

Starting new adventures at BAM. The Focus Area Projects ProMoAM and AGIL

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Kurzfassung

While additive manufacturing (AM) is blossoming in nearly every industrial field, and the most different process are being used to produce components and materials, little attention is paid on the safety concerns around AM materials and processes.

Leveraging on our leading expertise in non-destructive testing (NDT) and materials characterization, we approach AM at BAM under two important viewpoints: first the on-line monitoring of the process and of the product, second the evolution of the (unstable) microstructure of AM materials under external loads.

These two subjects are the core of the two new-born internal projects ProMoAM and AGIL, respectively.

A detailed view of the goals and the organization of these two projects will be given, together with the expected output.

Symposium Zerstörungsfreie Materialcharakterisierung

Charakterisierung additiv gefertigter Komponenten- 28.11.17

**STARTING NEW ADVENTURES AT BAM.
THE FOCUS AREA PROJECTS PROMOAM AND AGIL**

Giovanni Bruno, Christiane Maierhofer

BAM- Bundesanstalt für Materialforschung und -prüfung

Safety in technology and chemistry



BAM is a senior scientific and technical federal authority with responsibility to the Federal Ministry for Economic Affairs and Energy (BMWi)



Federal Ministry
for Economic Affairs
and Energy





Organisation

11 departments divided into

64 divisions and sections

September 2016

- 1** Analytical Chemistry; Reference Materials
- 2** Chemical Safety Engineering
- 3** Containment Systems of Dangerous Goods
- 4** Materials and the Environment
- 5** Materials Engineering
- 6** Materials Protection and Surface Technologies
- 7** Safety of Structures
- 8** Non-Destructive Testing
- 9** Component Safety
- S** Accreditation, Quality in Testing
- Z** Administration and Services

Focus areas at a glance



FOCUS AREA
ENERGY



FOCUS AREA
INFRASTRUCTURE



FOCUS AREA
ENVIRONMENT

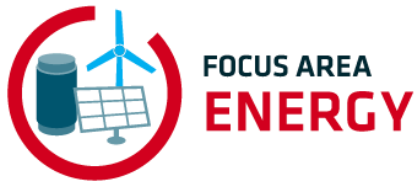


FOCUS AREA
MATERIALS



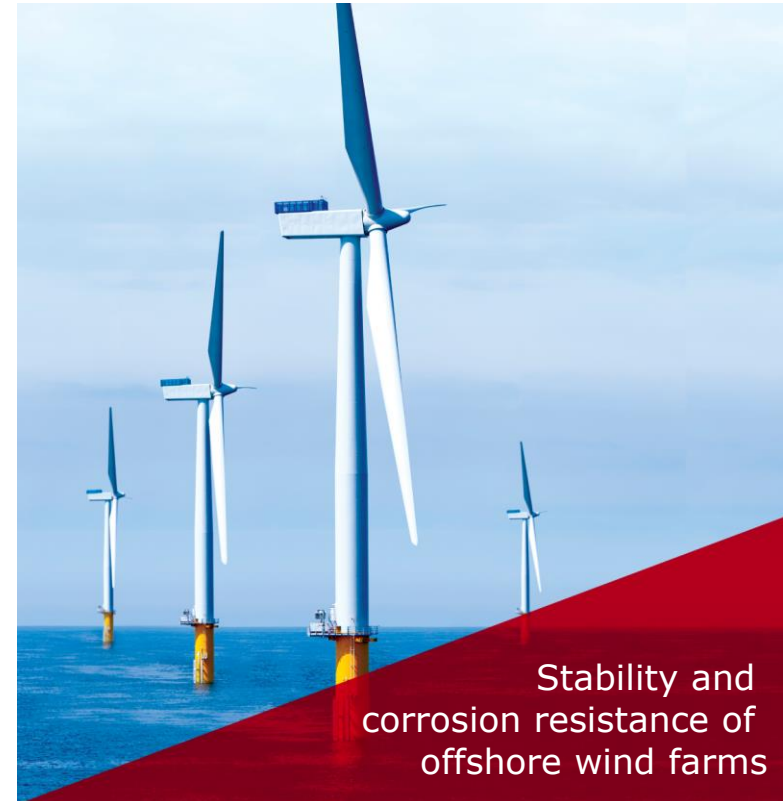
FOCUS AREA
ANALYTICAL SCIENCES

Five focus areas



Activities

- Energy storage
- Energy conversion
- Energy transport
- Nuclear waste management



Stability and
corrosion resistance of
offshore wind farms

Five focus areas



Activities

- Safety of structures
- Safety of industrial facilities and traffic
- Transport and storage of dangerous substances and goods
- Fire science
- Security



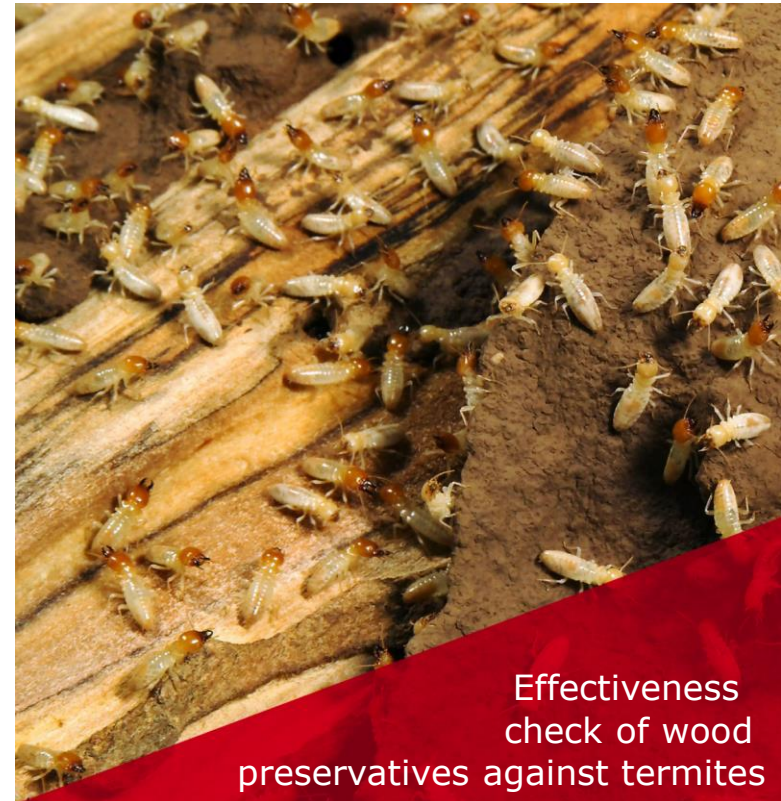
Safety
of transport routes

Five focus areas



Activities

- Environmental pollutants
- Behaviour of materials and products in the environment
- Recycling



