

# Photonics in Manufacturing and “3-D-Printing”

**IWF / INSPIRE**

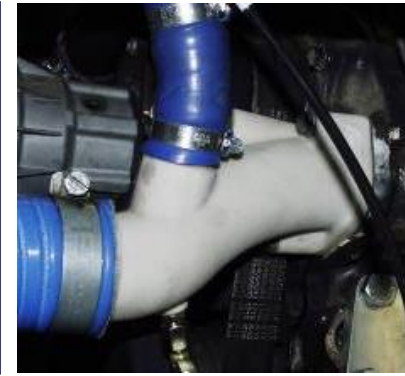
Konrad Wegener

25.11.2014

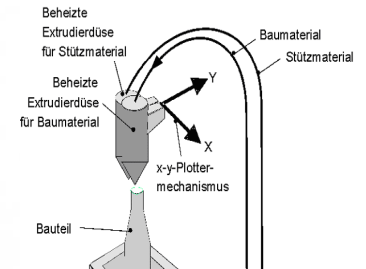
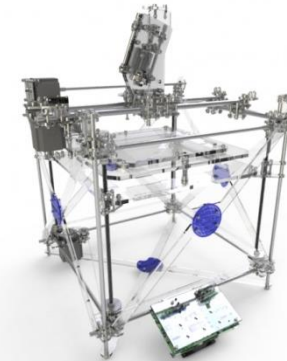
- Additive Manufacturing
- IWF-inspire activities

# Trend (google – Abfrage)

## «Rapid Prototyping»



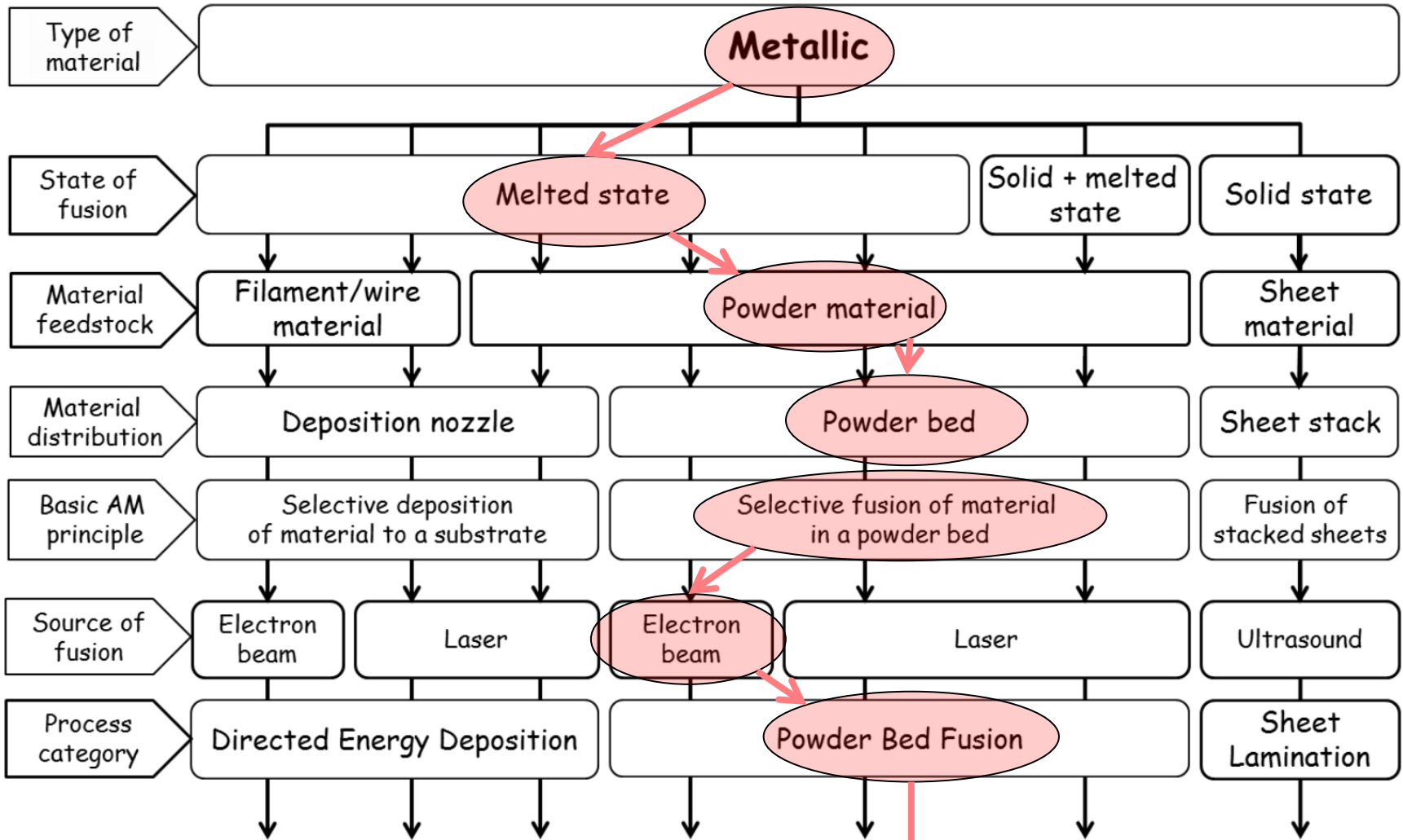
## «3D Printing»



