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EDURES
EDUcation RESearch

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HOCHSCHULE FURTWANGEN UNIVERSITY | HFU

Ultra-short pulse laser for creating profiles, textures and functional surfaces

Kompetenzzentrum für Spanende Fertigung (KSF)

Prof. Dr.-Ing. Bahman Azarhoushang

Hochschule Furtwangen - Kompetenzzentrum für Spanende Fertigung (KSF)
Leitung: Prof. Dr.-Ing. Bahman Azarhoushang
Jakob-Kienzle-Str. 17 · D-78054 Villingen-Schwenningen +49 (0)7720 / 307 – 4215
aza@hs-furtwangen.de · www.ksf.hs-furtwangen.de

KSF

5-axis UKP laser machining - project (KSF/GF)

- Introduction and motivation
- Micro- and sub-microstructuring of functional surfaces
  - Superhydrophobic and superhydrophilic surfaces
- Micromachining and tribological optimization
- Profile creation
- Laser assisted machining

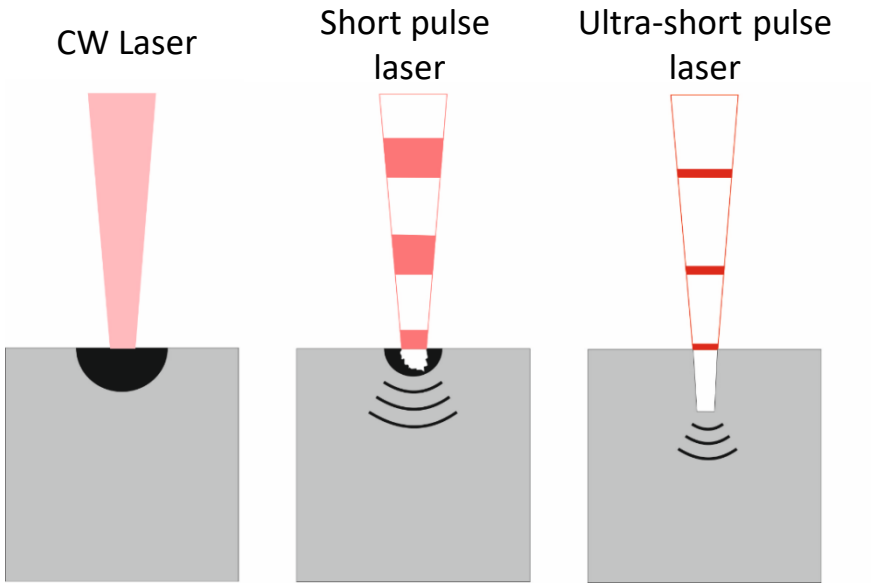
Characterization of laser processing

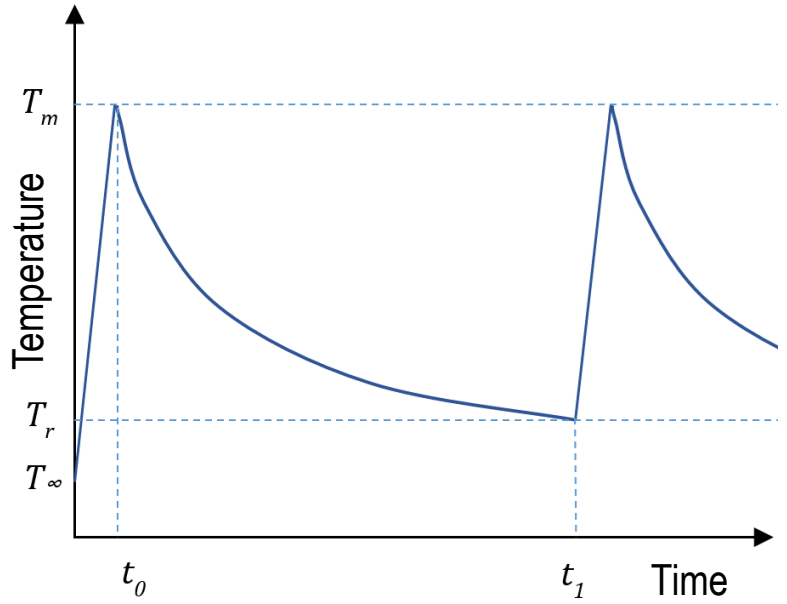
- continous (CW) laser: $t_p > 250$ ms >> t_l >> t_e
- Short pulse laser : Nanosecond range $t_p \approx t_l$
- Ultra-short pulse laser : $t_p < t_e \approx 10$ ps << t_l

t_p : pulse duration

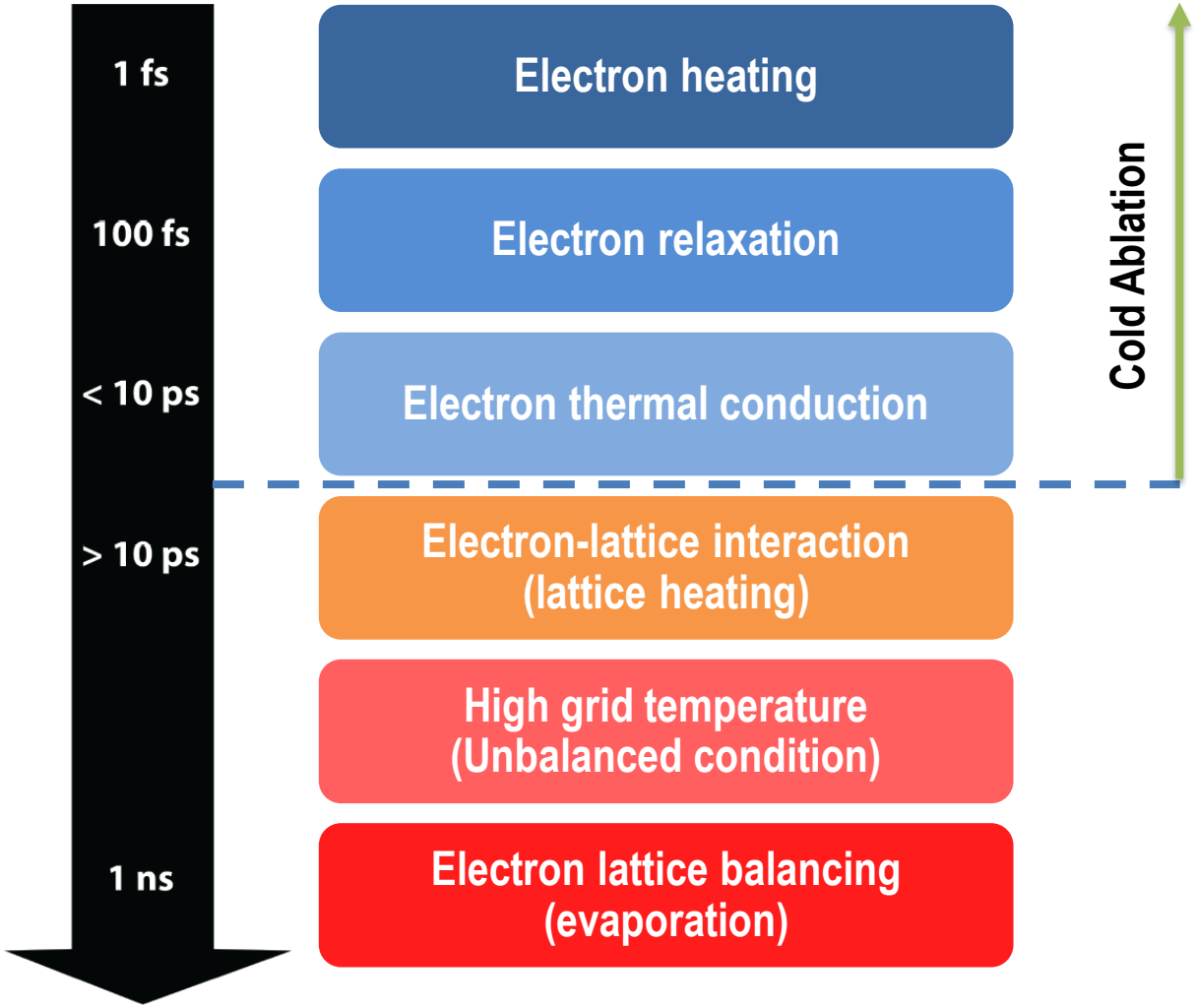
t_e: Electron cooling time

t_l : Heating time of crystal lattices

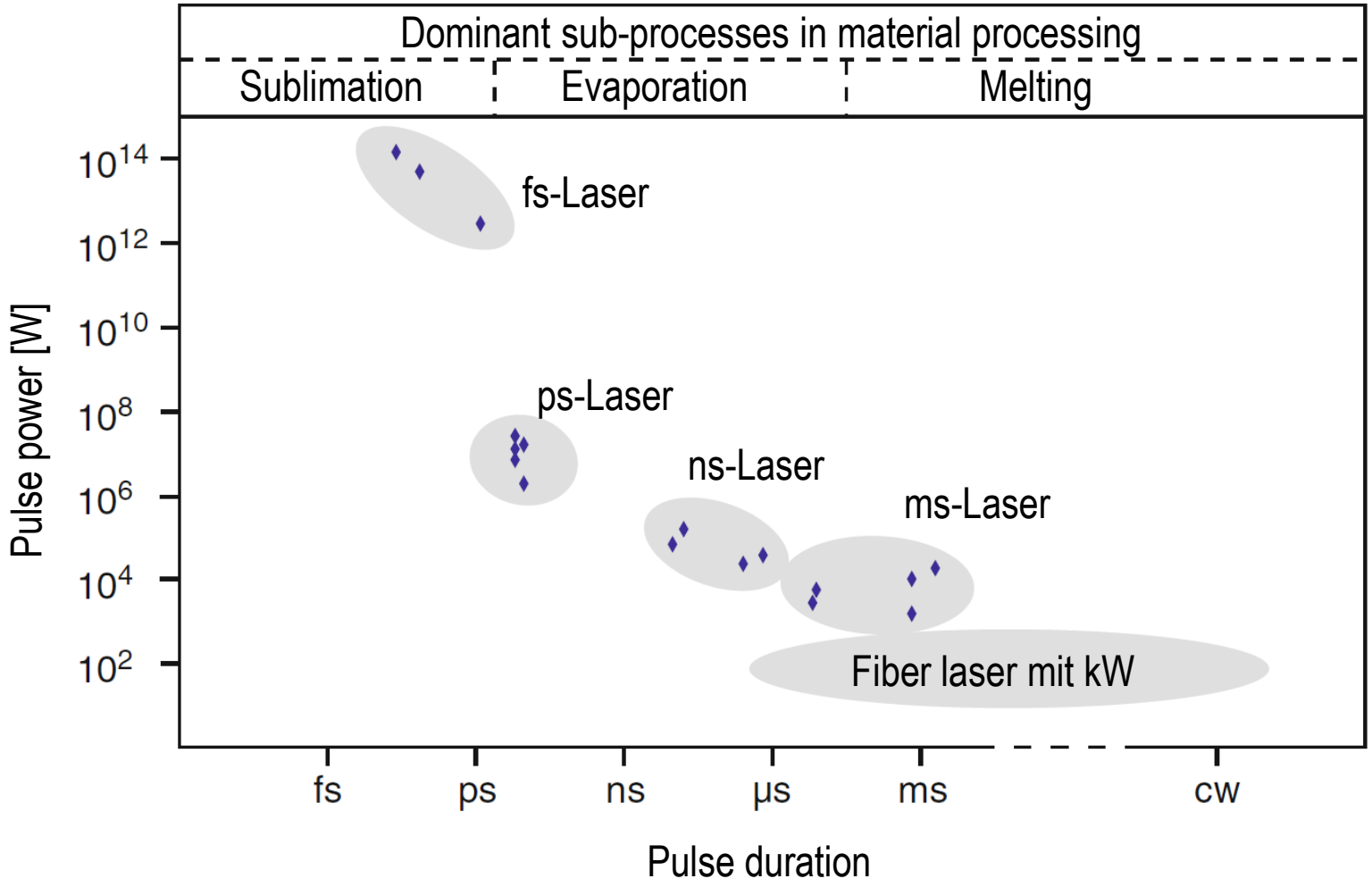




Laser ablation with ultrashort laser pulses

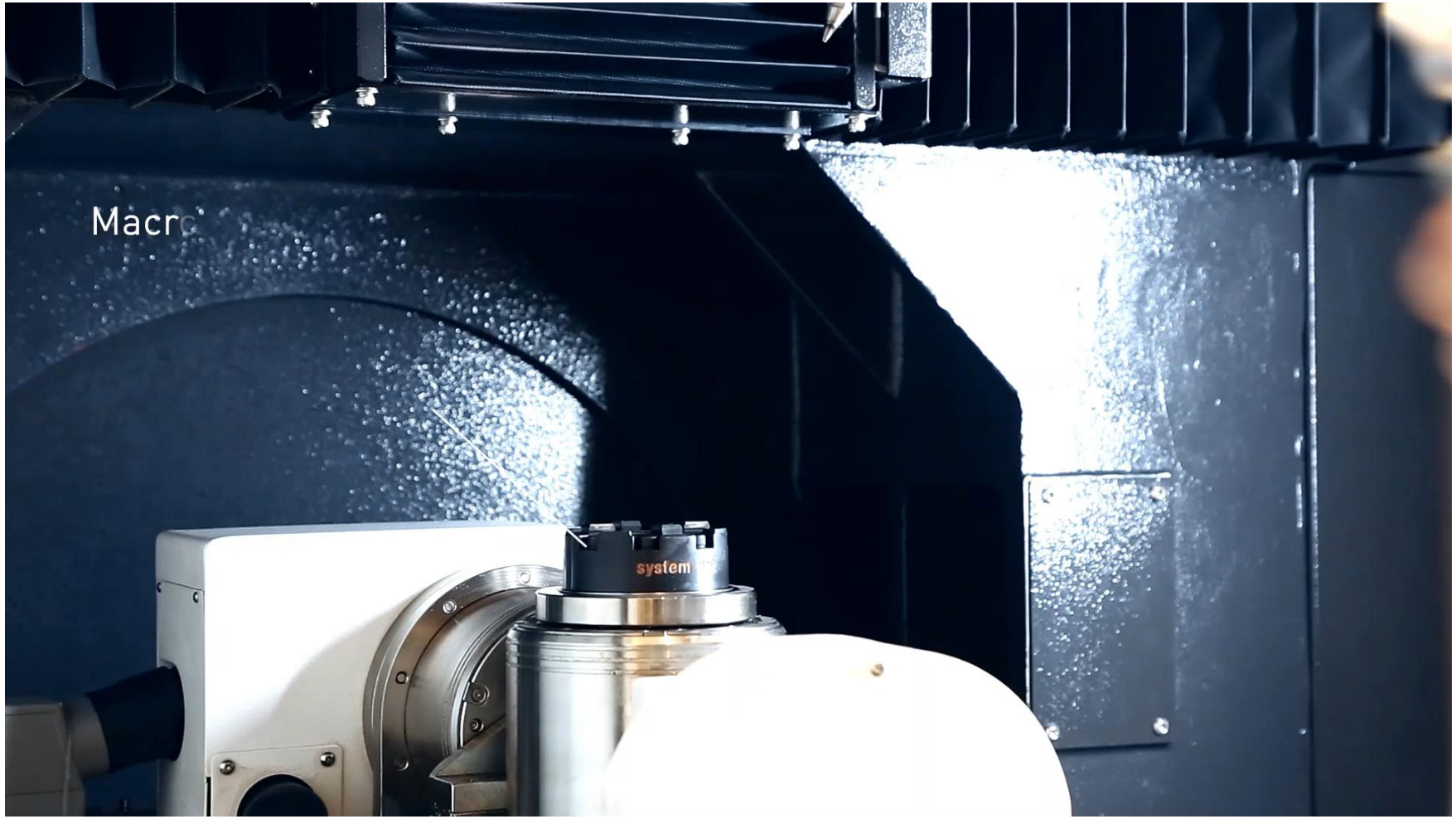


Laser ablation with ultrashort laser pulses



(Source: Suttmann)

