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New Enhanced Technical Capabilities of the ALD SMARTcoater

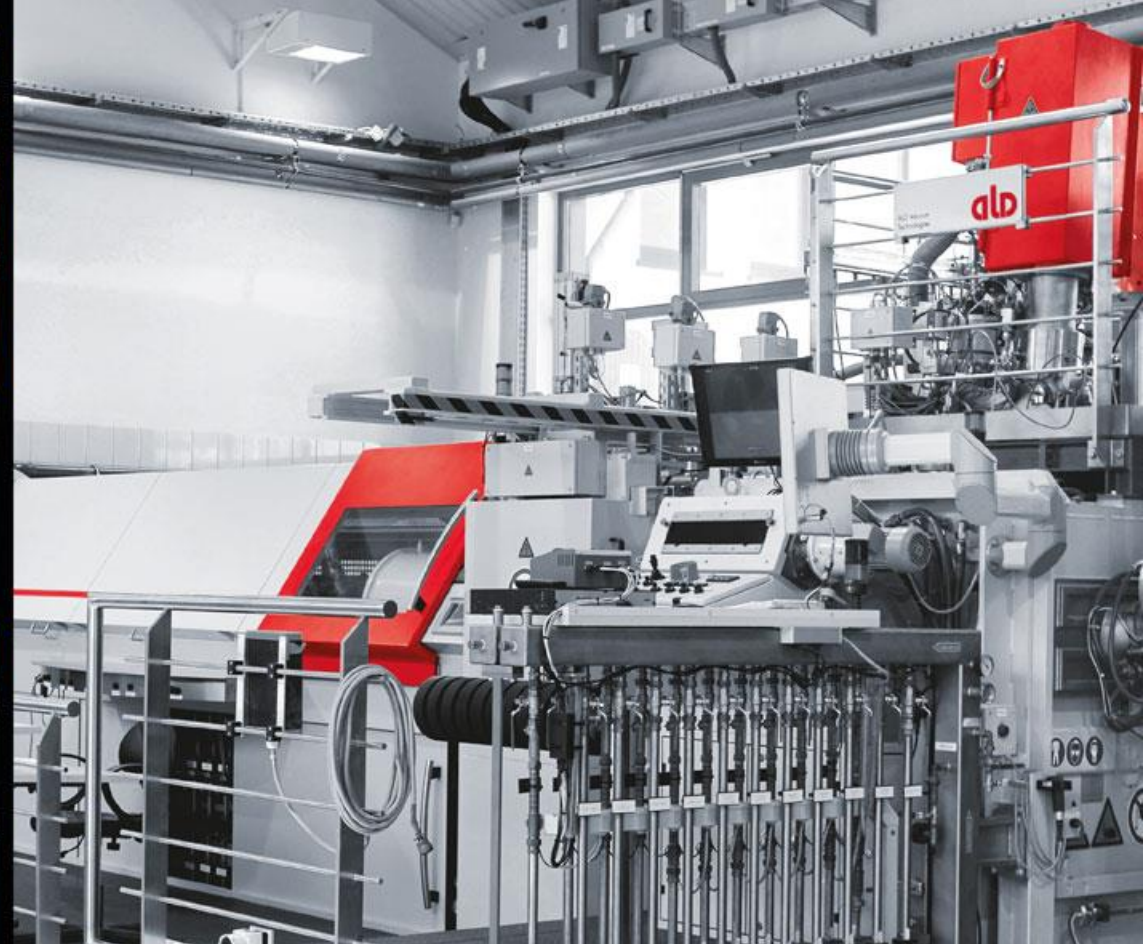
Ole Hinrichs

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Dr. Andrzej Nowotnik

Thomas Schösser

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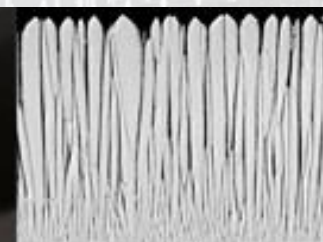
AMG ENGINEERING



Thermal & Environmental Barrier Coatings VI

*„New enhanced technical capabilities
of the ALD SMARTcoater“*

JUNE 19-24, 2022
IRSEE, GERMANY



- **Dr. Ole Hinrichs**, ALD Vacuum Technologies GmbH
- **Thorsten Hohmann**, ALD Vacuum Technologies GmbH
- **Dr. Andrzej Nowotnik**, Rzeszow University of Technology
- **Dr. Thomas Schösser**, ALD Vacuum Technologies GmbH

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- EB-PVD PLUS Plasma assistance
- Simulations for influence of hollow cathode system
- First results of coating runs with plasma activation