## «Additive Manufacturing»



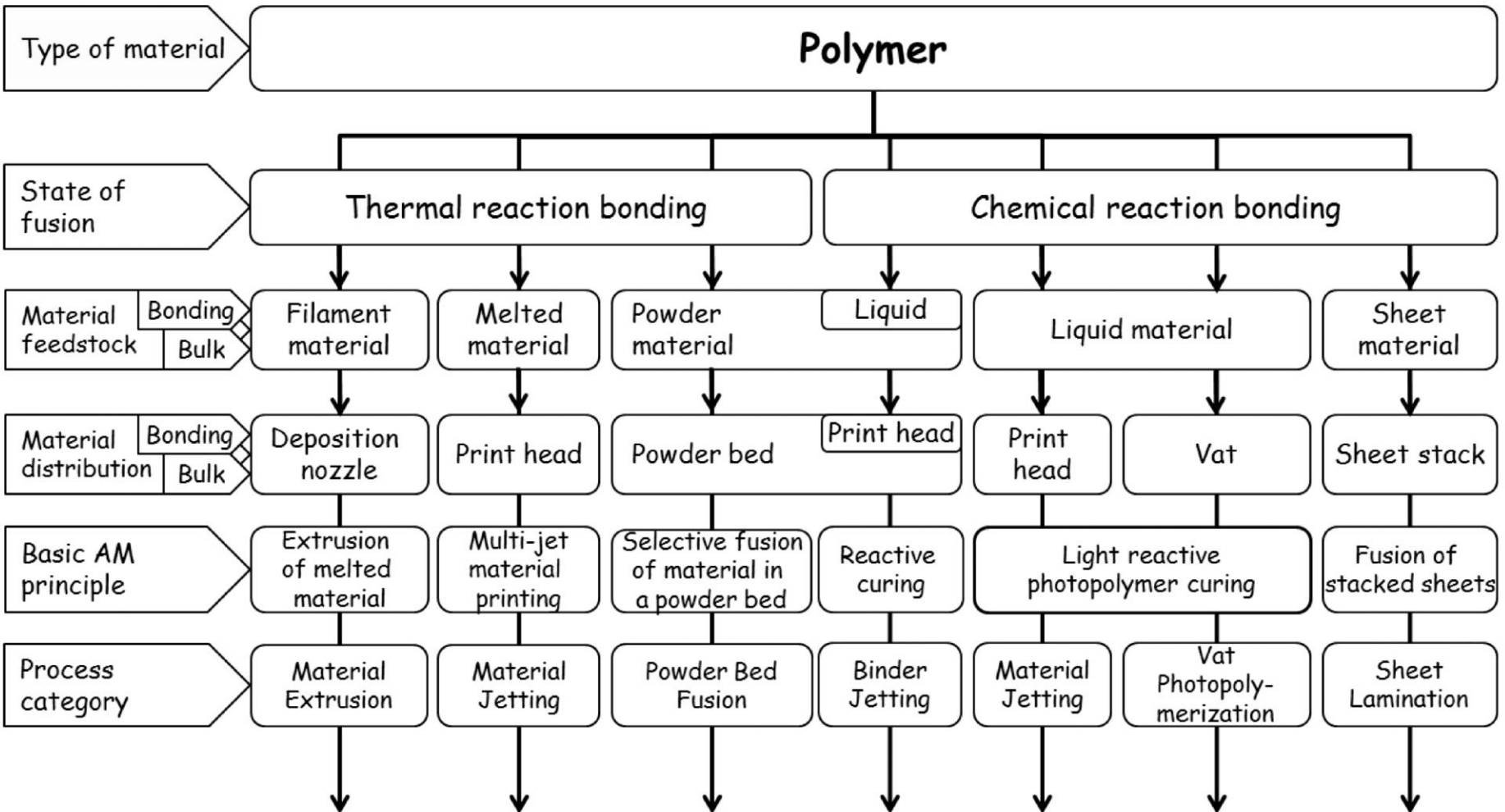
# Classification of AM-processes: metals



