Laserinstitut
Hochschule Mittweida

HOCHSCHULE MITTWEIDA
University of Applied Sciences

Laser Surface Texturing for Advanced Tribological Performance

Jörg Schille

Agenda

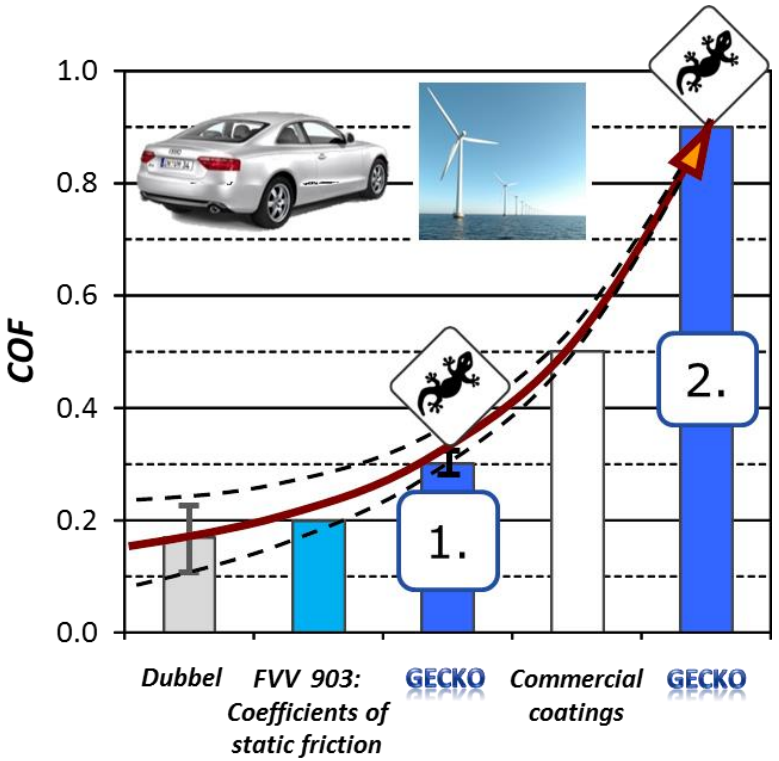
- Motivation
- Laser surface texturing
- Analysis method for CoF characterization
- Dimple-shaped micro structures
- Deep penetration welding dots
- Tribomaps

Motivation

- ***Coefficient of Friction (CoF) enhancement***

Source 1	Source 2	Source 3	Source 4	Source 5	Source 6	Source 7
dry	dry	dry	dry	uncoated	rusty	un-lubricated
0,45-0,80	0,15	0,2	0,15-0,30	0,10-0,15	0,12-0,20	0,15

KÖHLER (2005)

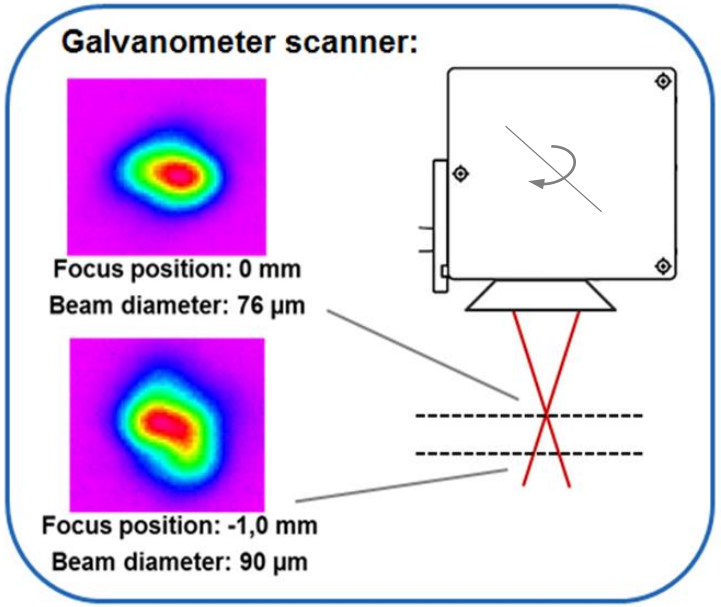


- Delivery of **reliable and stable static CoF**
- **Increase of static CoF** offers great potential to
  - ✓ decrease friction torque (seals, piston rings, thrust bearings, …)
  - ✓ increase load capacity and efficiency of tribological systems
  - ✓ save energy and material (less weight)
- Applicable in automotive, heavy industry (wind turbine, ship building, …)

⇨ *AiF/DFG Cluster:* Gestaltung und Ermittlung charakterisierender Kennwerte von reibschlussoptimierten Oberflächen (GECKO), **TP-V: Reibwerterhöhende Laserstrukturierung** (2011-2014)

⇨ *AiF:* Entwicklung von **Tribomaps** für reibwerterhöhende Laserstrukturen (seit 2019)

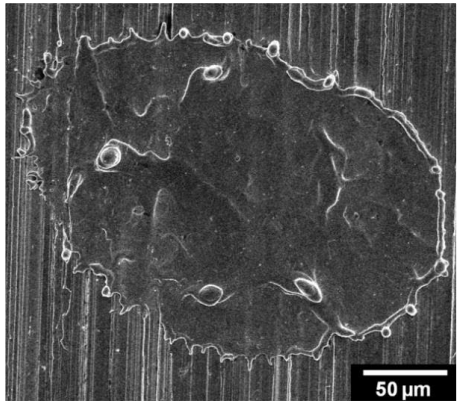
Laser surface texturing



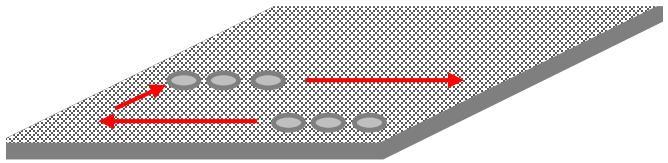
Laser system 1

- pulsed NIR laser
- pulse duration: 110 ns
- max. pulse energy: 9 mJ
- pulse repetition rate: 5 kHz
- average laser power: 45 W
- focusing lens 100 mm

