New materials and customizing of properties by powder technology

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CERN 27.8.2019

Erich

MATERIALS. PERFECTLY. TUNED.

OUR PRODUCTS

THIN FILM MATERIALS

Sputtertargets with Customized Composition and Geometries
Technology Consulting
Manufacturing Partnerships

POWDER INJECTION MOULDING

Ceramics. Metals and Composites
Manufacturing Partner for in-house Production
Developments along the whole Process Chain

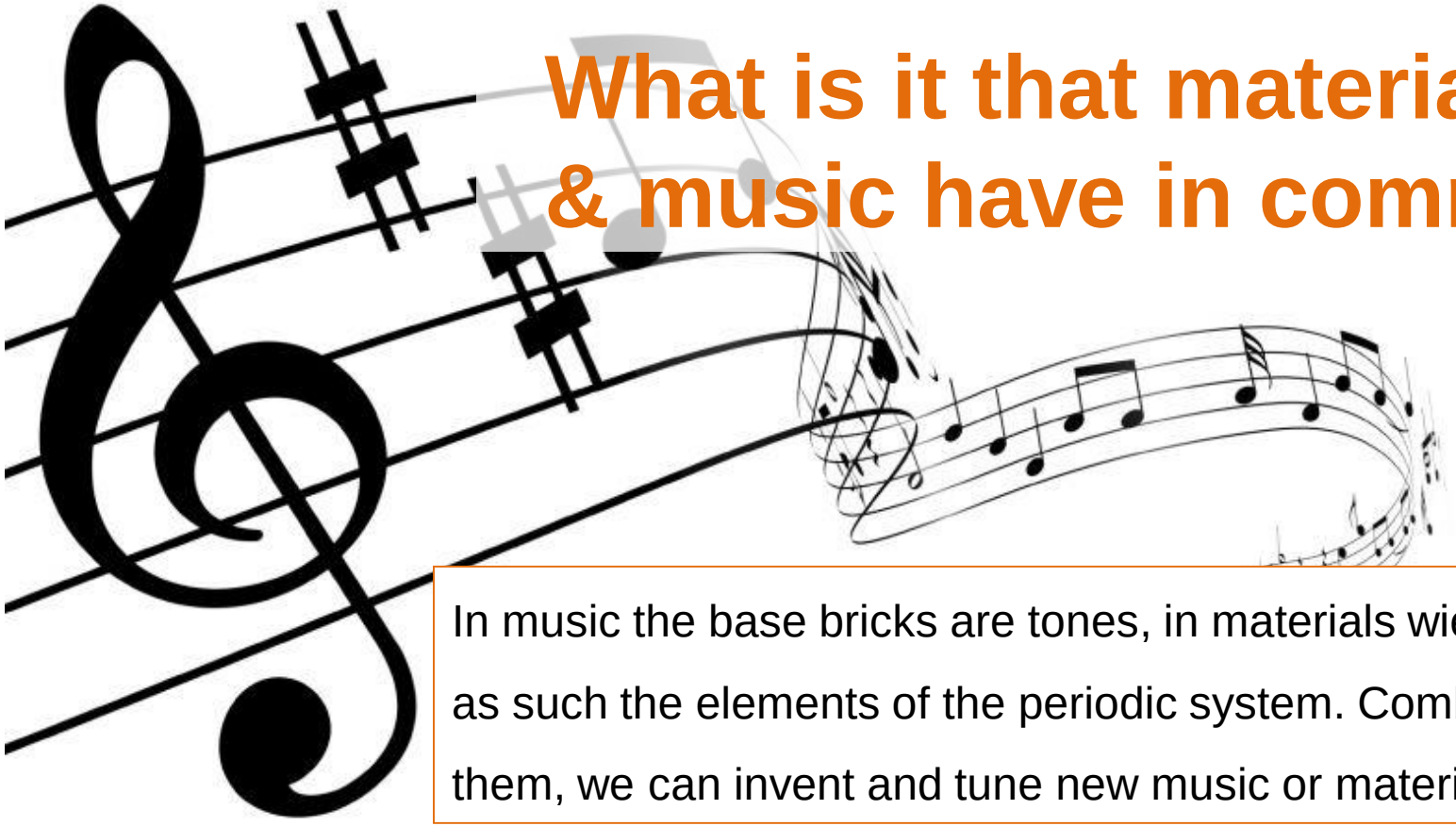
PROCESS AND MATERIAL DEVELOPMENT

from Powder to Bulk
by Fast Hot Pressing, Sintering, Injection Moulding and Additive Technologies
Tailored Processing, Services and Consulting

ADDITIVE MANUFACTURING

3D printer development for XXL Metal parts
Multi-Material Manufacturing
New Materials for printed Ceramics

What is it that materials & music have in common?



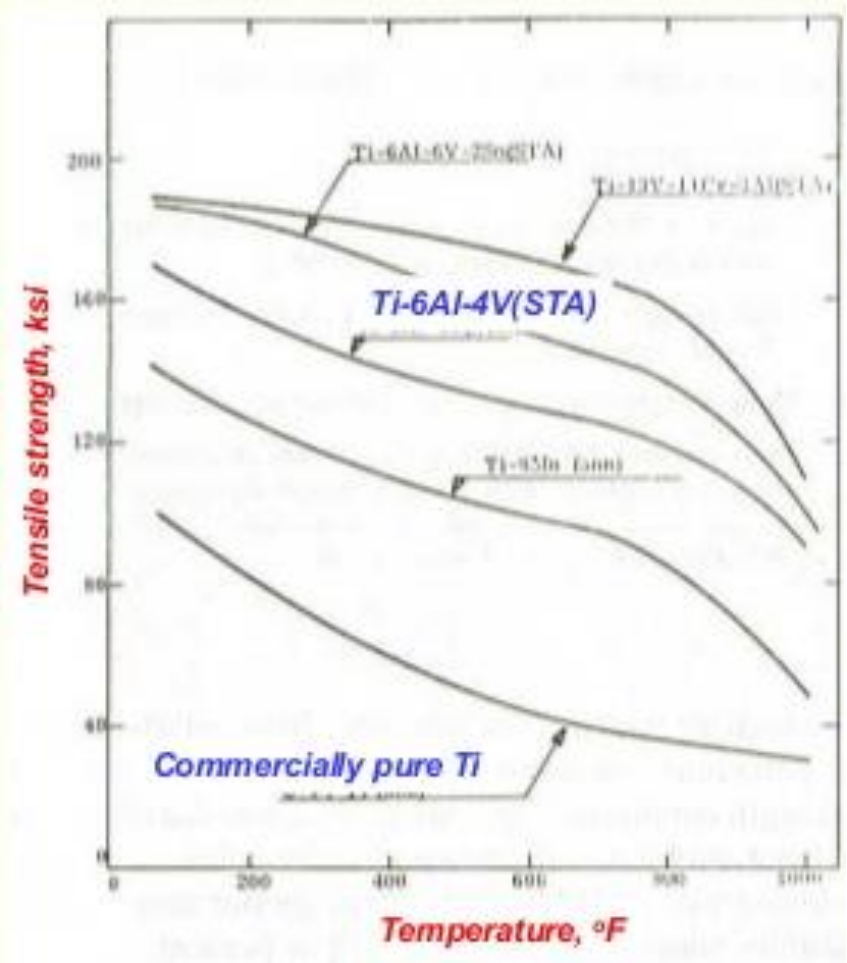
In music the base bricks are tones, in materials wie count as such the elements of the periodic system. Combining them, we can invent and tune new music or materials!

Our „tones“ used for material developments ...

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	*P*	*S*	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	*As*	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	*Sb*	Te	J	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	*Bi*	Po	At	Ra
Fr	Ra	Ac															
		Ce	Pr	*Nd*	Pm	Sm	*Eu*	*Gd*	Tb	Dy	Ho	*Er*	Tm	Yb	Lu		

- Not all „tones“ we CAN play on our insturments
- Not all „tones“ we WANT TO play
- We can combine a big variety of different „tones“
- Several „tones“ do not sound harmonic, when played together
- Some „tones“ can only played in combination with others. (e.g. O, N,...)

a single element – a row of elements together



- sounds „nicer“

- sounds „well“

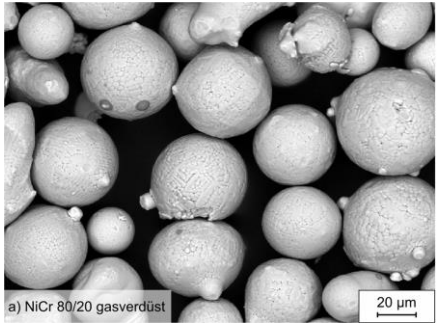
For a material to sound excellent we do need in addtion?

- **The right instrument (process/machine)**
- **The right timing (speed)**

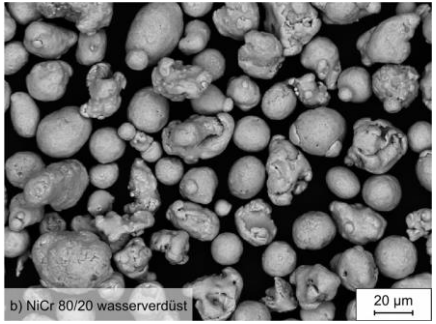
... and now let‘s talk TECHNOLOGY!

How to invent customized materials?