LaserP400U



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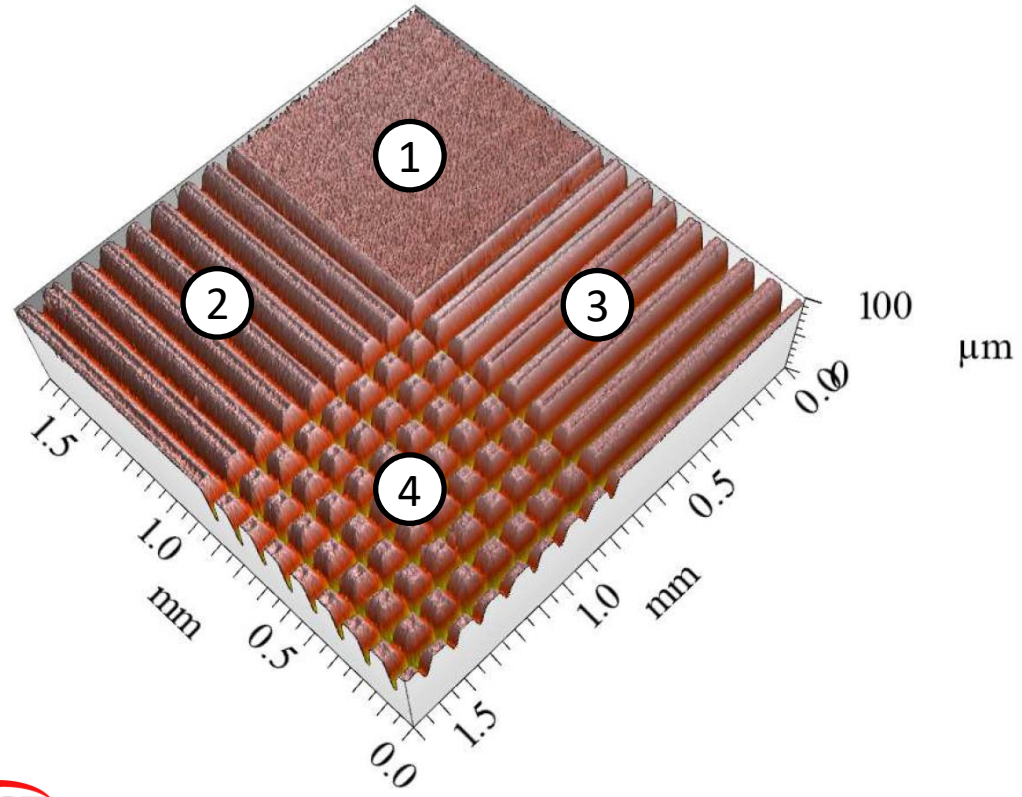
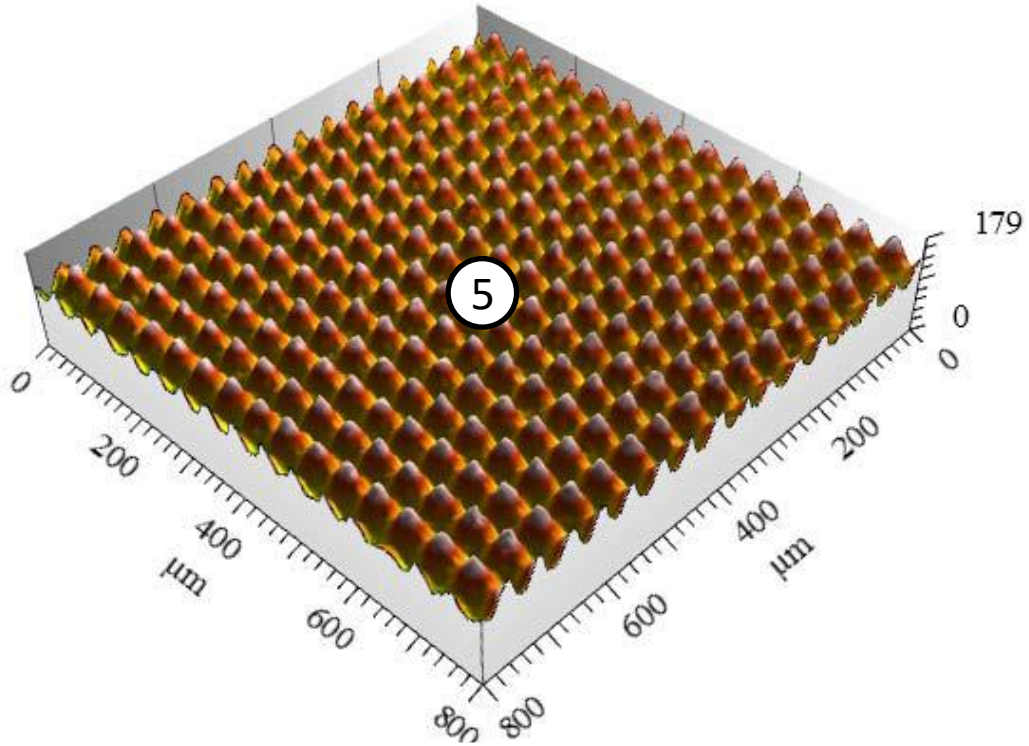
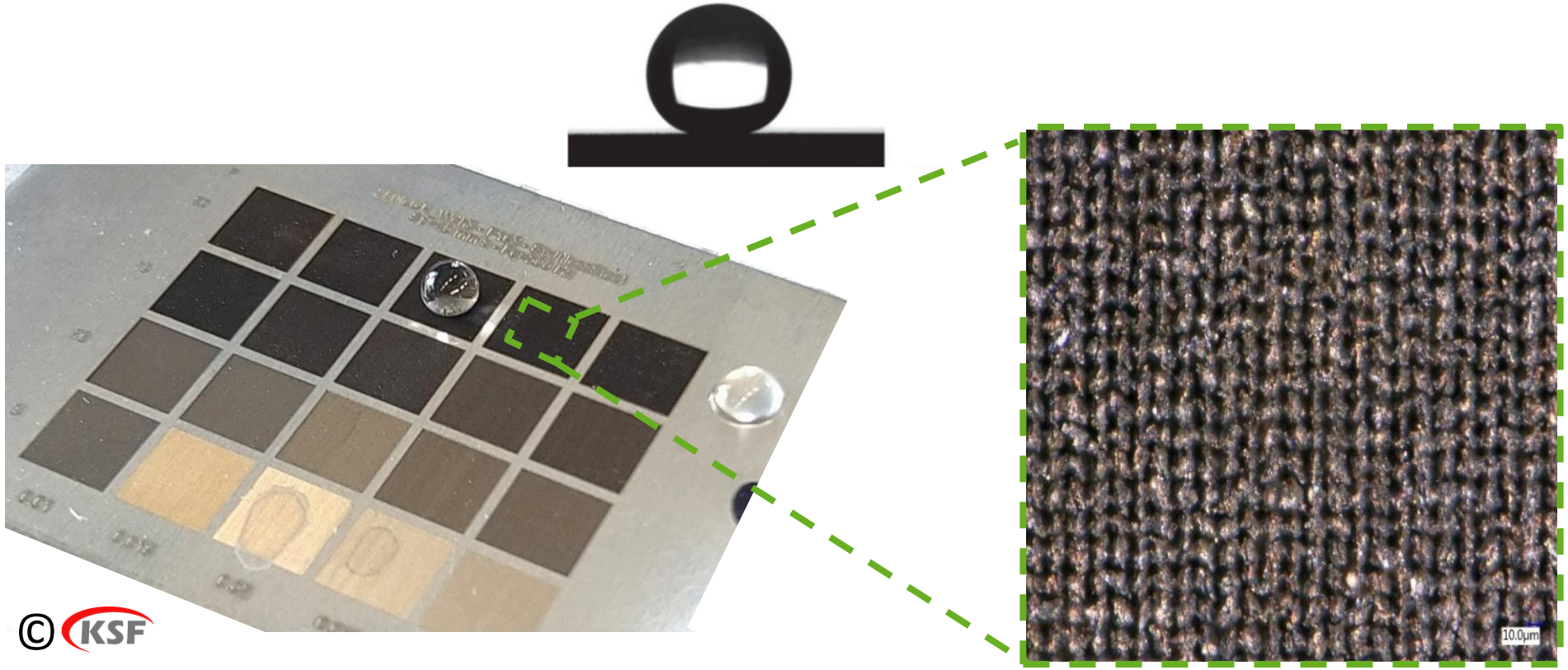
Micro- and sub-microstructuring of functional surfaces

- Roughened surfaces (1) for desired functionality (layer adhesion, cell adhesion, ...)
- Generation of direction-dependent (2&3) and -independent (4&5) properties

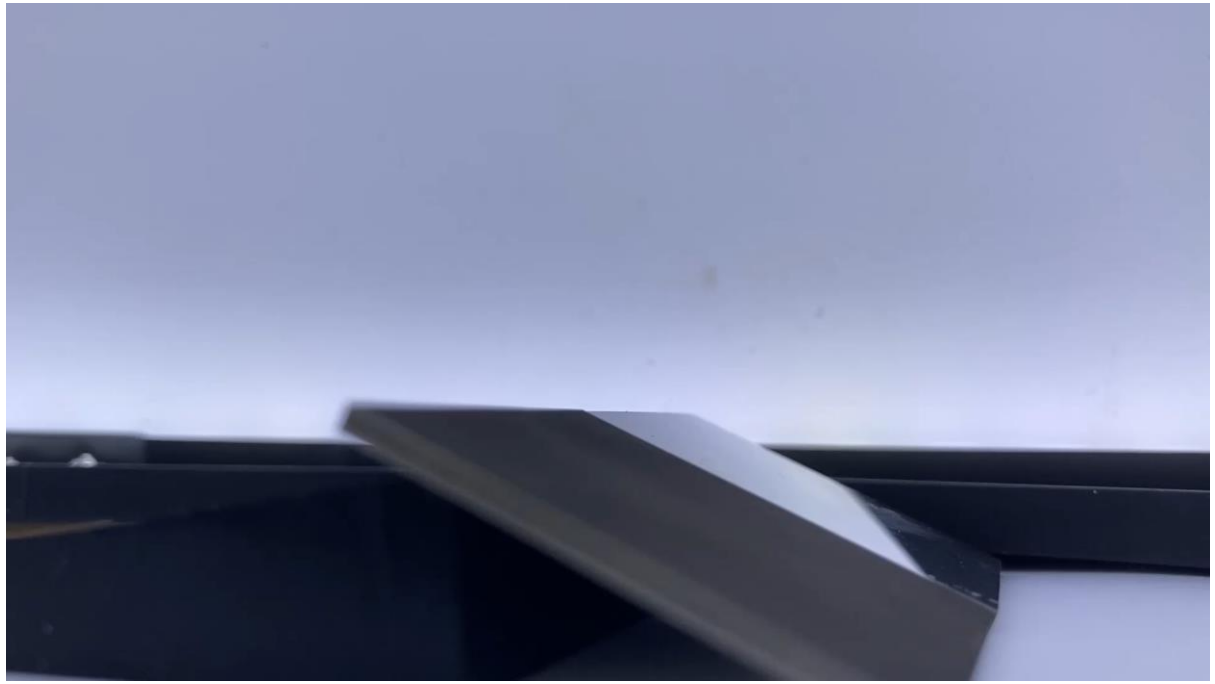


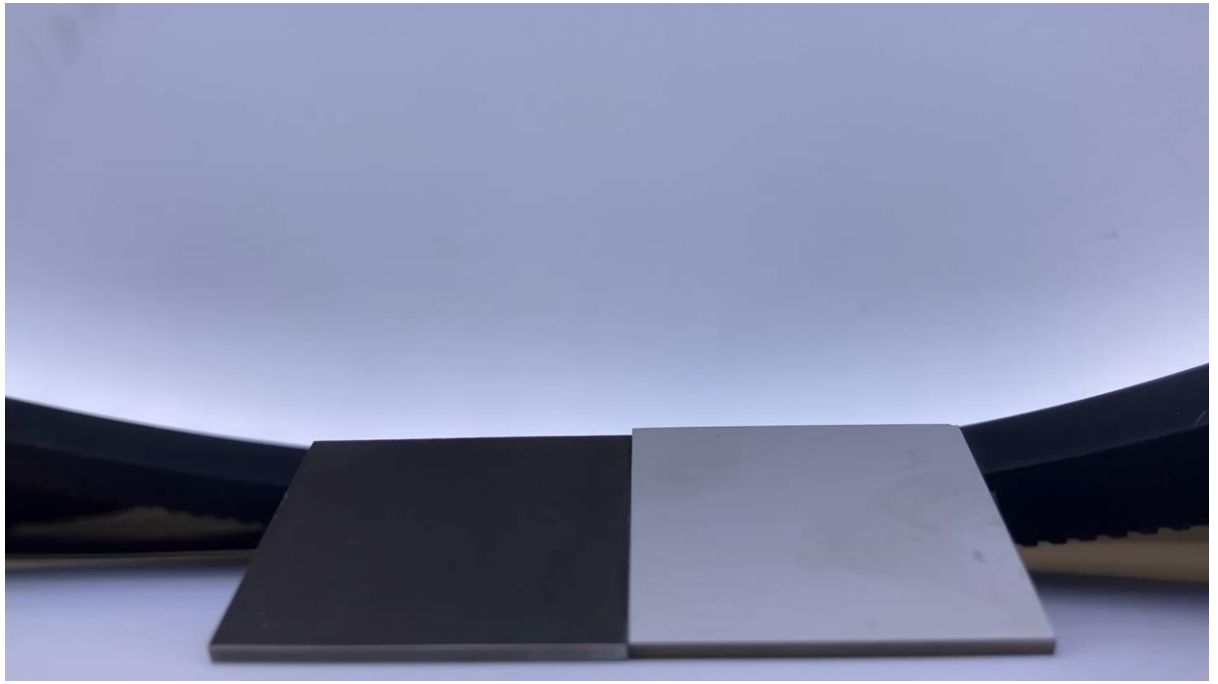


Superhydrophobic and superhydrophilic surfaces

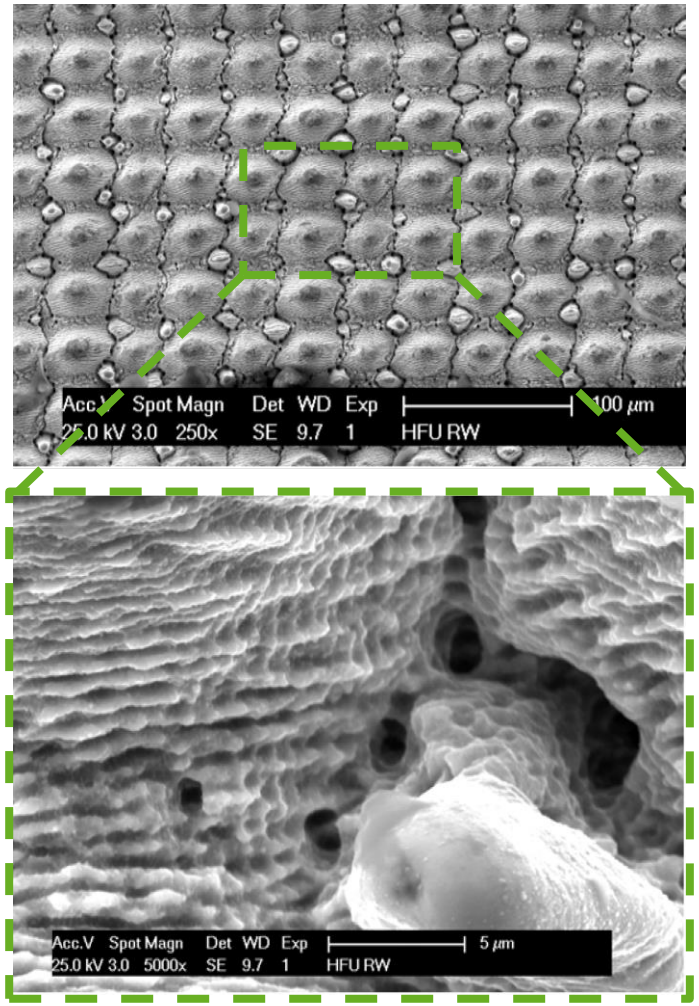


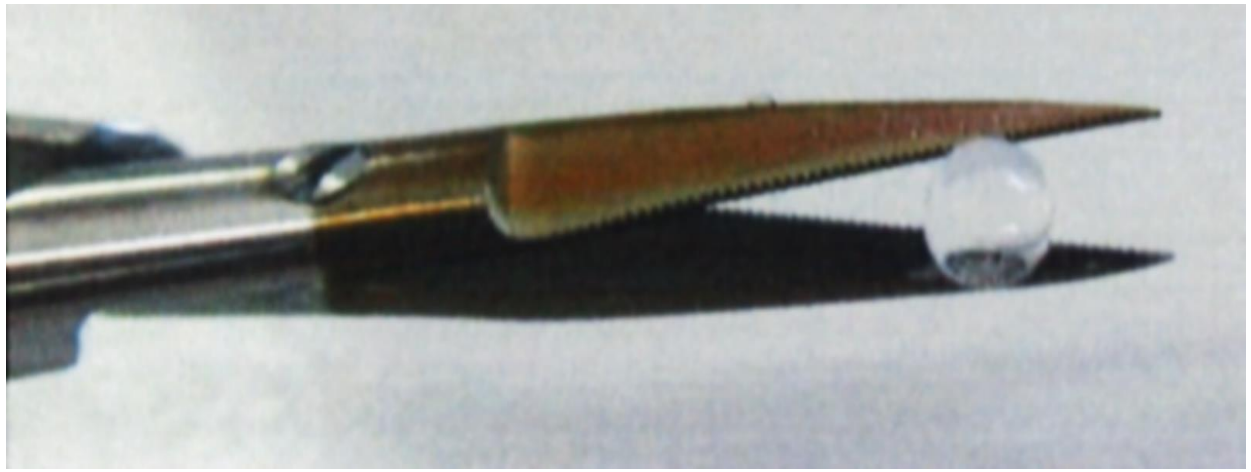
Superhydrophobic and superhydrophilic surfaces





Superhydrophobic surfaces





5-axis UKP laser machining - project (KSF/GF)