Dimple-shaped micro structures



Laser beam raster scanning

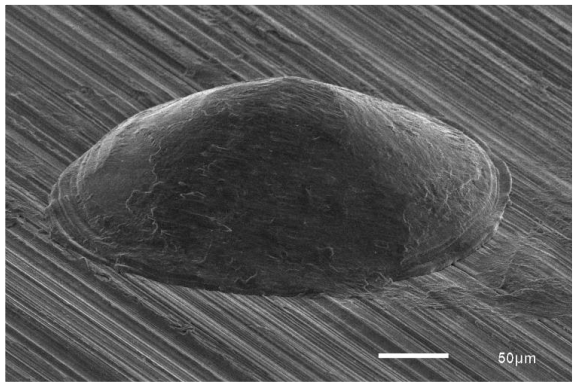


$v = d * f$

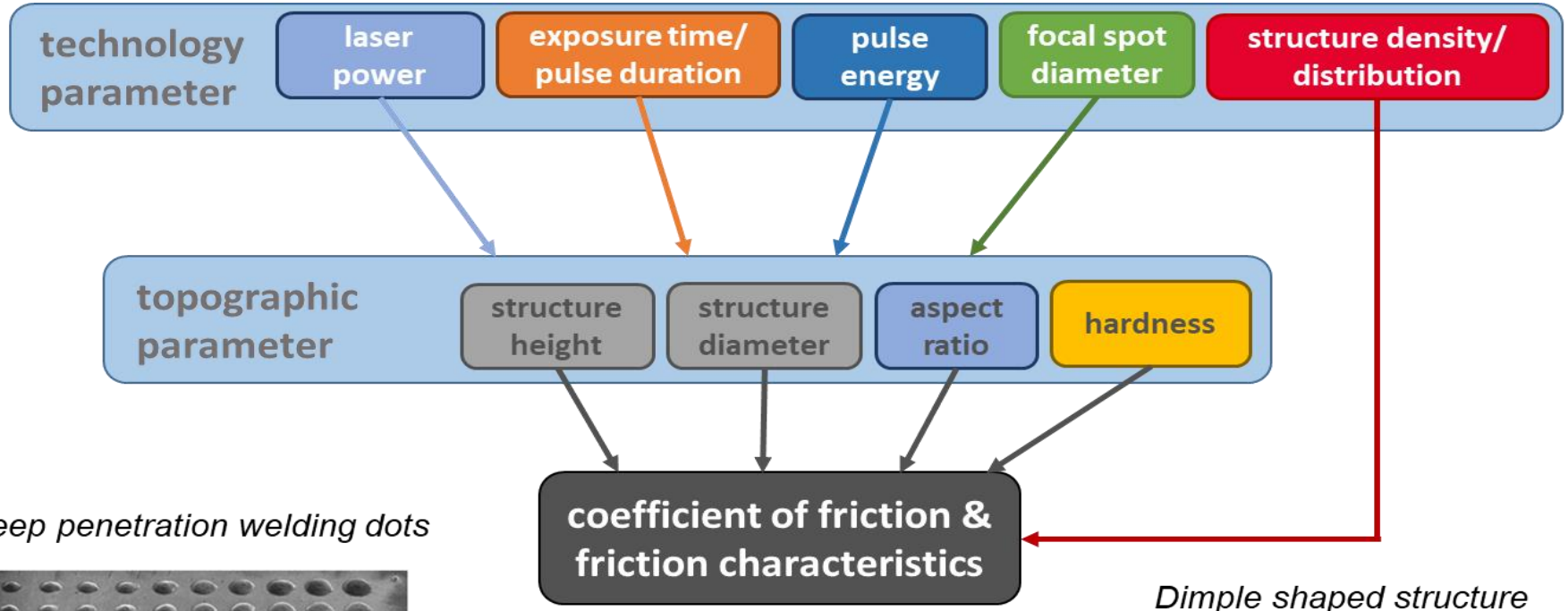
Laser system 2

- high-brillant cw fibre laser
- laser power: 1000 W
- irradiation time: 10…2000 µs
- PRF: 10 kHz