Five focus areas

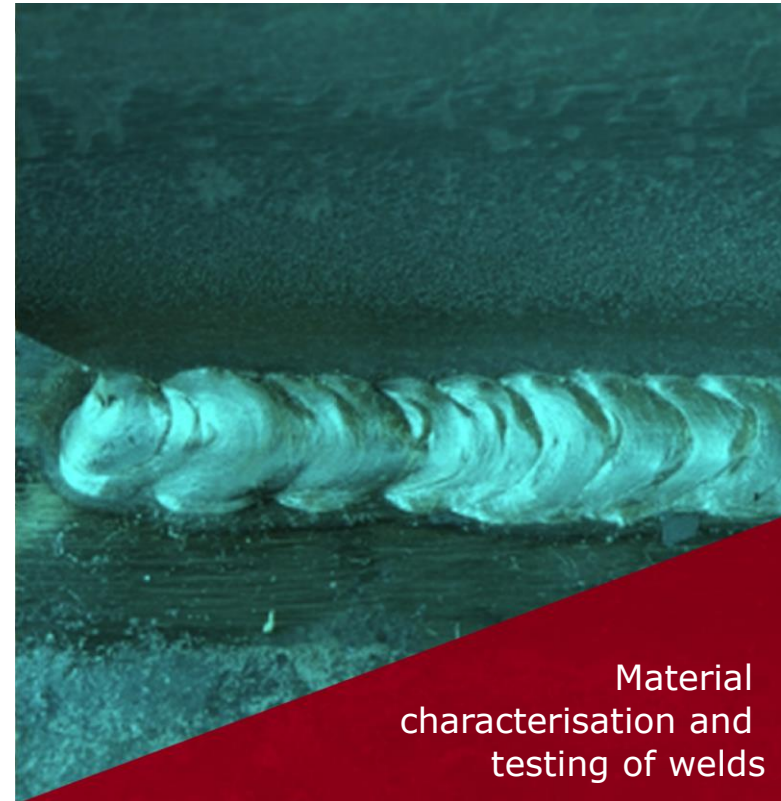


Activities

- Life cycle of components
- Degradation of materials
- Materials and substances

New Activity

- Additive Manufacturing

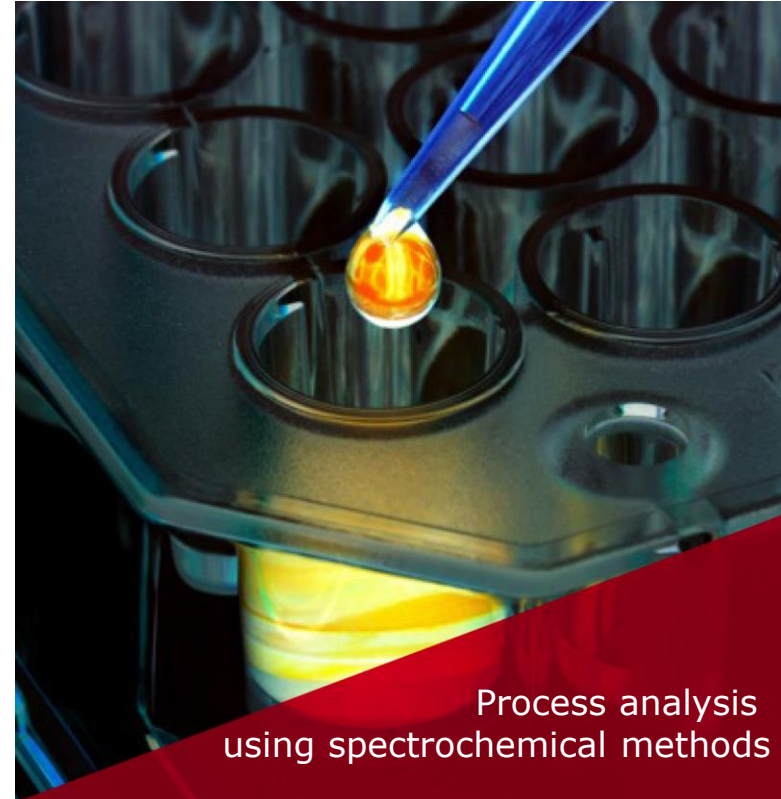


Material characterisation and testing of welds



Activities

- Chemical composition and trace analysis
- Surface and interface analysis
- Non-destructive testing and spectroscopy
- Structure analysis and materialography
- Sensor technology
- Quality assurance



Departments dealing with AM

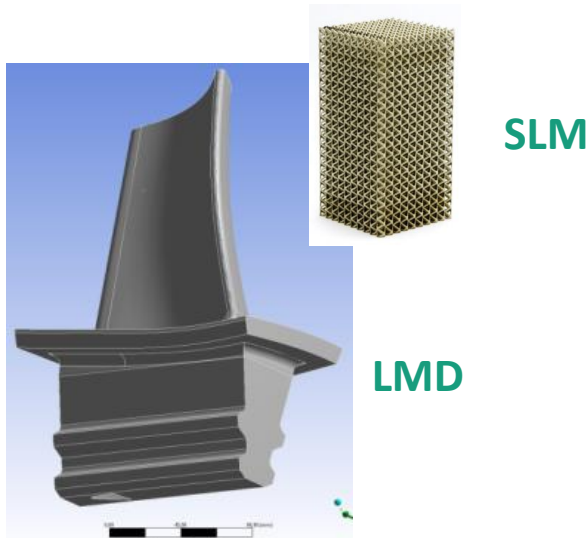
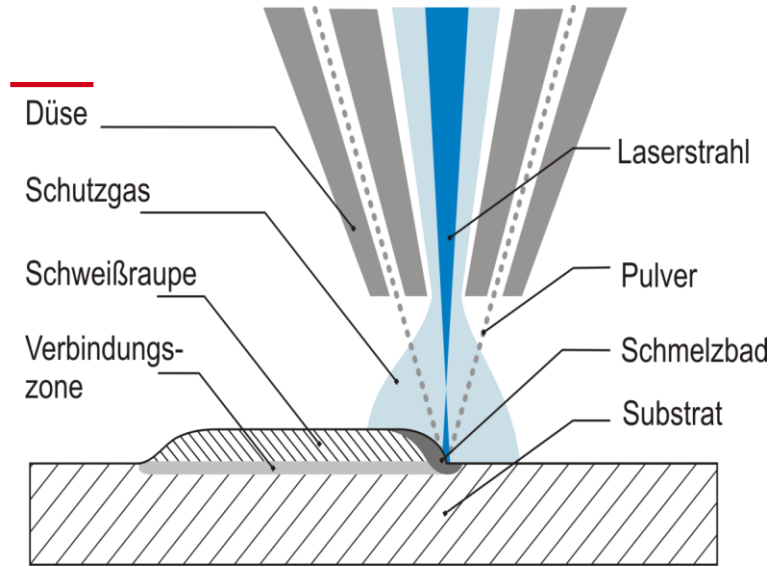


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Laser-Metal-Deposition: Process

Welding of an additional structure through Laser

- › Laser beam creates a melting bath
- › Gas carrier conveys powder addition
- › Laser beam heats and melts the bath
- › Welded material solidifies into ‚caterpillars‘



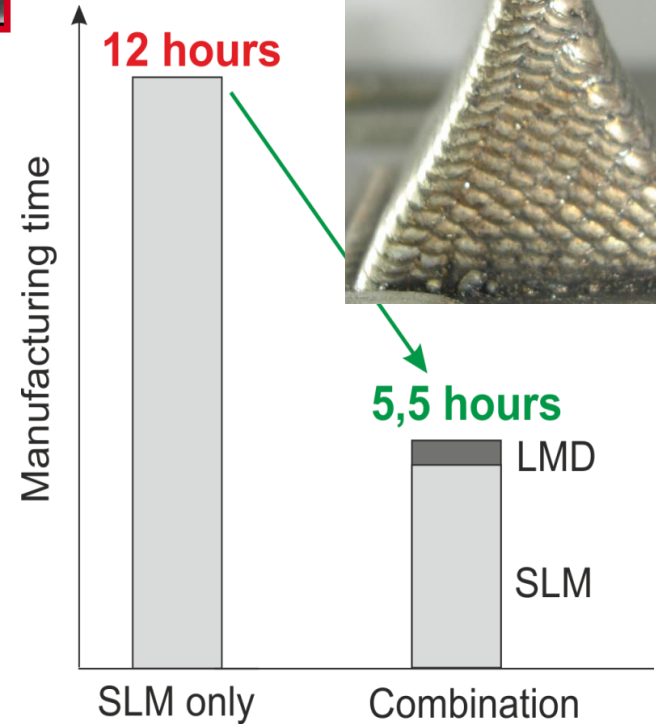
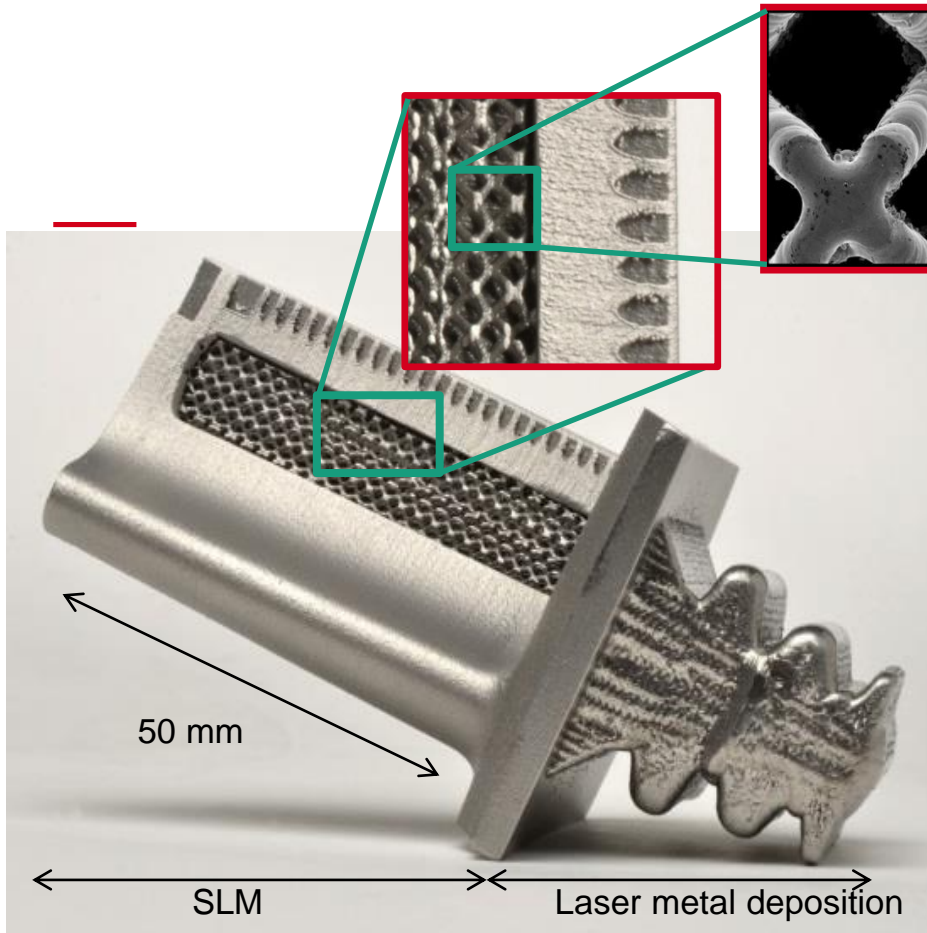
SLM for Turbine Blade