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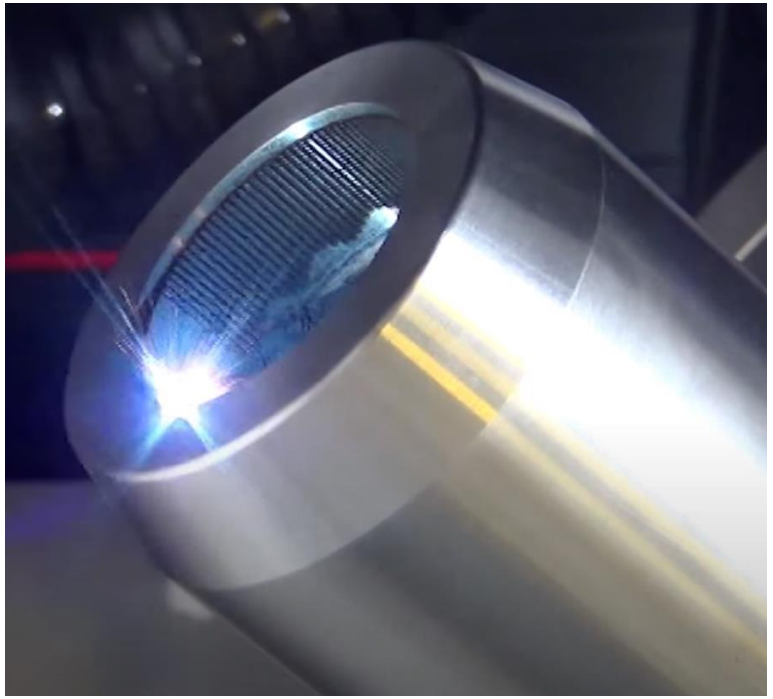
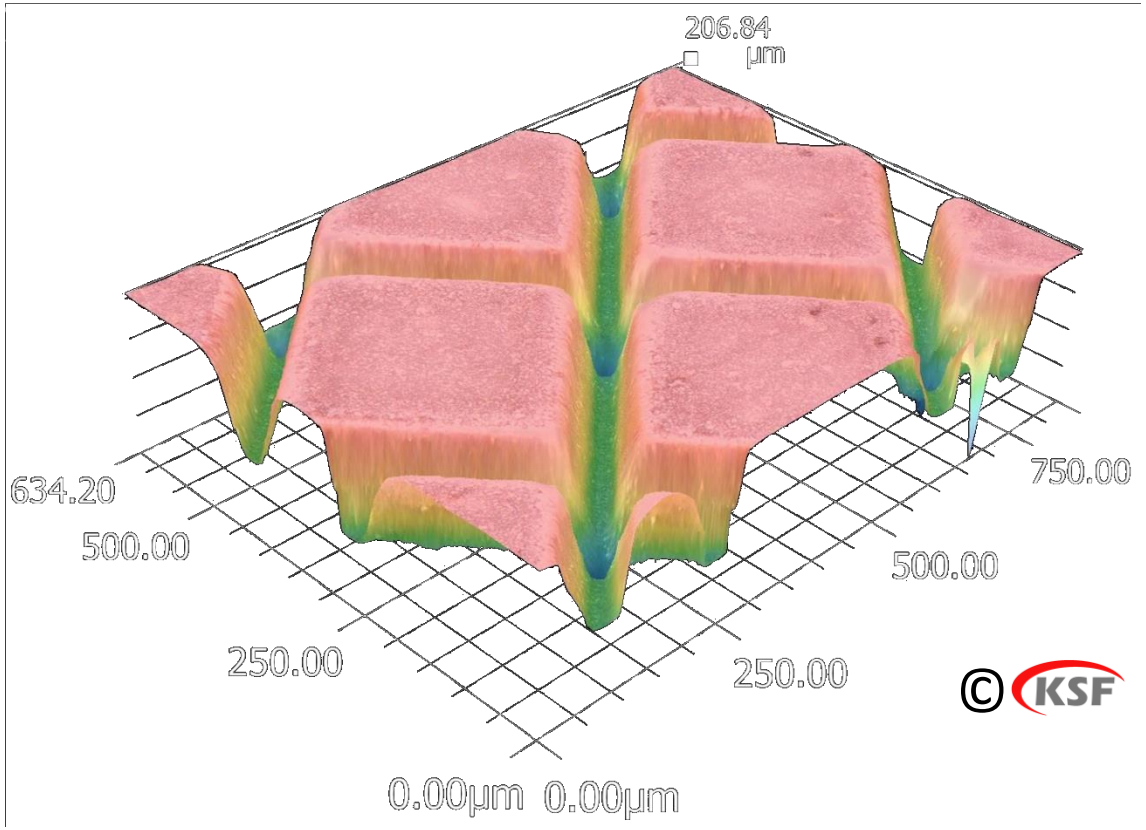
Micromachining

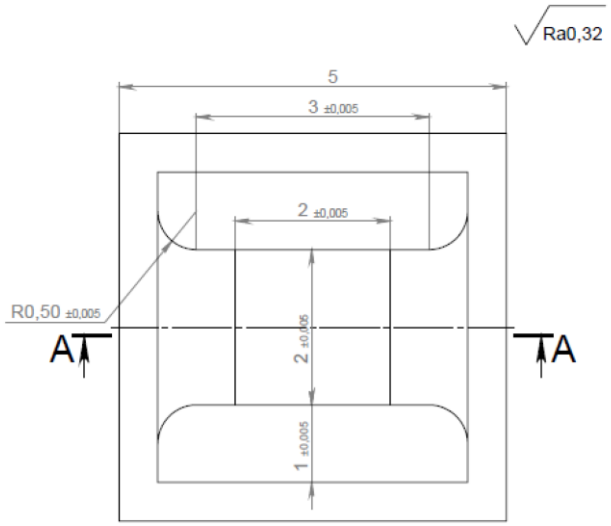


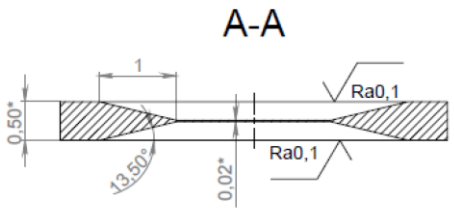
Laser micromachining (structuring) of ceramic guides

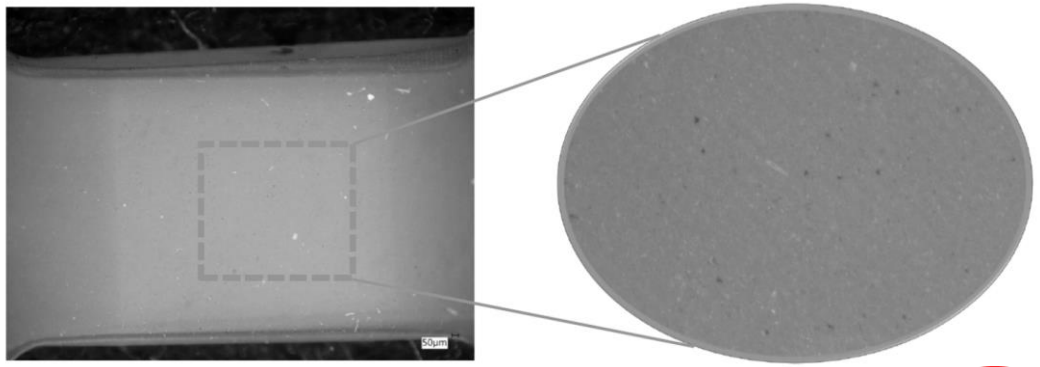
- Micro-structured friction surfaces on a ceramic component (silicon nitride) with controlled surface area for load-bearing and friction-optimized applications

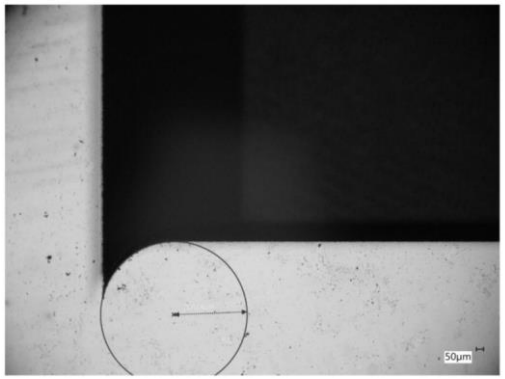


Micromachining - Suprasil 300 Glass

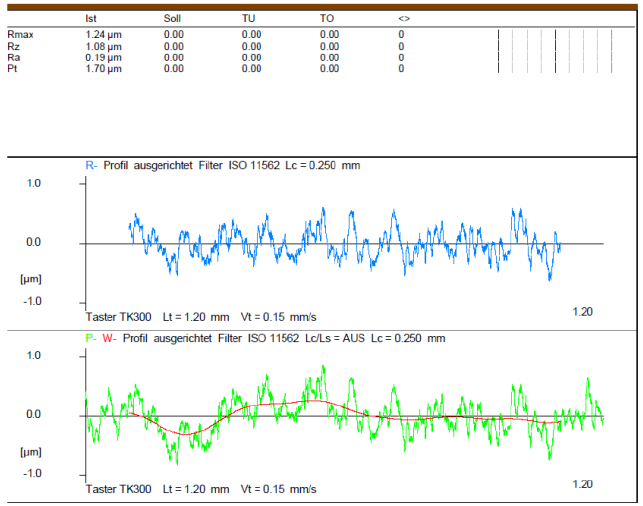


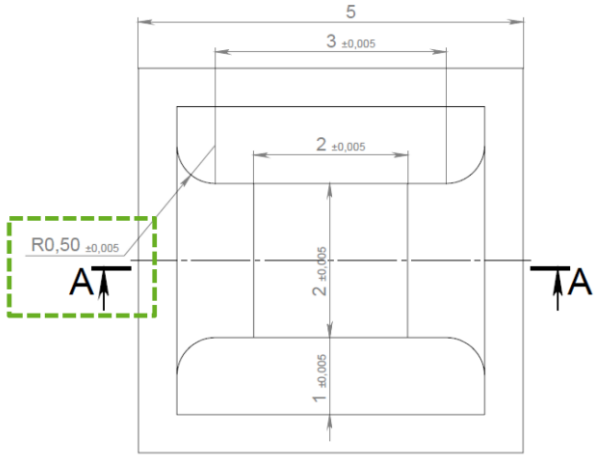






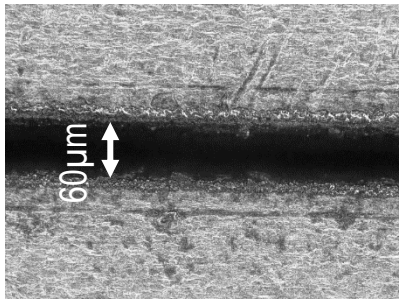
© KSF

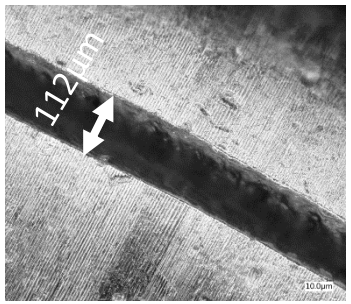




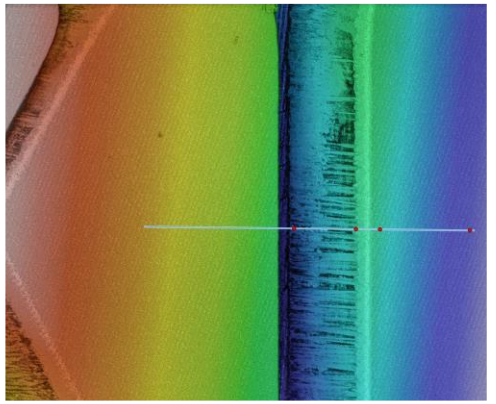
Micromachining - Nonferrous metals

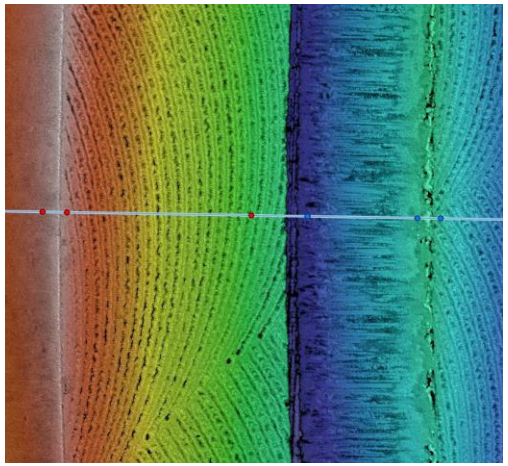
- Production of micro parts for 5G telecommunication technology
- Creating grooves with a width of 70 µm
- Thin-walled parts
- Surface quality without oxidation

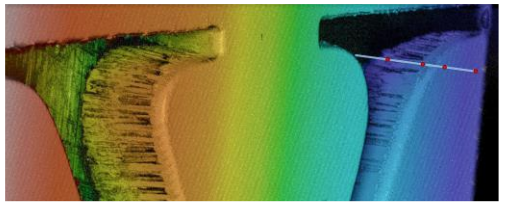




Micromachining - Hologram surface / refraction

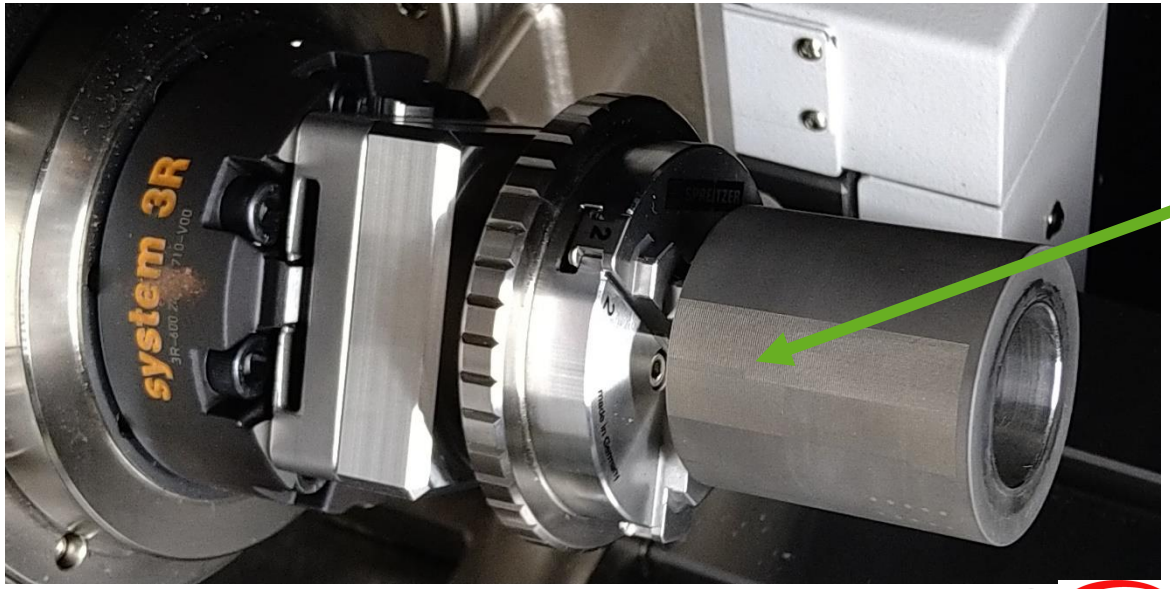


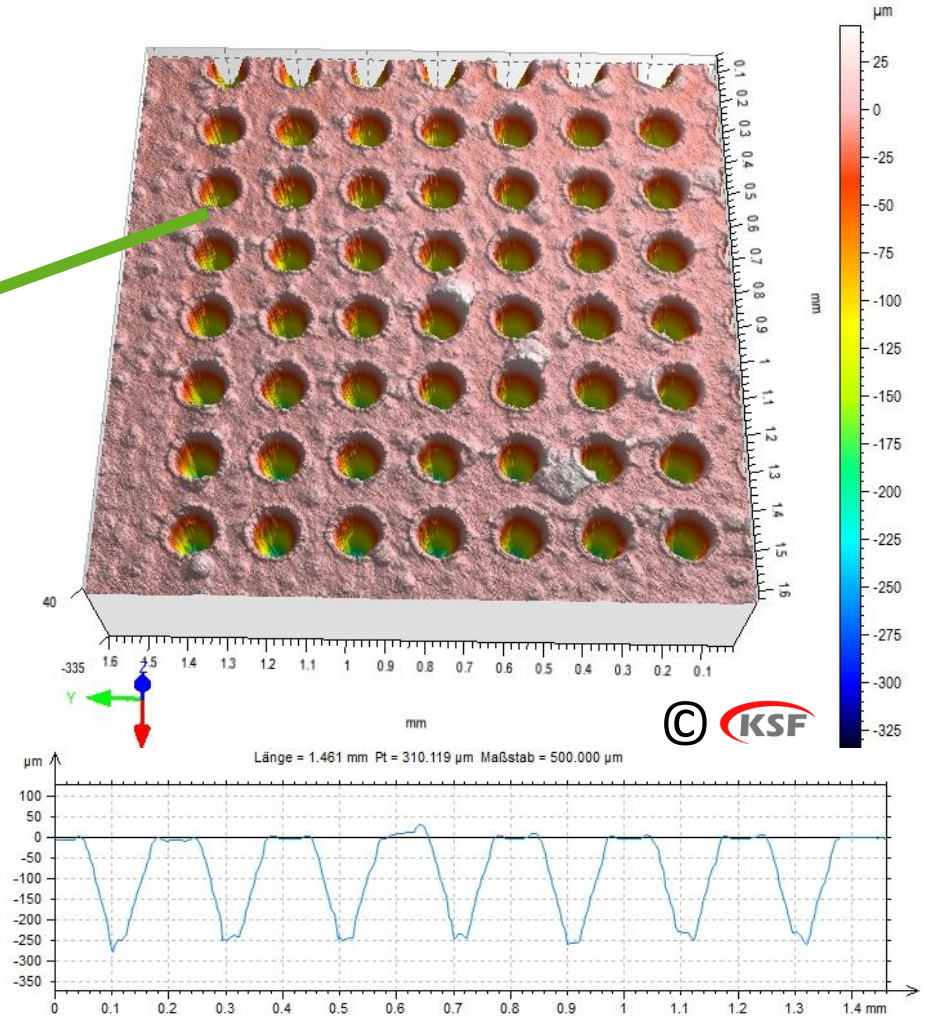




Tribological optimization – Bushing (Cr3C2 / Cr2O3)