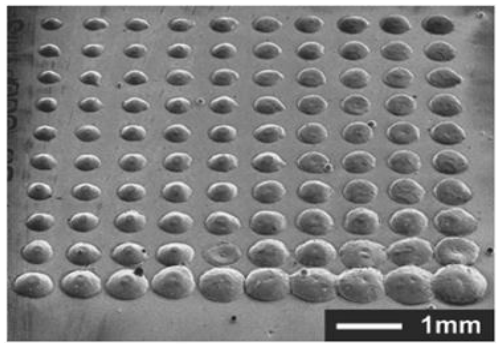
Deep welding dots



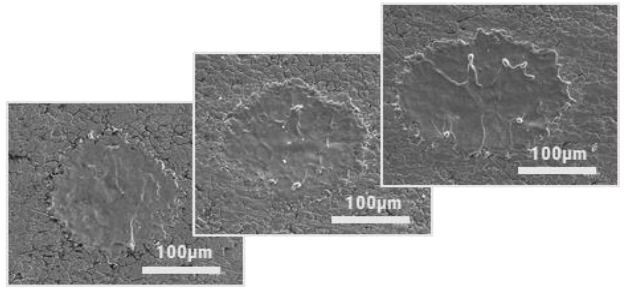
Laser surface texturing



Deep penetration welding dots

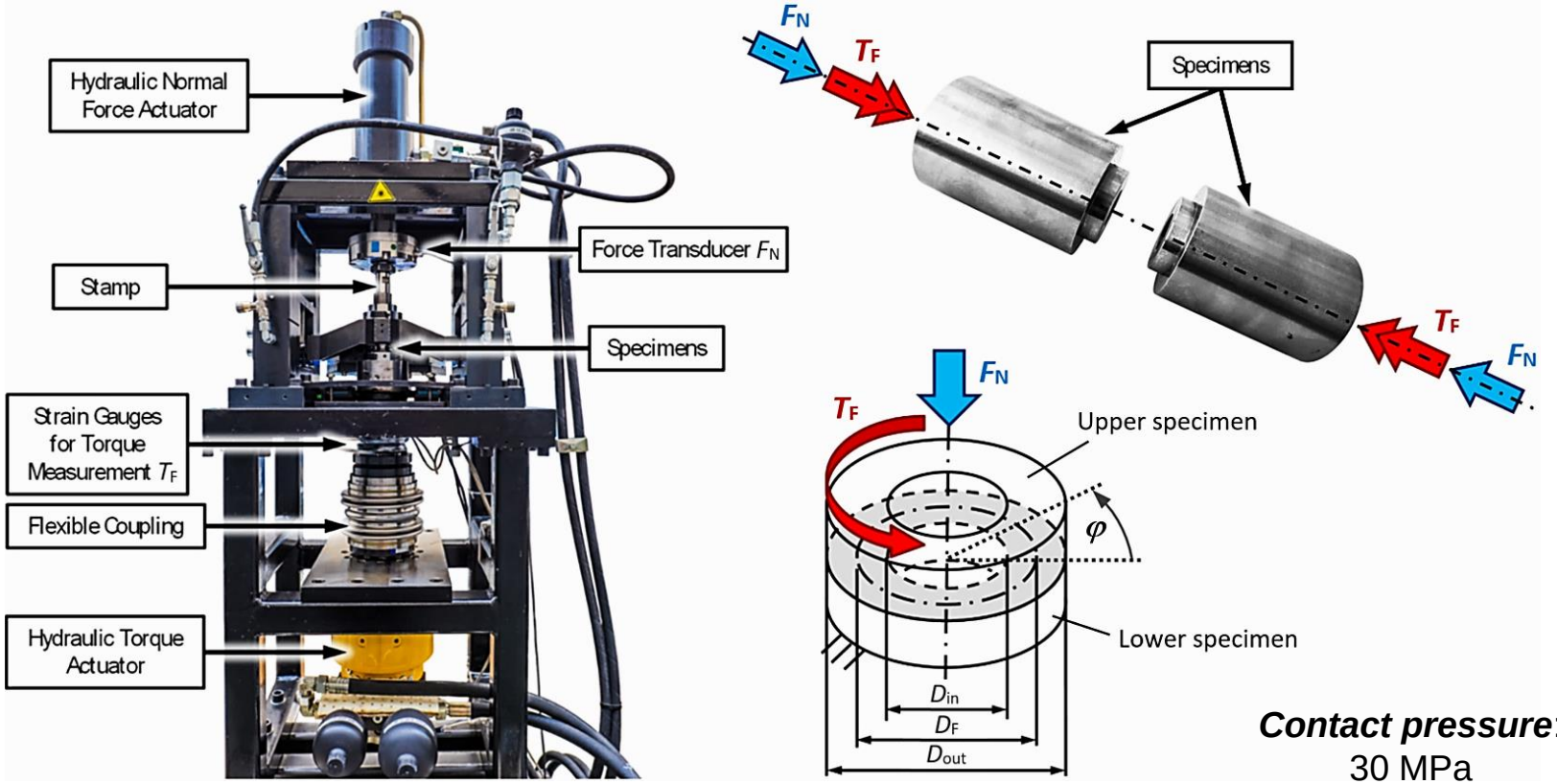


Dimple shaped structure



Analysis method for CoF characterization

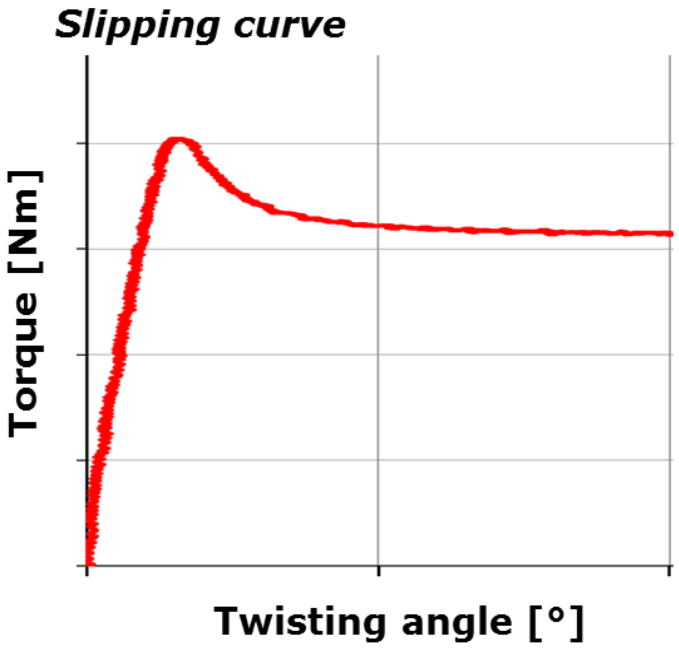
- ***Torsion test bench – IKAT TU Chemnitz***