THE ALD SMARTCOATER – AN OVERVIEW

ALD'S LINE OF EBPVD COATERS

SMARTCoater



R&D System

- One load chamber
- One EB gun

XXL Coater

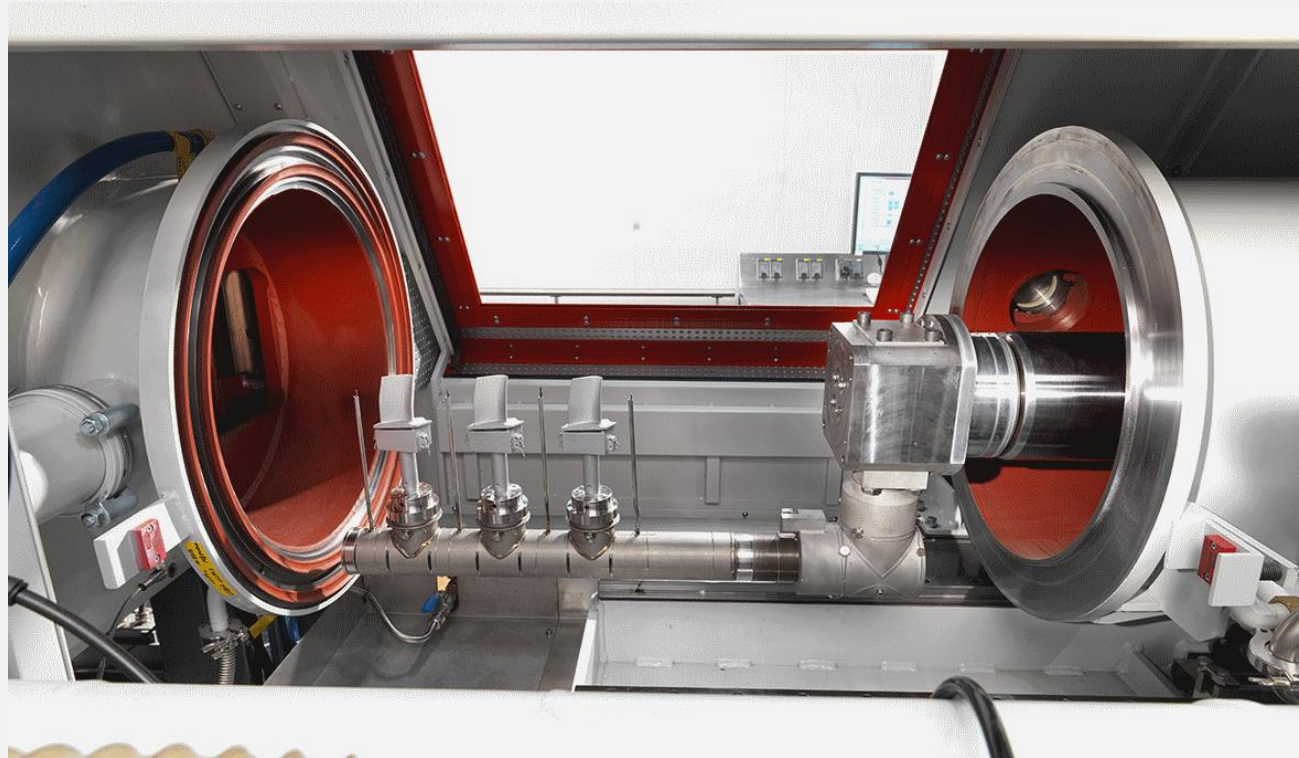


Production Systems

- 1, 2, or 4 feeder configurations

THE ALD SMARTCOATER – AN OVERVIEW

LOADING CHAMBER

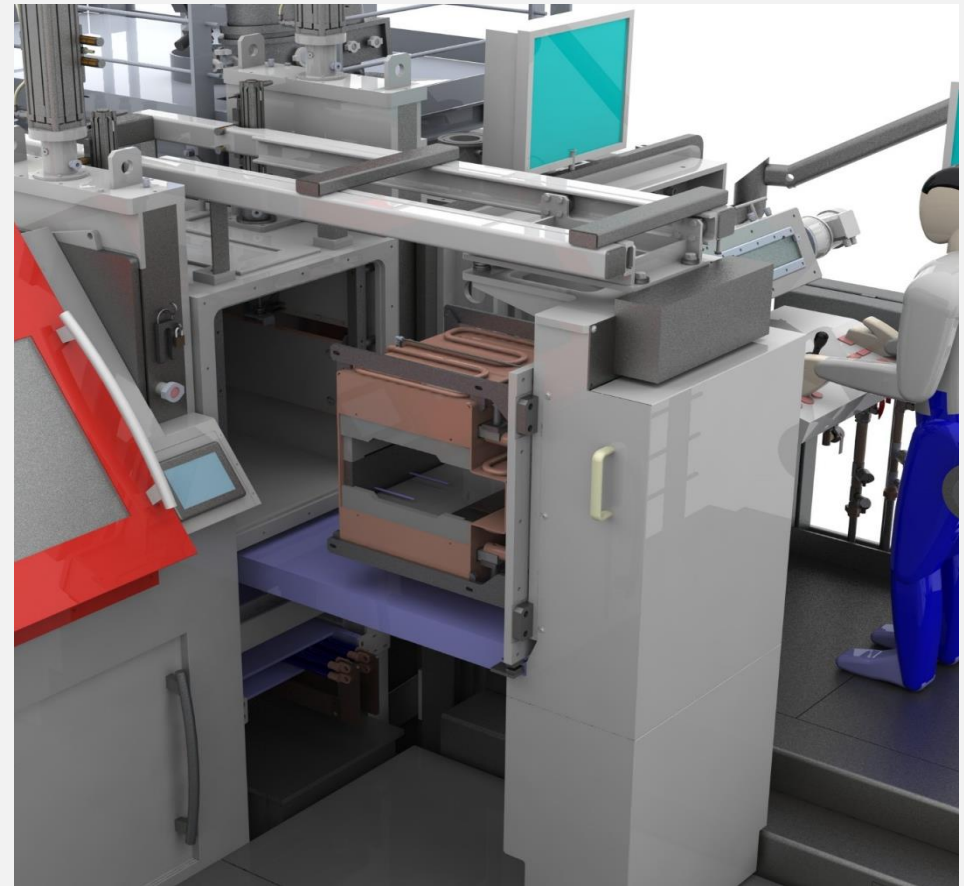


- Venting with inert gas prevents moisture pick up
- All drive components shielded against heat and dust
- High performance pumping system with optimized dust protection