**Electron Beam Melting EBM**

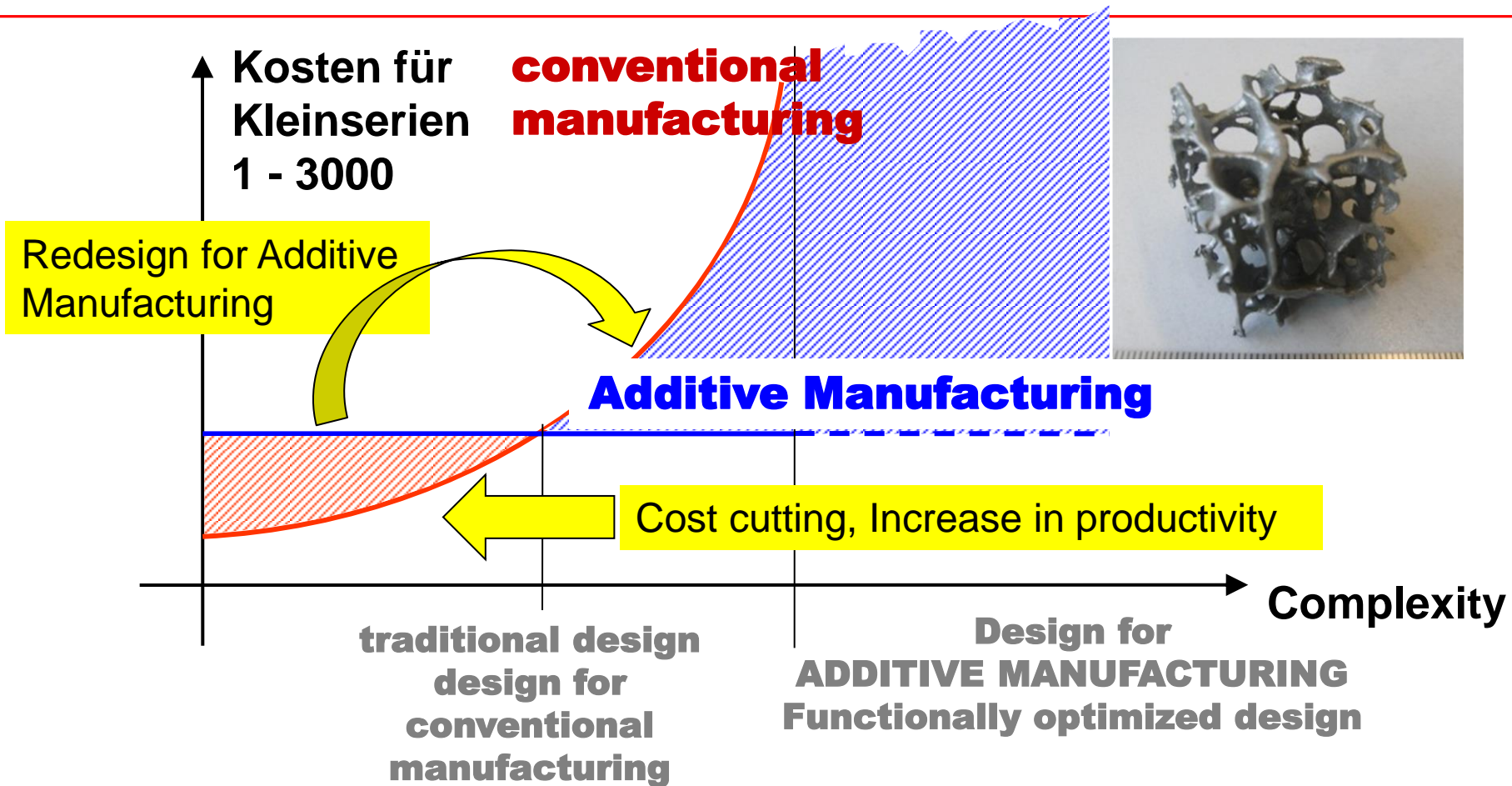
Source: ISO17296-1

# Classification of AM-processes: polymers



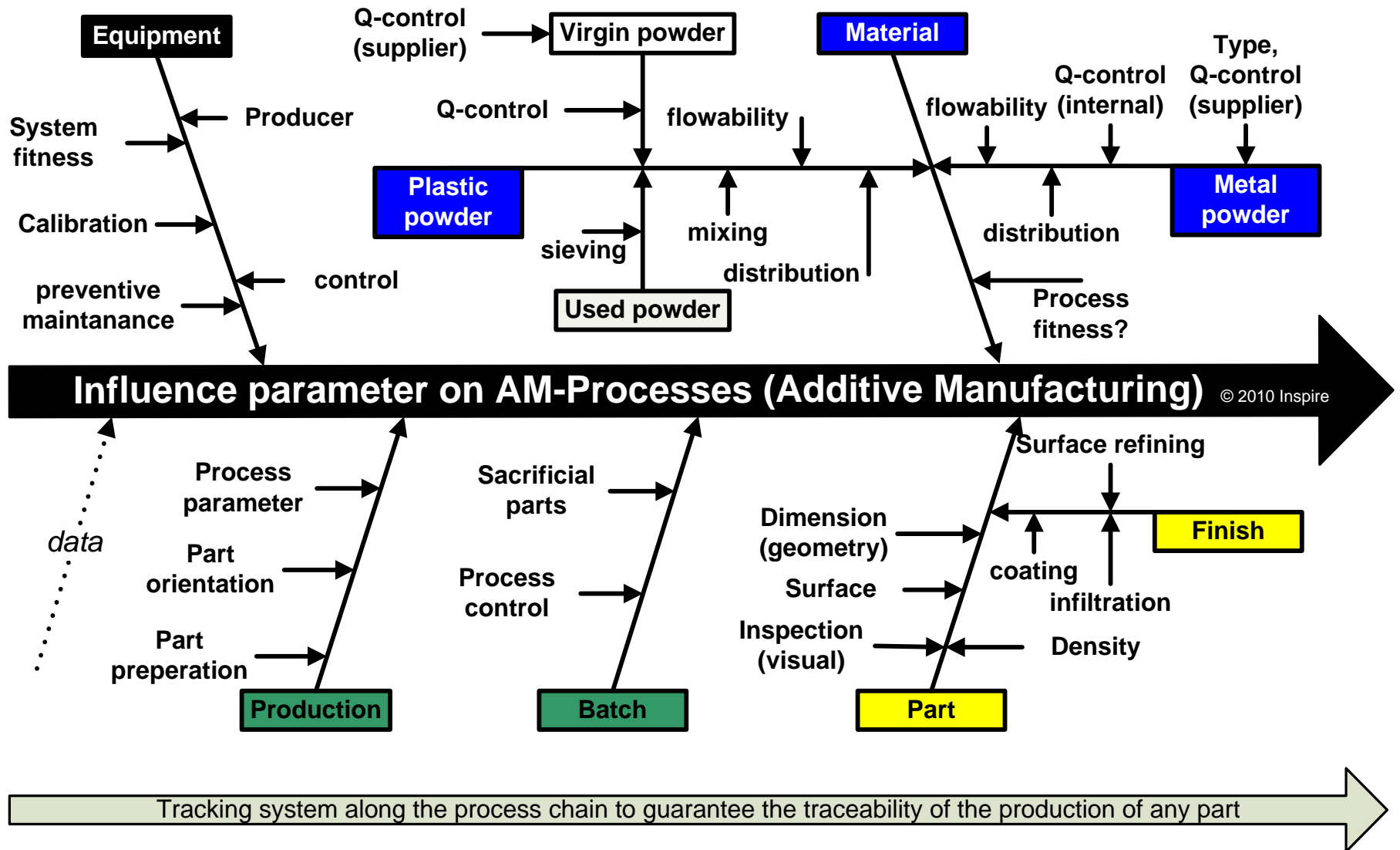
## 3D printing, noun

fabrication of objects through the deposition of a material using a print head, nozzle, or another printer technology

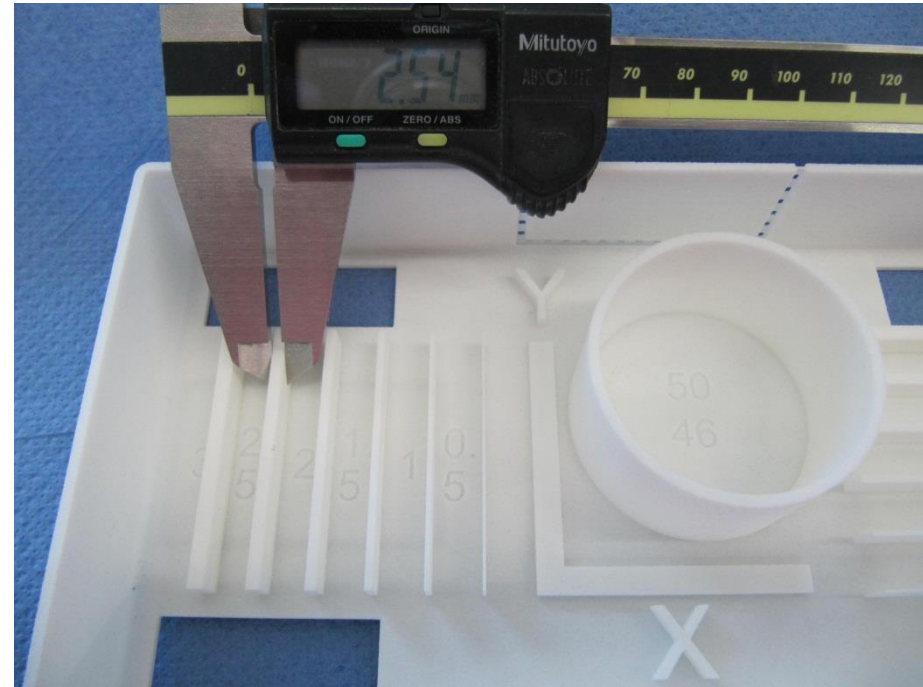
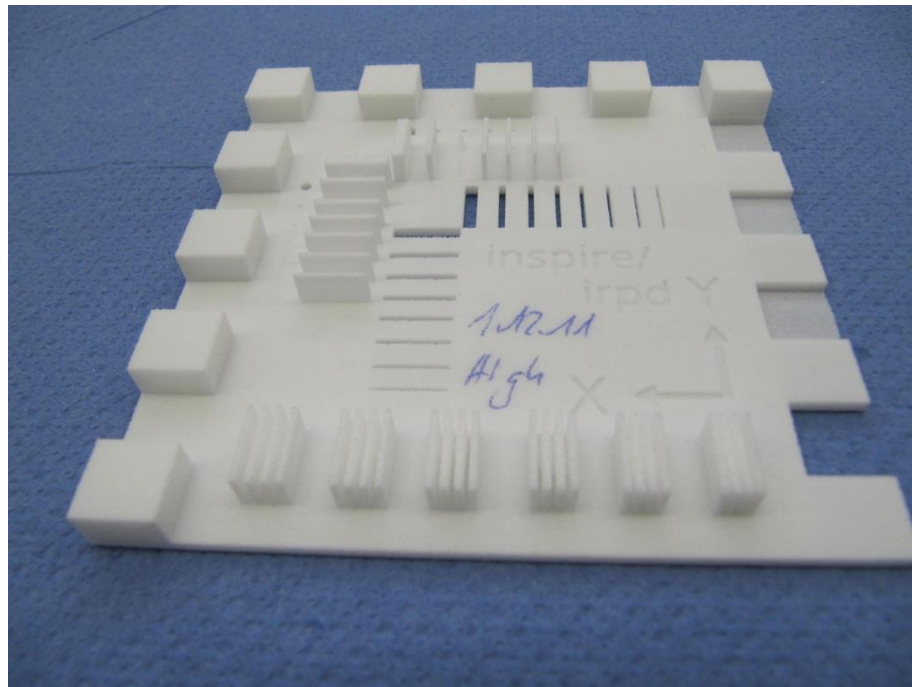