© E. Leidich, IKAT TU Chemnitz

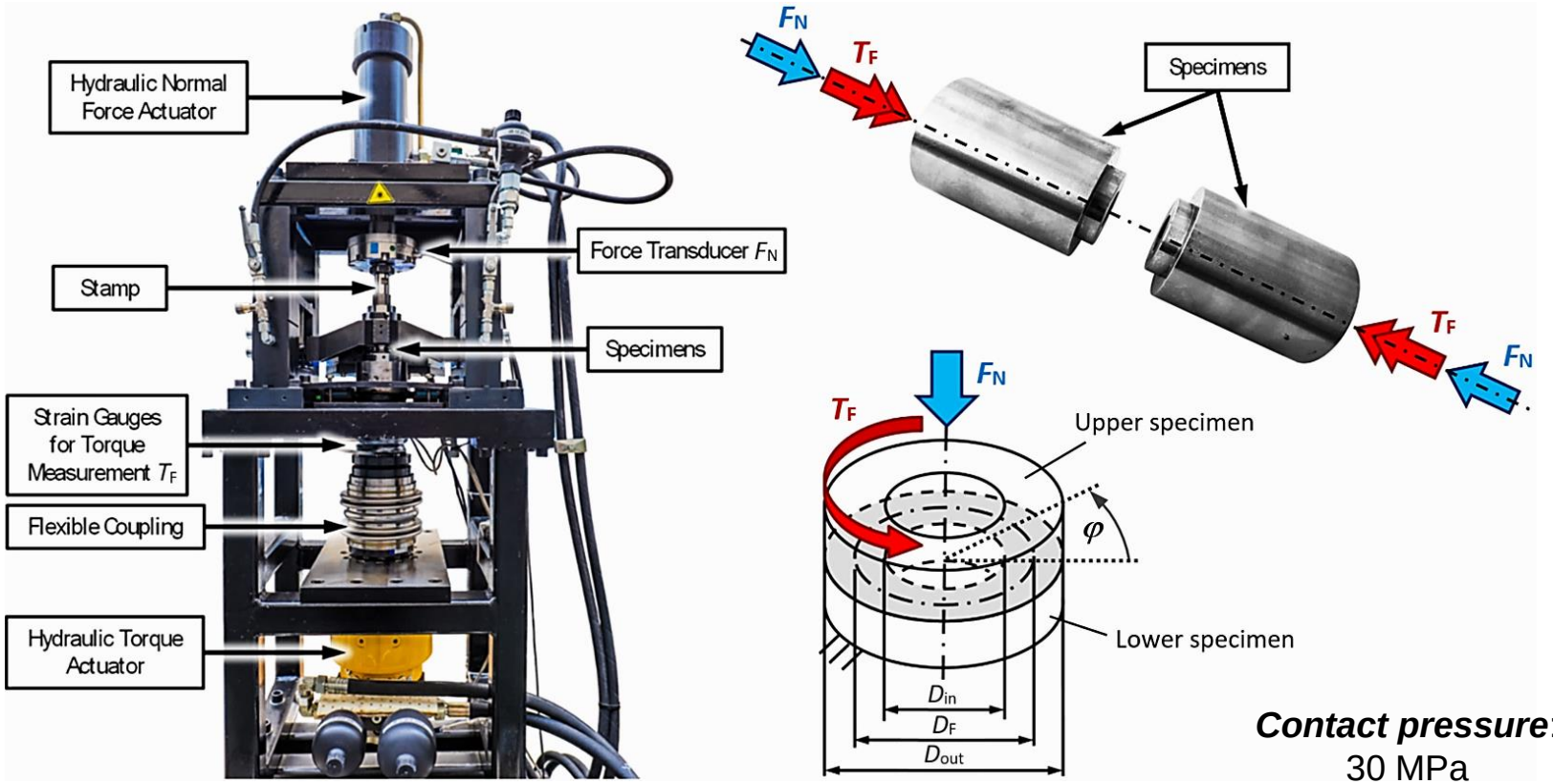
$$\mu = \frac{F_R}{F_N} = \frac{2 \cdot T_F}{D_R \cdot F_N}$$

Contact pressure:
30 MPa
100 MPa
300 MPa



Analysis method for CoF characterization

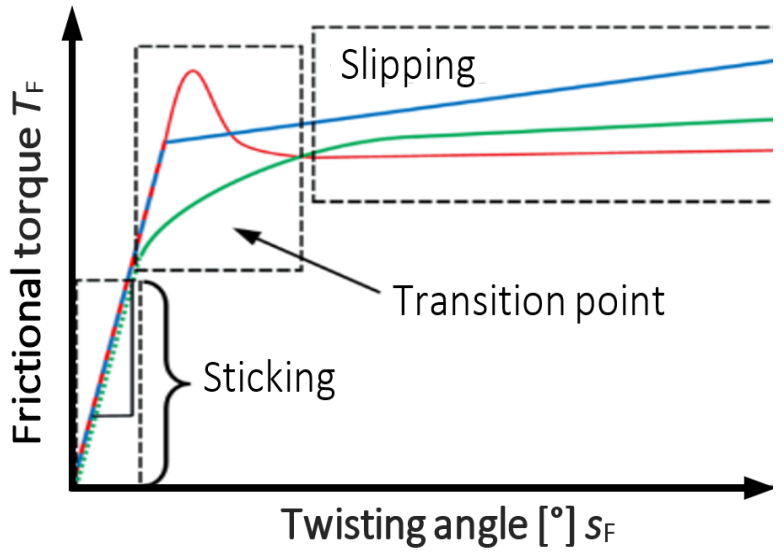
- ***Torsion test bench***



© E. Leidich, IKAT TU Chemnitz

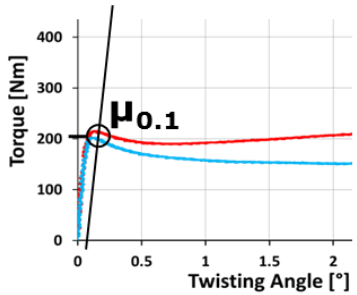
$$\mu = \frac{F_R}{F_N} = \frac{2 \cdot T_F}{D_R \cdot F_N}$$

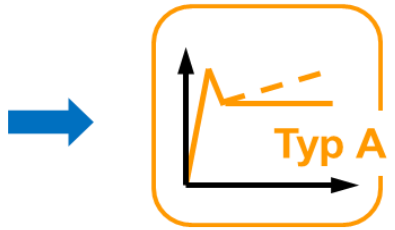
Contact pressure:
30 MPa
100 MPa
300 MPa



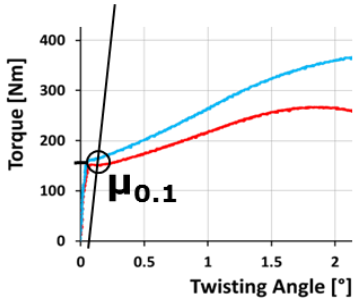
Analysis method for CoF characterization

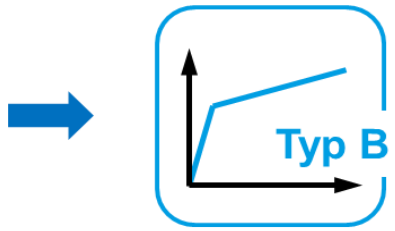
- ***Types of friction characteristic***



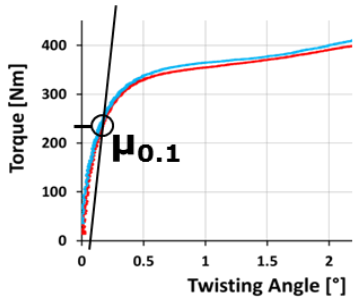


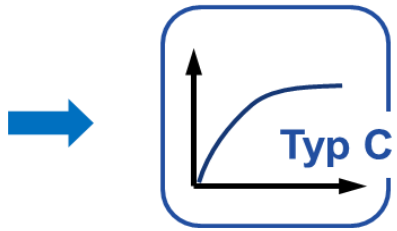
local maximum at transition point from sticking to sliding; decreasing slipping curve after reaching transition point;
COF may increase again