THE ALD SMARTCOATER – AN OVERVIEW

PREHEAT CHAMBER

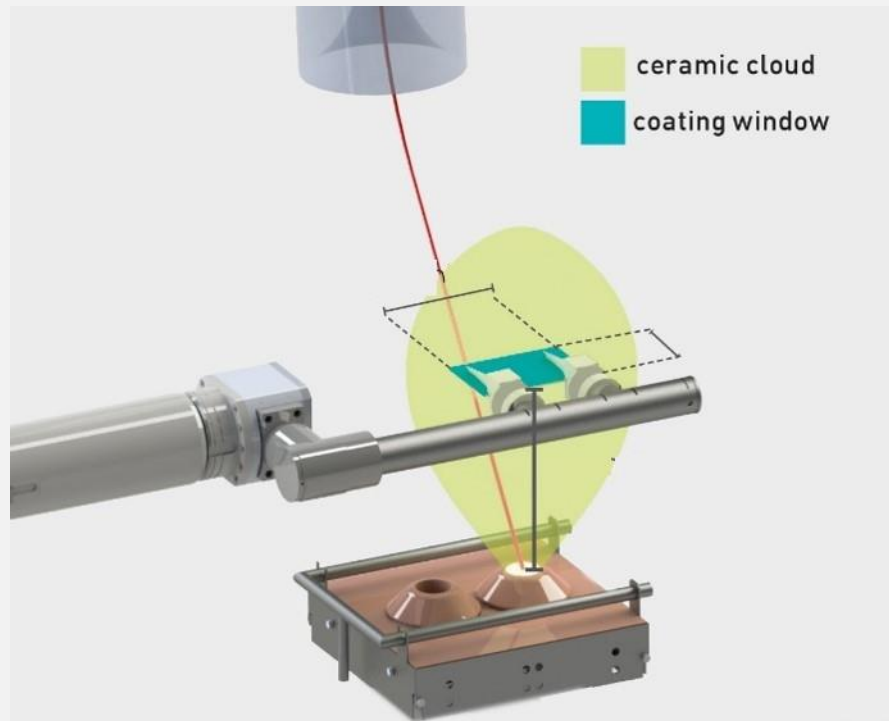
- Separate preheat chamber with dedicated high vacuum pumping system
- Oversized graphite heater with massive heating elements for optimum temperature uniformity
- Preheat temperature up to 1100 °C
- Heating temperature homogeneity <math>< \pm 40\text{K}</math>
- Recipe driven preheat process
- Redundant heater control thermocouples for reliable operation