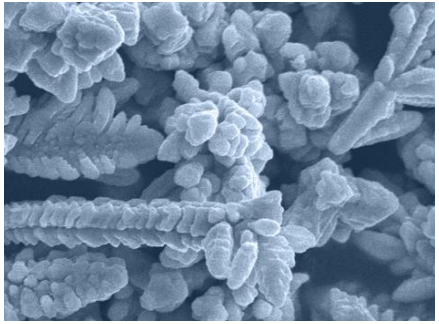
Step 1: POWDER MORPHOLOGY



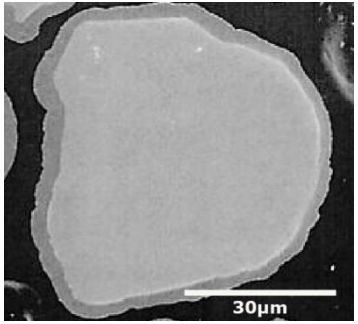
Gas atomized NiCr 80/20



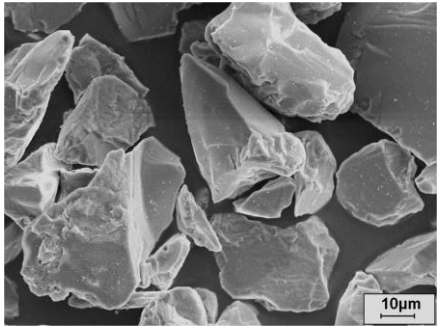
water atomized NiCr 80/20



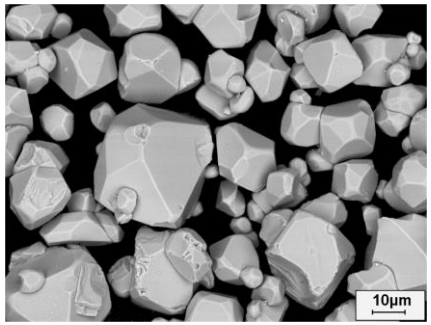
dendritic Cu



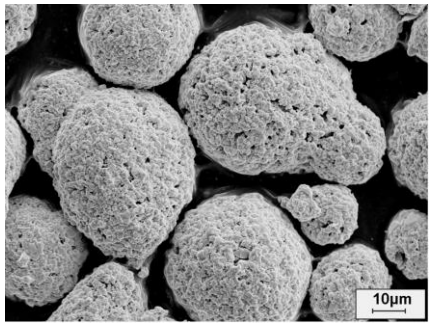
copper coated W



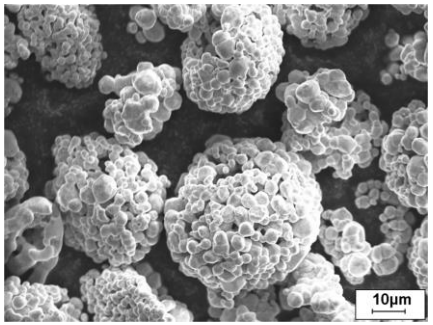
molten and broken
Al2O3/TiO2



molen, broken
and thermally annealed
Cr2O3 Powder

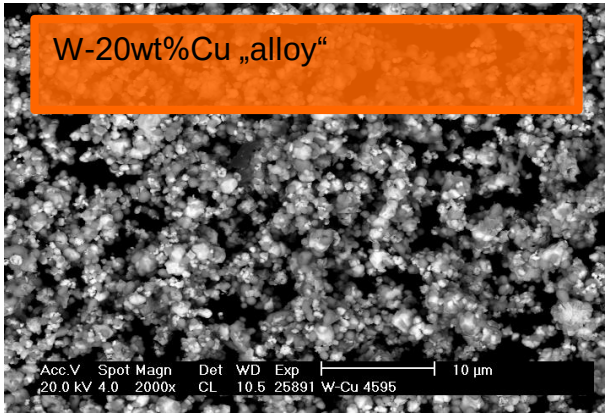


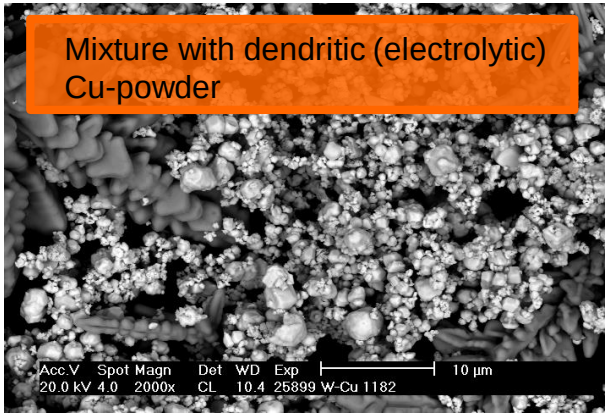
agglomerated, sintered
WC/Co 88/12

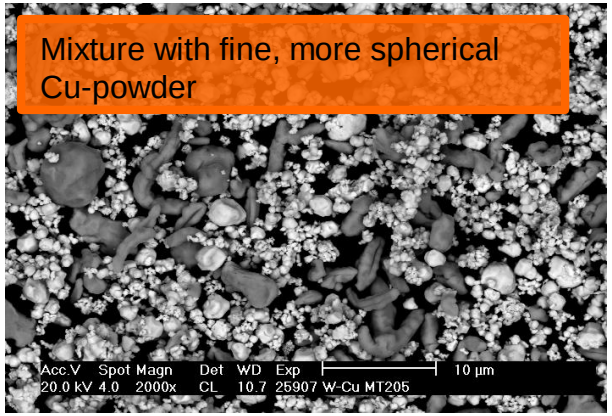


agglomerated, sintered
Molybdänpulver

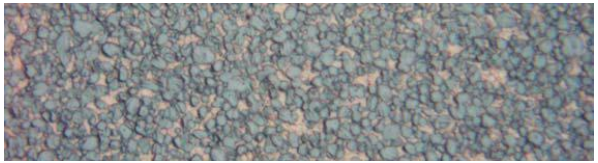
Step 2: MIXING and MICROSTRUCTURE

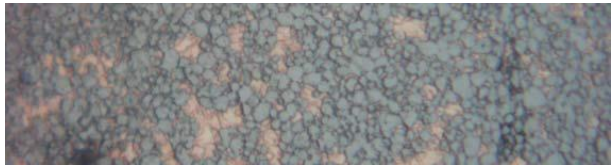


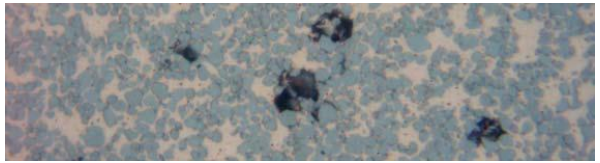




CROSS SECTIONS AFTER COLD COMPATION AND FREE SINTERING:







Step 3: MANUFACTURING PROCESSES - „Instruments“

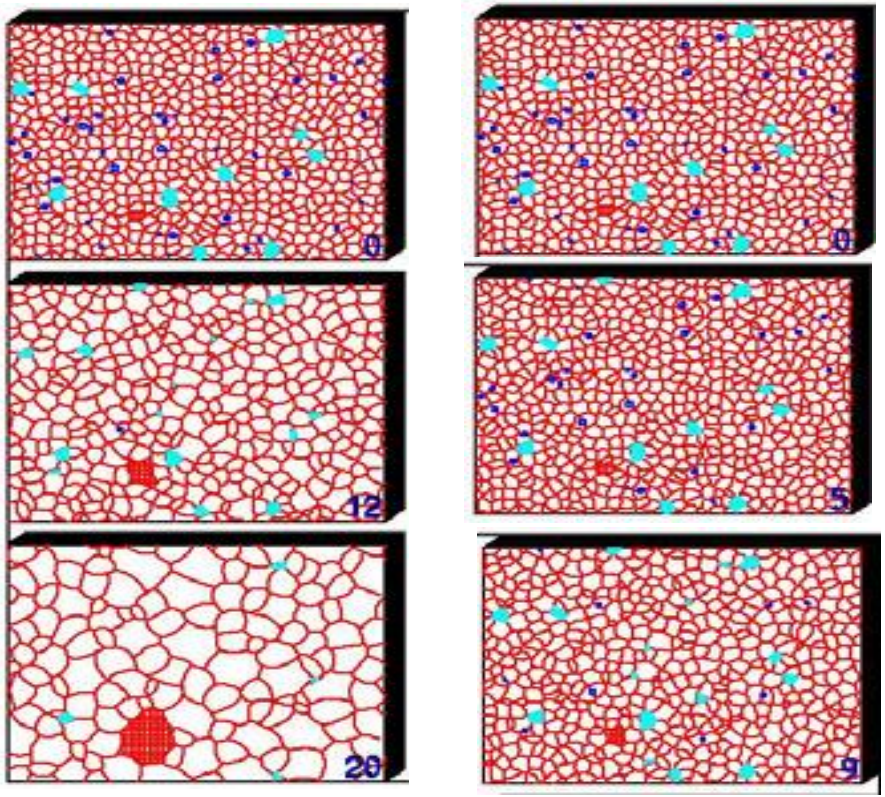
MATERIALS. PERFECTLY. TUNED.

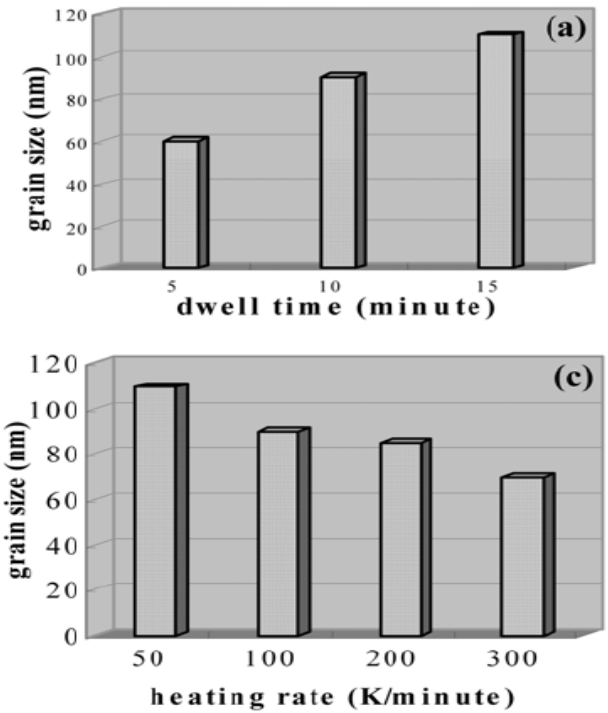
... A brief story about knowledge on instruments

Michael

INFLUENCE OF INSTRUMENTS ON MATERIALS

SLOW FAST

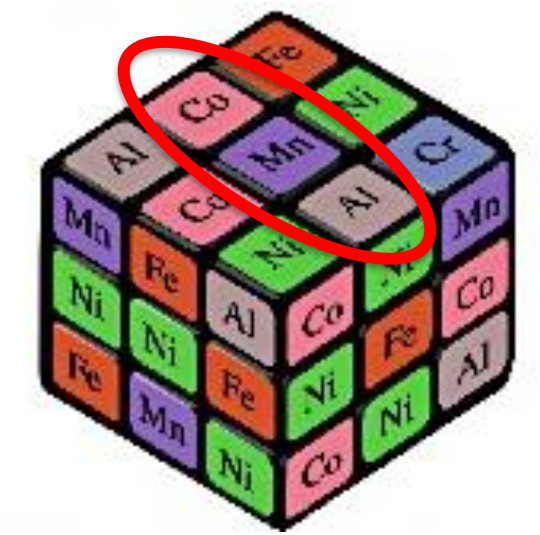


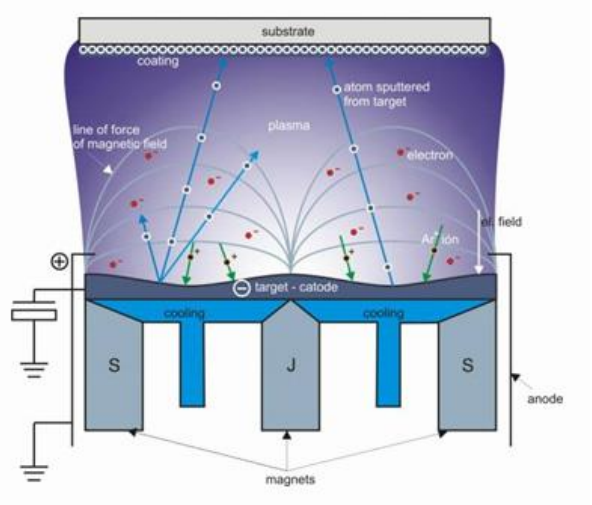


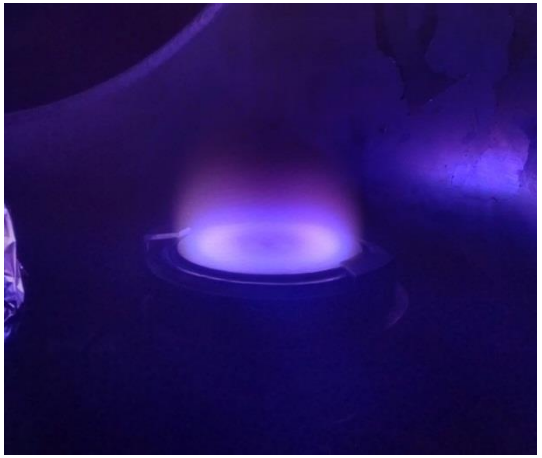
STRUCRURE: CORSE FINE

Journal of Ceramic Processing Research. Vol. 7, No. 4, pp. 307~310 (2006)

„MUSIC ON DEMAND“ - MATERIALS by „WISH“

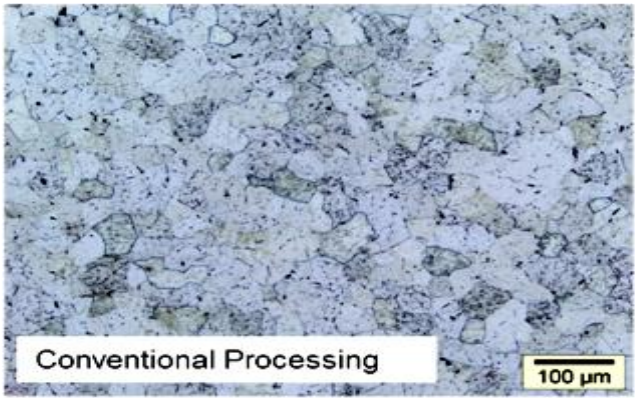


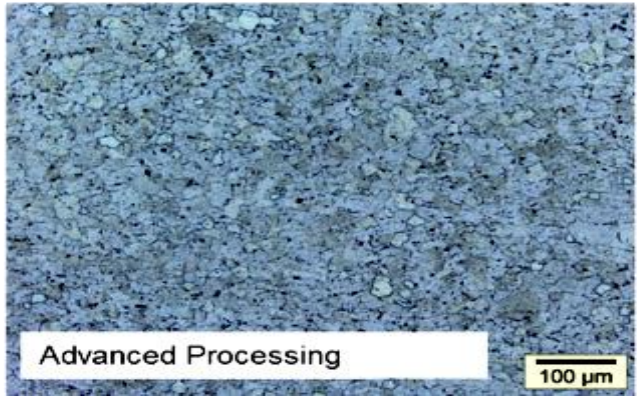




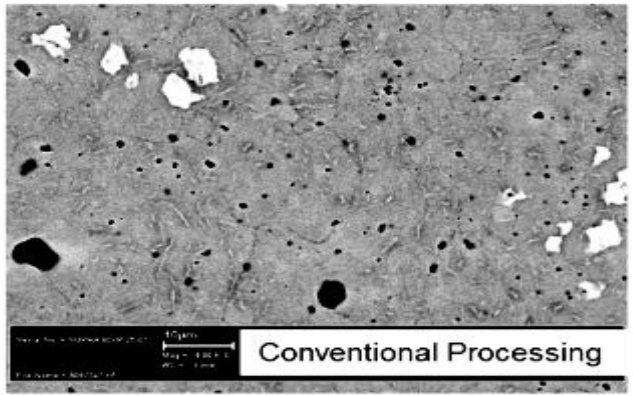
- Besides „pure elements“ we an use combinations like with Oxygen („Oxides“), Nitrogen („Nitrides“), Carbon „Carbides“), …
- Applications e.g. „Sputtering targets“