- › Integration of lightweight structures
- › Decreased weight with still good stiffness

LMD for bead profiles

- › Smaller geometrical complexity
- › Higher build-up rate

Additive Manufacturing: Combined Process Chain



55 % time saving through combined additive process chain

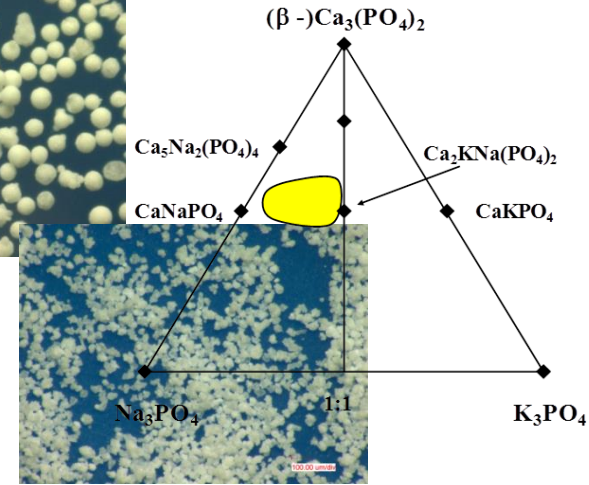
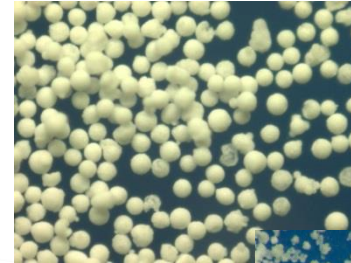
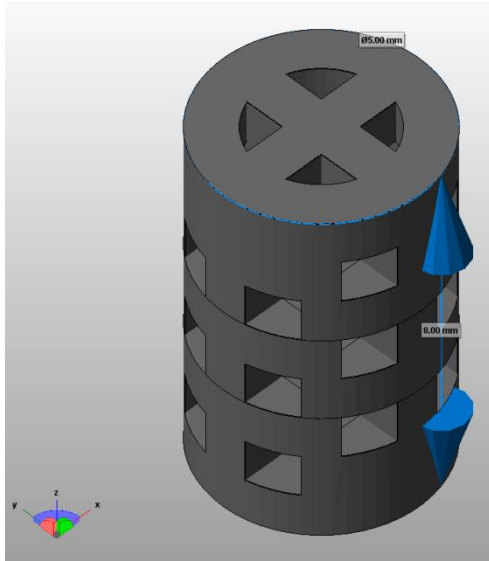


Departments dealing with AM

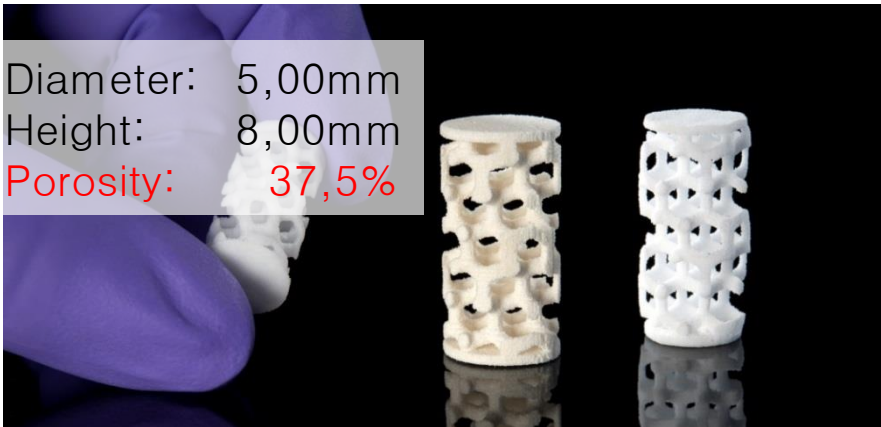
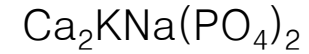


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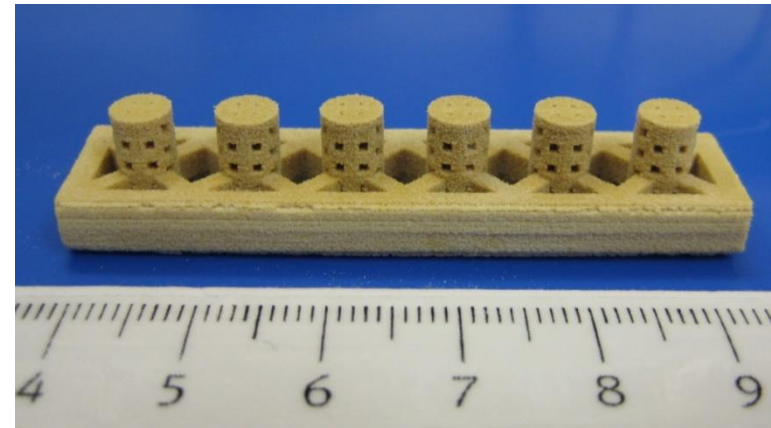
Ceramic Powders: Bioceramic Scaffolds by 3D Printing