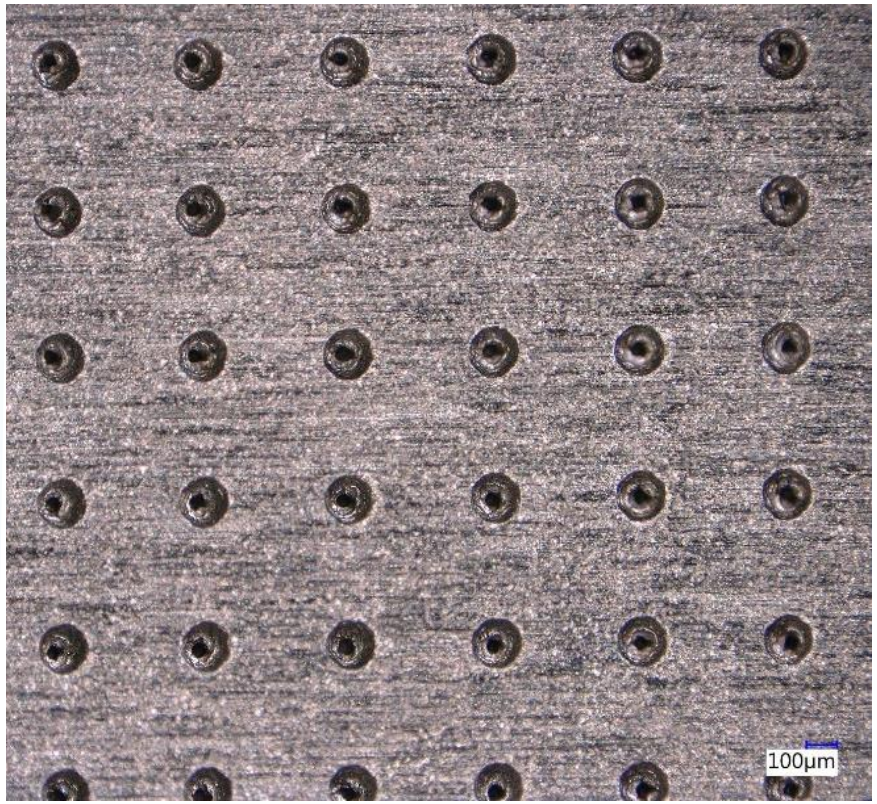
Innovative plain bearing technology for media-lubricated systems in pumps

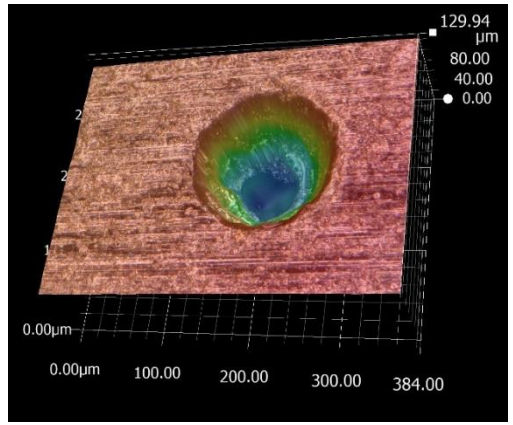


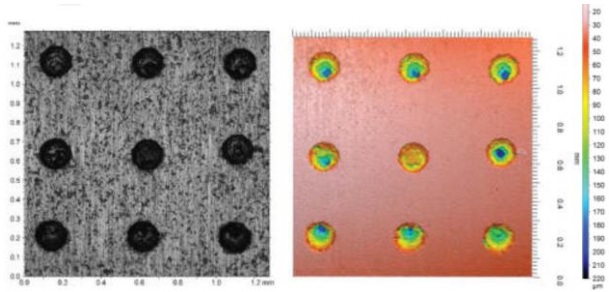


- Microstructuring of the ceramic surfaces
- Lubricant reservoirs
  - Cell structure
  - 100 - 300µm Diameter
  - 5 - 20% Area percentage

Tribological optimization – Bushing (Cr3C2 / Cr2O3)



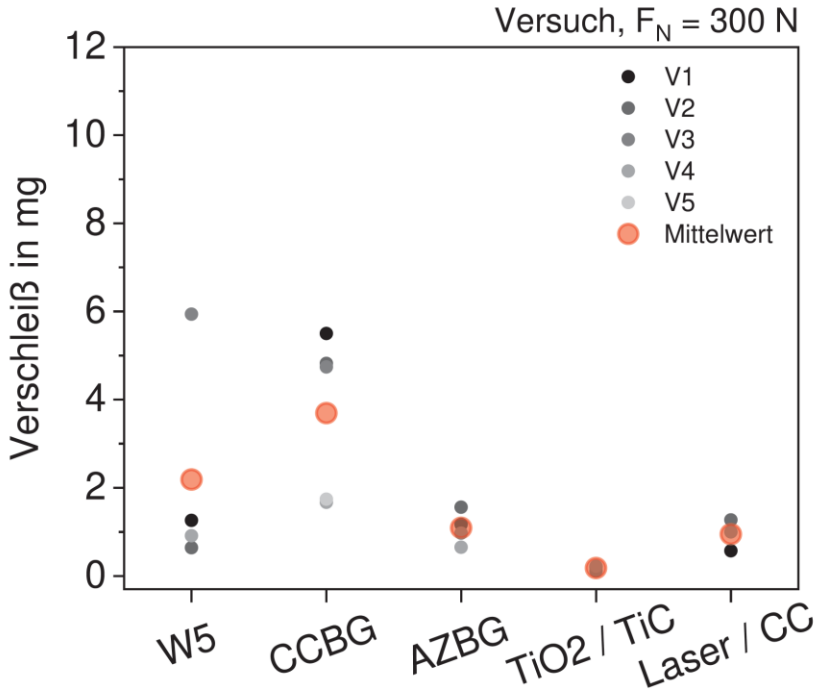


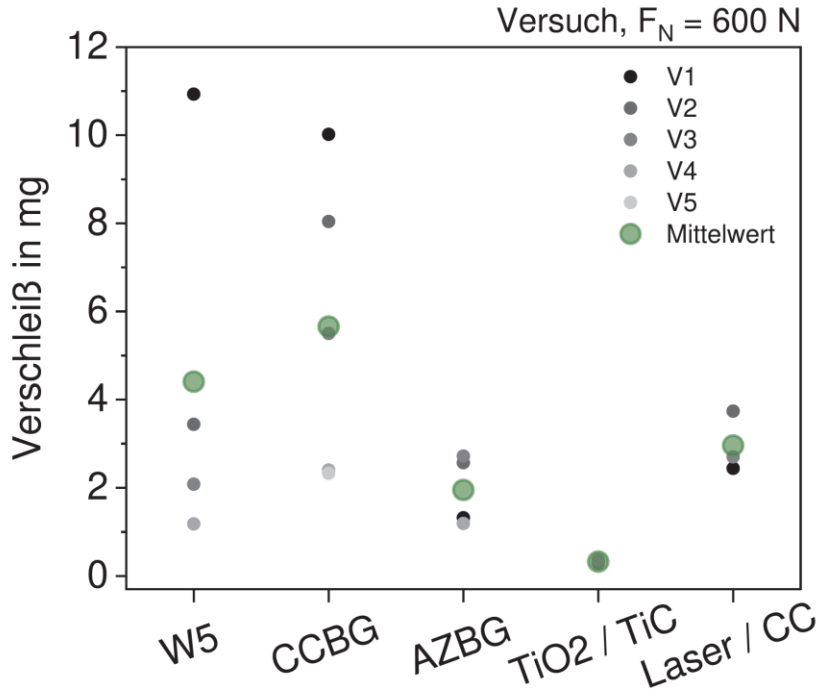


Tribological optimization – Bushing (Cr3C2 / Cr2O3)

- Innovative plain bearing technology for media-lubricated systems in pumps

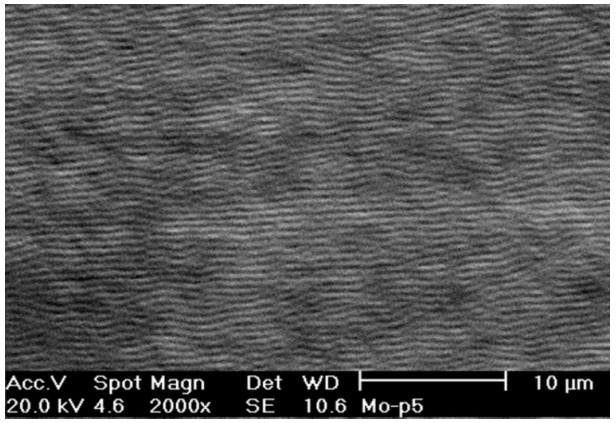
Results bearing test :



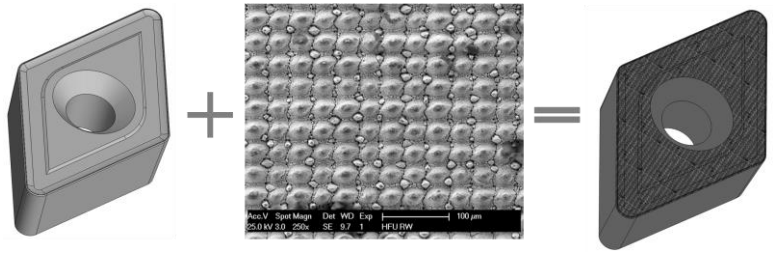


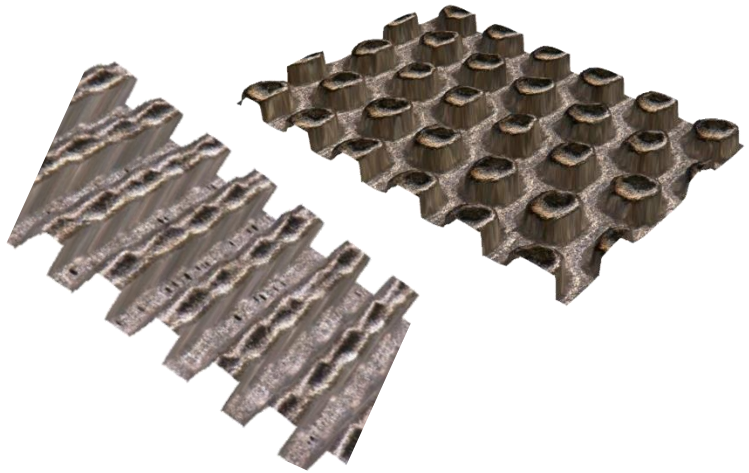
Fraunhofer IWM

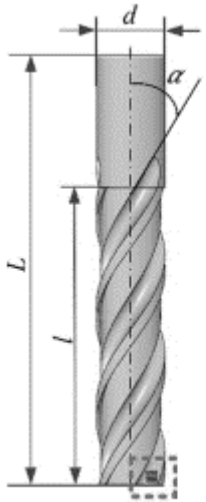
Laser structured cutting tools

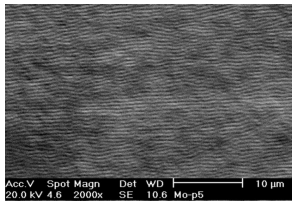


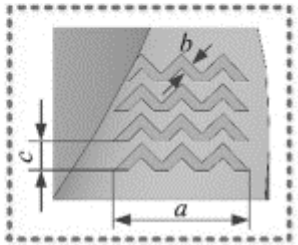
- Micro- and nanostructuring
- Coated tools
- Optimization of coating adhesion
- Tribological optimization (built-up edge, wear,...)



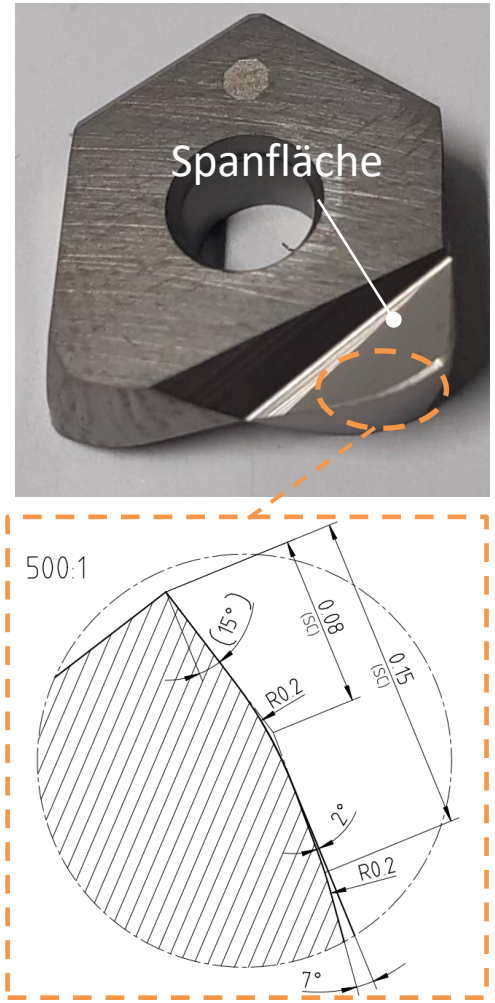




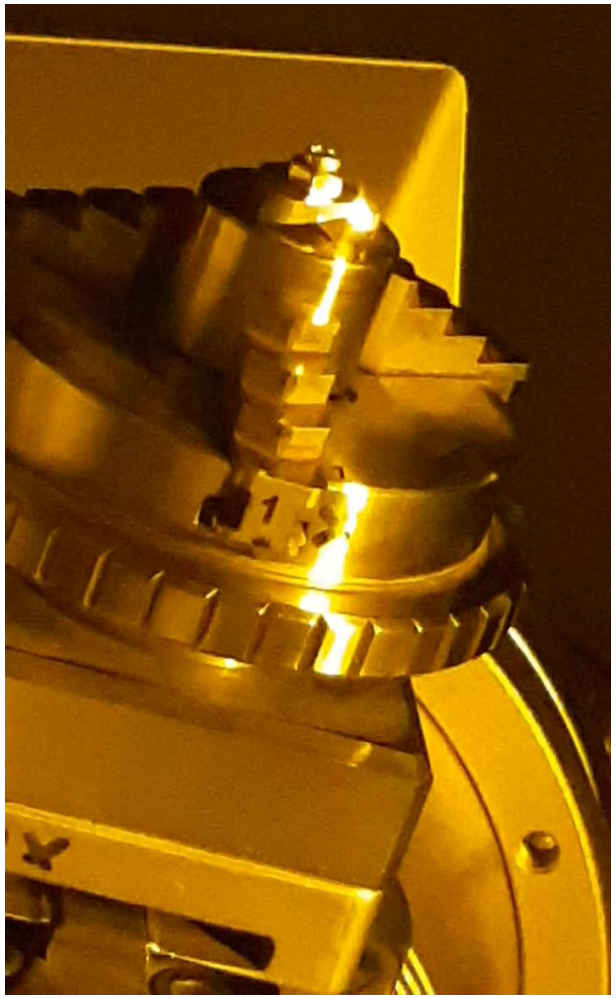




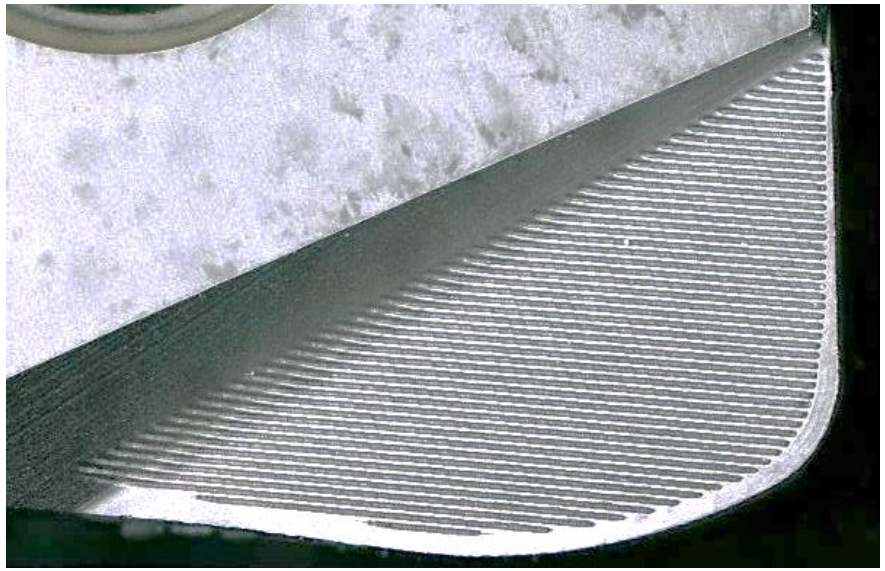
Laser structured insert



Indexable insert



Laser processing



Microstructure

Macro-geometry

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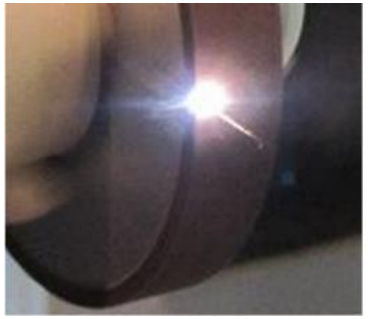
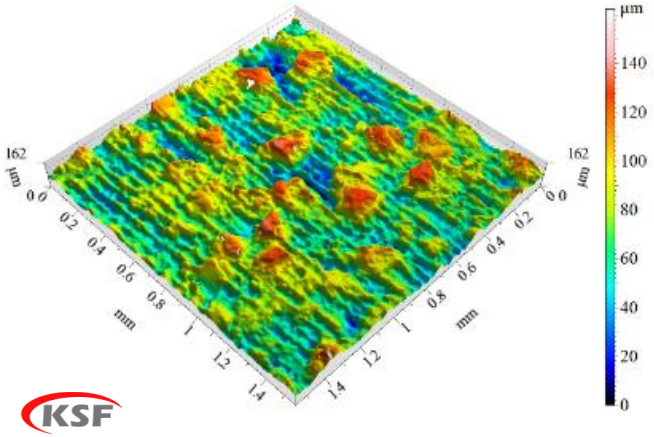
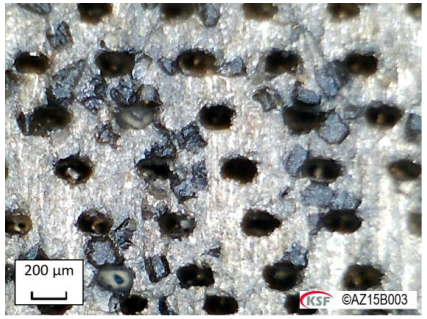
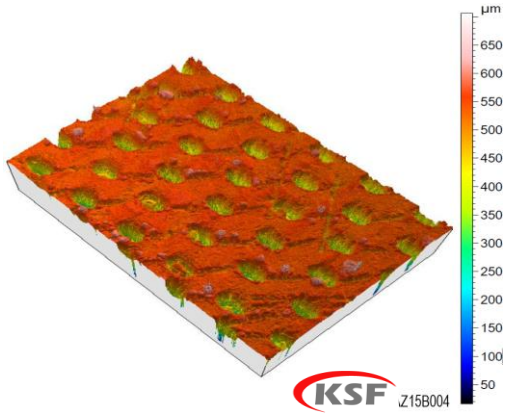
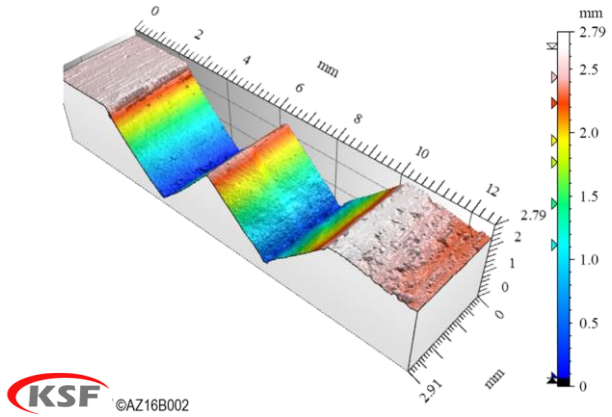
Laser conditioning of the grinding tools