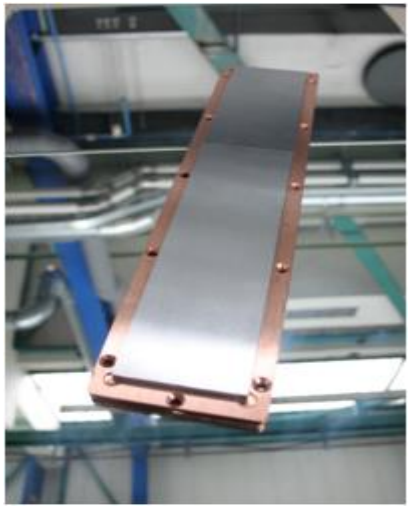
PROCESSING OF MATERIALS BY DIFFERENT PARAMETERS

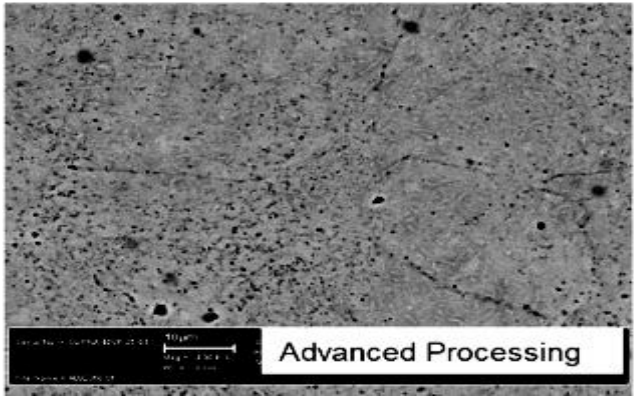


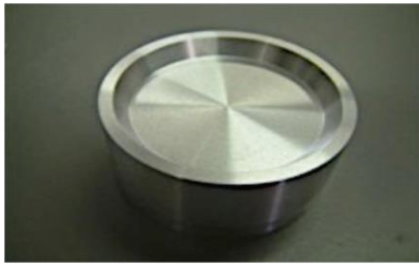


Influence of the mixing process



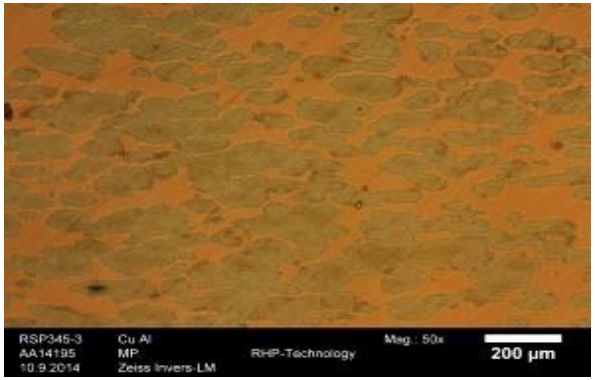


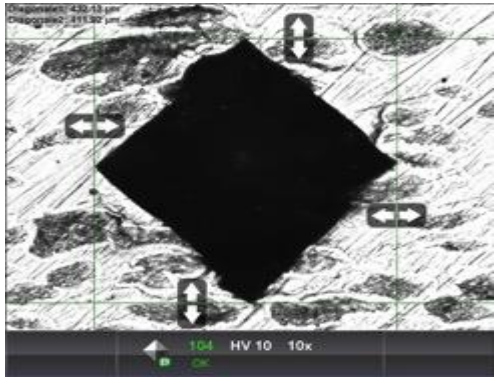




Influence of the hot pressing process

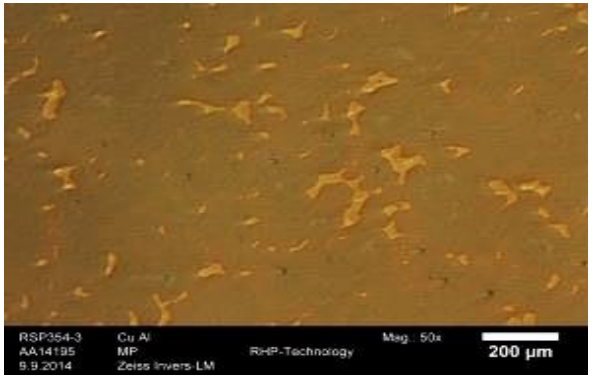
COMPARISON OF PROCESSING SPEED: Al-Cu

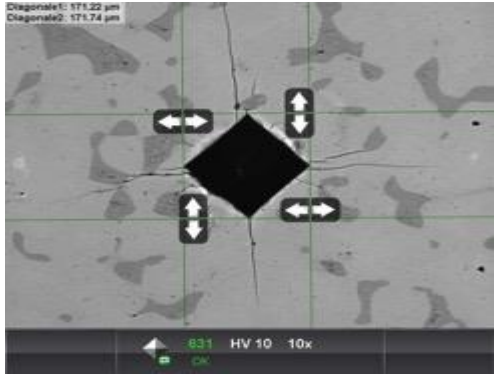




"Composite Structure"

- Hardness: 104 (HV5)
- **Thermal Conductivity: 227 W/mK**
- Easy to machine/ "ductile"





"Intermetallic Structure"

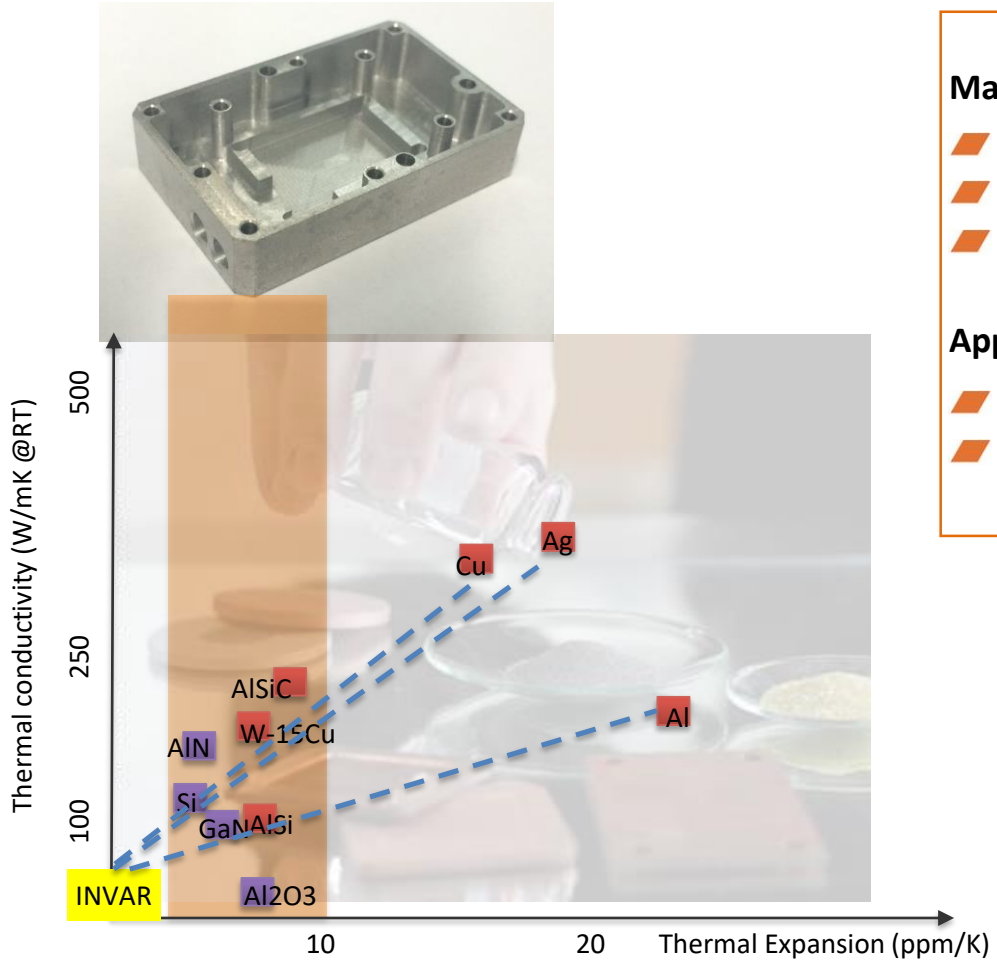
- Hardness: 631 (HV10)
- **Thermal Conductivity: 83,7 W/mK**
- Difficult to machine/"brittle"

- Same raw material but different processing conditions (very fast densification vs. slow densification)

„TUNING“ of Material Properties

Erich

Metal-Invar „Composites“

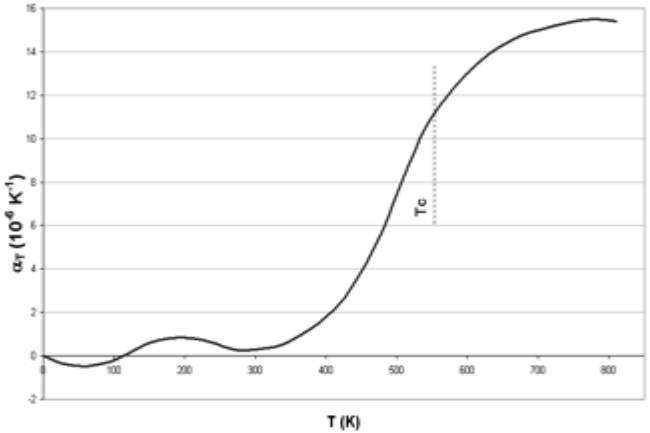


Matrix and Filler Materials:

- High thermal conductivity: 100 – 250 W/mK
- customized thermal expansion: 6 – 10ppm/K
- Easy to machine

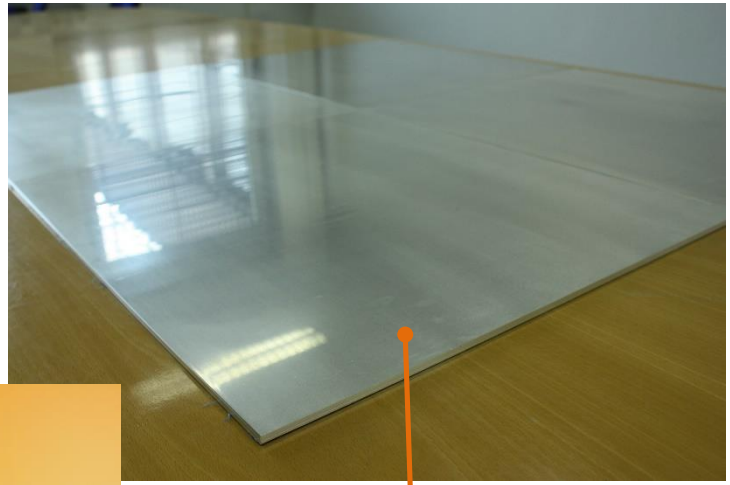
Applications

- Housings for electronics
- Structural parts for advanced thermal management



ROTARY TARGETS and XXL PLANAR

Higher yield compared to planar targets
Process for ceramic rings developed
Stable process for high throughput coatings

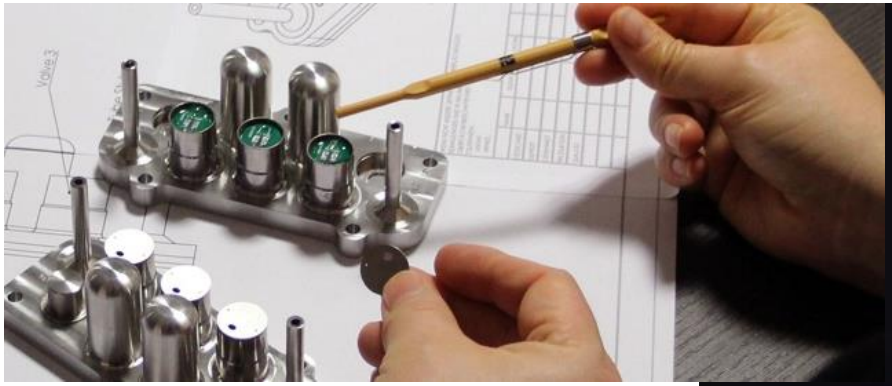


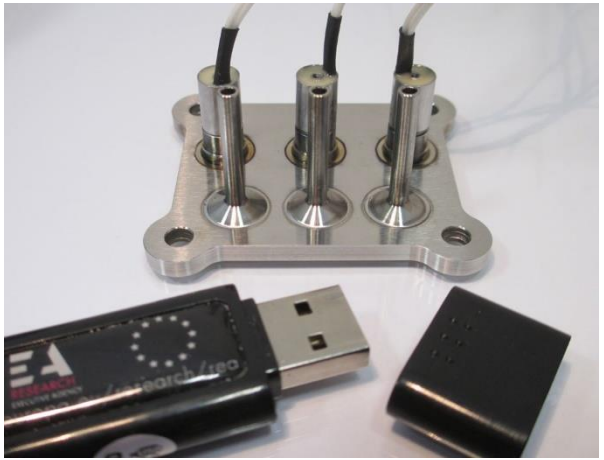
XXL size targets for display coating

TiB_2 Rotary Targets

Boron Carbide rings used in special R&D applications like for neutron absorbtion and neuton reflection

MODULES FOR COMMUNICATION SATELLITES





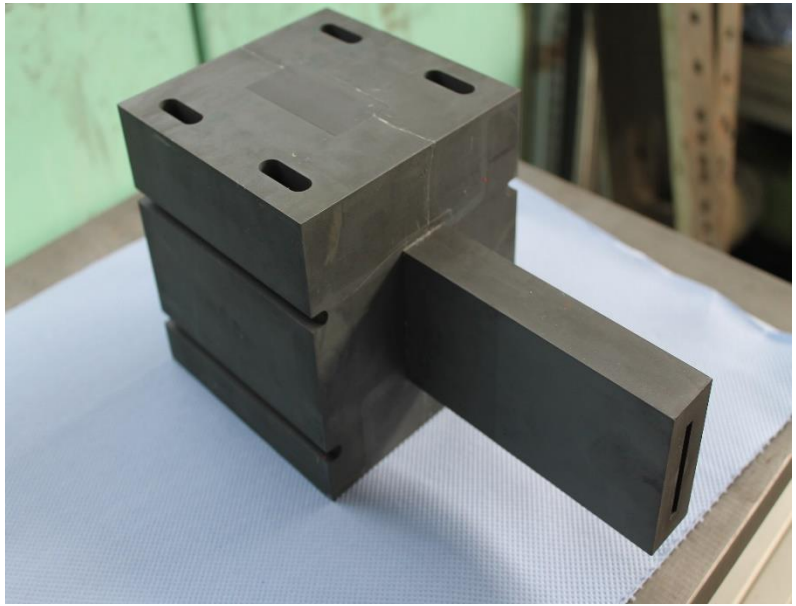
- Google, Samsung plan for the operation of large satellite constellations.
- The RHP Module is responsible for Xe gas distribution to the satellite thrusters.