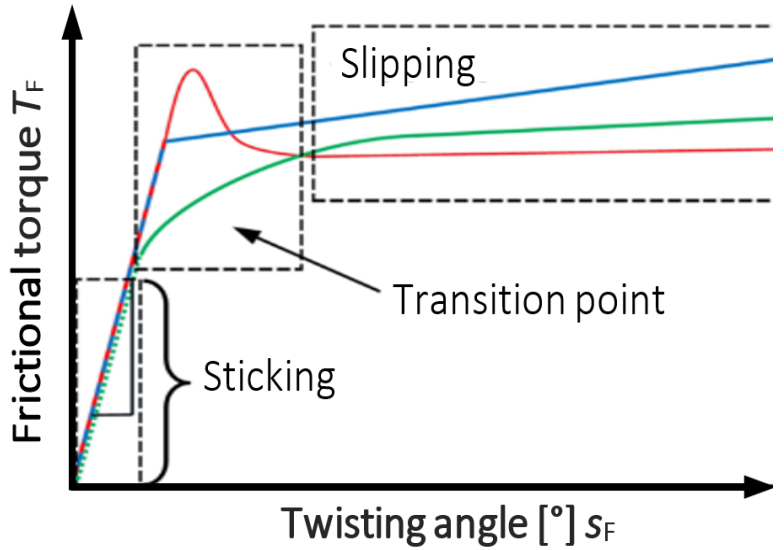
abrupt transition between sticking and sliding, stable or increasing COF after reaching the transition point





continuous transition of the slipping curve from sticking to sliding (kinetic COF))

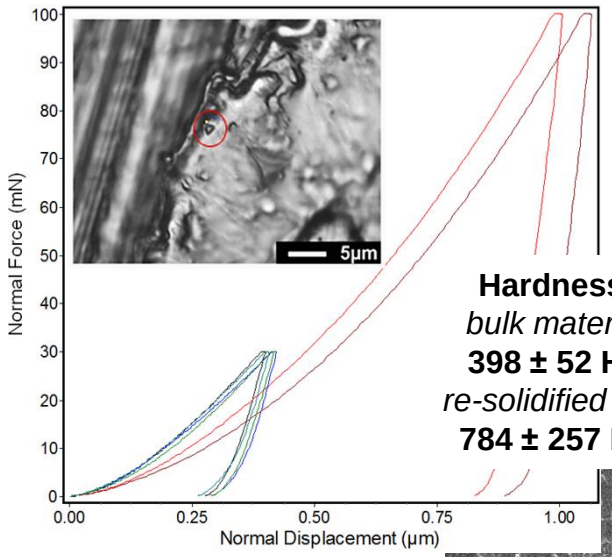
$$\mu = \frac{F_R}{F_N} = \frac{2 \cdot T_F}{D_R \cdot F_N}$$



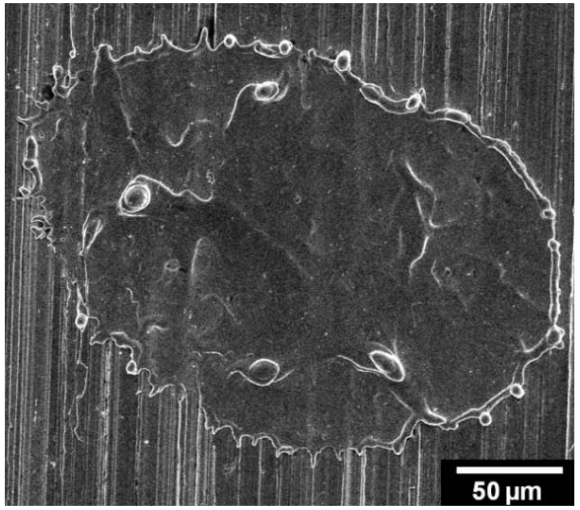
Schille et al.: High-Rate Laser Surface Texturing for Advanced Tribological Functionality. *Lubricants* **2020**, *8*, 33.

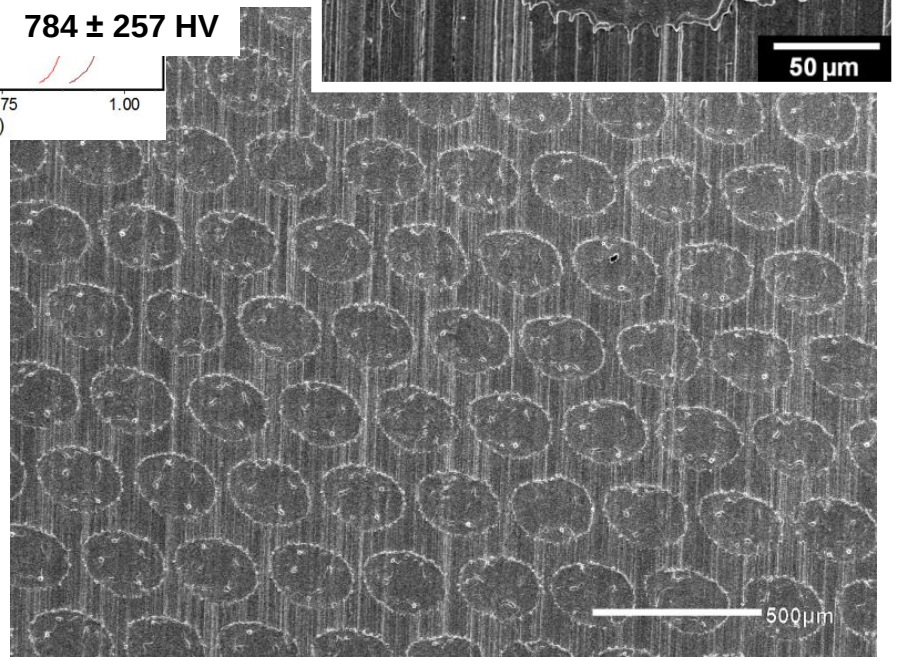
Dimple-shaped micro structures

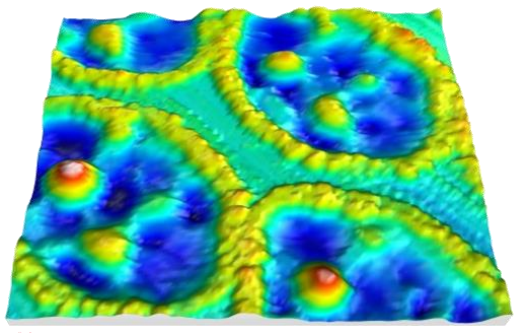
- ***Characteristic***
  - dimple-shaped micro structures (Ø 200 µm)
  - molten and re-solidified wall structure
  - plasma melt dynamics
    - ✓ energy → melting
    - ✓ intensity → plasma