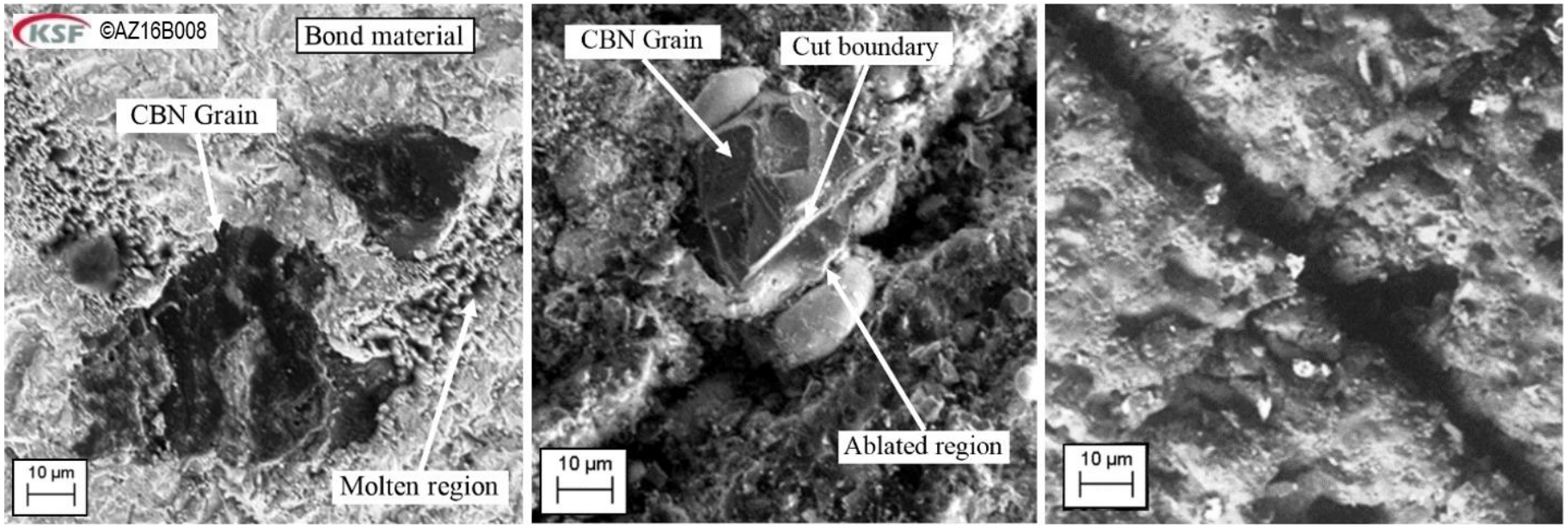






Selective processing

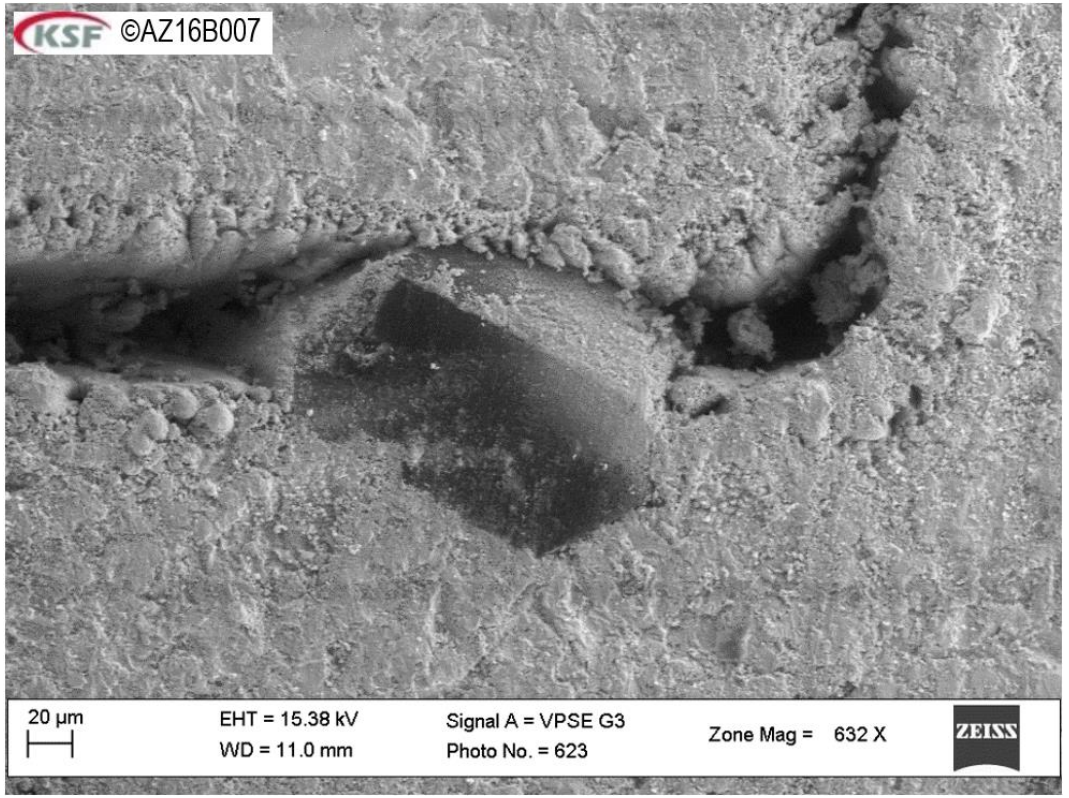
- D1A1W D:30 T:15, B91-C100



Ceramic bonded CBN grinding wheel, scanning speed: 10 mm/s Laser power:
15W (left); 25W (center); 50W (right)

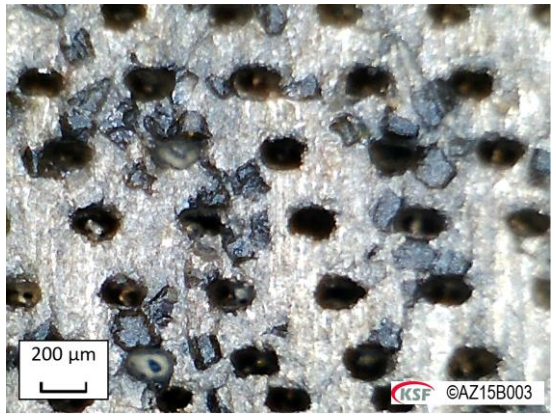
Selective processing

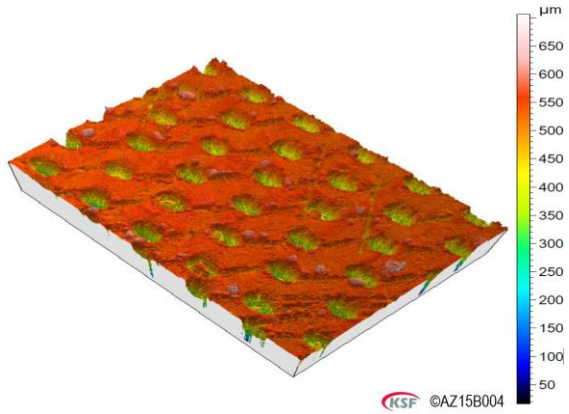
- D1A1 D:100 T:15, B151-C75-MBR,
- 50 µJ Pulse energy (20W),
- 10 mm/s Scan velocity



Laser microstructuring

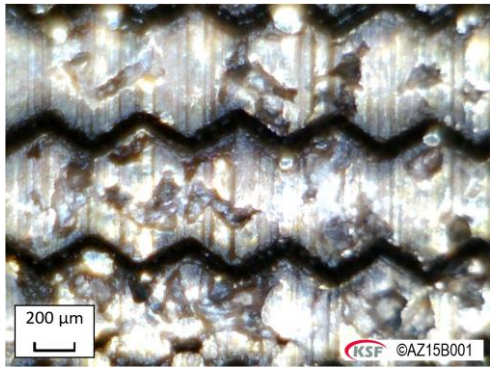
B1A1 D:100, T:10, H:20H7 - B151 C50 M, 85% contact

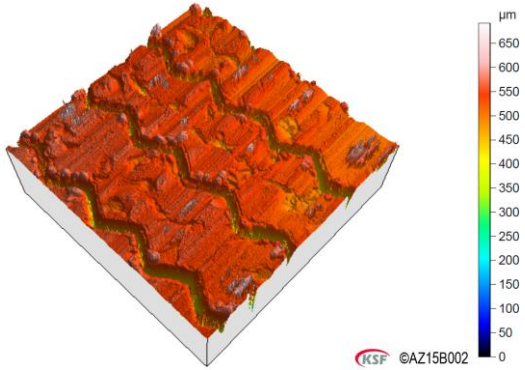




Elliptical microstructures

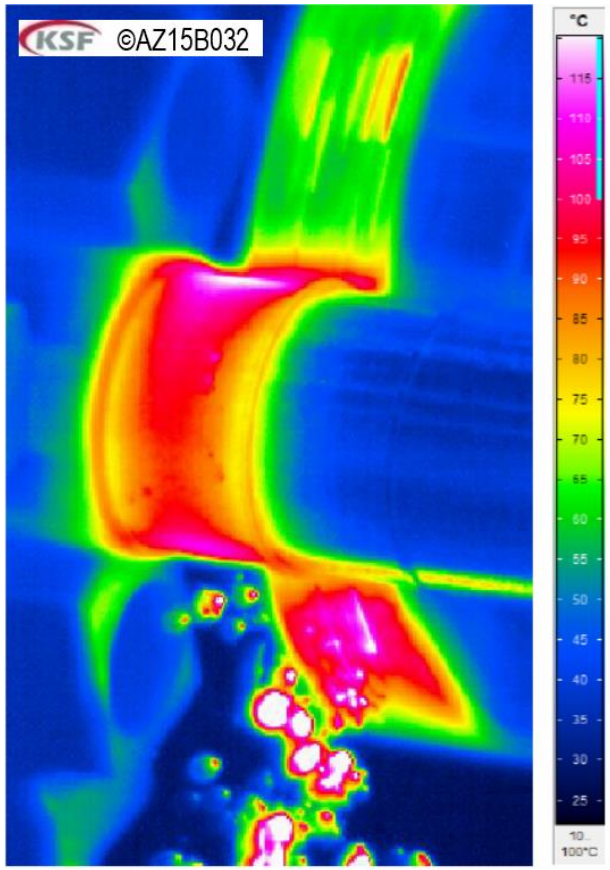
- Pulse energy (µJ): 100
- Scan velocity (mm/s): 100
- Laser frequency (kHz): 400
- Structure depth: ca. 400 µm

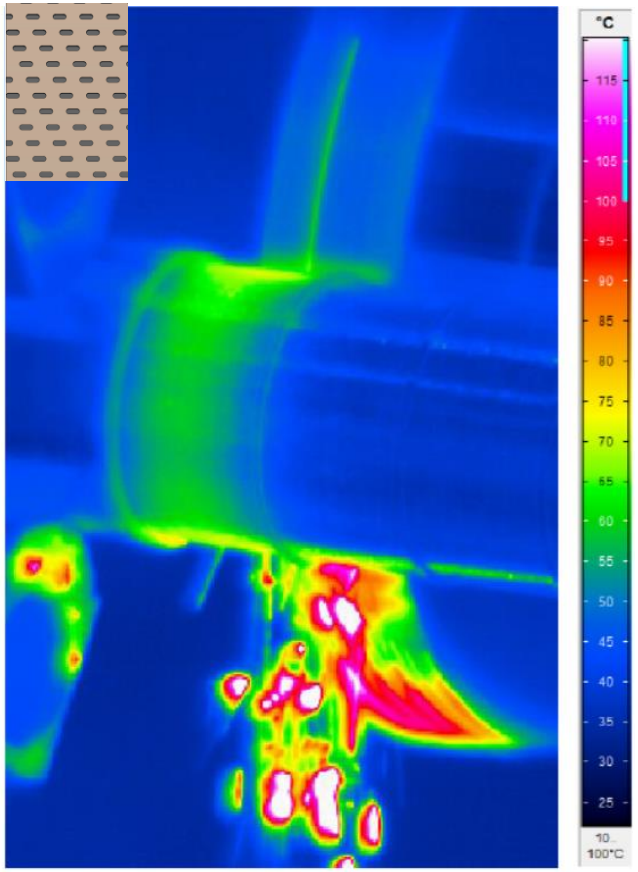




Zigzag microstructures

Laser microstructuring





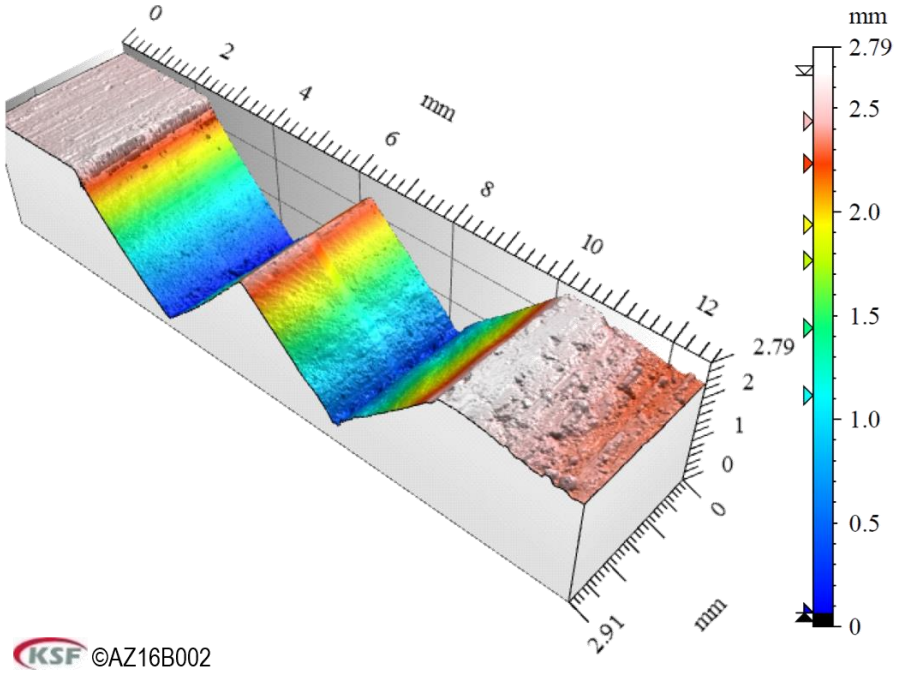
Grinding wheel
B1A1 D:100 T:15
B151 C75 MB

Workpiece
100Cr6 , 56 HRC

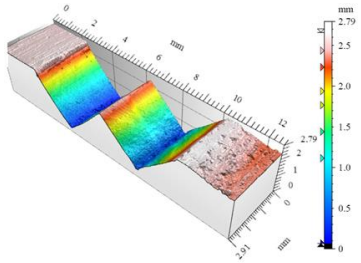
Grinding paramter
v_s = 50 m/s
v_{fr} = 1 mm/min
q_s = -60 (Gegenlauf)