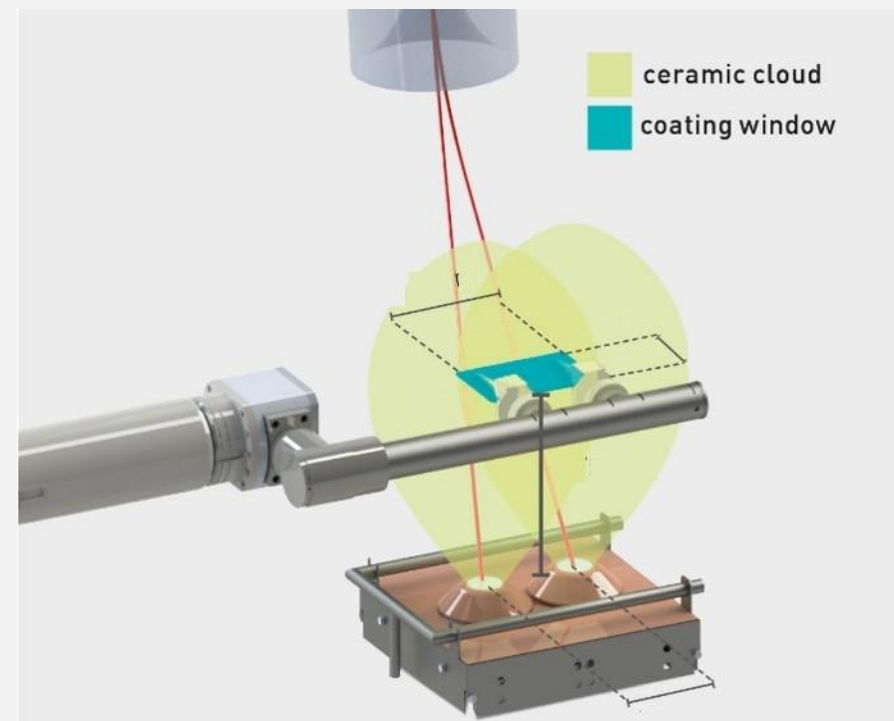
THE ALD SMARTCOATER – AN OVERVIEW

MULTI ELEMENT AND MULTI-LAYER COATING

- Ability to evaporate materials with vastly different vapor pressures to form future advanced coatings
- Jumping Beam or Split Beam Mode available



Single Pool Evaporation



Dual Pool Evaporation

Continuous improvement process to enhance quality and productivity of EB-PVD TBC coatings ongoing:

- “Classical” EB-PVD process window for ideal columnar microstructure is limited
- High productivity processes counteract the coating quality
- Next Generation EB-PVD coatings require new process windows, where classical EB-PVD process has restrictions

EB-PVD PLUS PLASMA ASSISTANCE

ALD'S APPROACH

Solution:

- **Plasma activation of EB-PVD energizes deposition process and allows to modify coating microstructure and texture over a wide range**
 - Plasma activation is known for many years and used for various PVD applications to predominantly create dense coatings
 - Plasma activation is a long-term strategic development goal at ALD since 2012
- **ALD has teamed up with Fraunhofer Dresden who have used plasma activation for EB-PVD TBCs** (Talk: Plasma-activated EB-PVD of protective coatings: tools and processes, Burkhard Zimmerman, Fraunhofer FEP, Germany)

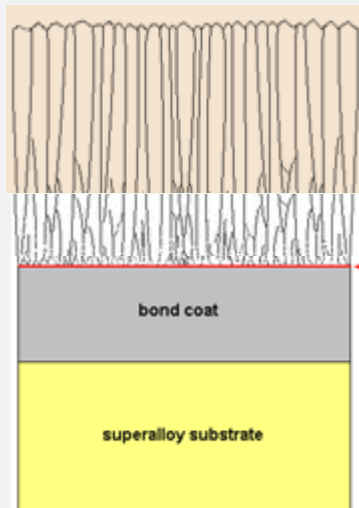
Realization:

- Realization on an industrial production system for
 - Enabling Solutions for Integration into EB-PVD systems
 - Enabling a test bench for major EB-PVD industrial partners
- Integration of a known hollow cathode system