Hardness:
bulk material
398 ± 52 HV
re-solidified wall
784 ± 257 HV

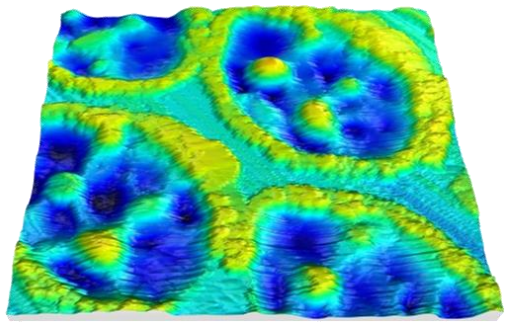






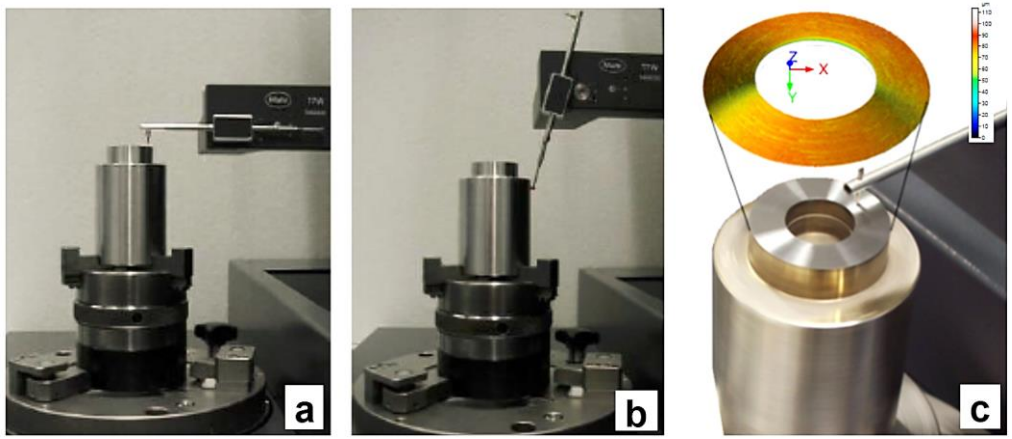
COF

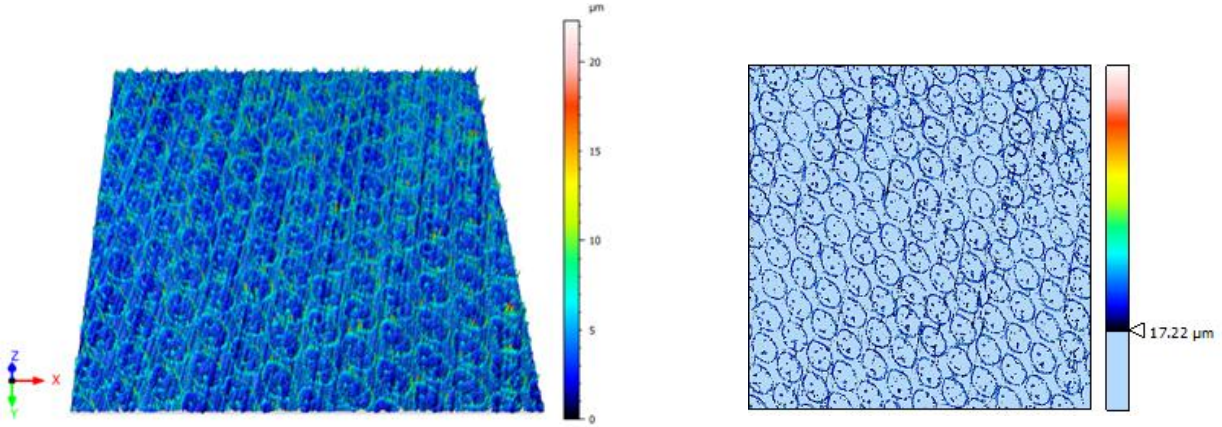
testing

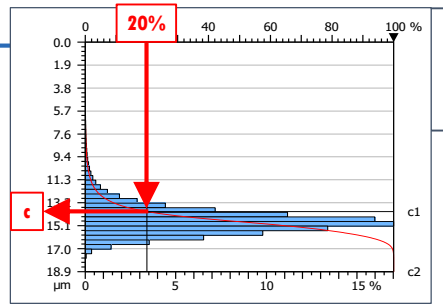


Dimple-shaped micro structures

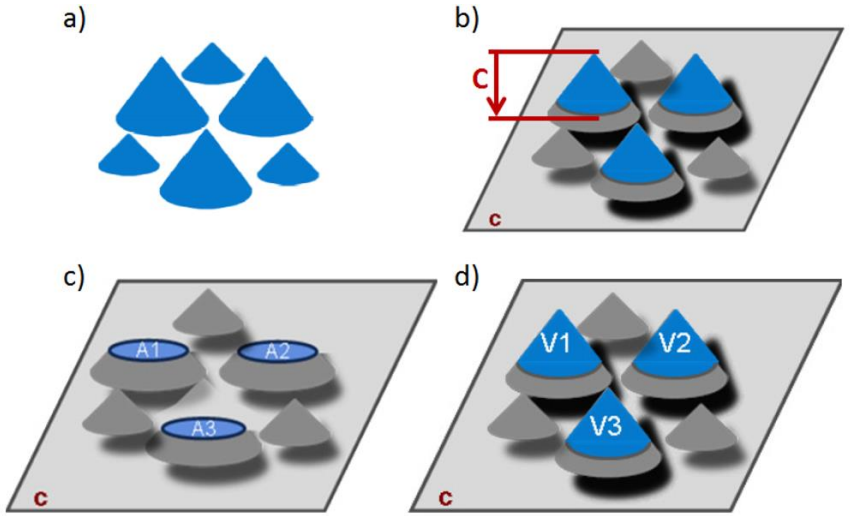
- ***Topography analysis***







Abbott Firestone curve 20%* material ratio defines *evaluation height c*



Surface Parameters:

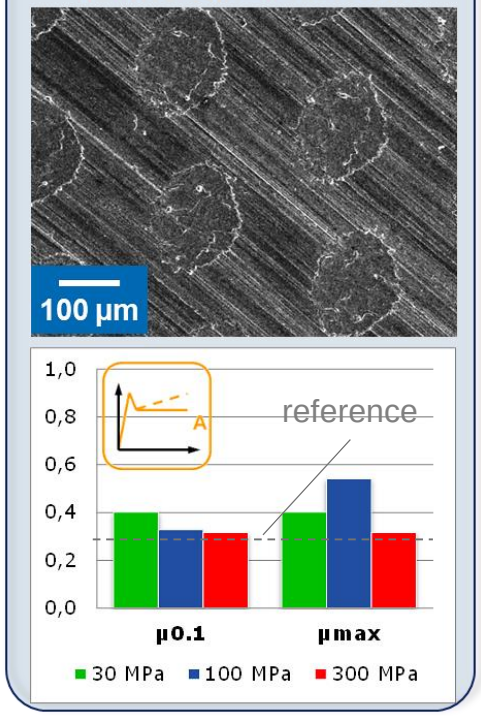
NI= 4579
MSI=225 µm²
MVM= 0,32 µm³/µm²

- number of islands
- mean surface of the islands
- mean material volume at specific height c

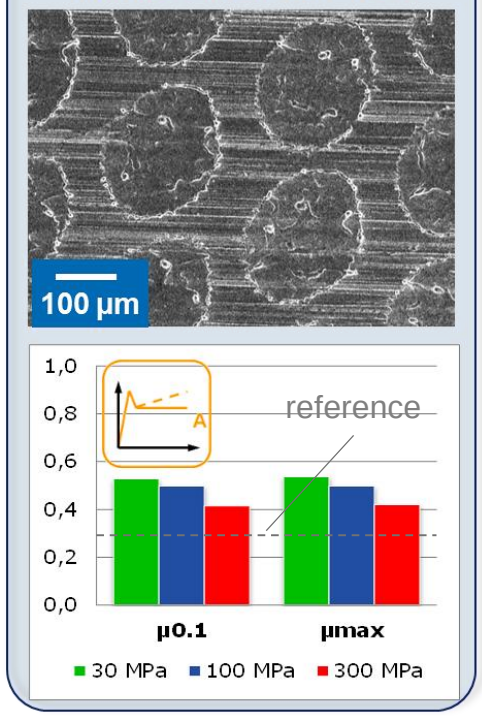
Dimple-shaped micro structures

- ***Friction analysis (fine-grinded counter parts)***

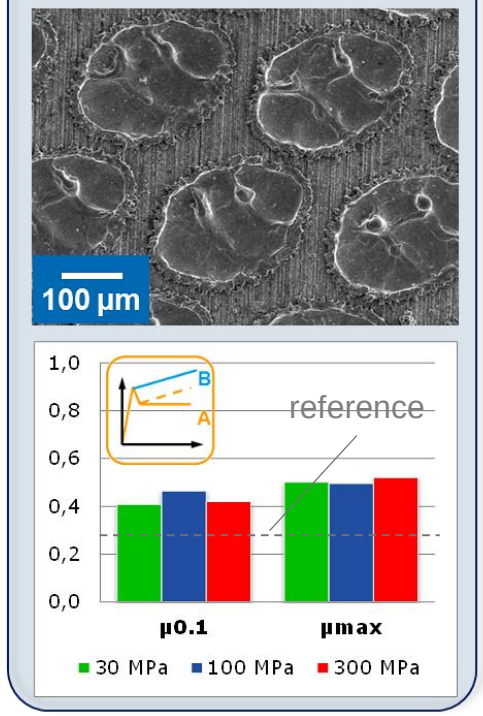
dimension: 200 x 130 µm²
height: 4 µm
number of islands: 2570

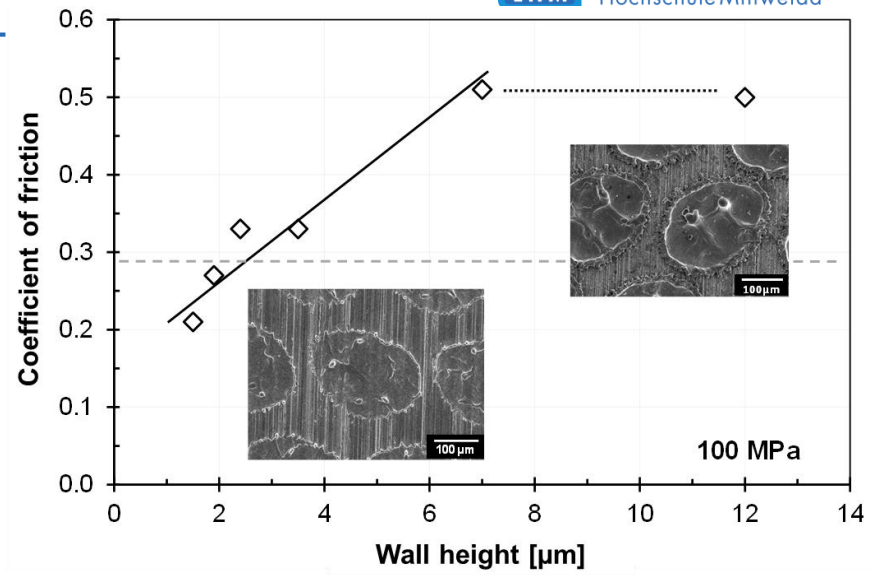


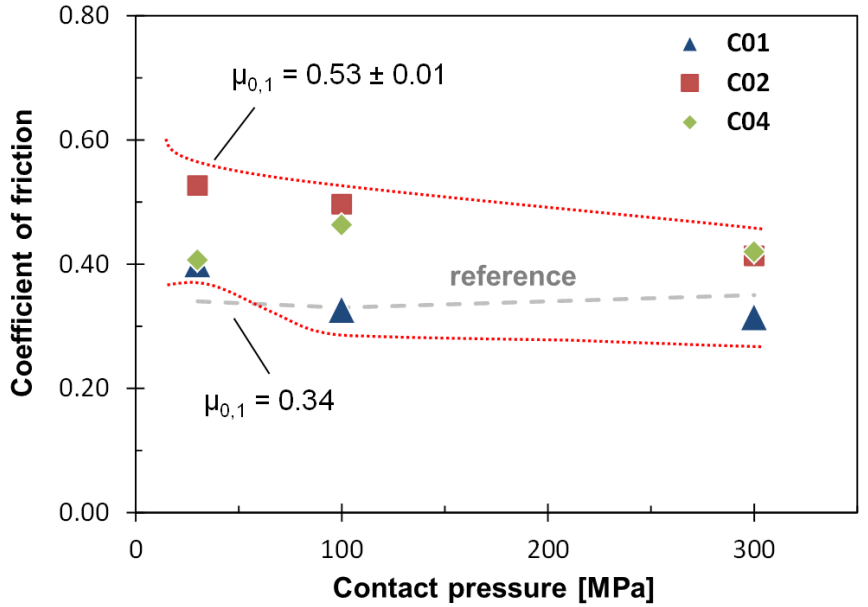
dimension: 250 x 160 µm²
height: 7 µm
number of islands: 4600