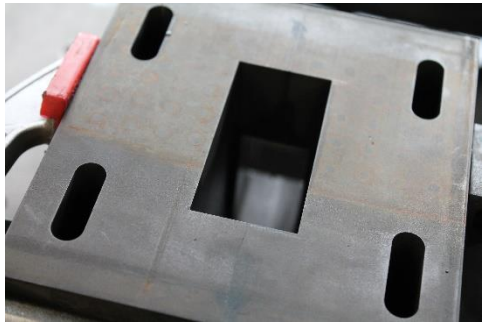
(Partner: AST)

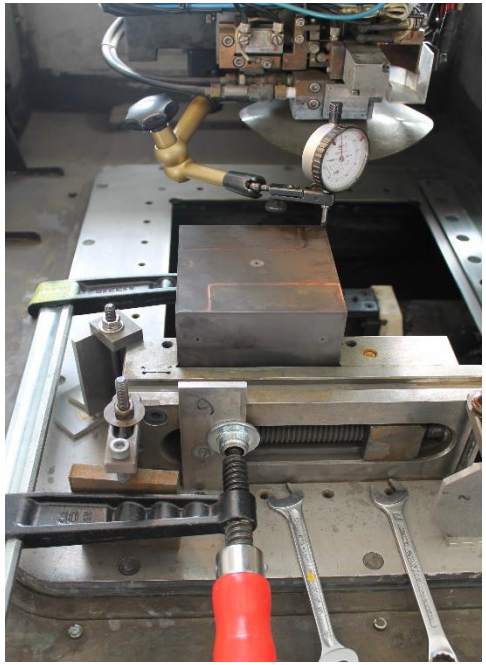
NEW MATERIALS FOR JEWELRY – NIELLIUM

Partner: Thomas Hauser

EDM CERAMICS







- ✓ Carbide ceramics modified for EDM machinability.
- ✓ Special techniques to join ceramics.
- ✓ Spark erosion and wire cutting is possible.

Metal Matrix Composites

Materials:

- Matrix: Al, Ti, Cu, Ag and their alloys
- Filler materials: Carbon-fibres, nanofibres, nanotubes or particles such as MoS2, WS2, graphite, diamond, SiC, Cu_2O, ZrW_2O_8

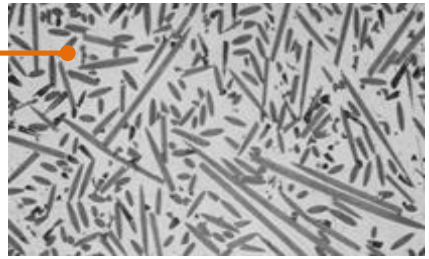
Tailorable material properties:

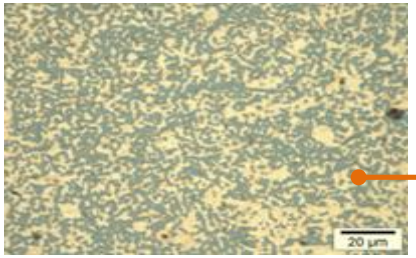
- High thermal conductivity
- Low thermal expansion
- Low coefficient of friction
- Increased wear resistance
- Increased strength/stiffness

Applications:

- Heat sinks for electronic devices
- Self lubricating bearings and slip rings
- Lightweight high strength materials for automotive/aerospace

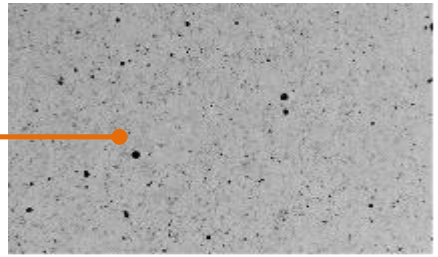
Cu-carbonfibre MMC



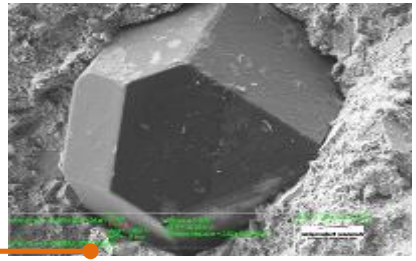


Cu-Cu_2O MMC

Ti-Boron MMC

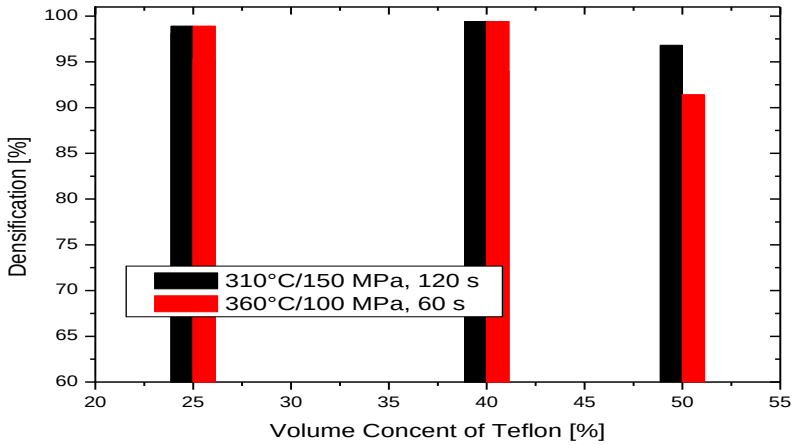


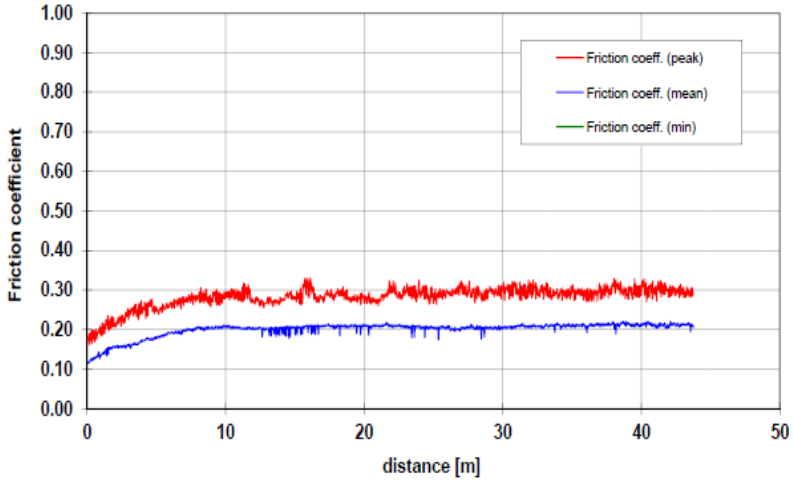
CuSn-MoS_2/Cf MMC



Al-Diamond MMC

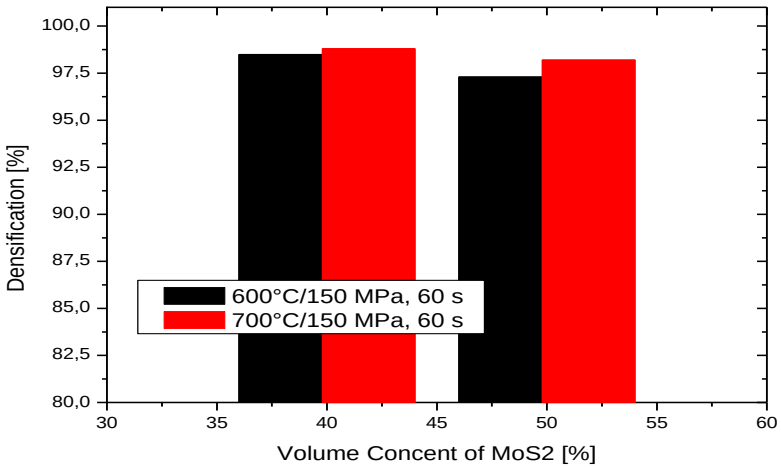
CuSn-Teflon composites

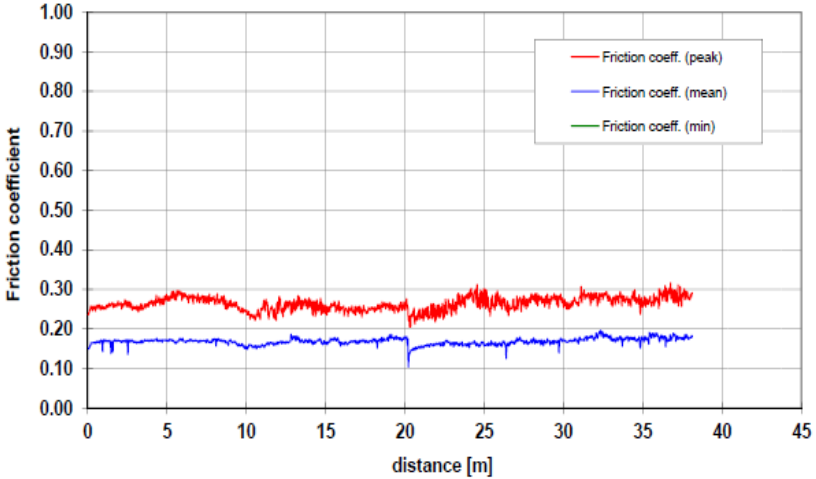




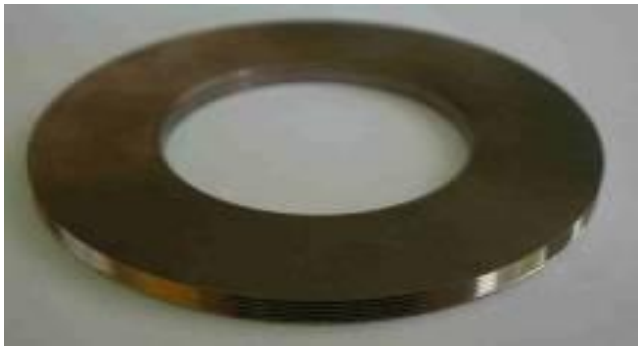
- Preparation of mixtures of CuSn+teflon
- Composites with 25, 40 and 50 vol%
- Densification using 100 and 150 MPa at temperatures between 310 and 360 ° C (melting point of teflon is 326,8 ° C)
- Densification time: 60 s and 120 s
- Coefficient of friction for 40 vol% teflon: 0,2 (mean value)

CuSn-MoS_2 Composites



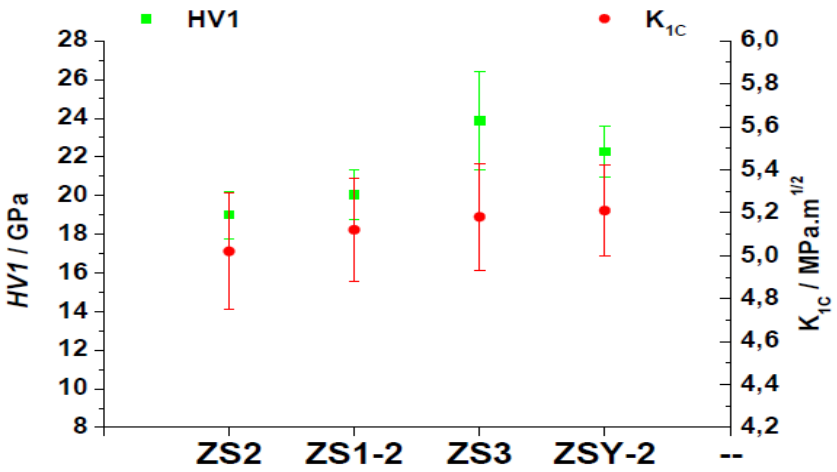


- Preparation of mixtures of CuSn+MoS_2
- Composites with 25, 40 and 50 vol%
- Densification using 150 MPa at temperatures between 600 and 700 ° C
- Densification time: 60 s
- Coefficient of friction for 40 vol% MoS_2: 0,18 (mean value)