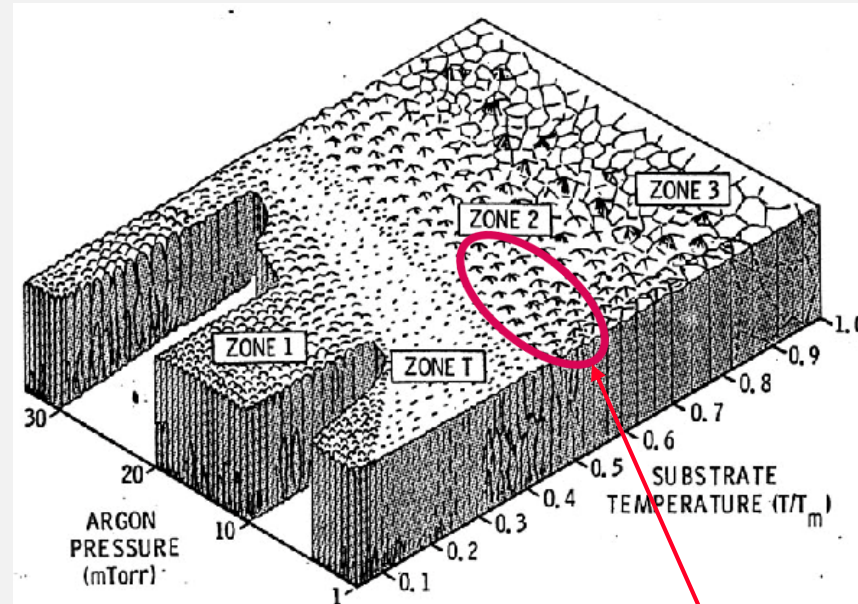
EB-PVD PLUS PLASMA ASSISTANCE

EB-PVD COATING MORPHOLOGY

- Today's TBC designed for the current application on superalloy parts
- Coating material 7YSZ is the standard
- Columnar structure required to cope with thermal stress
- Second layers for low-k and CMAS resistance becoming more common



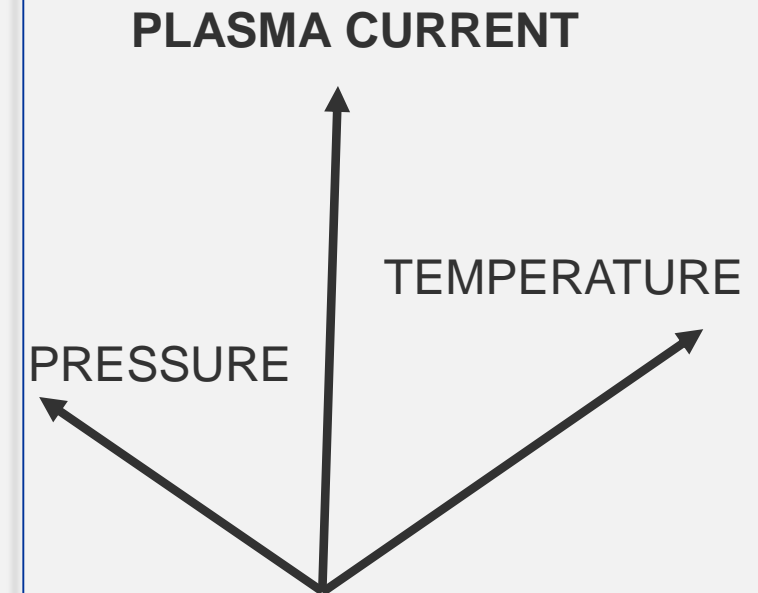
- **Control parameter today: pressure and temperature**
- Influence shown on Movchan Thornton Diagram:



Source: J. A. Thornton, J. Vac. Sci. Technol. A 4, 3059 (1986)

TBC Columnar

- **New dimension with plasma activation:**
- Additional control parameter plasma current:



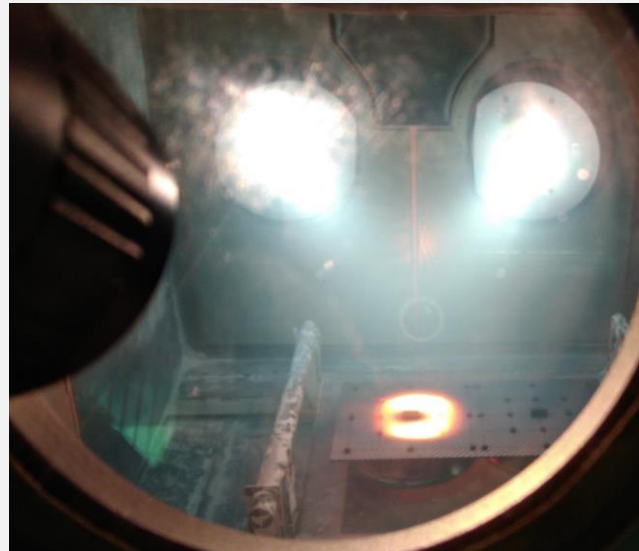
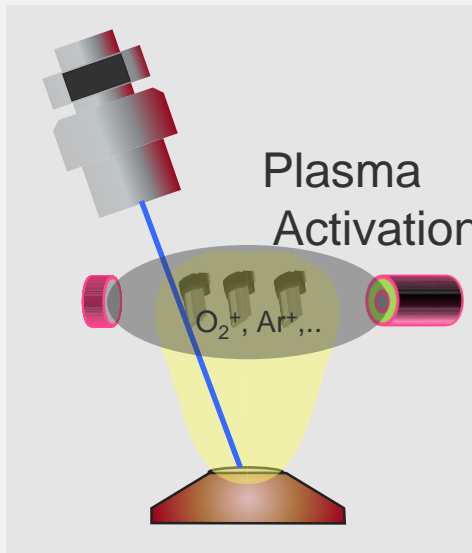
EB-PVD PLUS PLASMA ASSISTANCE