- Nearly unlimited freedom of design → exploitation
- → Permitted design opportunities (and not restrictions of freedom)
- Process optimization, Increase in reliability, Standardization

# Ishikawa – diagram SLS



- Dependency on build place within working envelope
- Similar to casting: delivery of test piece with the part



Testpiece irpd1  
Focus visual

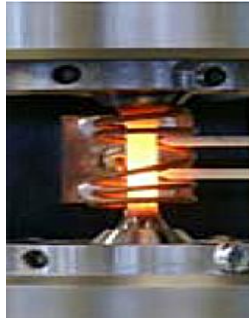
Testpiece irpd2  
Focus: quantitativ



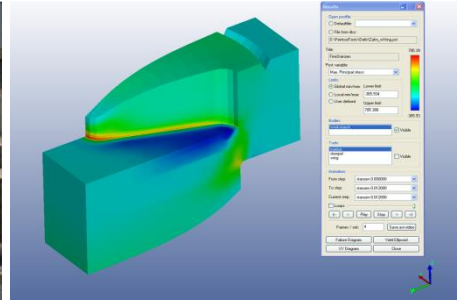
**ics**  
P. Ermanni



**icmi**  
E. Mazza



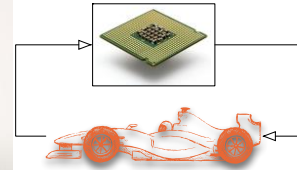
**ivp**  
P. Hora



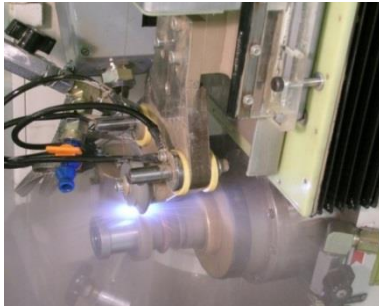
**ipdz**  
M. Meboldt



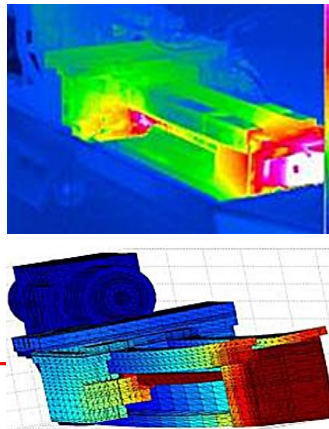
**ifa**  
M. Morari



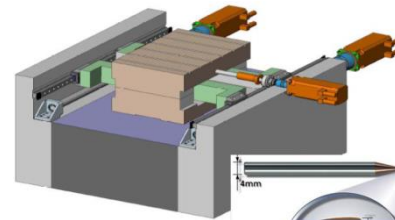
**iwf Processes**  
K. Wegener



**iwf Machines**  
K. Wegener



**iwf Laser/Micro**  
K. Wegener



**irpd** Beirat iwf, irpd  
K. Wegener

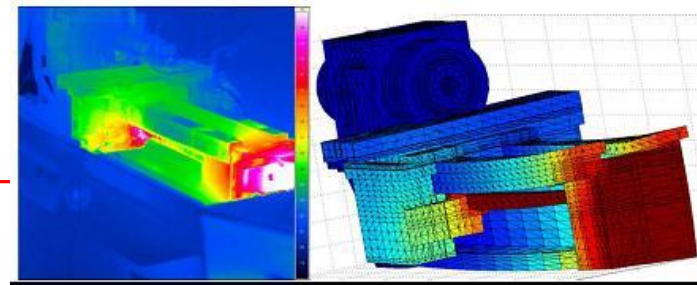
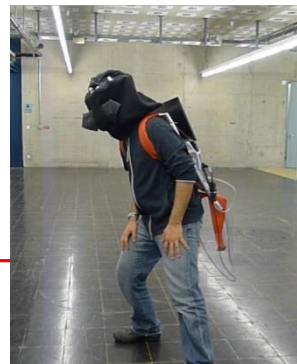
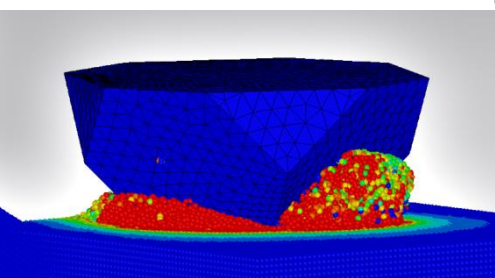
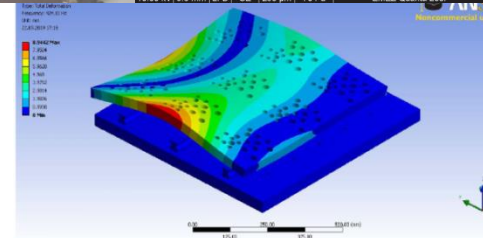
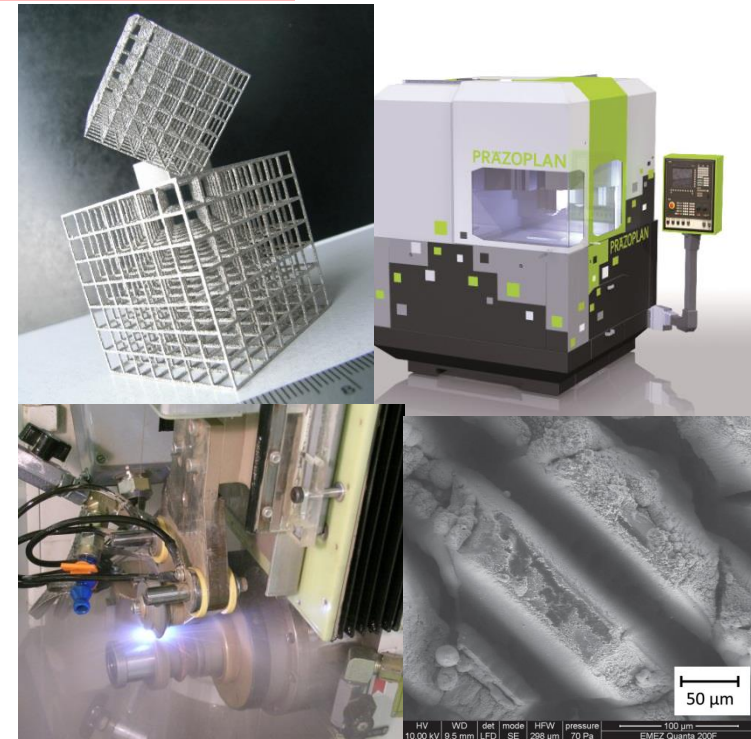