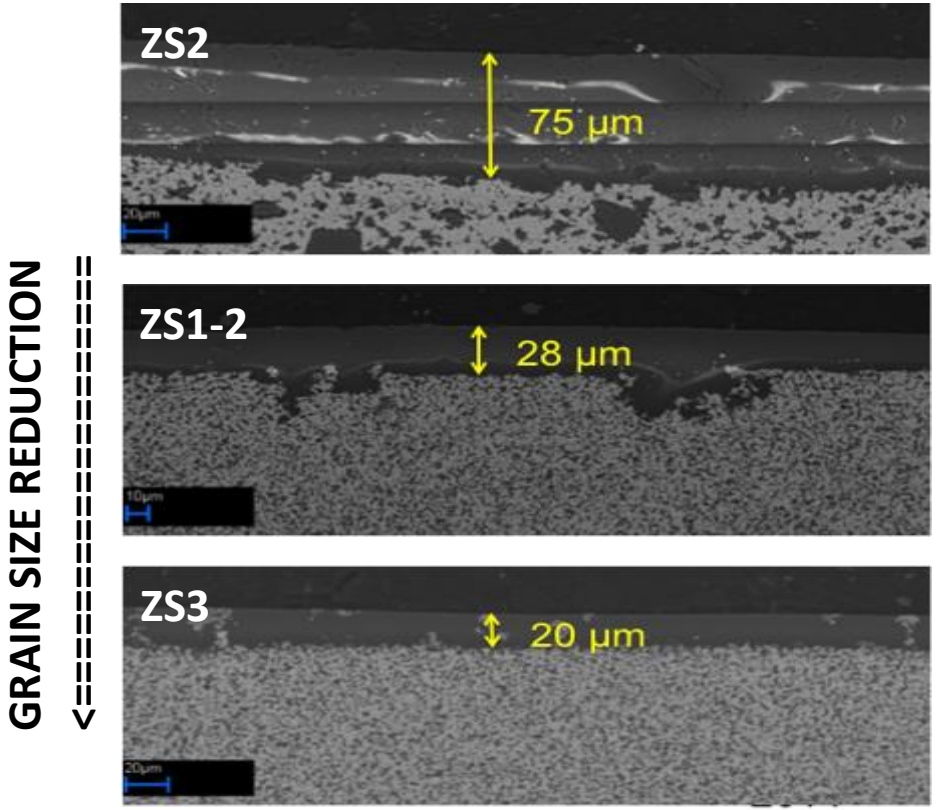


High temperature oxidation tests of ZrB_2 composites

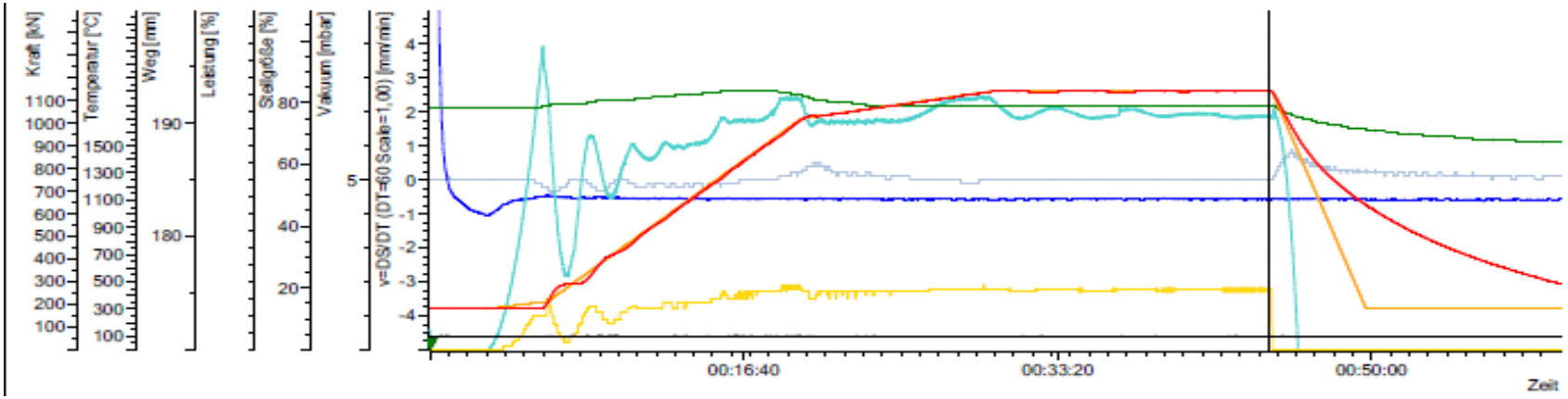
- Reduction of the grain size improves the oxidation resistance
- Reduced grain size results in high hardness of ca 24 GPa and a fracture toughness of 5,2 MPa $m^{1/2}$



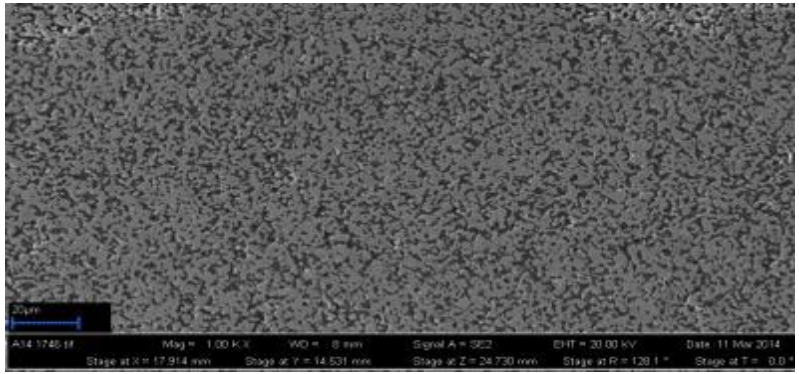
- Oxidation test at 1.500° C /1 hour

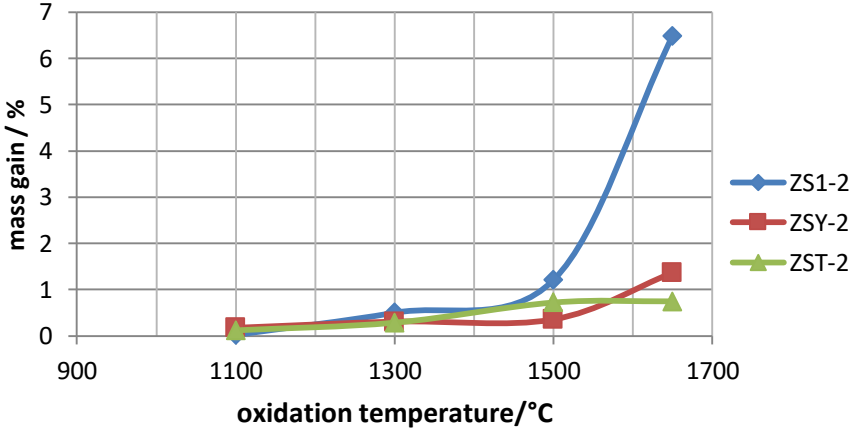


Densification of ZrB_2 based composites



- Densification of powder mixtures by Rapid Hot Pressing; cycle time < 1 hour

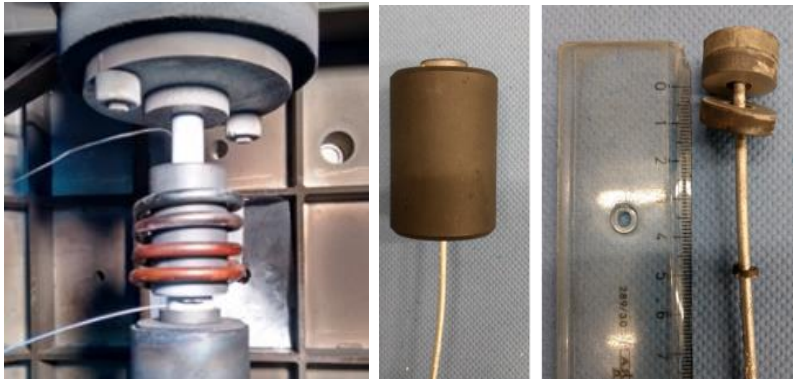


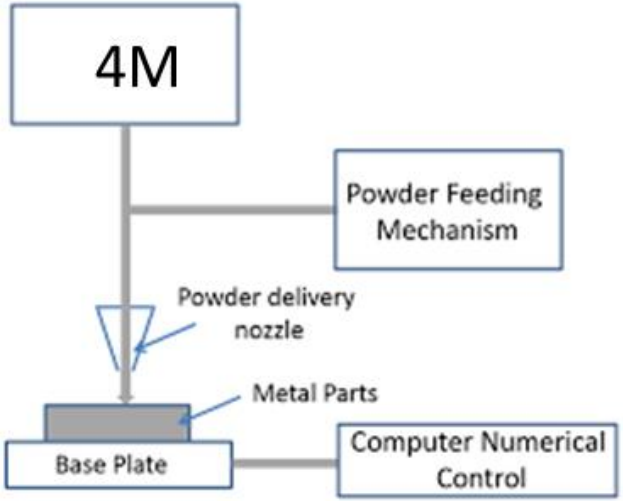


- Microstructure of ZrB_2-composite
- Oxidation tests at T > 1.100° C

HOT WIRE EXTRUSION

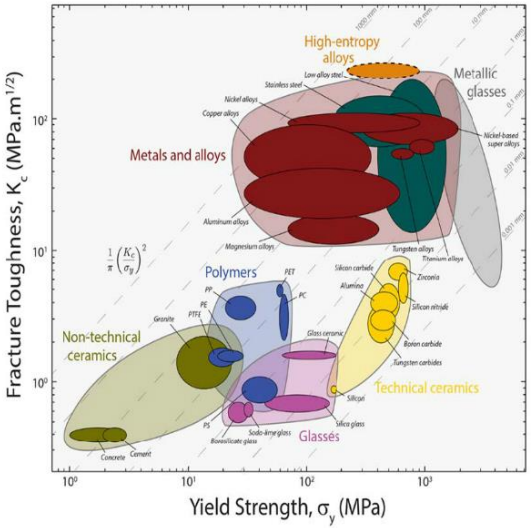
- Pressing-Sintering (focus on high temperature ceramics)
- Gas Pressure Sintering (up to 2.200° C)
- Direct wire extrusion (up to high temp.)
- Liquid Phase infiltration of porous pre-forms
- Plasma Arc Deposition/Material Synthesis

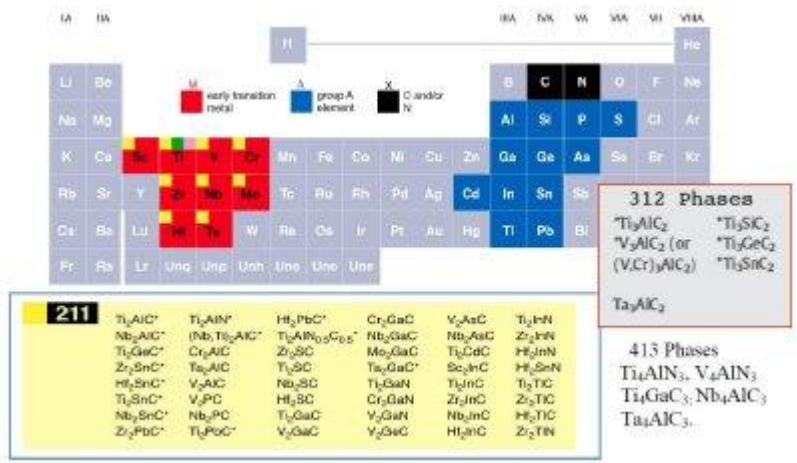




Ongoing Material Developments

- Quasicrystalline materials
- MAX Phase materials
- High entroy alloys
- Bulk metallic glasses
- Coloured metals and ceramics
- PGM alloys
- Porous materials





MATERIALS. PERFECTLY. TUNED.

SOME MORE INSTRUMENTS

Michael

AM TECHNOLOGIES @ RHP

XL SHAPE WELDING

3M System

4M System

ROB4M System

GREEN BODY PRINTING - SINTERING

Filament MEAM

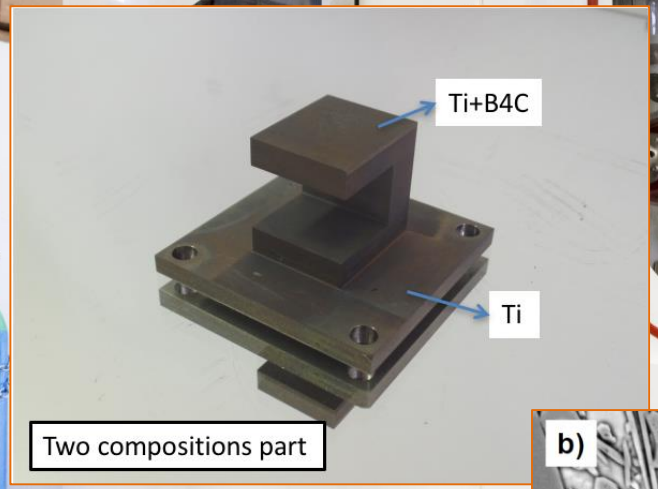
Granules MEAM

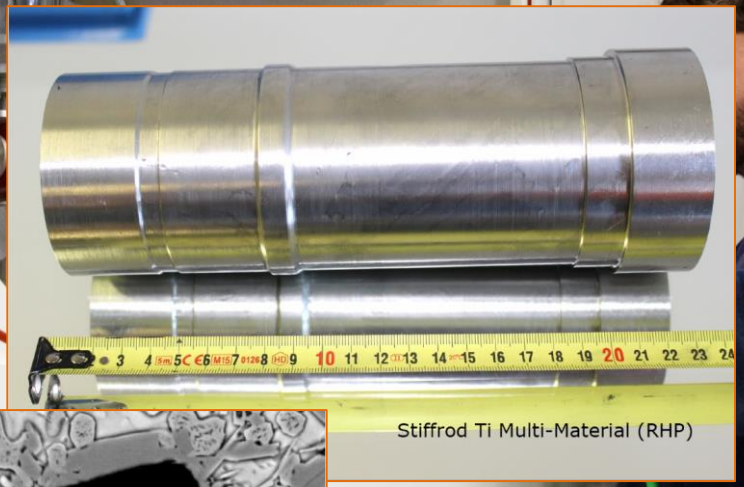
Metal/Ceramic STL

3M SYSTEM (WIRE & POWDER ARC)

MATERIALS. PERFECTLY. TUNED.