ADVANTAGES

- Additional energy source:
 - Lower temperature of parts at same coating quality
 - Coating window is larger (columnar structure in larger volume)
- Analysis of vapor cloud during coating process via optical emission spectroscopy (OES)
 - > Basis for automatic process adjustment and control

EB-PVD PLUS PLASMA ASSISTANCE REALIZATION

Plasma Activation by hollow cathode - Integrated at the SMART Coater in Poland



- Installation at SMARTCoater in Poland allows optimization and testing esp. regarding interaction E-Beam, hollow cathode and substrates in a production like environment.
- Cooperation and access for ALD and ALD Customer was the basic selection criteria for the University of Rzeszów (Politechnika)

FIRST RESULTS OF COATING RUNS WITH PLASMA ACTIVATION

SMART COATER – SETUP AND TEST

Test setup :

- One EB-gun ALD (KSR 250)
- Two hollow cathodes
- Single pool evaporation
- Standard three-port rake with test pins

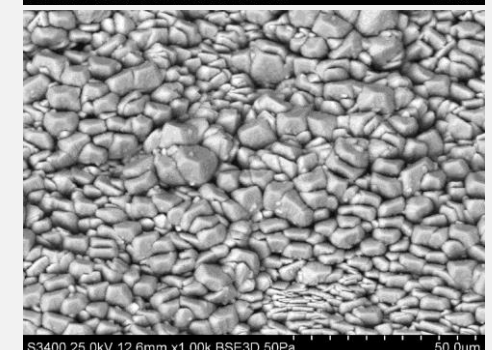
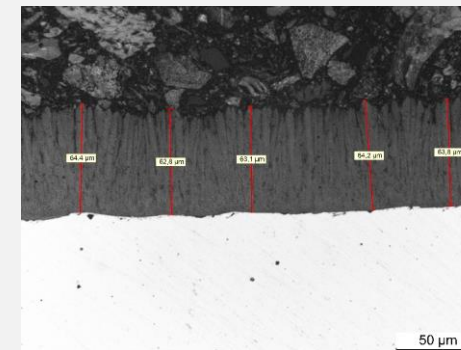
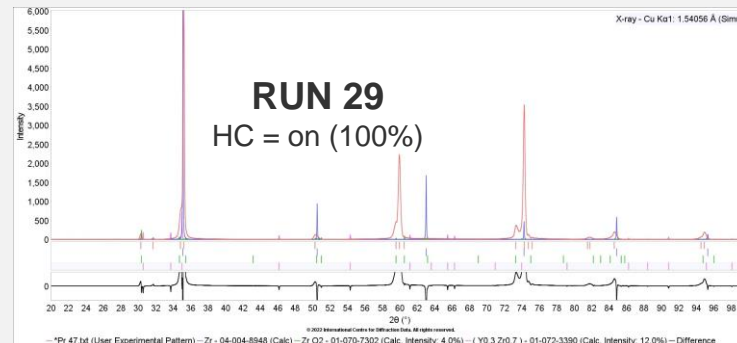
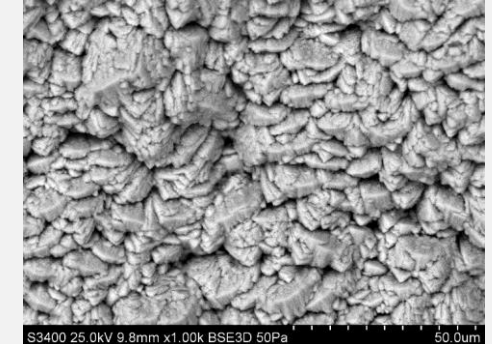
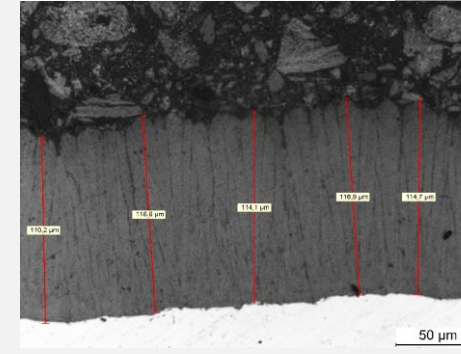
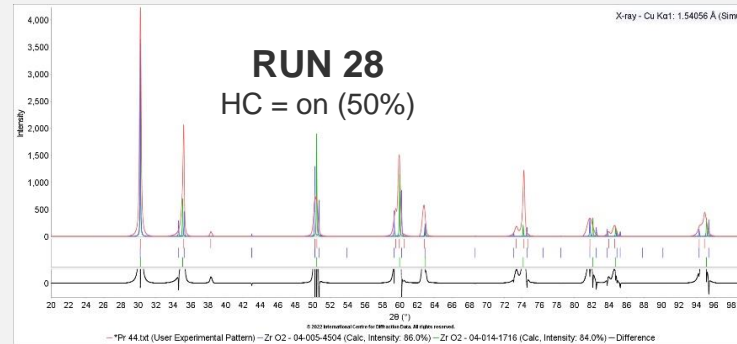
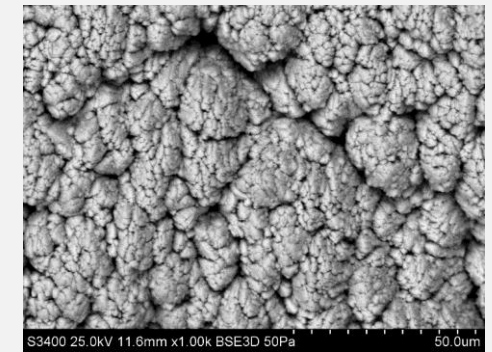
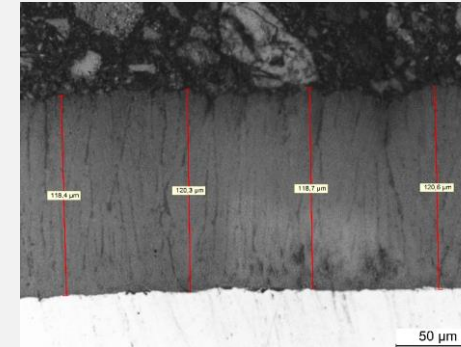
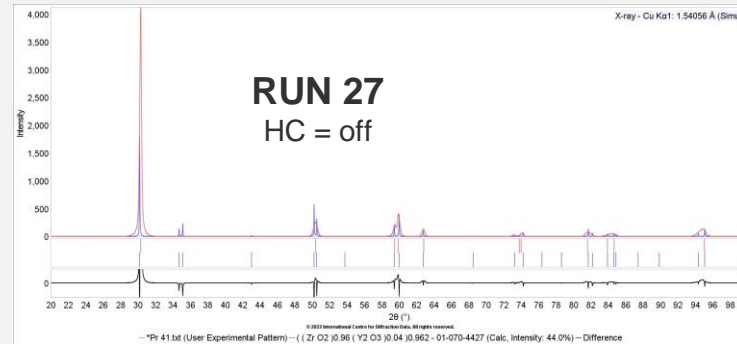