3D
Printing



←
sintering
up to
1200 °C



Departments dealing with AM

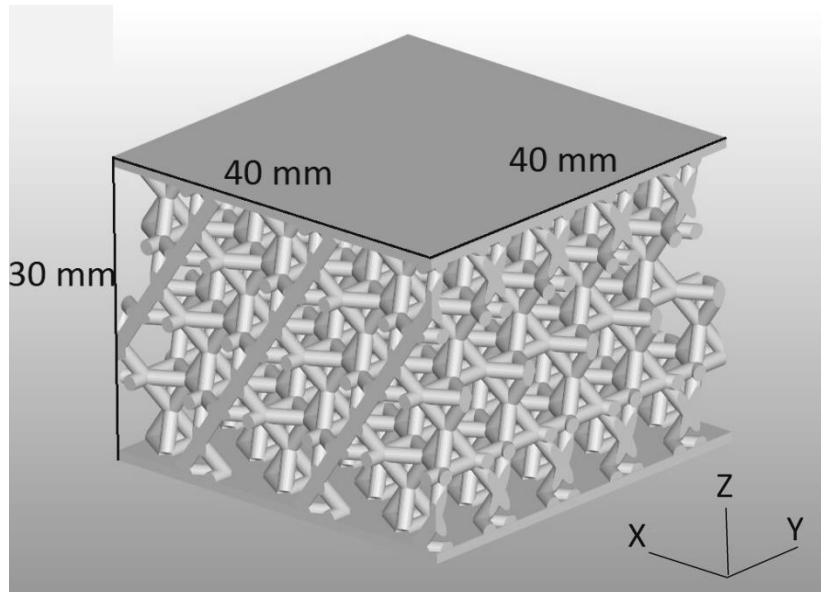


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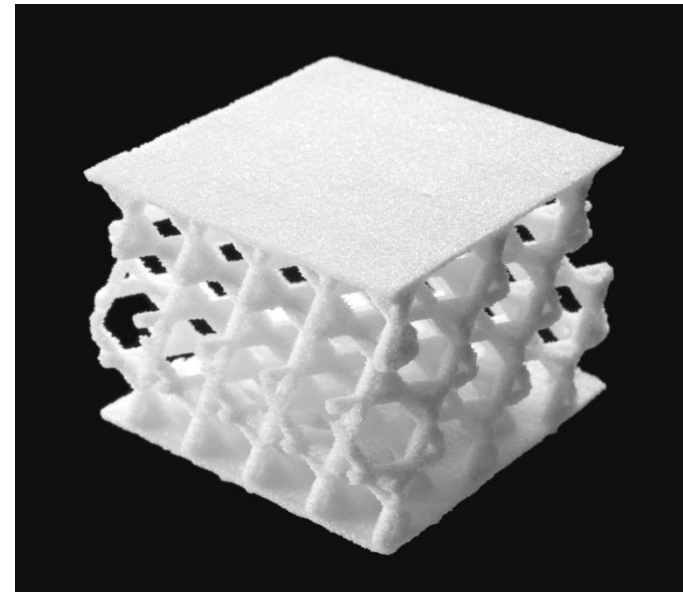
Case Study: 3D Printed SiOC

Task: determine scale and form of

- 3D-printed porous polymer-derived ceramic parts against STL-file
- cerammed part against printed part



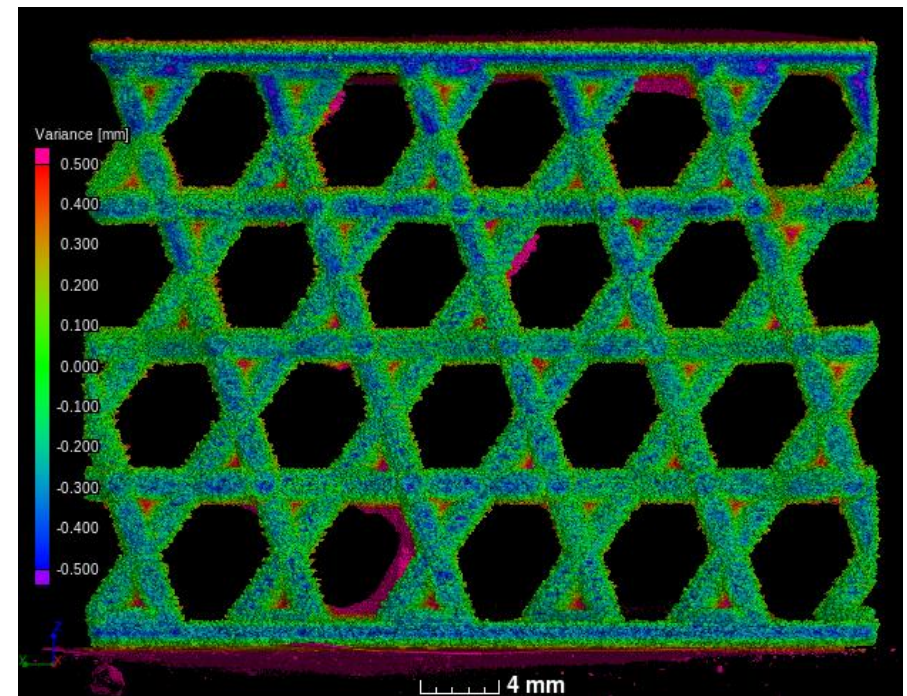
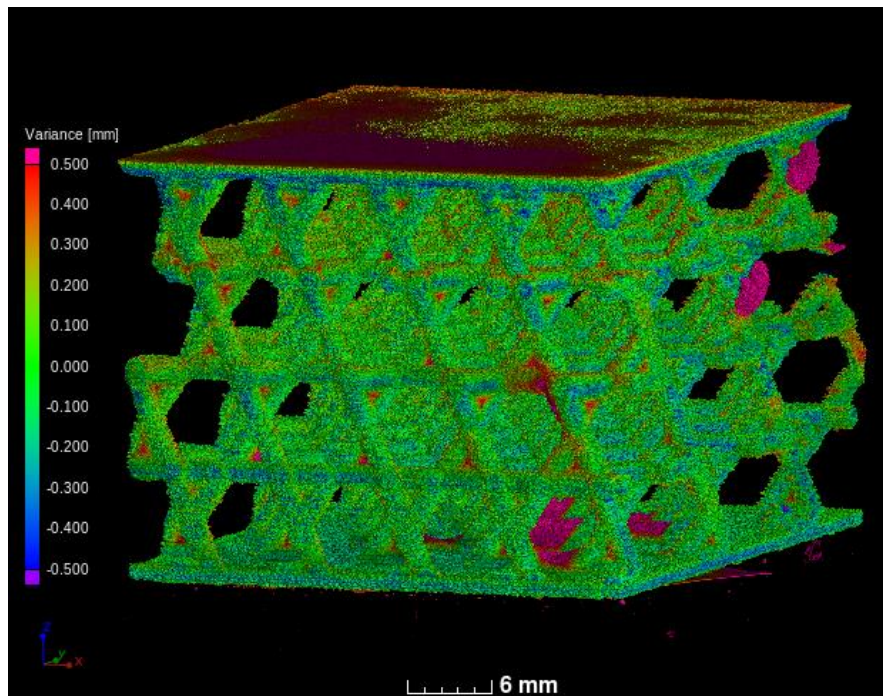
STL-file of kagome lattice



printed kagome lattice

μ CT with 80 kV, 31 μ m voxel-size
analysis with VGStudioMax 2.1

- Re-normalization scale-correction with distances of cylinders fitted onto the struts
ratios: x:0.996, y:0.996, z:0.978
- nominal/actual comparison:



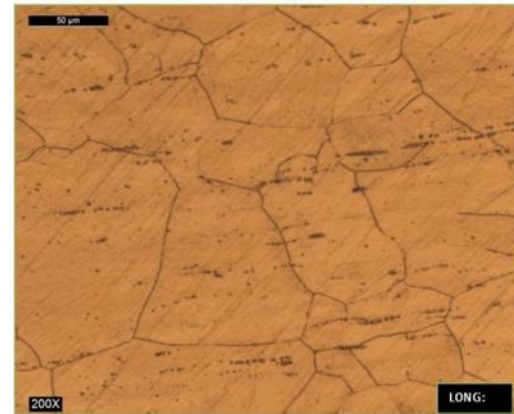
printed part against STL

The Project AGIL:

Mikrostrukturentwicklung in **additiv gefertigten metallischen**
Komponenten: vom **Pu**lver zum **mechanischen Versagen**

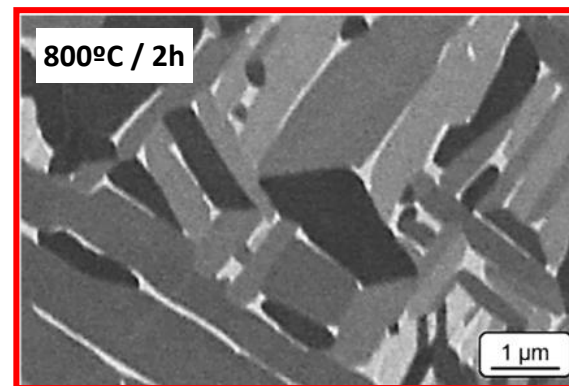
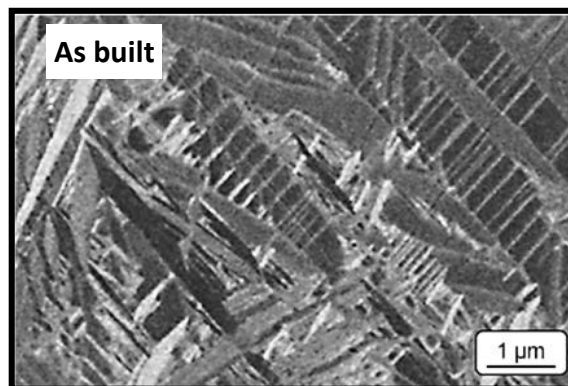
Motivation:

1- Unexpected (?) Change of Microstructure under conventional cyclic load



AISI 316L

CNR, Italy

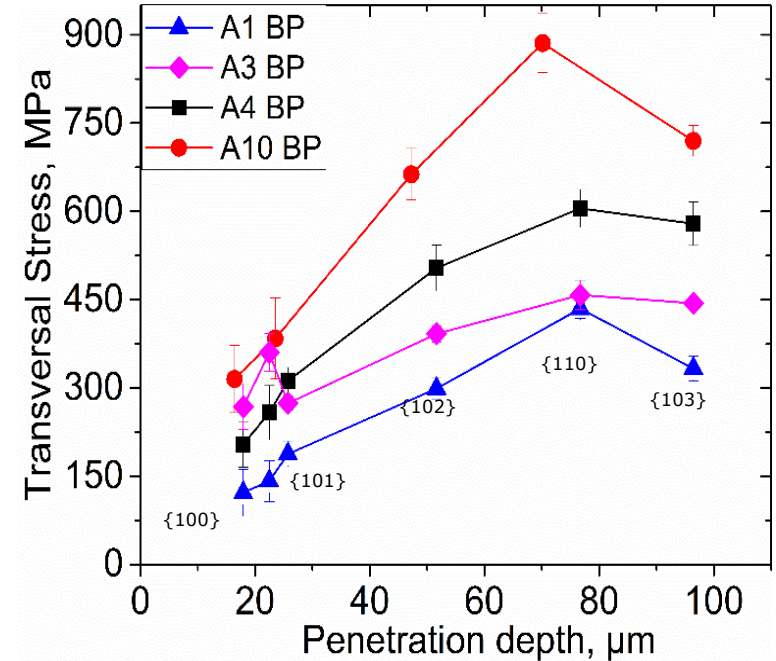


Ti6Al4V

DLR, Germany

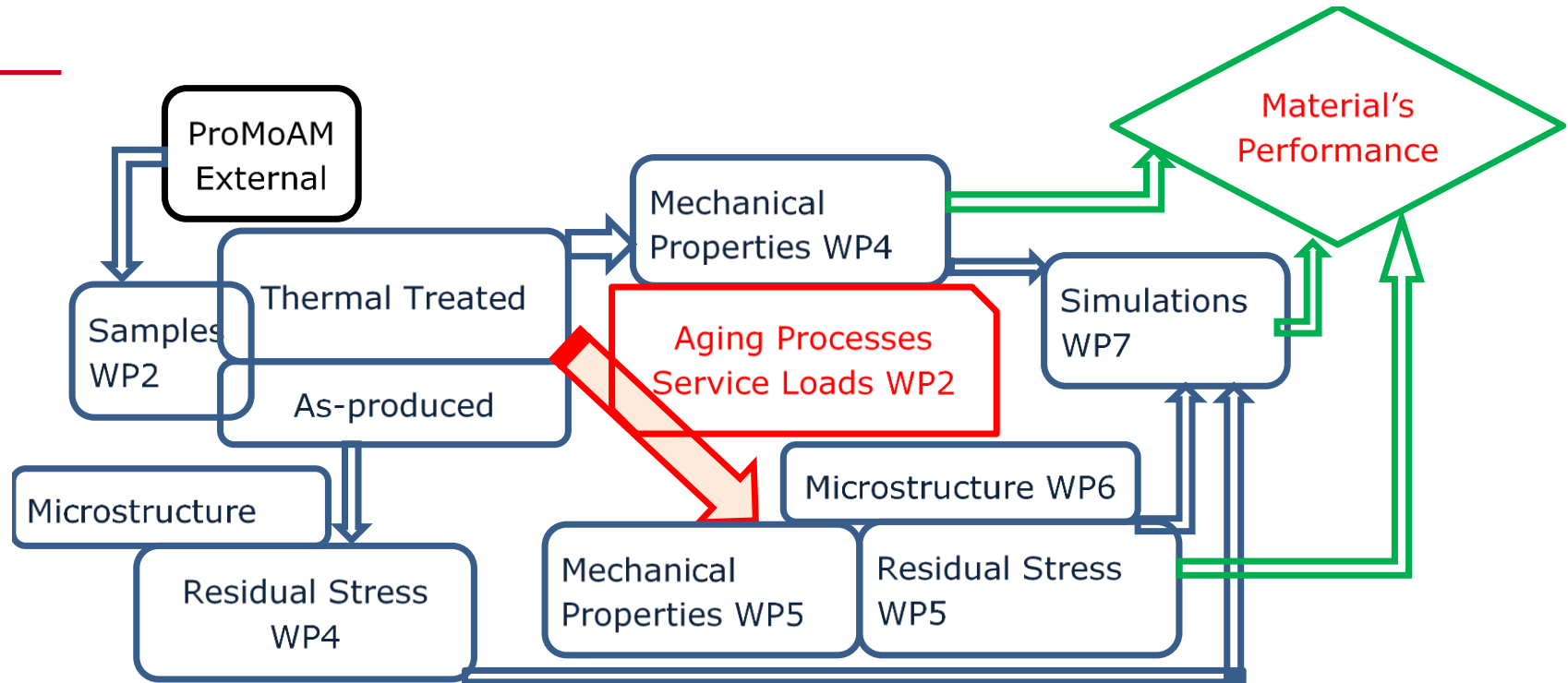
2. Presence of large tensile Residual Stress

- Evolution of those stresses with
 - Release from base plate
 - Thermal treatment



Change of mechanical properties and Materials performance

The Project AGIL: Plan



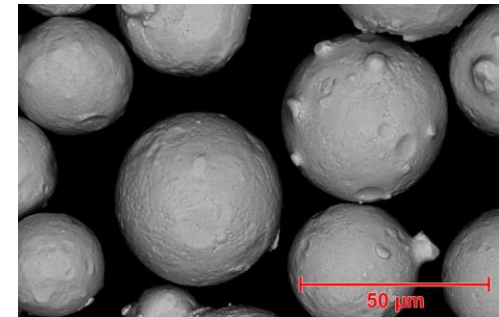
Aging of Materials: How the Microstructure and the Residual Stress affect the mechanical properties (as a function of thermal and mechanical loads)

4 Departments, 10 Divisions involved: 9 FTE

Stand-der-Technik in der Qualitätssicherung in der Additiven Fertigung (AM)

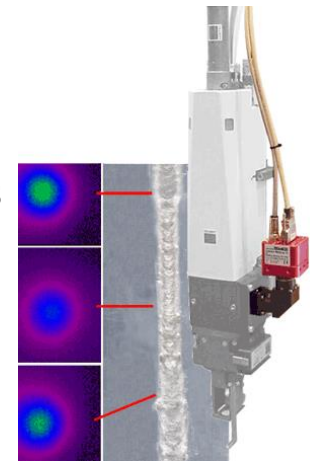
Stand-der-Technik in der Qualitätssicherung:

- Qualifizierung des Ausgangsmaterials
 - Pulver, Draht, Folie
- Überwachung des Fertigungsprozesses über Prozessgrößen
 - z.B. Laserleistung, Scangeschwindigkeit, Temperaturmessung, Kontrolle des Pulverbetts
- Prüfung der Zustandsgrößen des fertigen Bauteils
 - CT
 - Ultraschall
 - zerstörende Prüfung



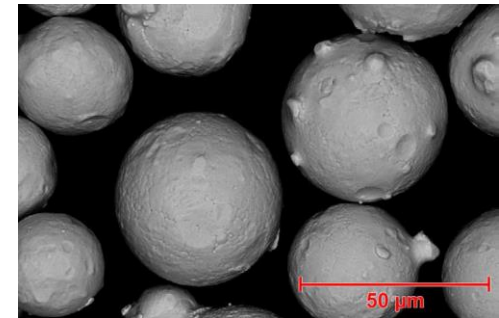
Gas atomisiertes Pulver, 316L-SI,
Quelle: oerlikon metco