4M SYSTEM (WIRE & POWDER ARC)





- in-situ Multi-Materials
- Material-Hybrides

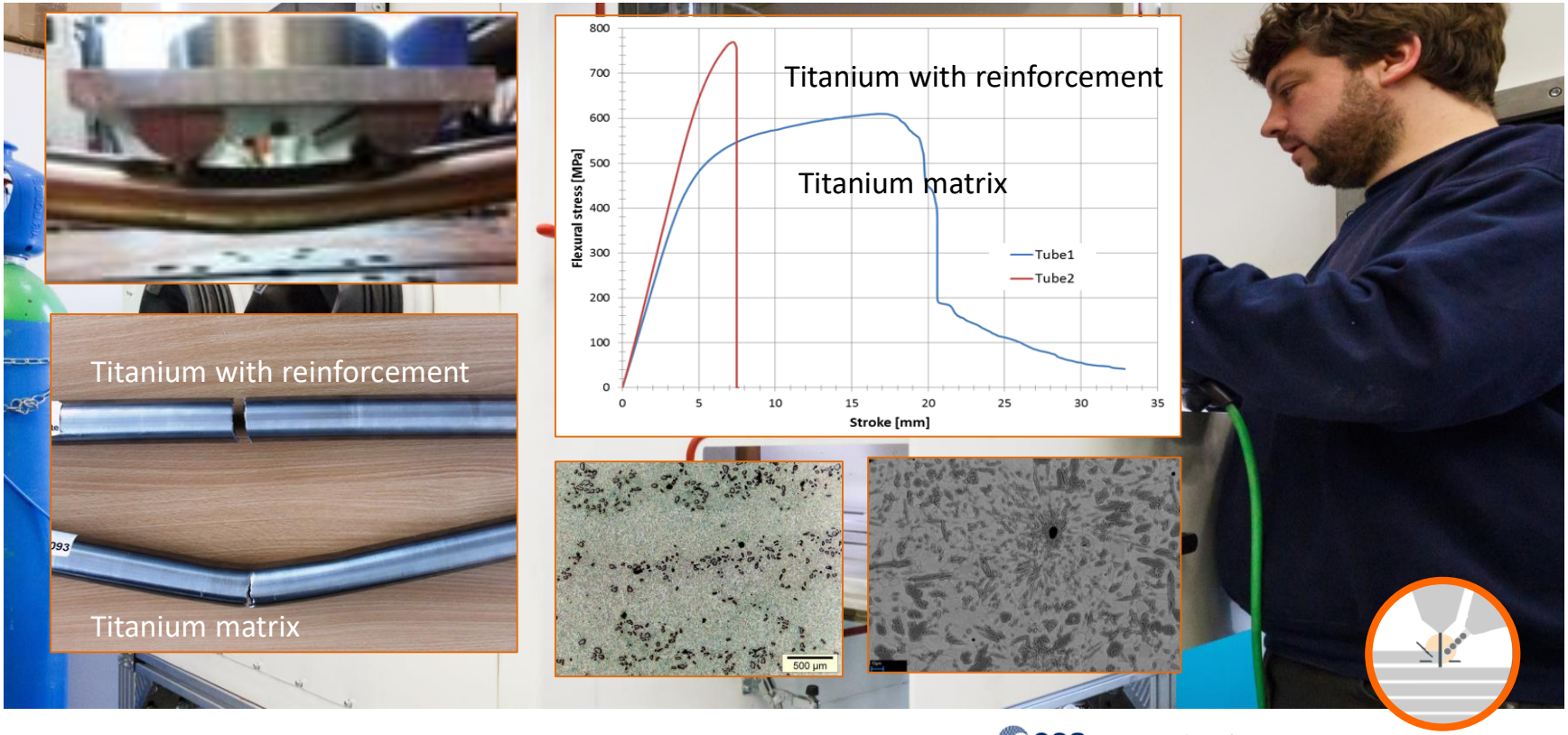
esa supported work

Horizon 2020 European Union funding for Research & Innovation

MATERIALS. PERFECTLY. TUNED.

RHP TECHNOLOGY

4M SYSTEM (WIRE & POWDER ARC)

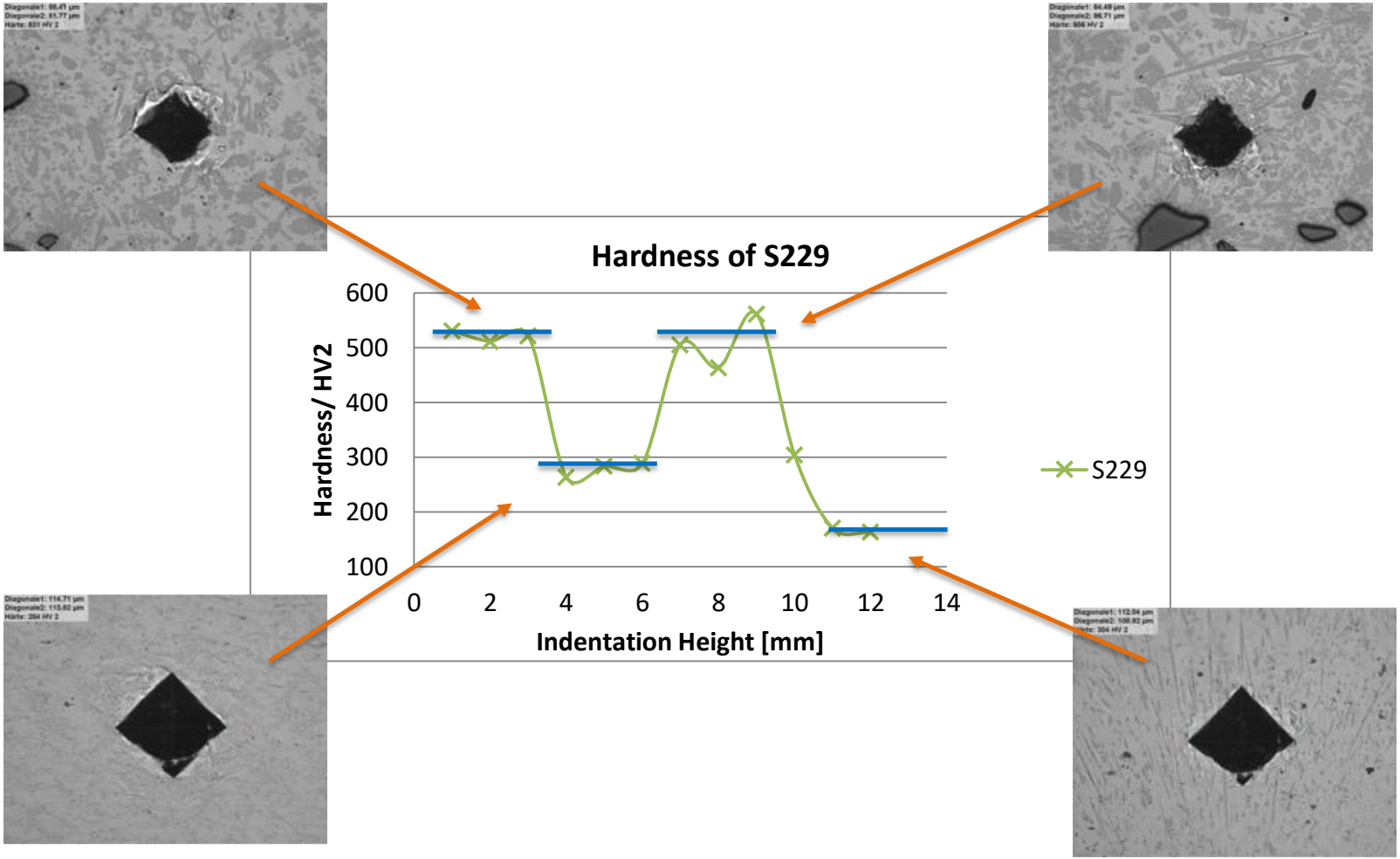


supported work

Horizon 2020
European Union funding
for Research & Innovation

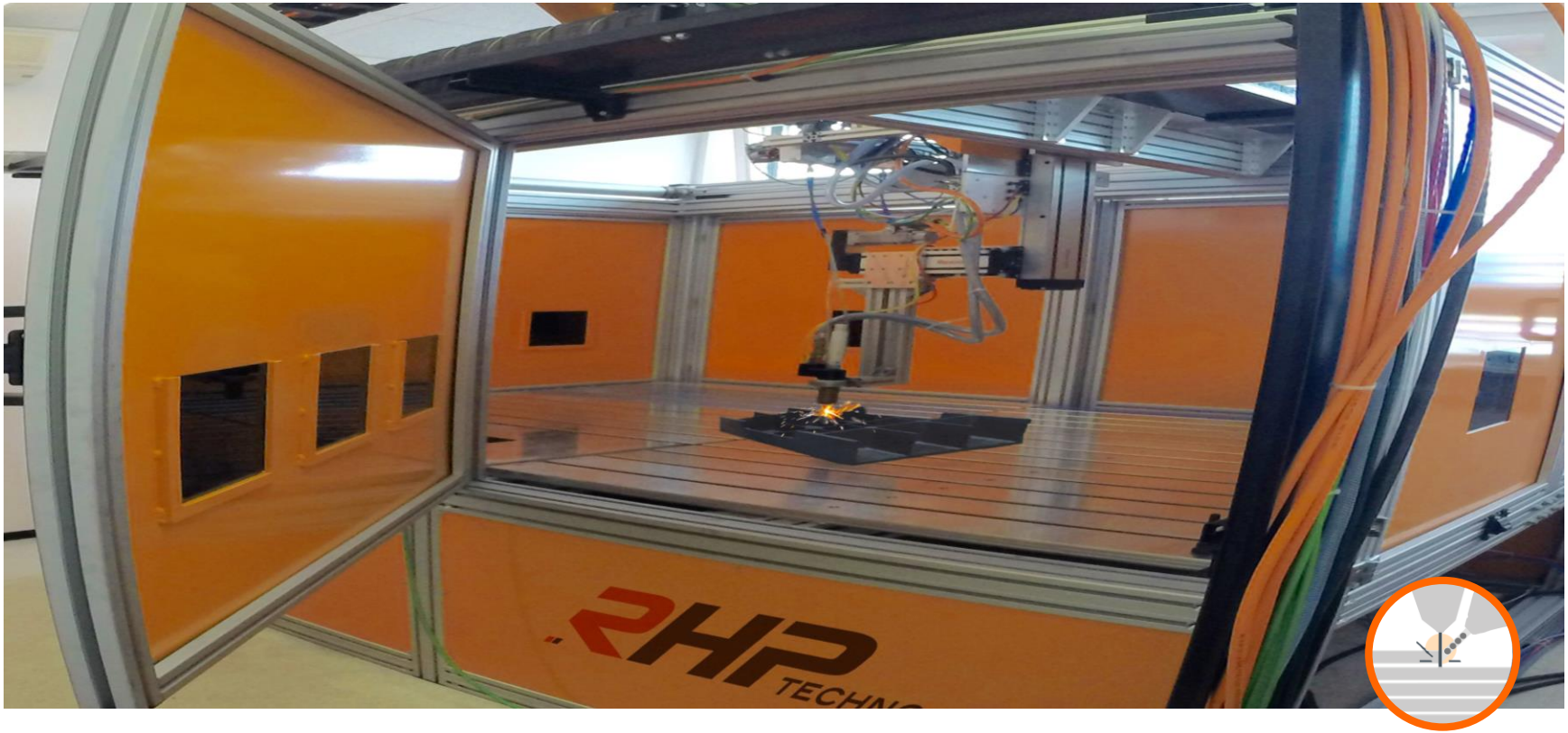
MATERIALS. PERFECTLY. TUNED.

Outlook: Multi-Material Structures



MATERIALS. PERFECTLY. TUNED.

4M SYSTEM (WIRE & POWDER ARC)



MATERIALS. PERFECTLY. TUNED.