FIRST RESULTS OF COATING RUNS WITH PLASMA ACTIVATION

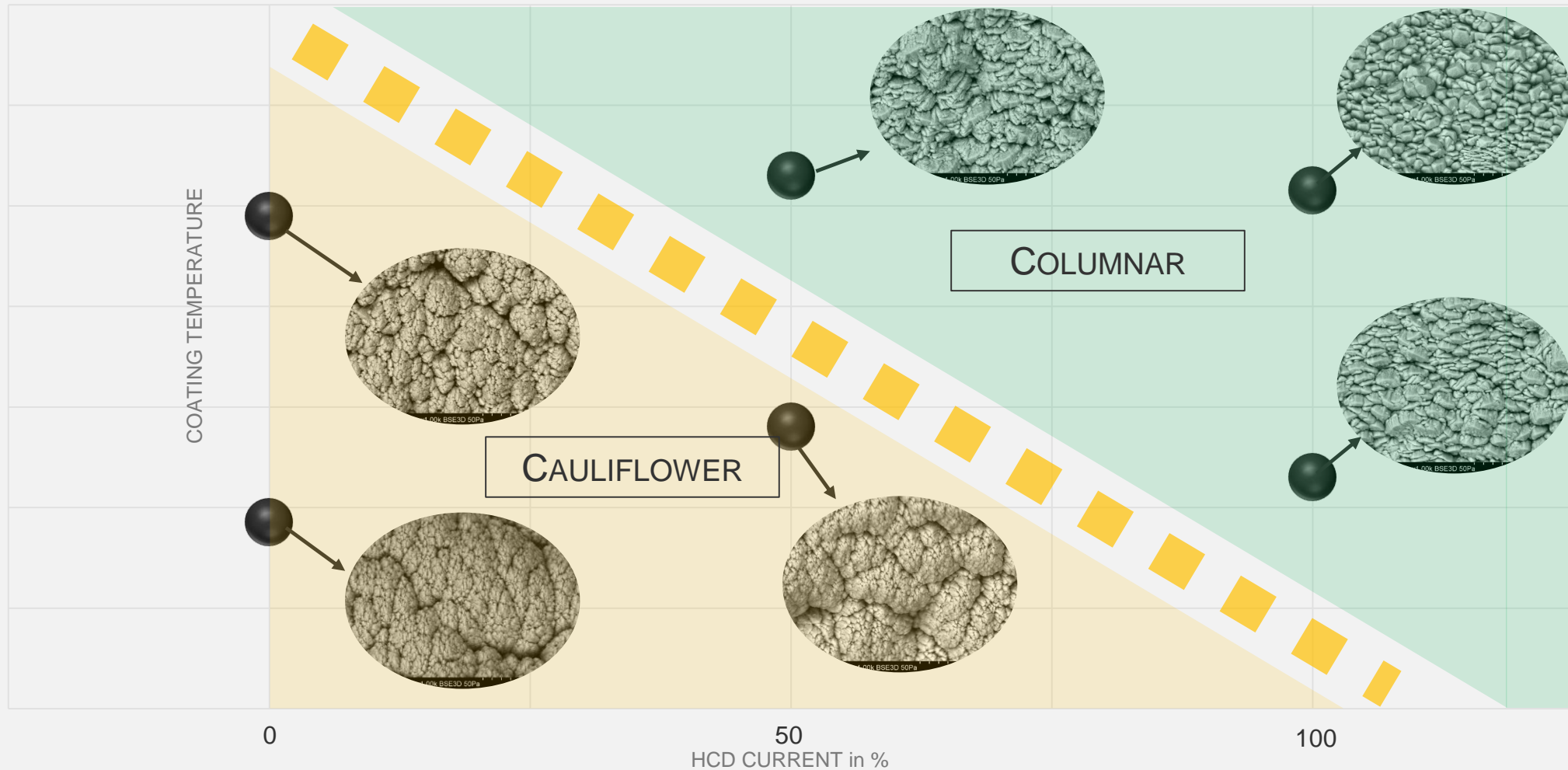
SMART COATER– TEMPERATURE AND STRUCTURE: XRD

Emission current
decreased

Substrate
temperature
constant



FIRST RESULTS OF COATING RUNS WITH PLASMA ACTIVATION COLUMNARITY VS. COATING TEMPERATURE AND HCD CURRENT



SUMMARY

- ALD SMARTCoater highly beneficial tool for process development and pilot production demands
- New plasma assisted high-rate EB-PVD coating process has been implemented into SMART Coater
 - Simulations show large influence on electron beam deflection (influence solved by FEP)
 - Improvement of columnar microstructure of 7YSZ TBC coatings has been demonstrated over wide temperature range
 - New process provides an additional tool to control and improve coating morphology (columnarity)
 - Process can be used to enhance quality and productivity of standard EB-PVD coaters
 - It provides unique control of the coating morphology for new coating systems (low-k, CMAS, EBC)
- Retrofit of existing ALD coating equipment is possible

OUTLOOK

- Enhanced SMARTCoater at Politechnica in Poland can support your development needs:
 - SMARTCoater is highly flexible with regard to coating window, coating material and coating process
 - Complex compositions by mixed material evaporation (two crucibles) possible
 - Plasma activated process
 - Allows optical emission spectroscopy for process monitoring
- **ALD is open for supporting your Trials at the enhanced SMARTCoater**
- **ALD's focus is on machine business for enabling your processes**



We would like to thank:

Dr. Andrzej Nowotnik and Damian Nagel from the Rzeszow University of Technology

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for the good collaboration!

THANK YOU!