Laser
Welding
Monitoring
with CMOS
camera
Quelle:
Prometec



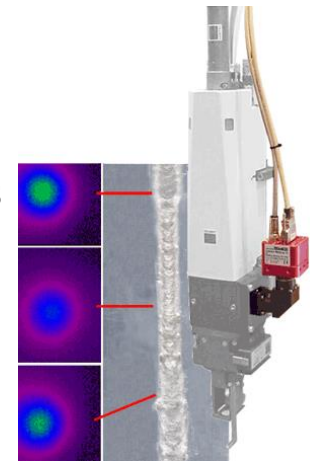
Neu in der in-situ Anwendung in ProMoAM:

- Überwachung der in-situ Zustandsgrößen mit ZfP und optischen Verfahren
 - Risse
 - Delaminationen
 - Poren
 - Elementverteilung



Gas atomisiertes Pulver, 316L-SI,
Quelle: oerlikon metco

Laser
Welding
Monitoring
with CMOS
camera
Quelle:
Prometec



TF-Projekt zur Additiven Fertigung - ProMoAM

Prozessmonitoring in der Additiven Fertigung



Opt.
Tomo-
grafie

Thermo-
grafie

Laser-
Thermo-
grafie

Photo-
akustik

Ultra-
schall

OES

Wirbel-
strom/
GMR

CT

Lami-
no-
grafie

Rück-
streu-
ung

Preprocessing der Einzeldatensätze

2D/3D Data Fusion zur Bestimmung der Zustandsgrößen des Bauteils als 3D-Darstellung

Risse (Zahl,
Länge)

Hohlstellen
(Zahl, Größe)

Poren (Zahl,
Volumen, Ra-
dienverteilung)

Dichte
(Porosität)

Gefüge
(Größe,
Orientierung)

Element/
Molekül-
verteilung

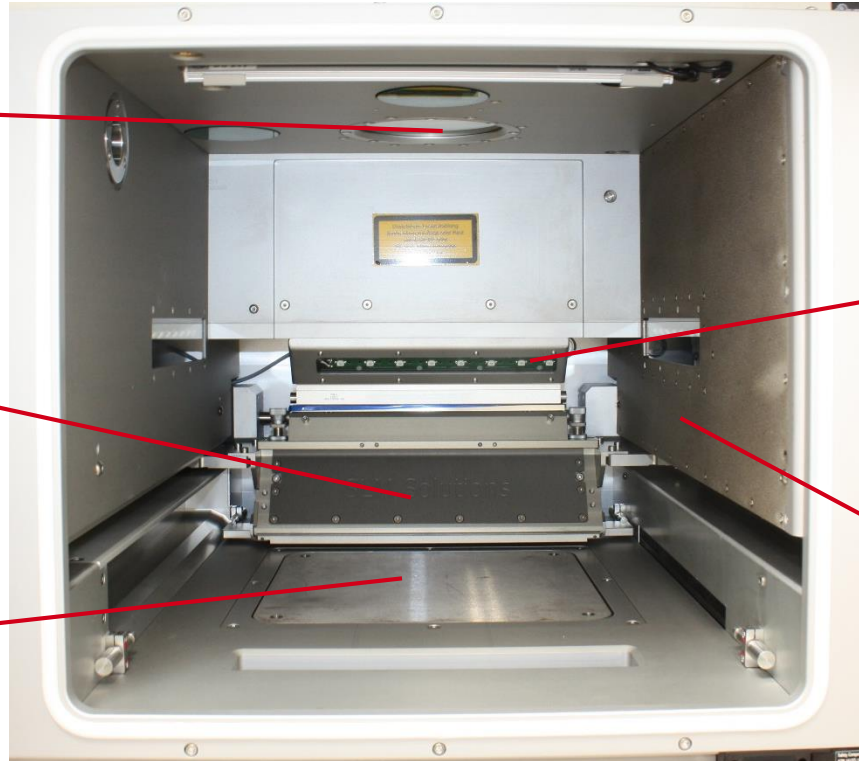
Selective-Laser-Melting-Anlage, SLM Solutions M280 (BAM 9.3, K. Hilgenberg)



Laseroptik
400 W
1070 nm
Fokus: 150 μm

Beschichter

Bauteil-
plattform



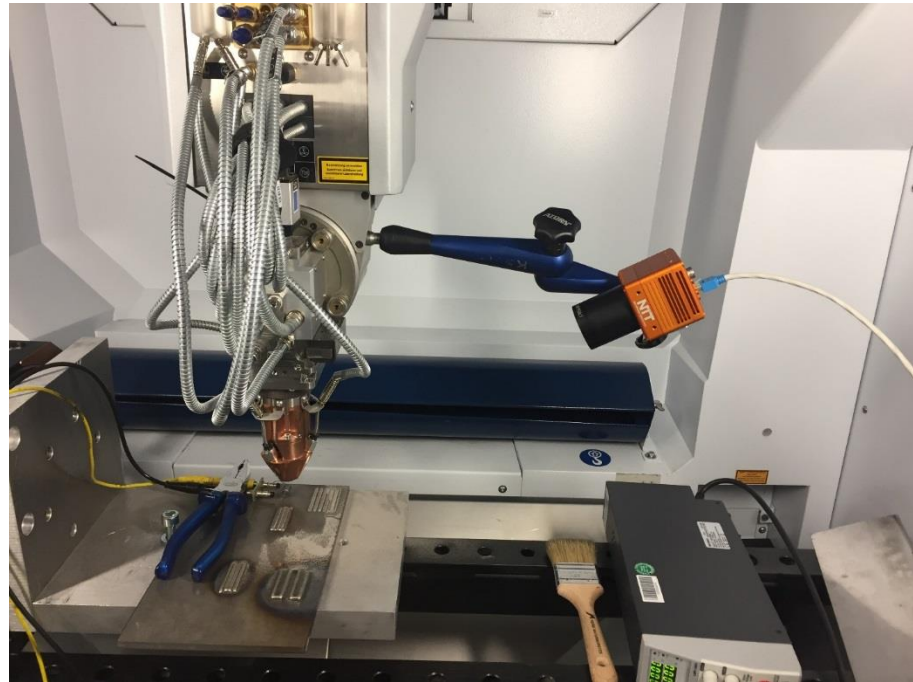
Melt-Pool-
und Laser-Power-
Monitoring

Layer-
Control-
System

Schutzgas-
zuführung

Laser-Metal-Deposition-Anlage , TruLaser Cell 3000 (BAM 9.3, A. Gumenyuk)