RHP TECHNOLOGY

AM TECHNOLOGIES @ RHP

XL SHAPE WELDING

3M System

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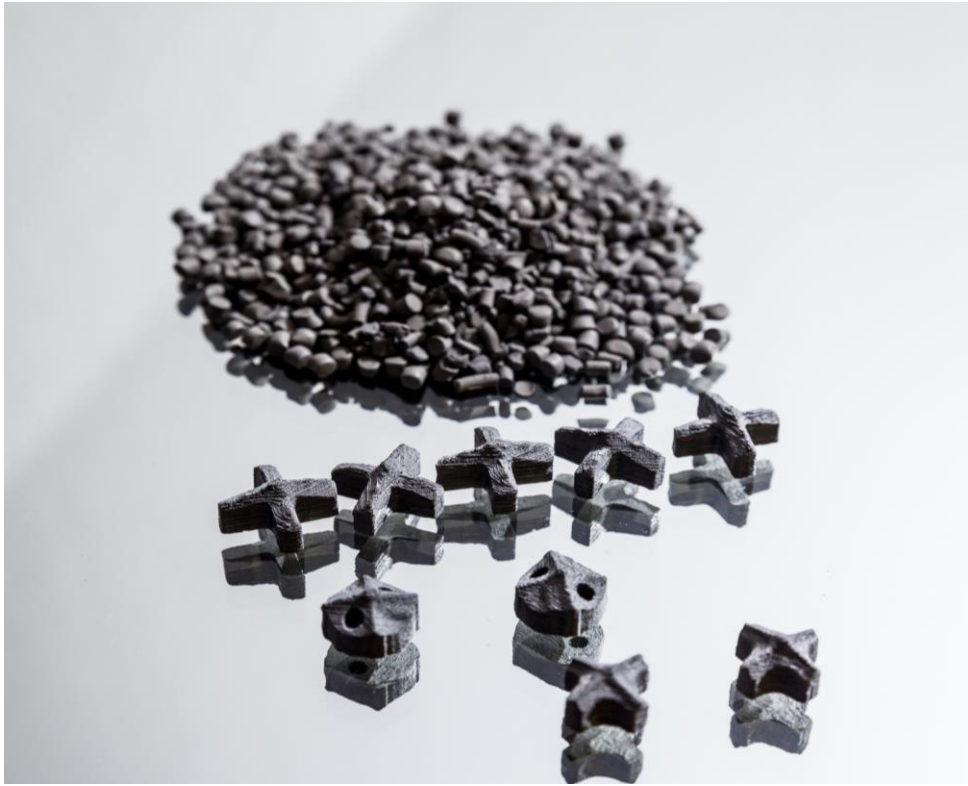
GREEN BODY PRINTING - SINTERING

Filament MEAM

Granules MEAM

Metal/Ceramic STL

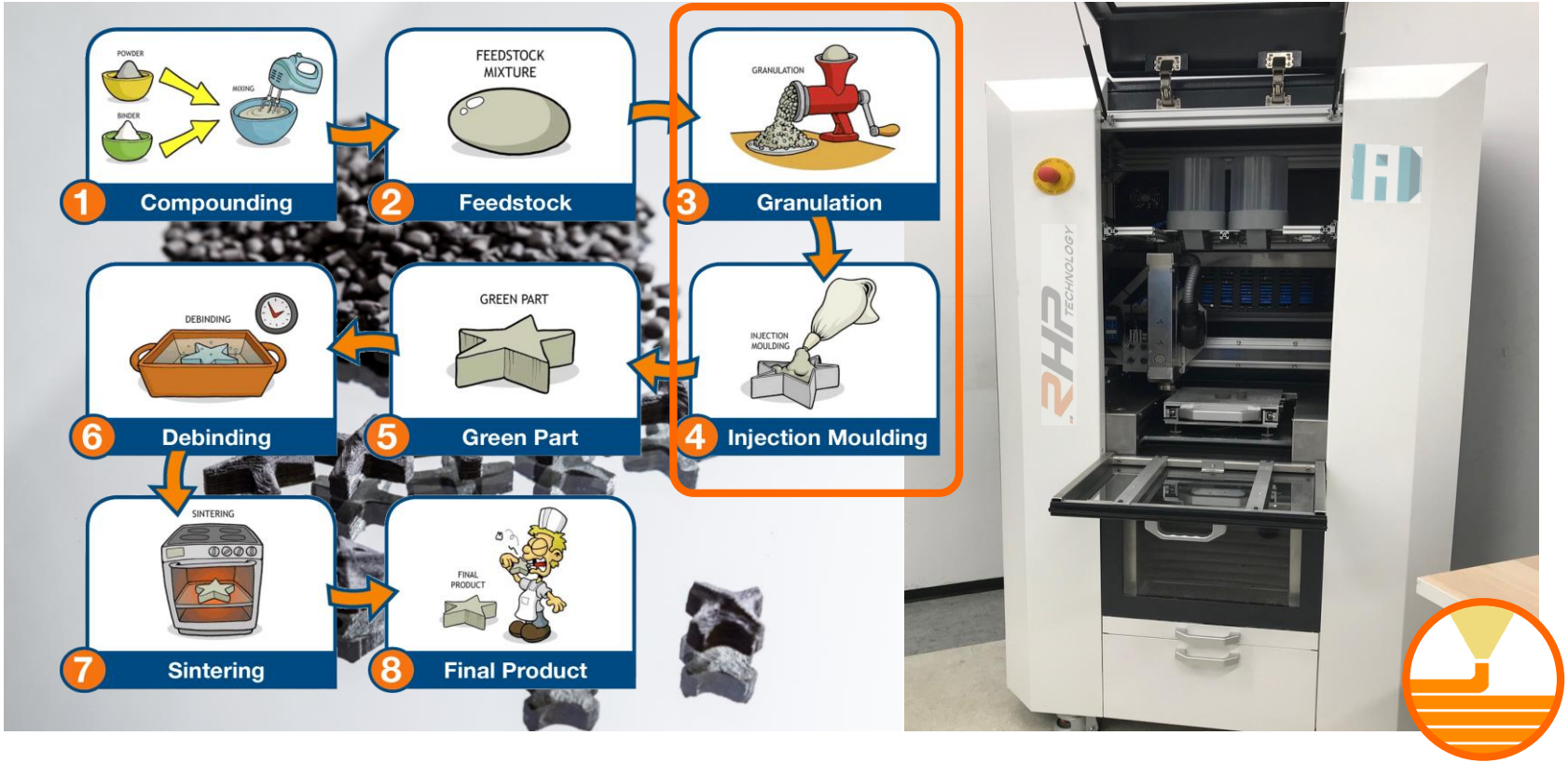
MATERIAL EXTRUSION AM (MEAM)



MATERIALS. PERFECTLY. TUNED.

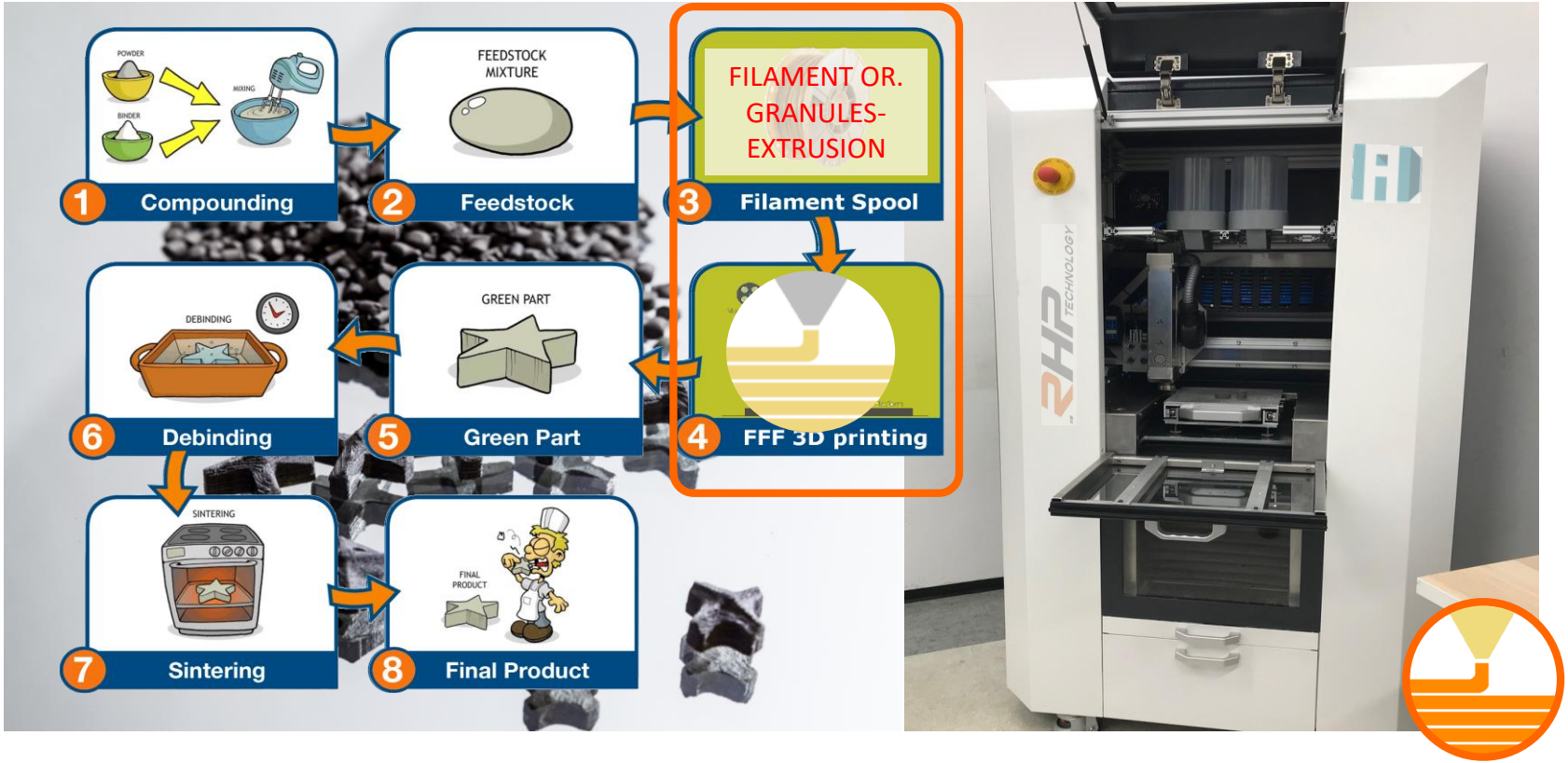
RHP TECHNOLOGY

MATERIAL EXTRUSION AM (MEAM)



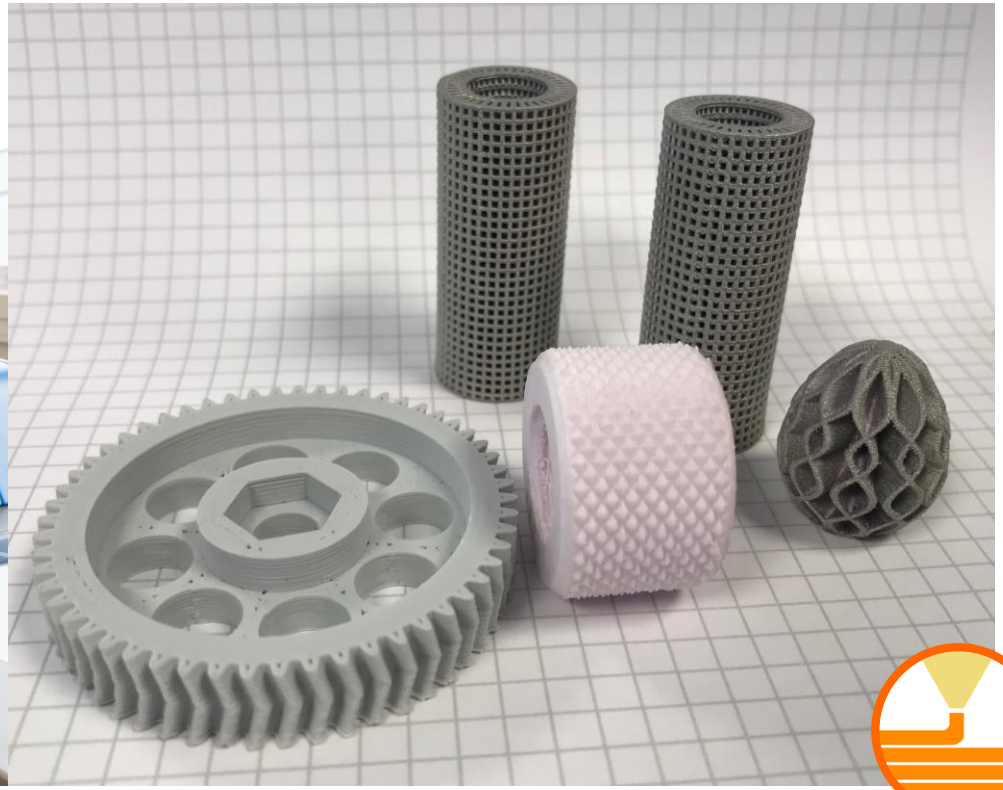
MATERIALS. PERFECTLY. TUNED.