## Key areas of research and transfer

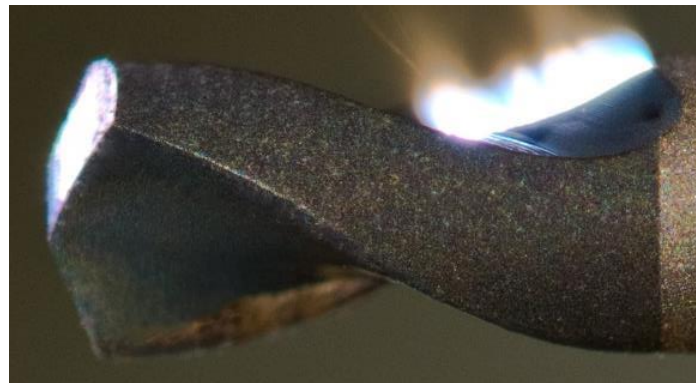
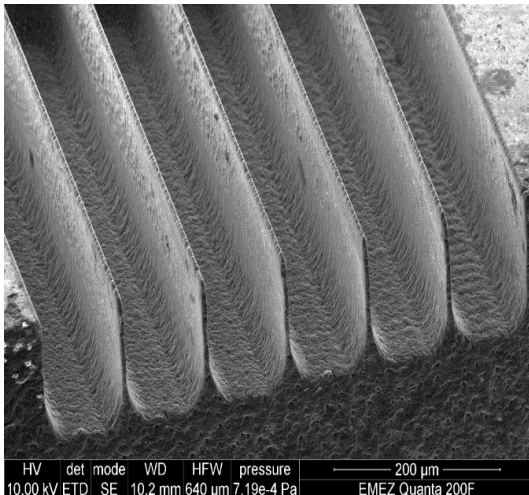
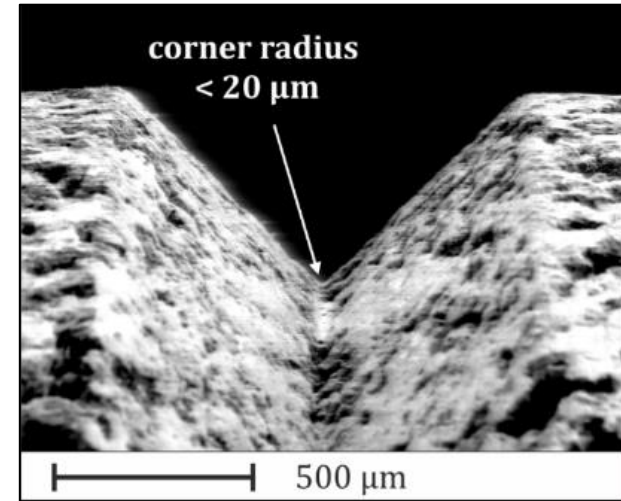
- Grinding, honing, lapping
- Optimization of machine tools
- Additive manufacturing
- High-energy beam manufact.: laser
- EDM
- Factory planning and virtual reality

## Emerging fields

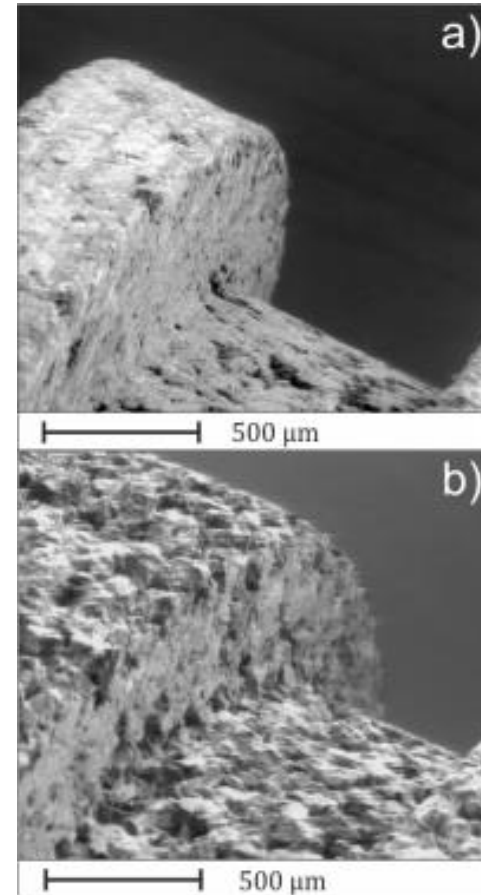
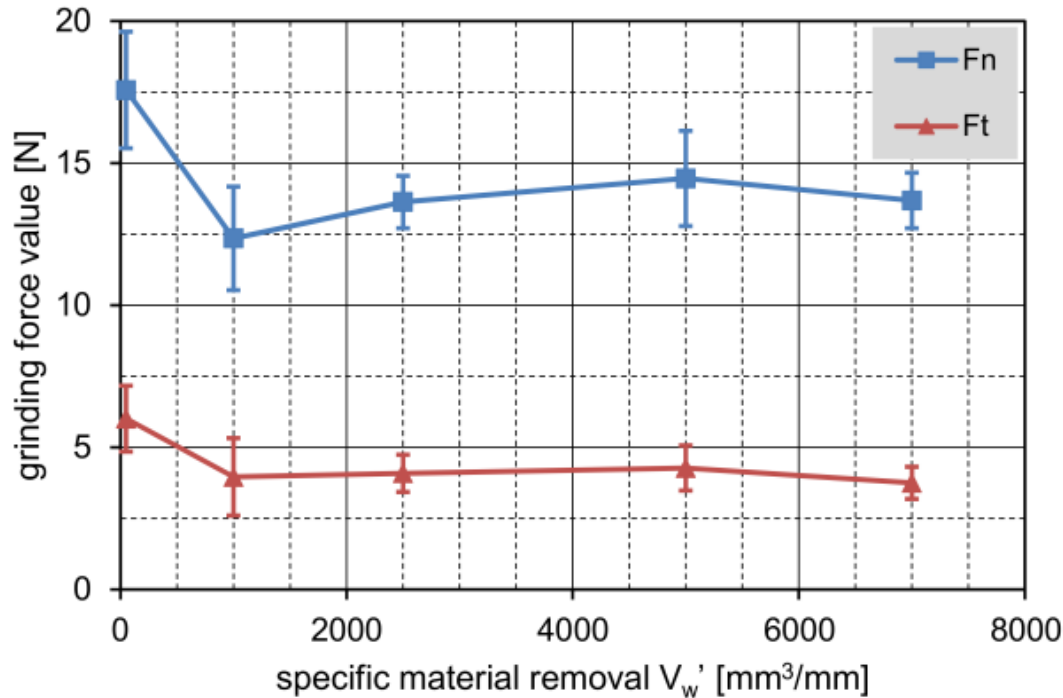
- Micro manufacturing
- Chip removal with geom. defined cutting edges
- Electro mobility



- Laser processing of diamond and CBN cutting tools
- Laser touch dressing of dressing wheels
- Conditioning of cubic boron nitride (CBN) grinding wheels
- Laser shaping of bulk metallic glass