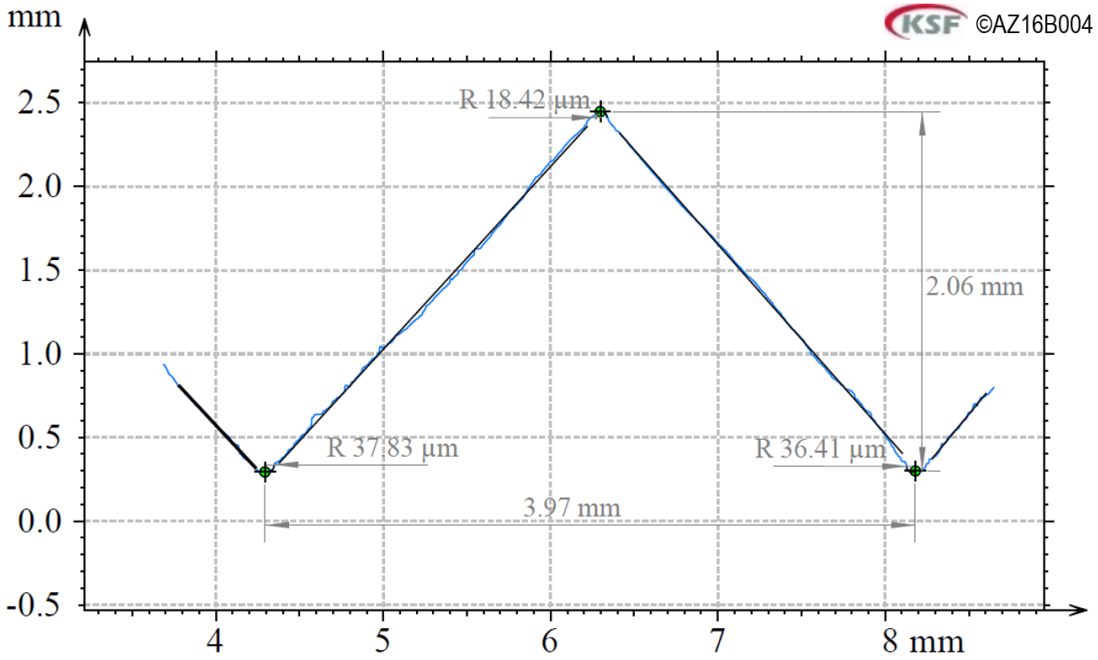
Dry Grinding

Laser Profiling

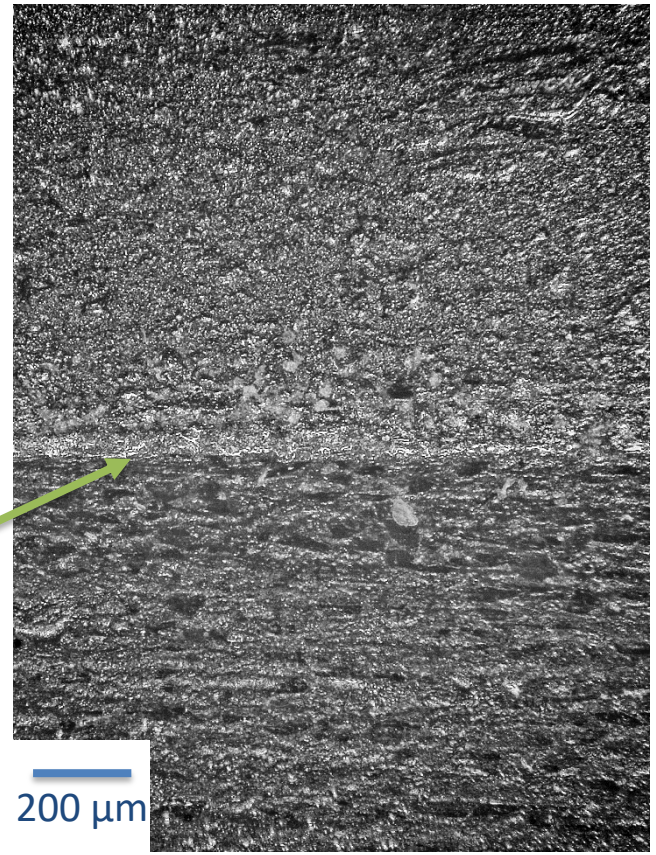


Laser Profiling

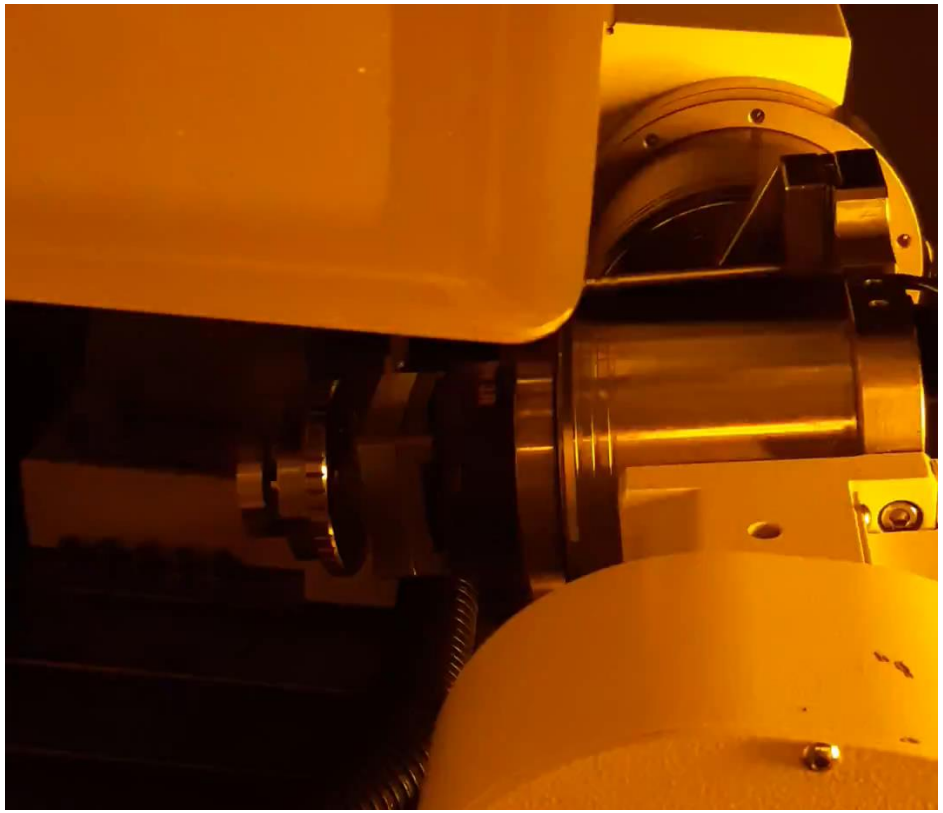




- D1A1 D:80 T:5, D76-C50-MBR
- Pulse energy: 100 µJ
- Scan velocity: 200 mm/s



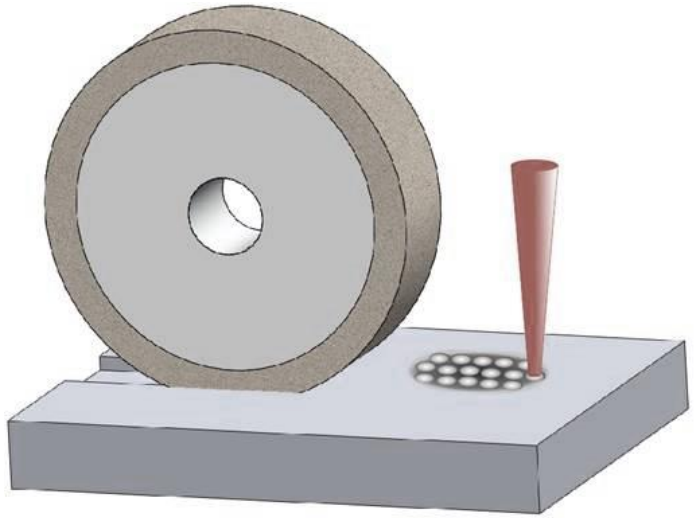
Laser Profiling

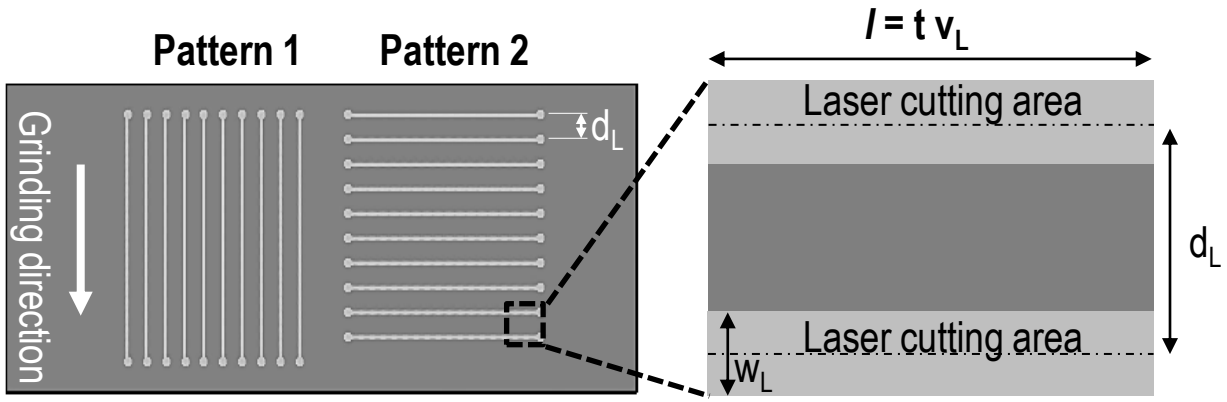


5-axis UKP laser machining - project (KSF/GF)

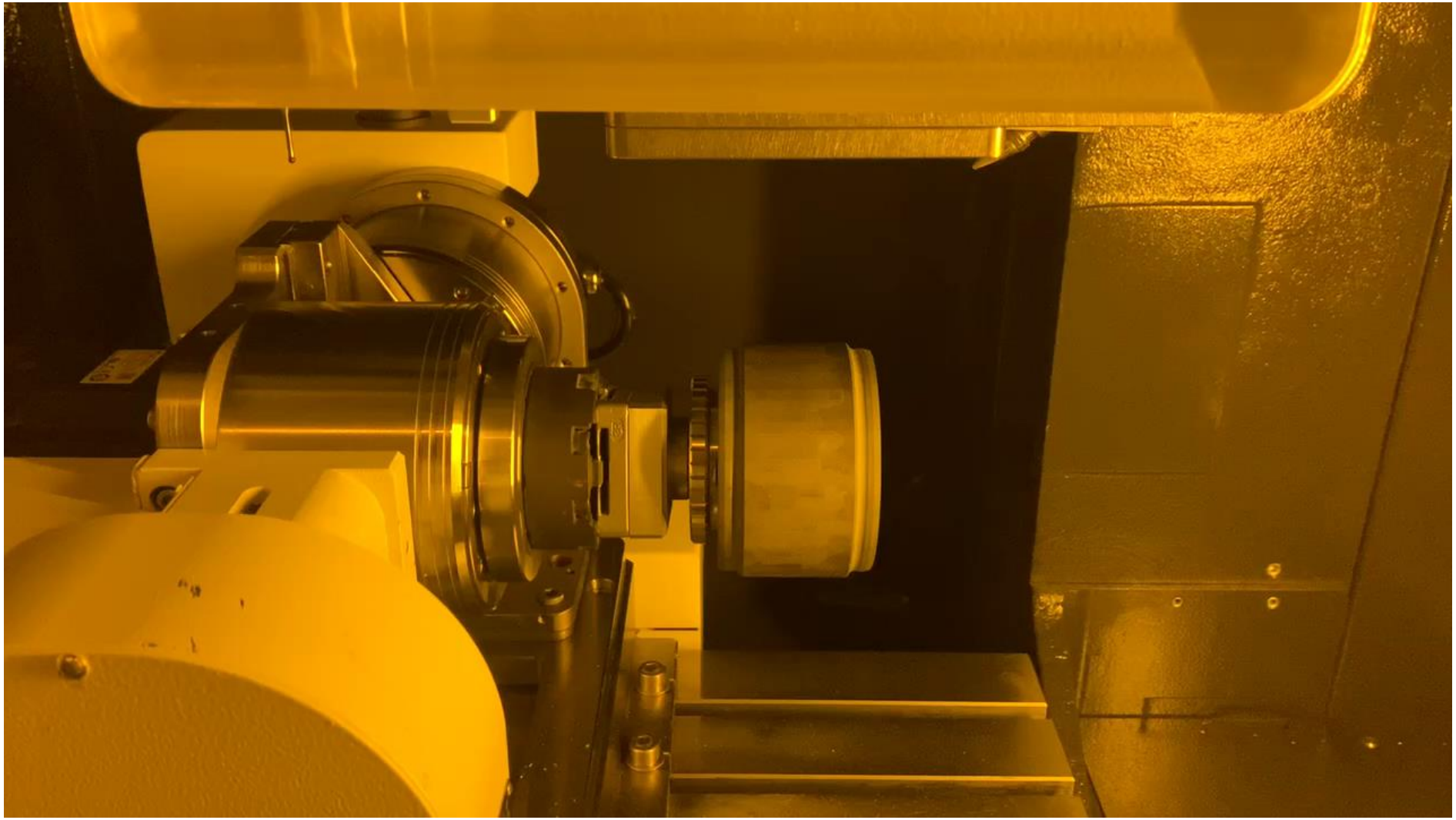
- Introduction and motivation
- Micro- and sub-microstructuring of functional surfaces
  - Superhydrophobic and superhydrophilic surfaces
- Micromachining and tribological optimization
- Profile creation
- Laser assisted machining

Laser assisted grinding

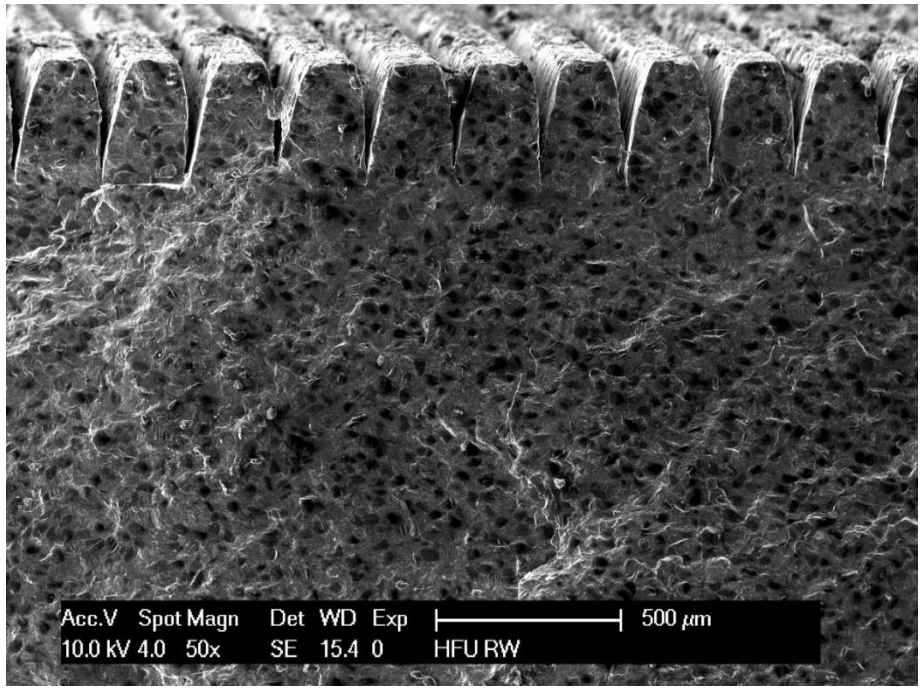




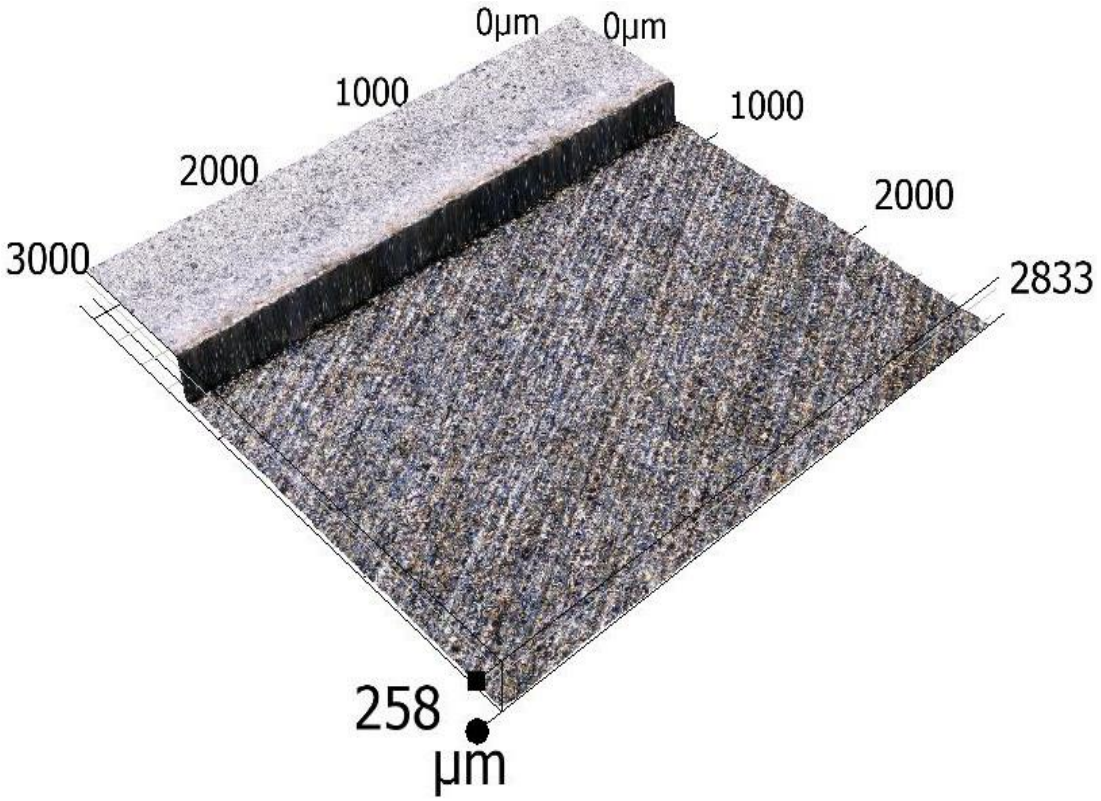
Micro structuring diamond shaft bearing sleeve