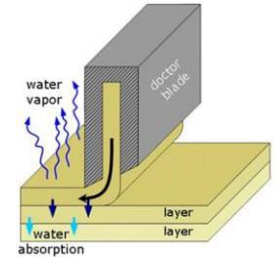
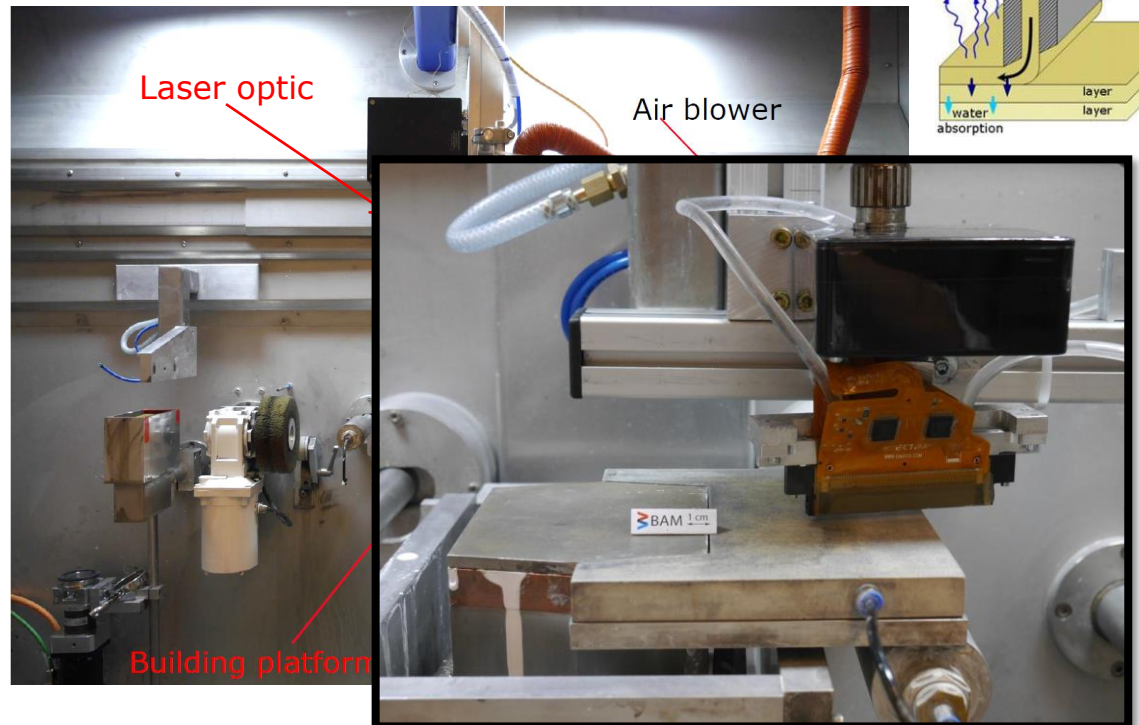
-
- Laseroptik
6 kW, 1030 nm
Pulverfokus 3,5 mm
 - Laserkopf ist beweglich
 - Tisch nur Rotation
 - 2 Pulverbehälter für gradierte Werkstoffe
 - Überwachungs-kamera
 - MWIR-Kamera



Lagenweise Schlickerdeposition (Keramik) (FB 5.4, J. Günster)

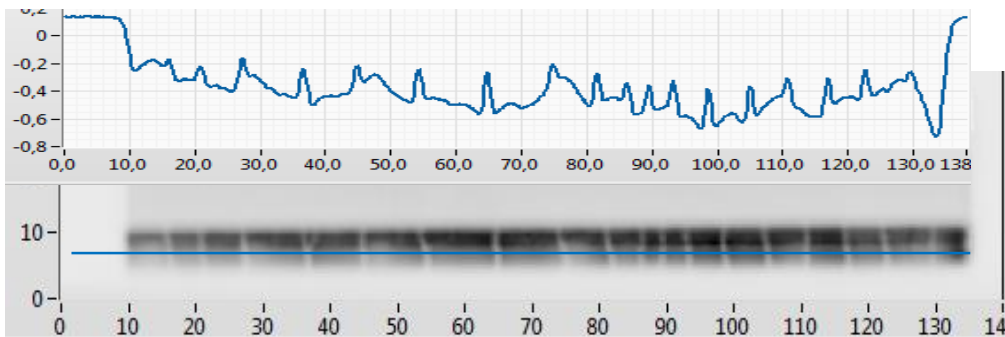
- Faserlaser
50 W, 1970 nm
Galvoscanner
- Tisch: Translation für
Schlickerauftrag
- Pulverbetttheizung bis
200 °C
- IR-Kamera

A. Zocca, P. Lima, T. Mühler,
J. Günster, ICC6 Int. Congr. on
Ceramics, 2016, Dresden



Wirbelstromprüfung an mit LPA wiederaufgefüllten Werkzeugkanten (BAM 8.4, R. Pohl, M. Pelkner)

Probekörper (BAM 9.3, M. Rethmeier):

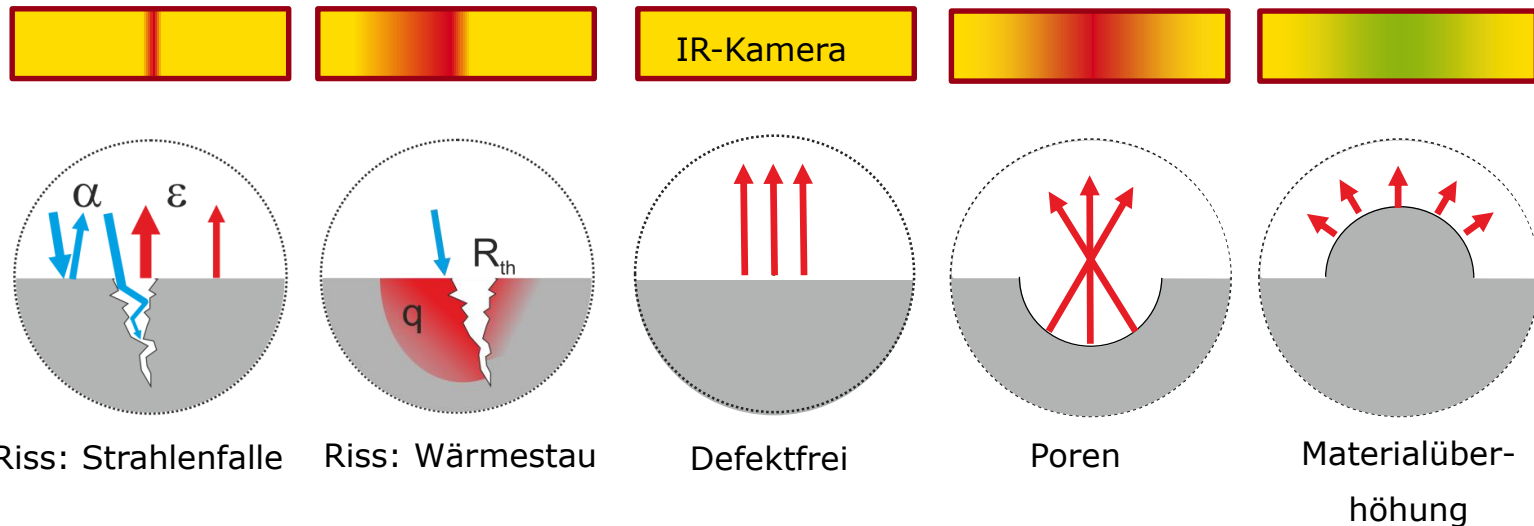


Wirbelstrommessung (ex-situ):

- Mechanisierte Prüfung mit Absolutsonde bei 500 kHz
- Prüfung mit Wirbelstrom weist Risse an den drei Aufträgen nach
- Materialcharakterisierung mit ET erscheint möglich
- Prüfabstände größer 1 mm sind möglich
- Keine Beeinflussung der metallischen Pulver durch elektromagnetische Felder der ET

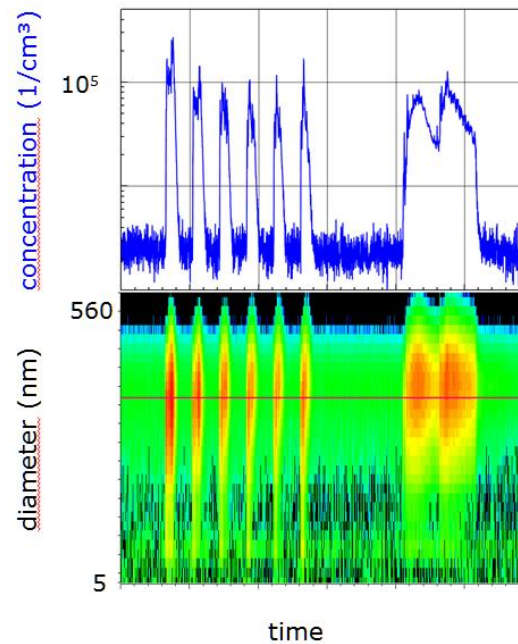
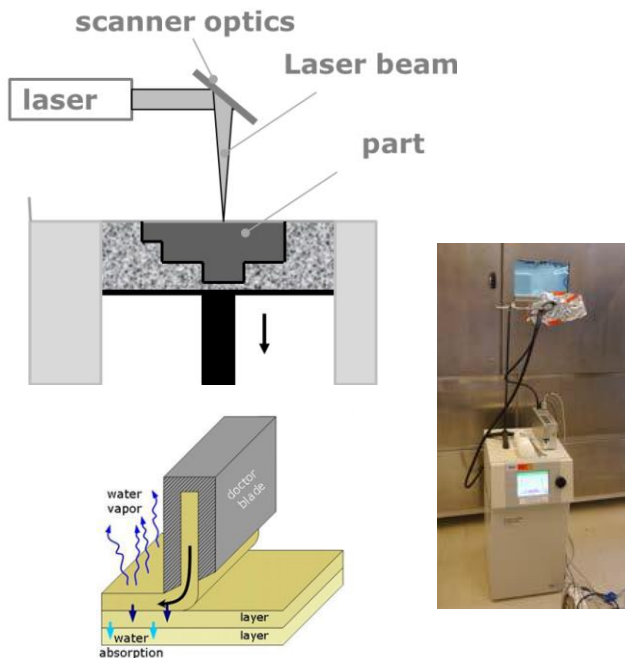
Fehlstellendetektion mittels Thermografie: Offene Risse, Poren, Materialüberhöhungen (FB 8.7)