- Wear test: force monitoring and wear measurement

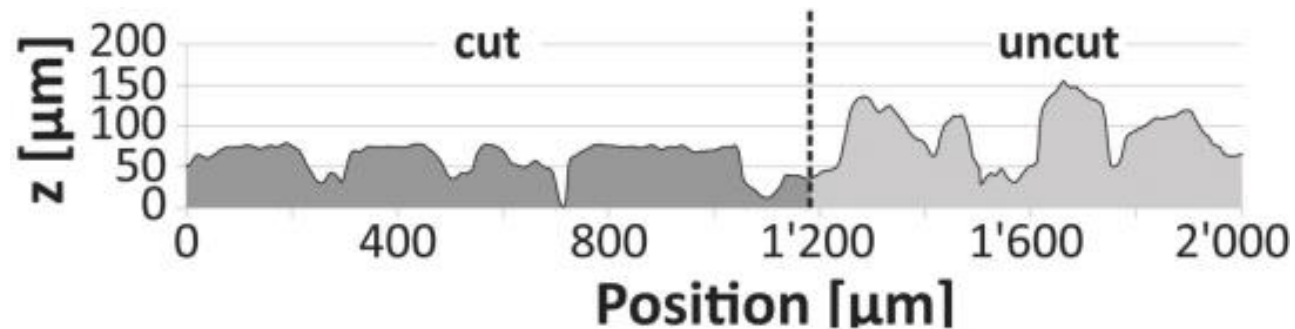
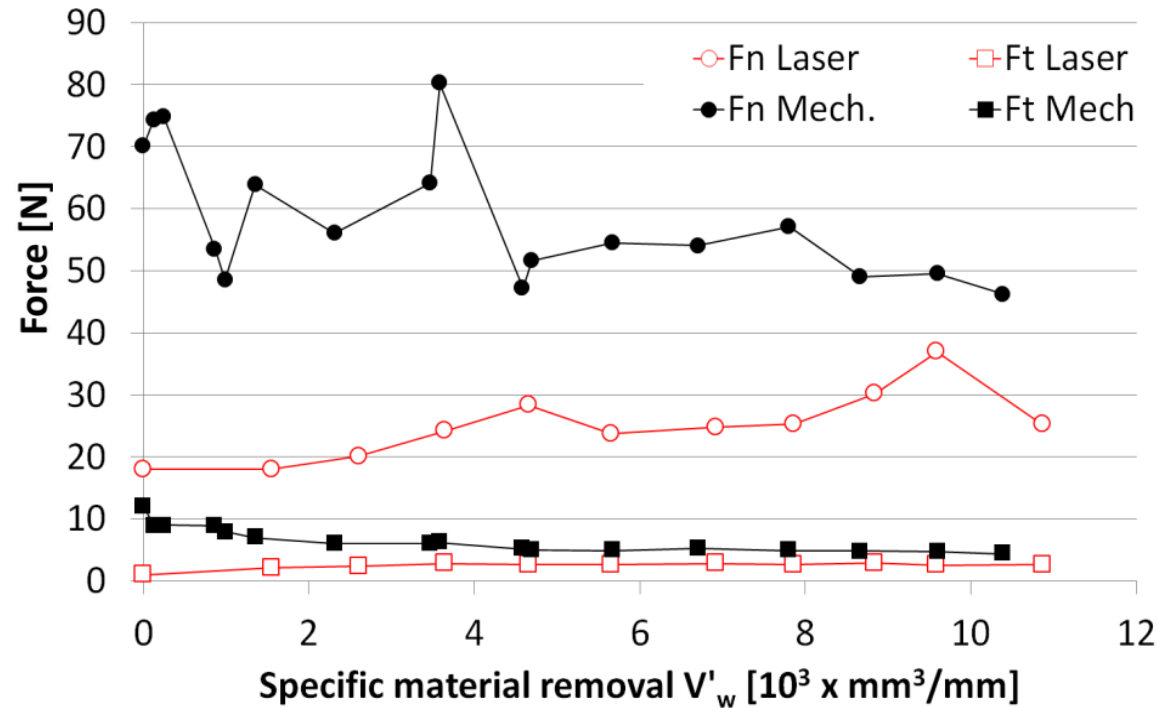


a) SEM-micrograph of laser generated profile

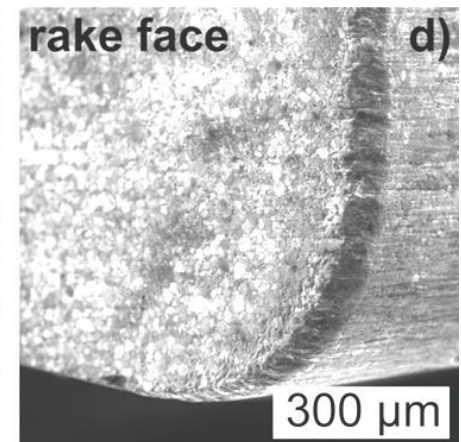
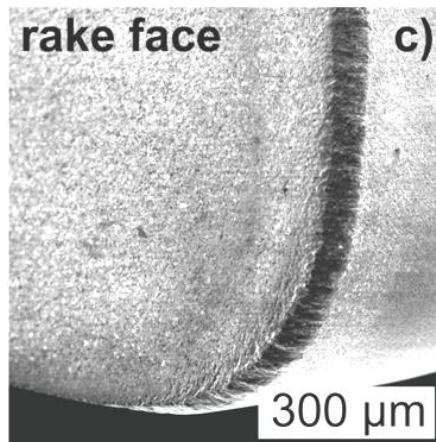
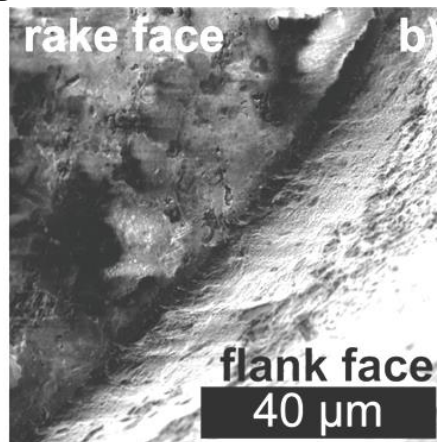
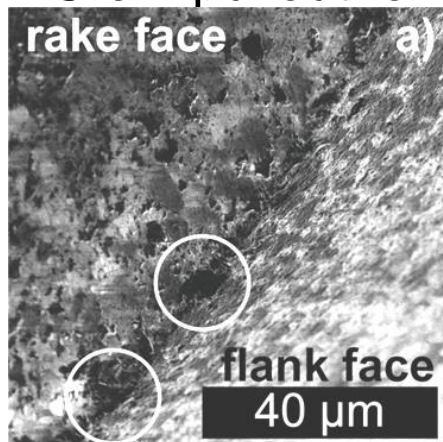
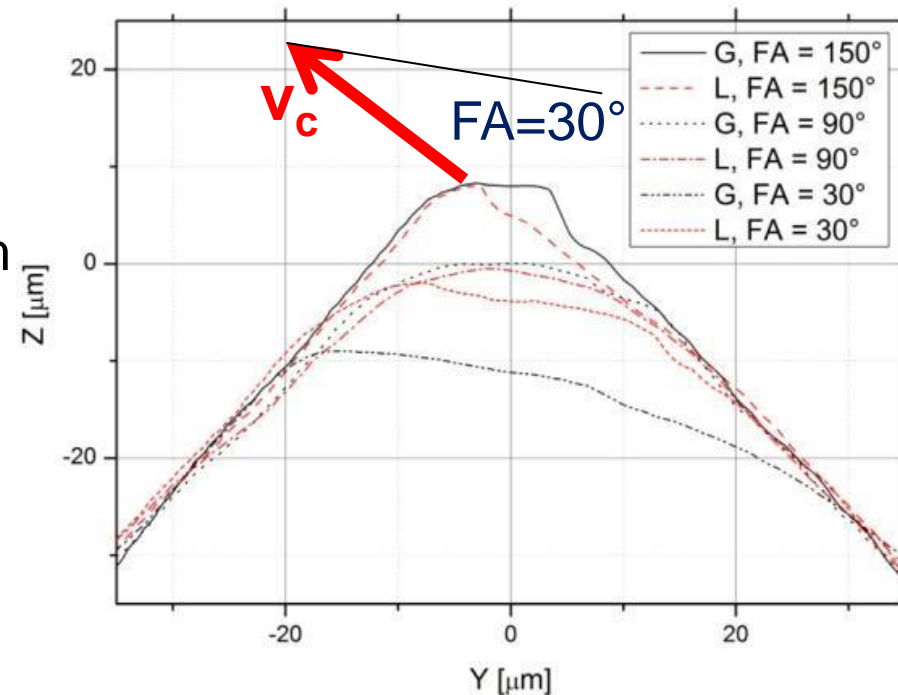
b) SEM-micrograph of tool after specific material removal  $V_w' = 7000 \text{ mm}^3/\text{mm}$