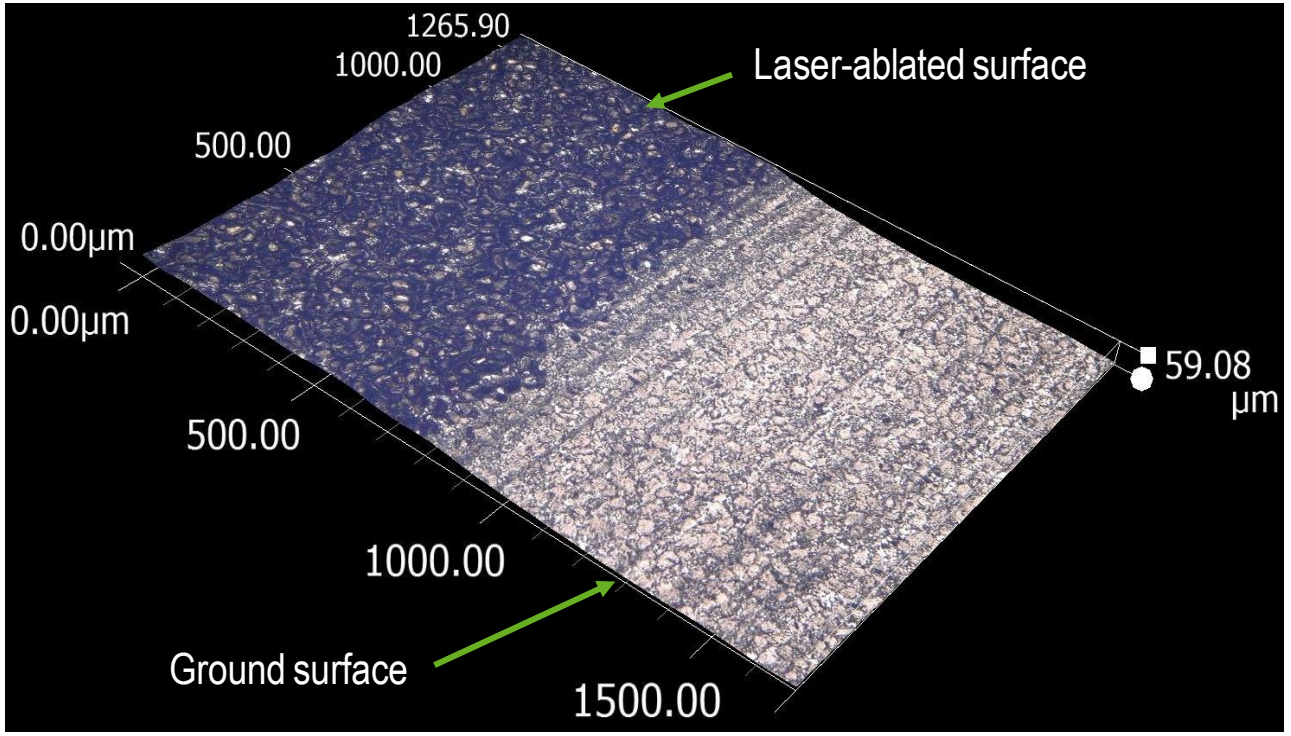


Micro structuring diamond shaft bearing sleeve

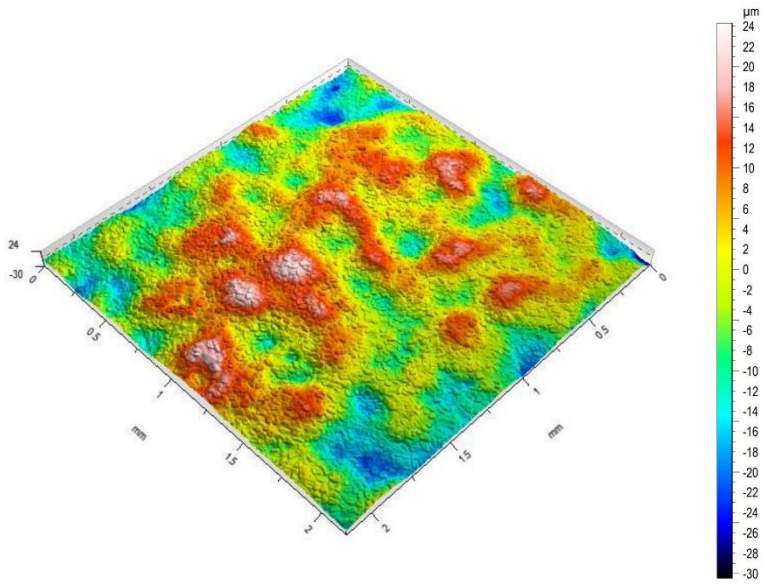


Laser-assisted grinding of shaft bearing sleeves containing diamonds

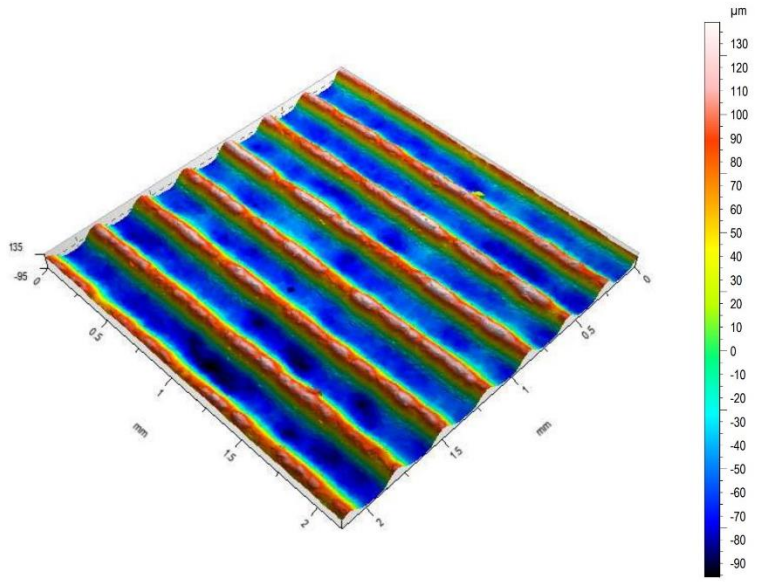




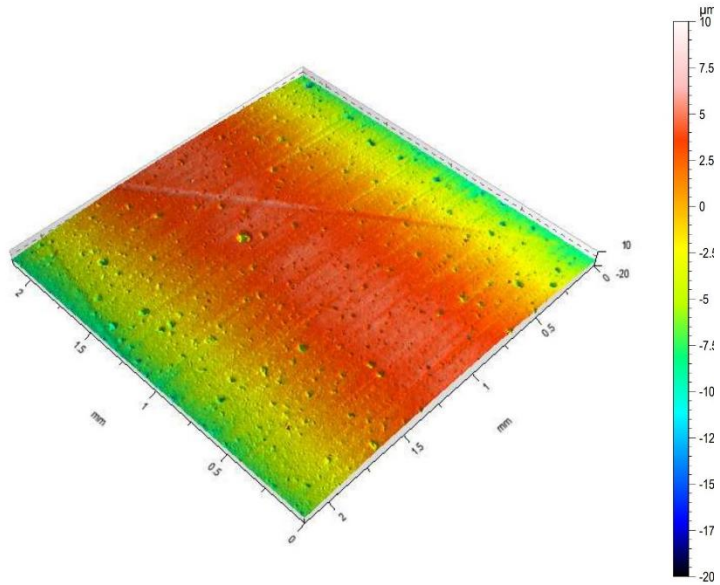
Machining shaft bearing sleeve - comparison lasered surfaces



Full ablation by laser SSiC with diamond



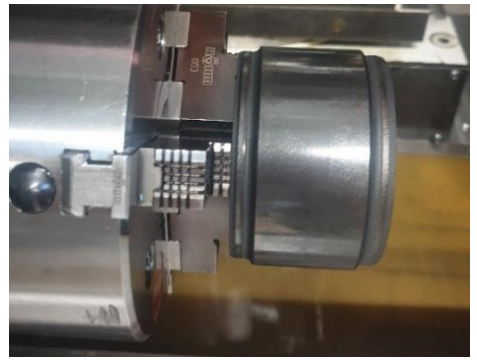
Laser textured surface

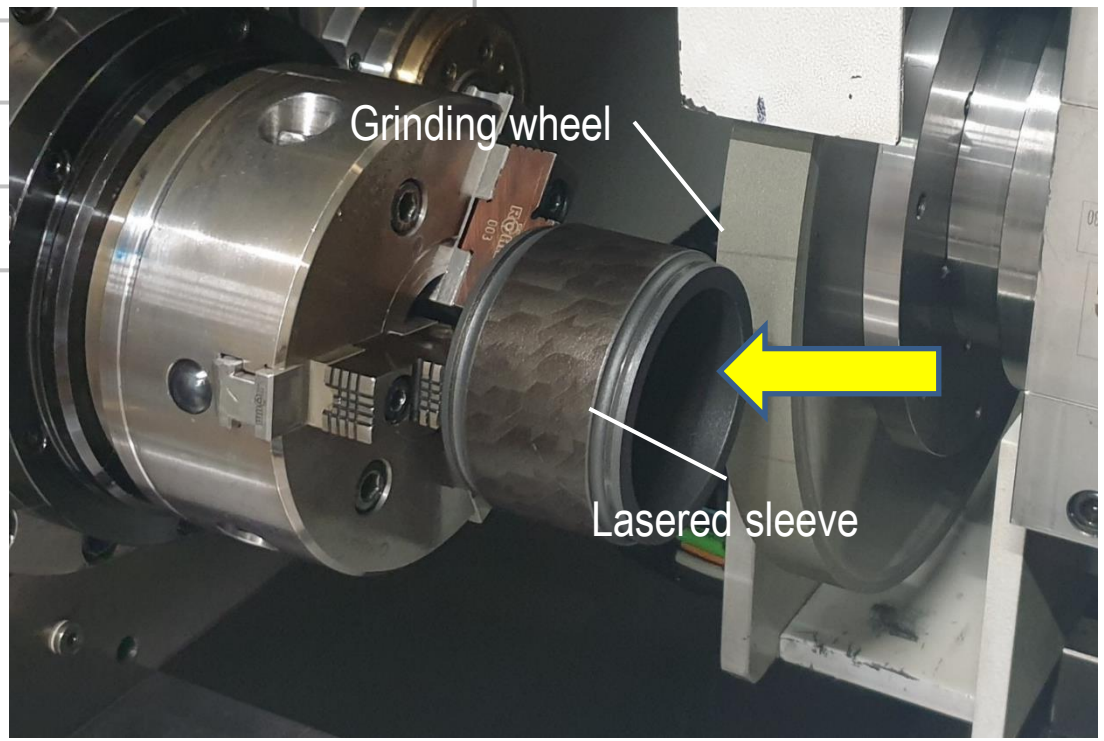


Ground surface (SSiC)

Machining shaft bearing sleeve parameters - Current

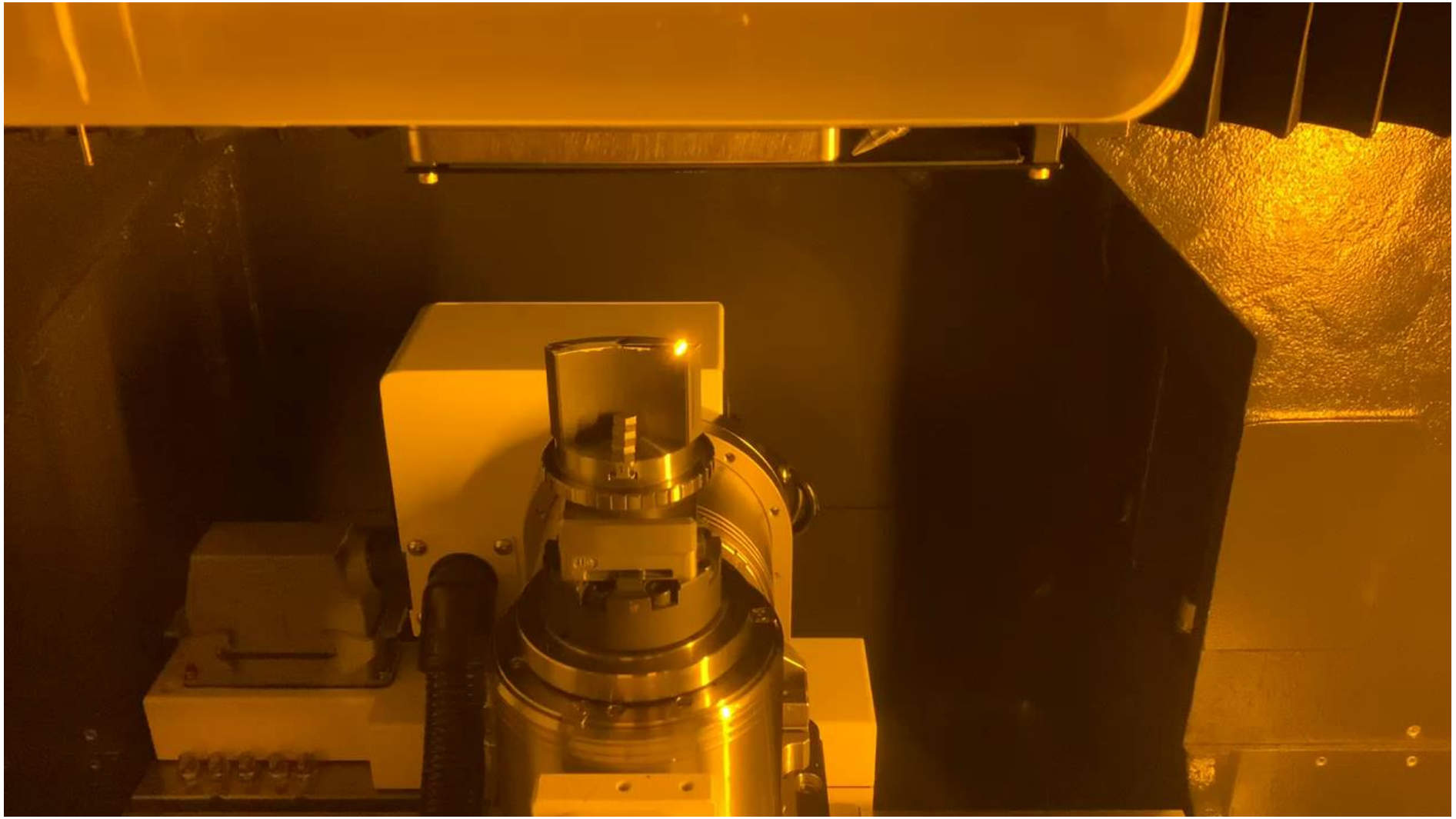
Grinding machine	Emag Karstens HG 204 Cylindrical Grinding Machine
Grinding wheels	Ceramic bond diamond grinding wheelD64 C125 ELBE (400x30x100)
Cutting speed, v_c, [m/s]	30-50
Speed ratio qs	40-50 (counter run)
Radial feed, v_{fr}, [mm/min]	0,001 – 0,005
Cooling lubricant	Öl