MATERIAL EXTRUSION AM (MEAM)

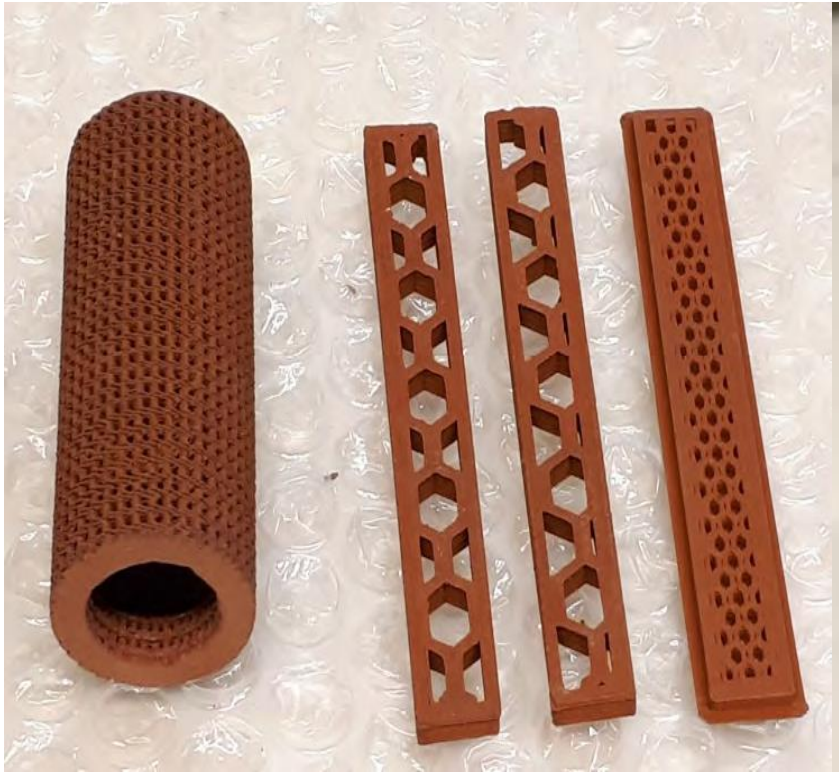


MATERIALS. PERFECTLY. TUNED.

MATERIAL EXTRUSION AM (MEAM)



MATERIAL EXTRUSION AM (MEAM)



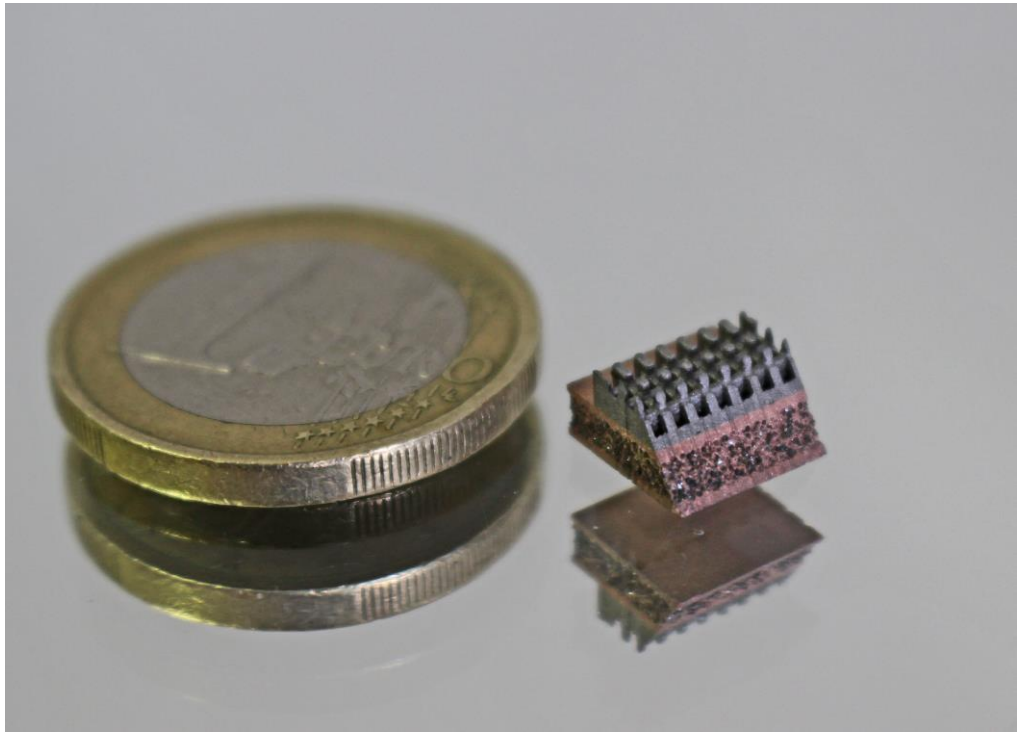
MICRO 3D PRINTING (METALS & CERAMICS)

MATERIALS AND MATERIAL HYBRIDES @ RHP

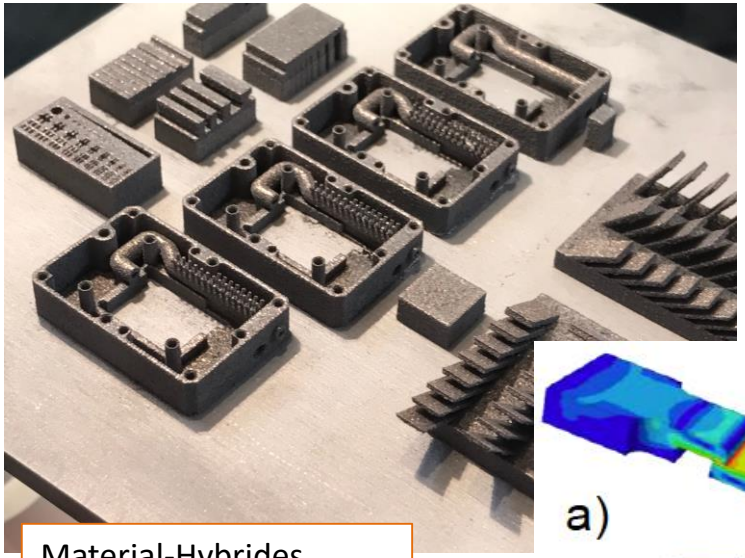
PROCESS DEVELOPMENT

MATERIAL DEVELOPMENT

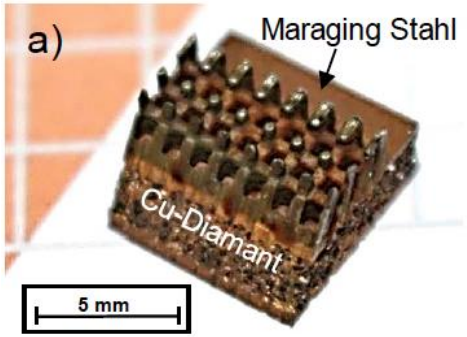
MATERIAL HYBRIDS

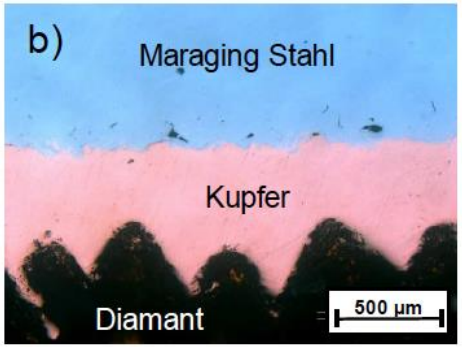


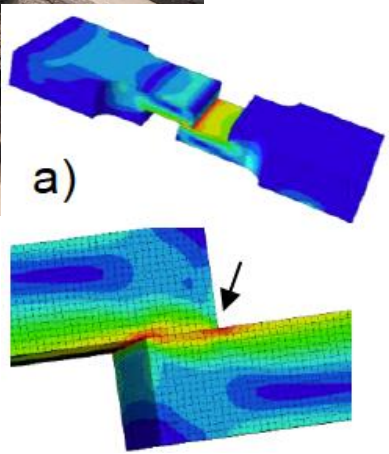
POWDER BED - SELECTIVE LASER MELTING (SLM)

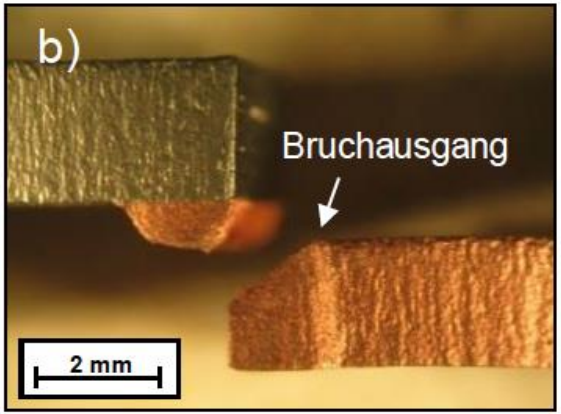


Material-Hybrides compounds









source: Ch. Wallis et al. RAPID.TECH 2017

RHP HYBRIDE STURCTURES – CuCD on Copper by SLM

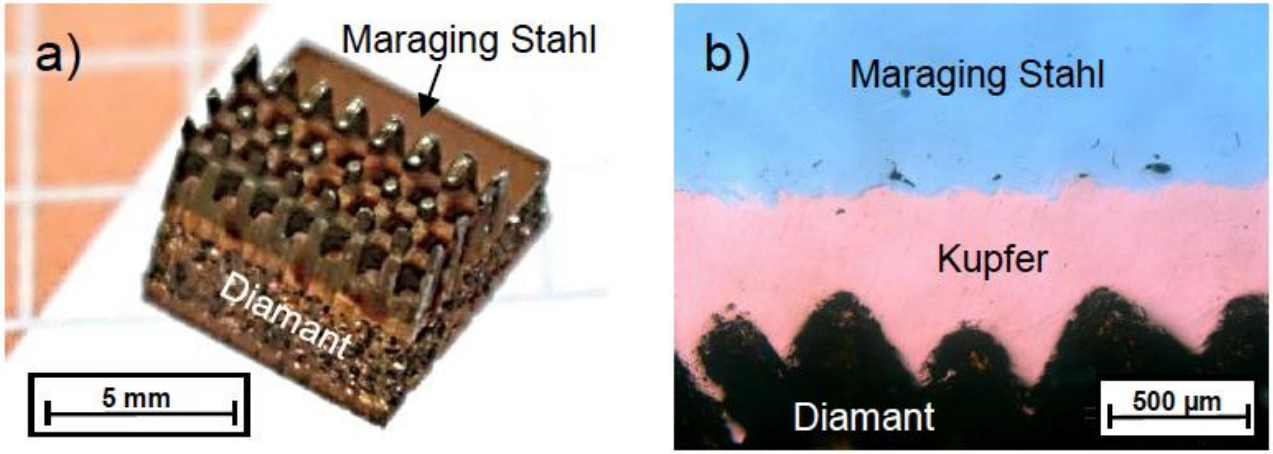


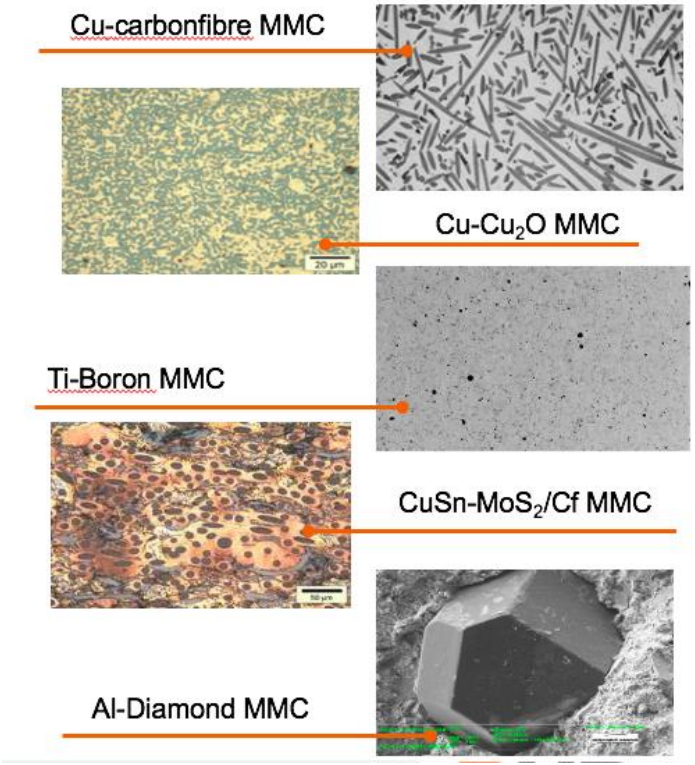
Abb. 3.6: a) erfolgreicher Aufbau einer Kühlstruktur auf einem Cu-MMC mit b) zugehöriger LIMI-Aufnahme der Bindezone Maraging Stahl/Cu-MMC.

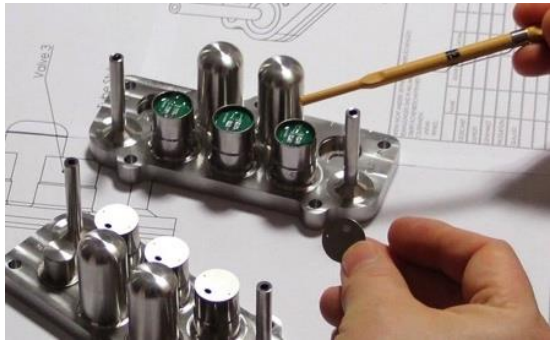
LET US SUMMARIZE

Erich

SOLUTIONS IN POWDER TECHNOLOGY
MANUFACTURING CUSTOMIZED PRODUCTS

FUNCTIONAL MATERIALS AND INDIVIDUAL APPLICATIONS POTENCIAL BY COMBINING THE POSSIBILITIES OF POWDER





Music only sounds well,

- if all the music and score can be played
- if polyphonical playing is practised
- if all needed instruments are available
- if agogic and musical variations are allowed
- and if you have ...

MATERIALS.
PERFECLY.
TUNED.

... musicians, that know their instruments by heart!

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