- Stable grinding conditions after run in with higher forces
- Dense surfaces from tangential laser truing
- Run in characterized by self sharpening, partly pull out
- Damage to grains from laser treatment negligible (not analyzed)

- dressing times reduced by factor 2
- no graphitization
- removal of bad (negative) flanks
- lower forces
- lower energy load on workpiece



- Cutting edge radii vs. fiber orientation angle (FA), relative to cutting direction
  - new G, L  $r_K = 4.3$  to  $6.5 \mu\text{m}$
  - at removed volume  $V'_w = 31 \text{ cm}^3/\text{mm}$ 
    - $150^\circ$  FA  $r_K = 8.6 \mu\text{m}$
    - $90^\circ$  FA  $r_K = 30.6 / 35.9 \mu\text{m}$
    - $30^\circ$  FA  $r_K = 36.4 / 32.0 \mu\text{m}$
- Similar wear on both (L,G) cutting tools
- Striations for FA= $30^\circ$ , especially for G
- Grain pullout for G

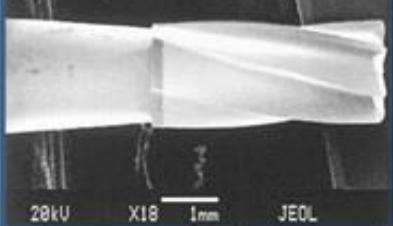


## DIPLAT – Applications & Tool Characteristics

### APPROACH I TOOLS

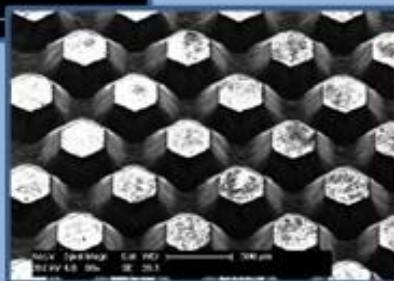
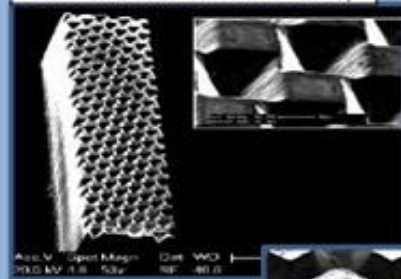
CVD/PCD/PCBN ultra-hard bulk material on a substrate

Diamond coated microdrill



- Ablation of defined patterns (rake angle, cutting edge etc.) for enhanced functionality of the ultra-hard surface
- Creation of cutting tool edges with superior quality

CVD diamond micro array



Laser patterned CVD diamond

#### Applications

- Mills, Drills and Cutting Tools
- Micro grinding tools
- Fine grinding/dressing pads
- Honing & Lapping tools

Integrated PLA Technology

### APPROACH II TOOLS

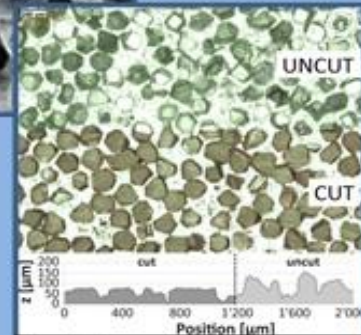
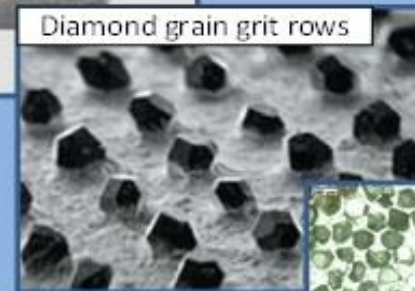
Ultra-hard grain/grit layer & bond material

Diamond grinding wheel



- Structuring of the grit layer (chip flow paths, rake angles) for enhanced tool performance
- Truing / Profiling of complex surface-set 3D freeform tools