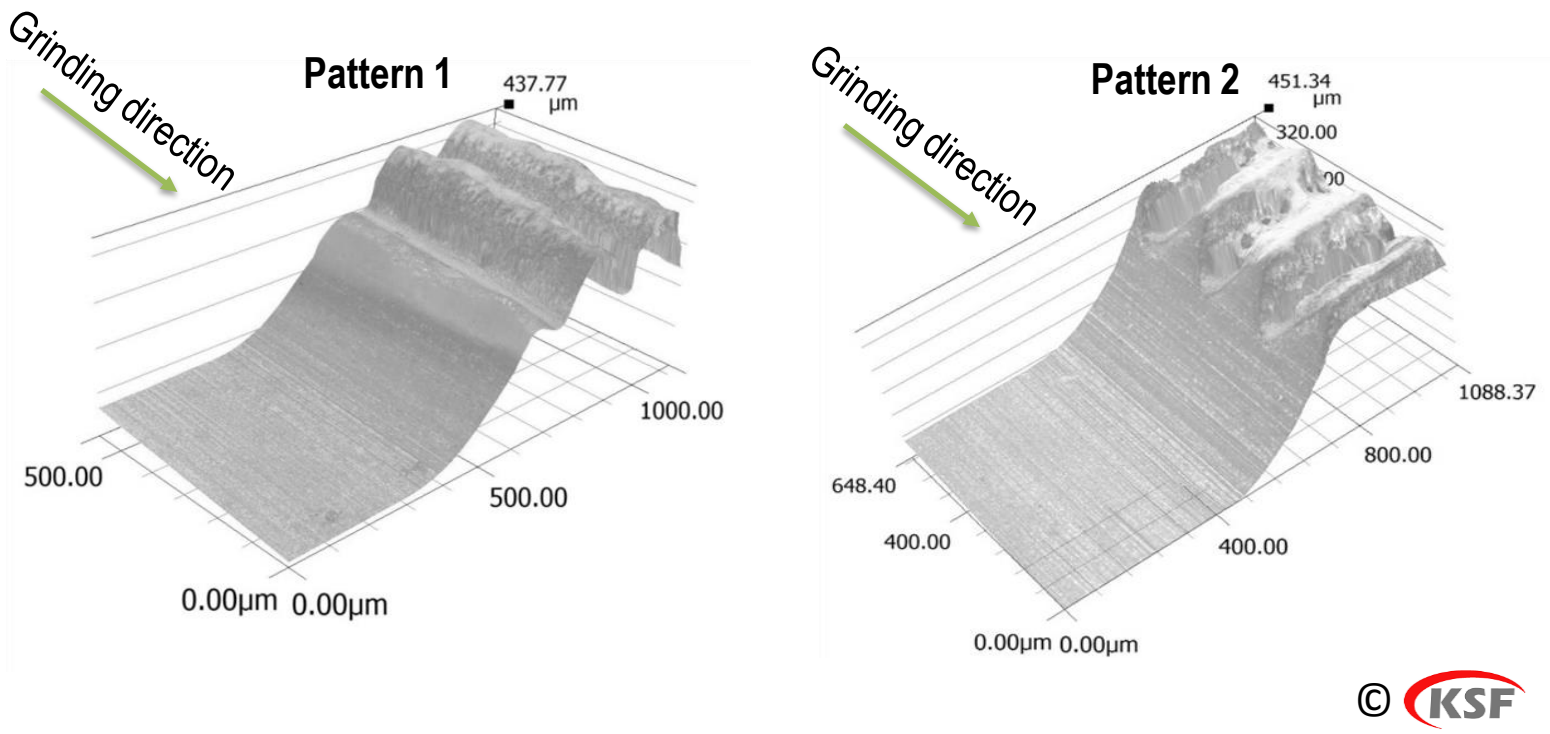
- High wear of the grinding wheel
- Regulated and small grinding forces
- Good surface quality

Laser processing segments



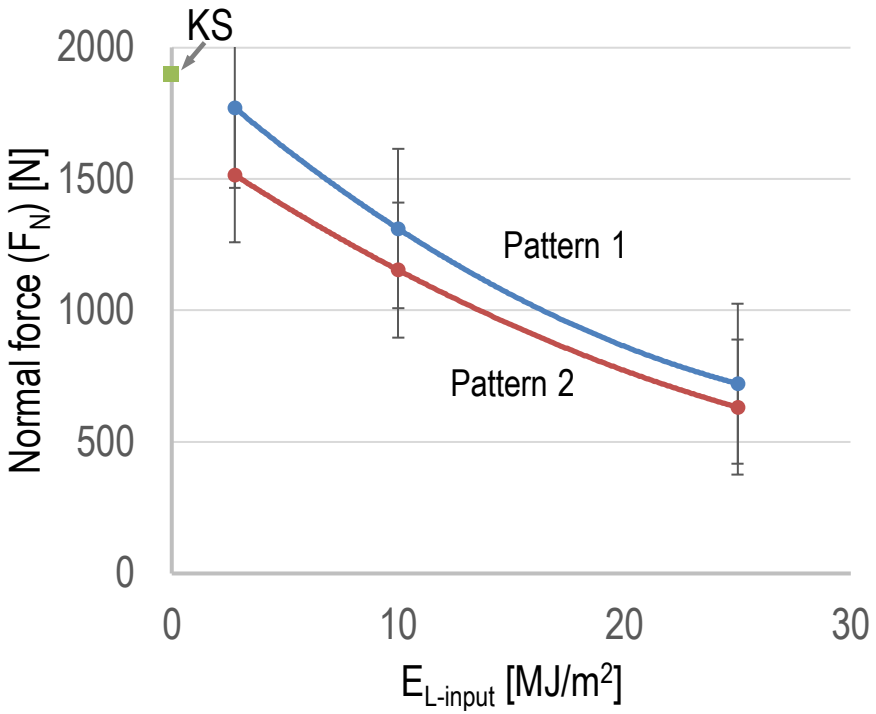
Laser assisted grinding of Si_3N_4

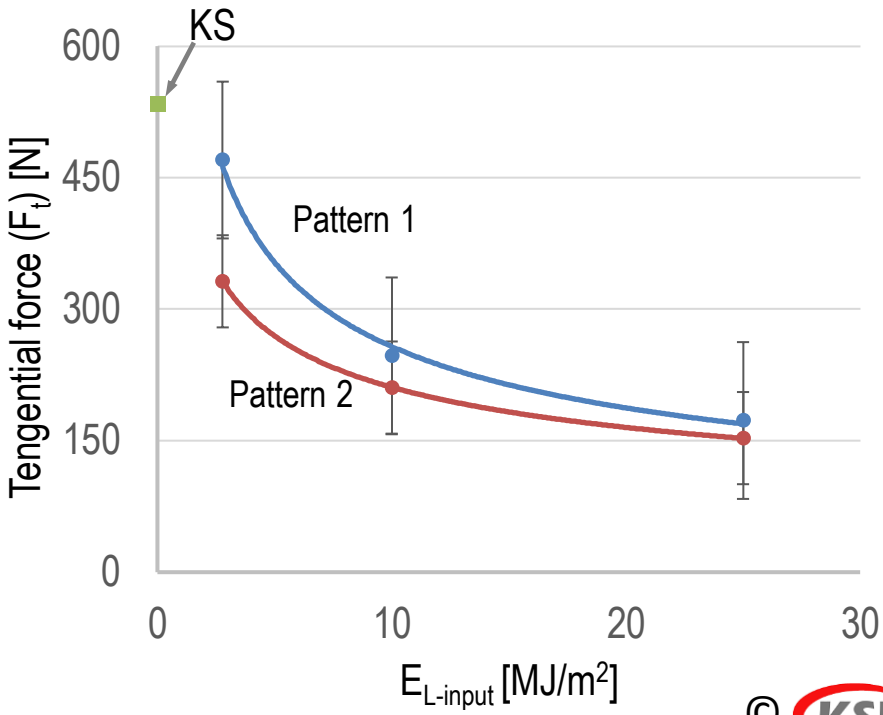
Grinding wheel	Workpiece	Grinding parameters	Laser parameters
D126 C100 M, D1A1 D:400 T:19	Si_3N_4 **Emulsion 50 l/min**	v_s = 30 m/s v_{ft} = 1 m/min a_e = 0,5 mm	v_L = 10 mm/s P_L = 50 W t_{pulse} = 10 ps



Laser assisted grinding of Si_3N_4 - Grinding forces

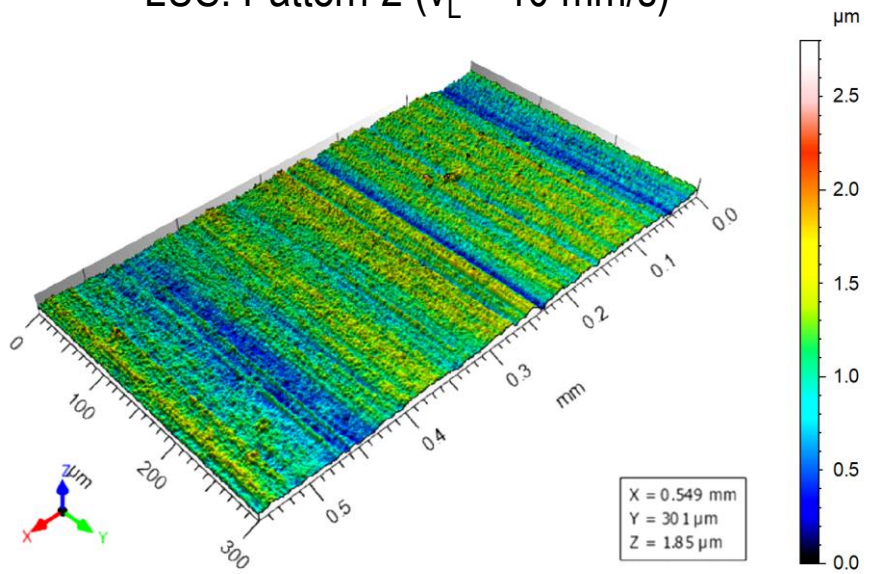
Grinding wheel	Workpiece	Grinding paramters	Laser paramters
D126 C100 M, D1A1 D:400 T:19	Si_3N_4 **Emulsion 50 l/min**	v_s = 30 m/s v_{ft} = 1 m/min a_e = 0,5 mm	v_L = 10, 100 mm/s P_L = 50 W t_{pulse} = 10 ps

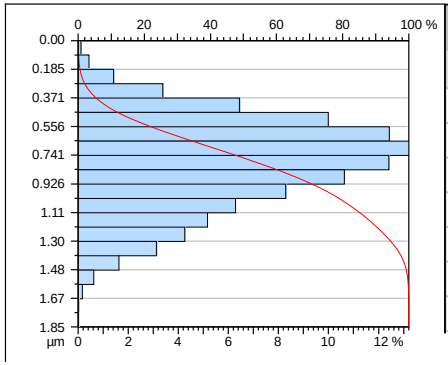




Laser assisted grinding of Si_3N_4 - Surface quality

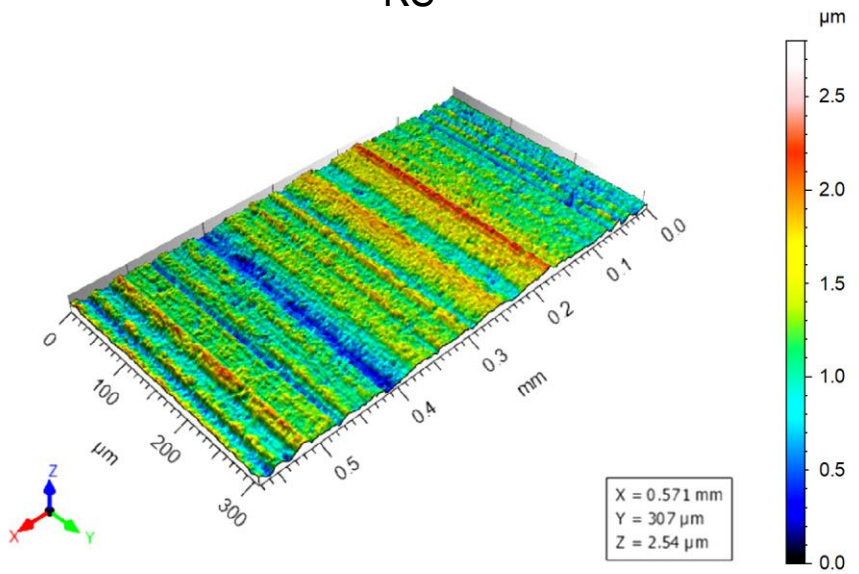
LUS: Pattern 2 (v_L = 10 mm/s)

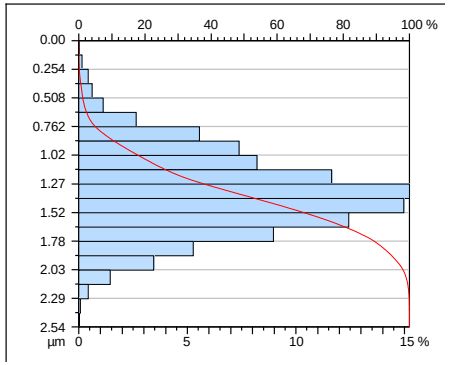




ISO 25178		
Höhen-Parameter		
Sa	0.231	µm
Sq	0.285	µm
Sz	1.85	µm
Ssk	-0.35	
Sku	2.67	
Sp	0.789	µm
Sv	1.06	µm

KS

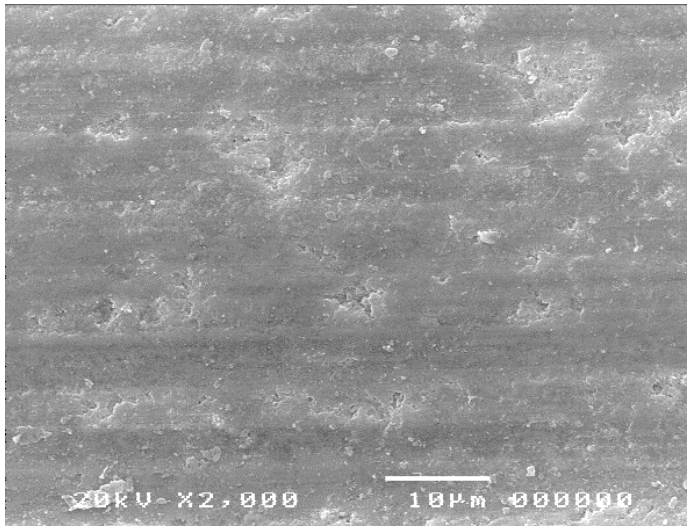




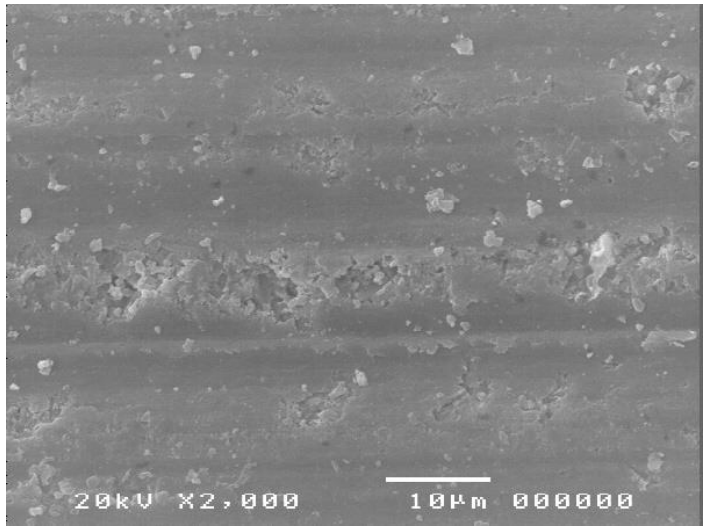
ISO 25178		
Höhen-Parameter		
Sa	0.278	µm
Sq	0.351	µm
Sz	2.54	µm
Ssk	0.227	
Sku	2.95	
Sp	1.35	µm
Sv	1.19	µm

Laser assisted grinding of Si_3N_4 - Surface quality

Grinding wheel	Workpiece	Grinding parameters	Laser parameters
D126 C100 M, D1A1 D:400 T:19	Si_3N_4 **Emulsion 50 l/min**	v_s = 30 m/s v_{ft} = 1 m/min a_e = 0,5 mm	v_L = 10 mm/s P_L = 50 W t_{pulse} = 10 ps



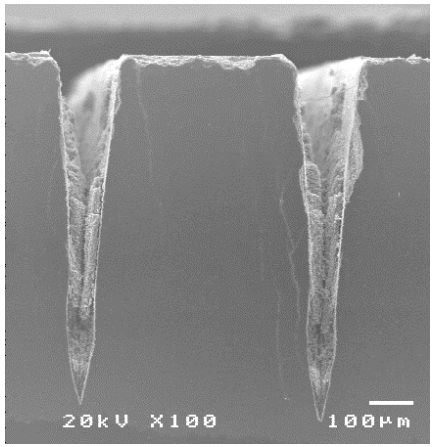
LUS: Pattern 2



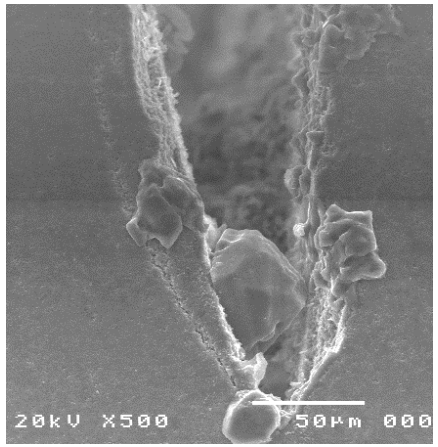
KS

Laserunterstütztes Schleifen von Si_3N_4 - Randzonenbeeinflussung

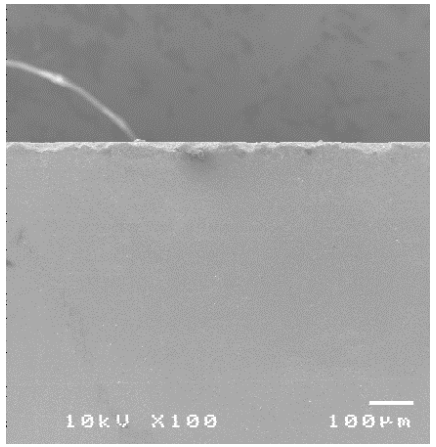
Grinding wheel	**Workpiece**	**Grinding parameters**	**Laser parameters**
D126 C100 M, D1A1 D:400 T:19	Si_3N_4 **Emulsion 50 l/min**	v_s = 30 m/s v_{ft} = 1 m/min a_e = 0,5 mm	v_L = 10, 100 mm/s P_L = 50 W t_{pulse} = 10 ps



v_L = 10 mm/s
$E_{L\text{-input}}$ = 25 MJ/m2



v_L = 10 mm/s
$E_{L\text{-input}}$ = 25 MJ/m2



Ground surface
$E_{L\text{-input}}$ = 25 MJ/m2