Resultierende Fehlstellen und deren Detektion durch Temperaturschwankungen im Schmelzprozess, Schmelzbadkontrolle (Größe)



Herausforderung: Emissionsgradunterschiede zwischen z.B. Pulver und verfestigtem Material

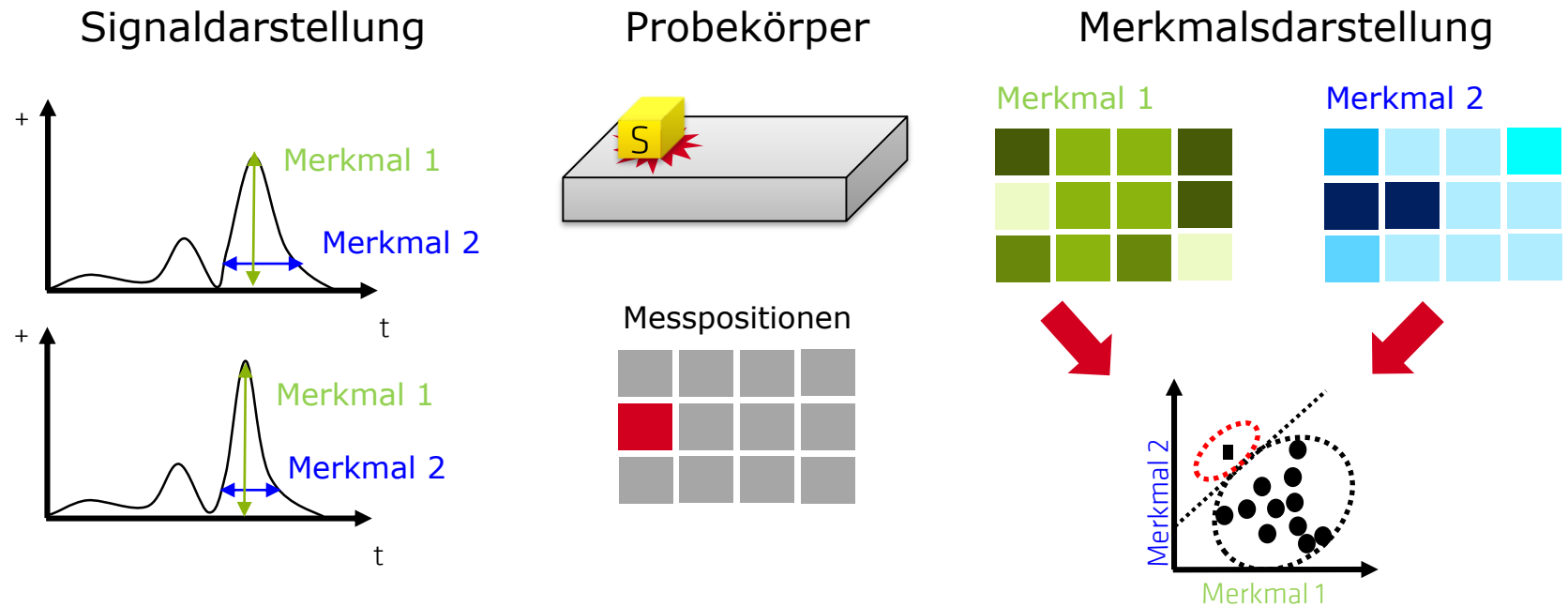
Erfassung der Partikelemissionen, (FB 4.2 S. Seeger)



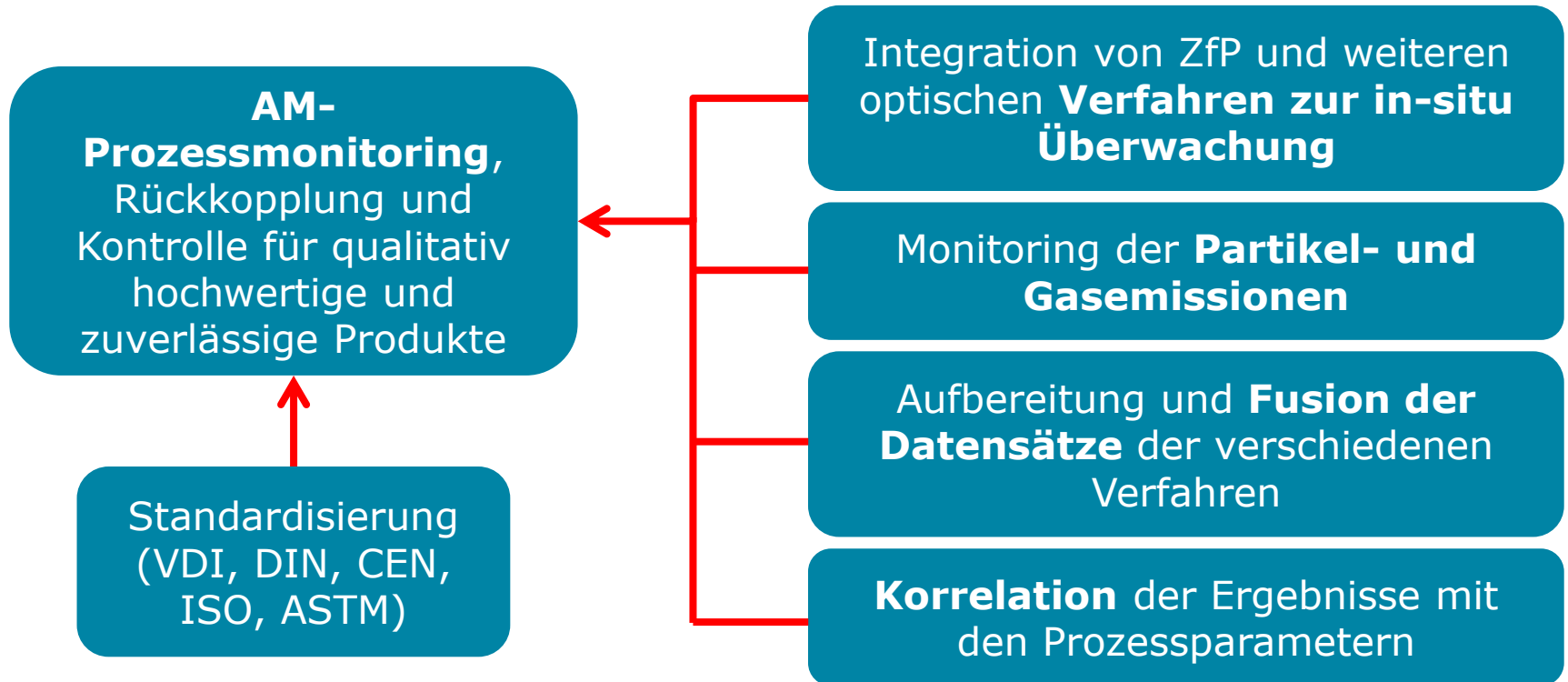
Beispiel: Lagenweise Schlickerdeposition (LSD) zur Herstellung keramischer Grün- körper (BAM 5.4 J. Günster)

- In-situ Messung der Partikelkonzentration als Funktion der Zeit
- In-situ Messung der Partikeldurchmesser als Funktion der Zeit

Datenvorverarbeitung und -fusion (FB 8.2 C. Völker, FB 5.4, Kooperation mit ZIB)



→ **Wie wird die Grenze zwischen gut und schlecht gezogen?**



Thank you

