing (low E-coatings)
 - ➔ Ice-free windshields (automotive, aerospace, ...)
 - ➔ Transparent heating (heatable)

HIPIMS Applications

Functional films - ITO

Ice-free windshield

- Short pulses prevent arcing
- High peak current
- Nano crystalline coating



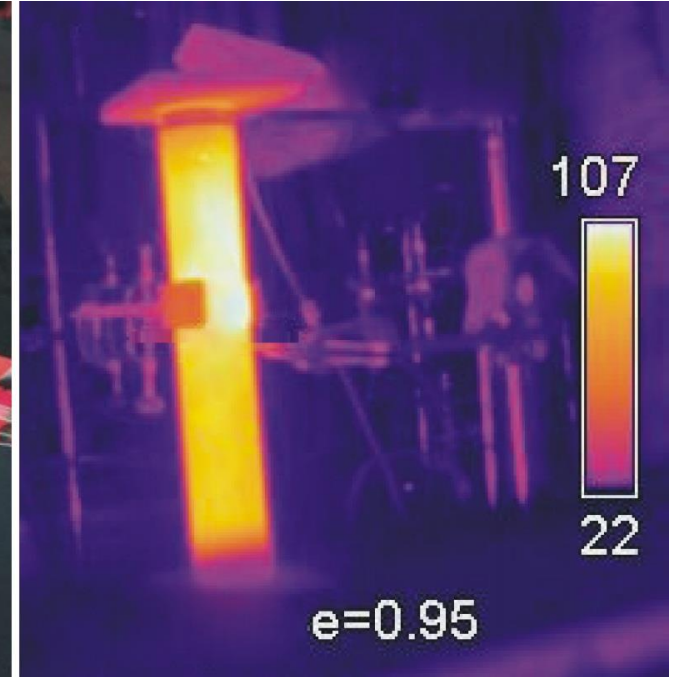
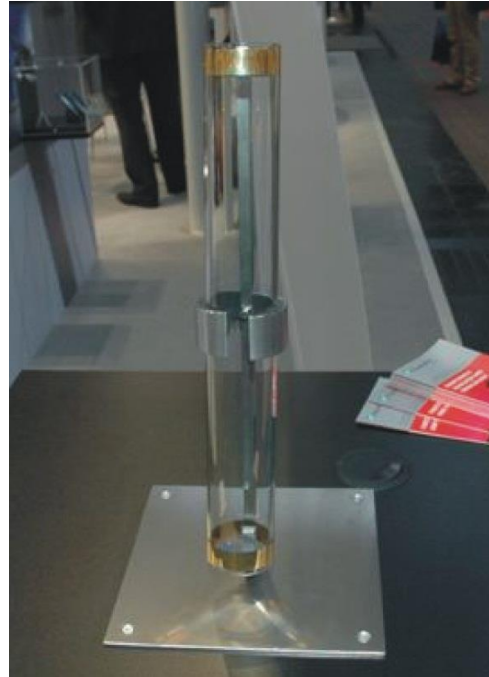
coated

uncoated

HIPIMS Applications

HIPIMS processes: ITO

- HIPIMS ITO
- Deposition on shaped glass (glass tubes)
- Thermal image of a heating coating on a glass tube from the BASF Group for protective heating in distillation columns



Source: Fraunhofer IST, BASF AG

- ➔ Uniform heating of liquids in distillation columns
- ➔ Heat insulating effect due to low emissivity

Acknowledgement

The authors gratefully acknowledge the support of the planar target process development by:



and for the tube target process development by:



Thank you for your attention!

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HIPIMS-Tea

Booth 434



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- Website: **www.hipimsconference.com**

The background of the banner shows a modern building with a glass facade and a large, ornate stone sculpture in the foreground.

Love never fails.
... where there is knowledge, it will pass away.

1. Corinthians 13,8