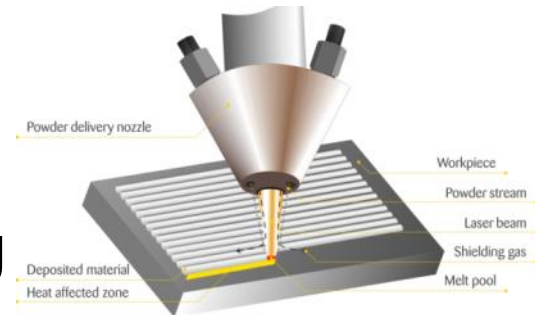
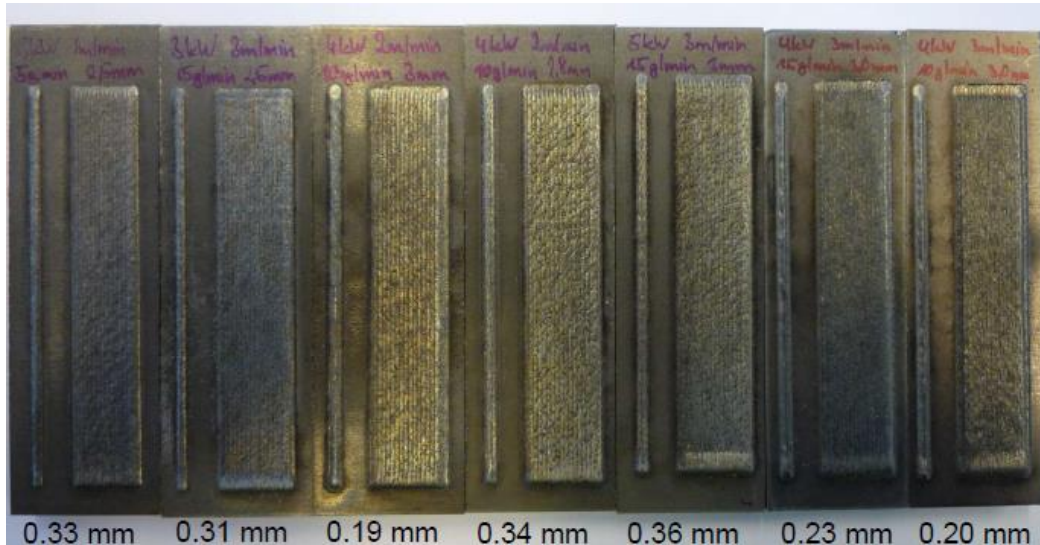
Diamond grain grit rows



Partly laser trued diamond dressing wheel

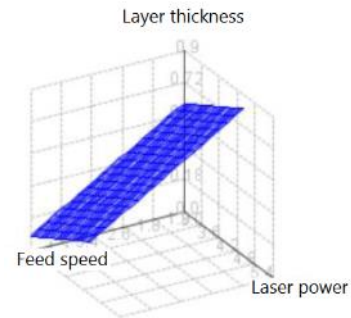
#### Applications

- Dressers & Truing Tools
- Grinding Tools
- Gear Grinding
- Broaching Tools



## ■ CTI-project Advanced Laser Cladding

- Thin layers  $< 200 \mu\text{m}$  with minimum dilution
- Dense and crack-free structures without delamination
- Exotic layer-substrate material combinations
- Laser cladding combination with thermal spraying



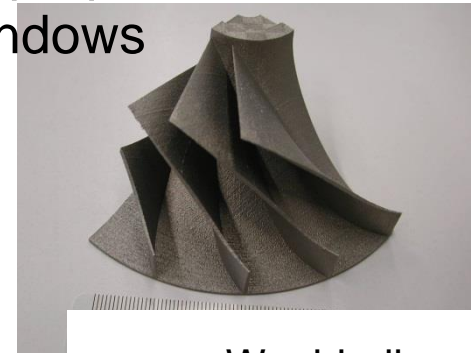


# Additive Manufacturing (AM)

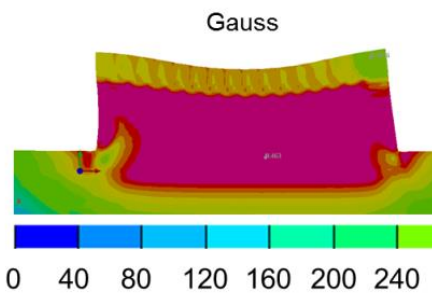
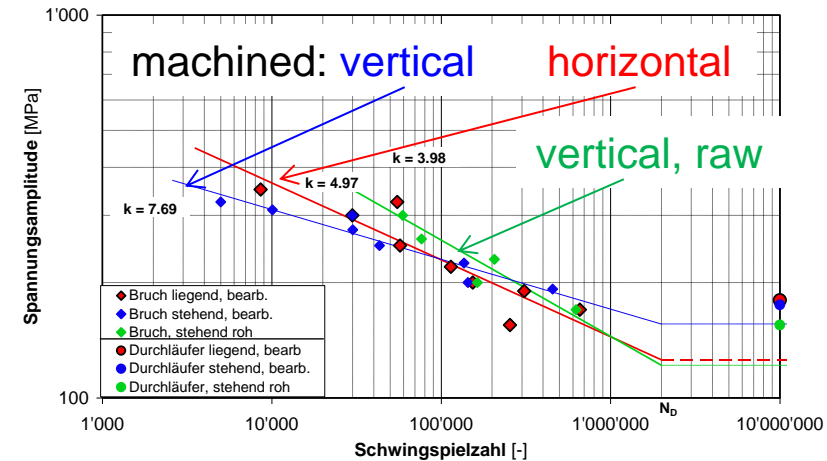


## Scientific goals:

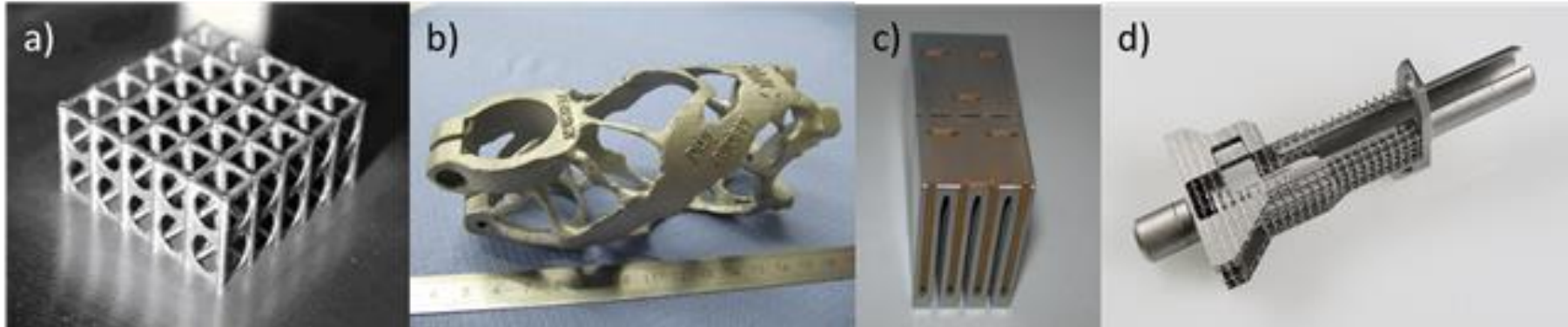
- additive processes for manufacturing SLM, SLS, DMD
- Prozess simulation, predictability of results
- Optimization of surfaces and material properties
- development of materials, process windows
- machines, test bench for AM
- medical manufacturing
- Process design and QM for AM



Woehlerline 1.4313\_QT 800



## ■ Selective Laser Melting



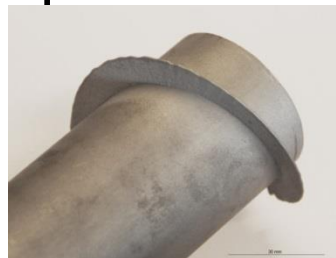
## ■ Selective Laser Sintering



Abb. 4



## ■ Direct Metal Deposition



Thank-you for your attention

wegener@iwf.mavt.ethz.ch