dimension: 250 x 160 µm²
height: 12 µm
number of islands:1790



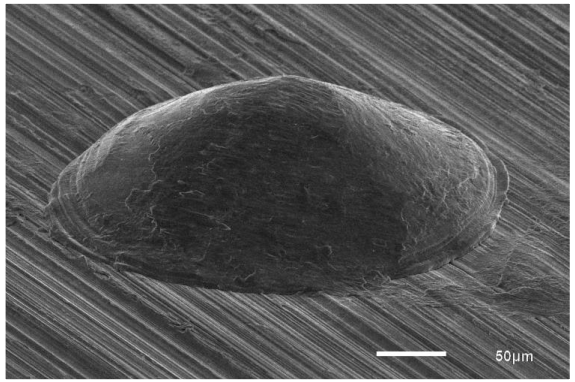


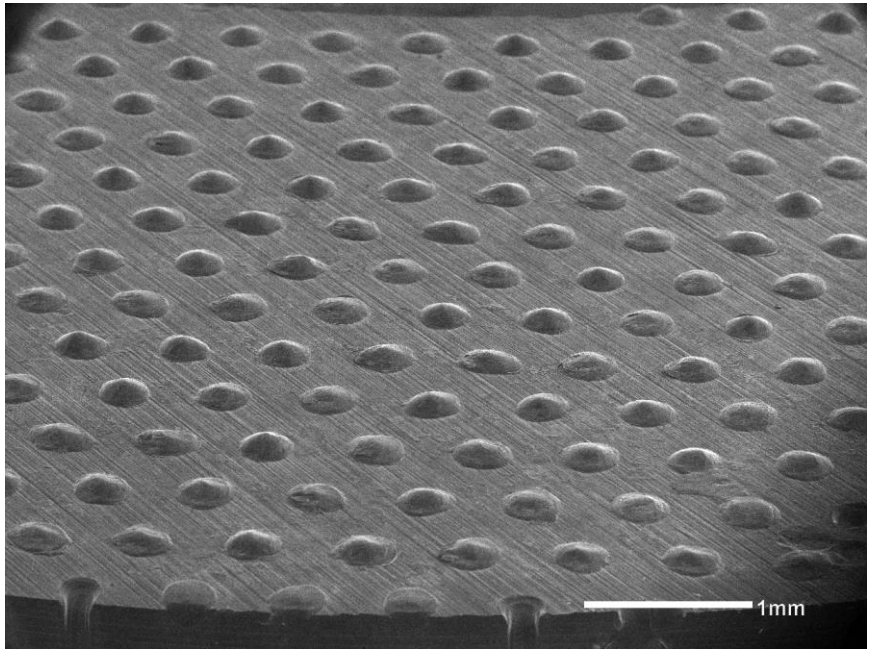


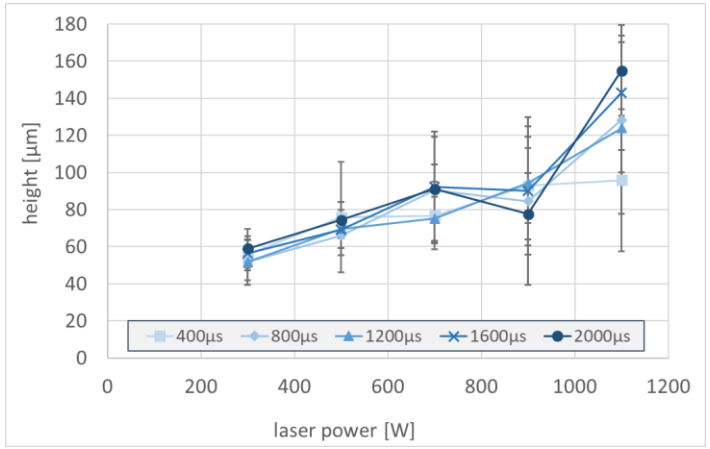
Schille et al.: Experimental Study on Laser Surface Texturing for Friction Coefficient Enhancement. Journal of Laser Micro/Nanoengineering 10 (2015), Nr. 3, 245-253

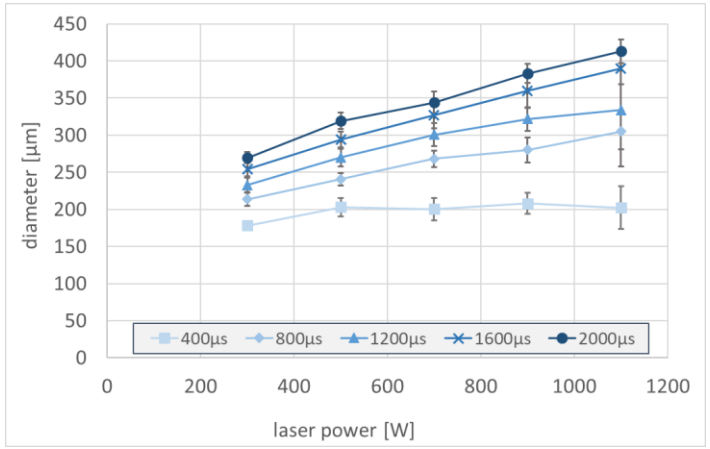
Deep penetration welding dots

- ***Characteristic***
  - lenticular-shaped bulges (Ø = 200 .. 300 µm; h = 100 µm)
  - deep penetration welding effects
  - keyhole → weld root
  - hardness increase (500 .. 800 HV)
  - geometry / hardness depend on laser power, irradiation time



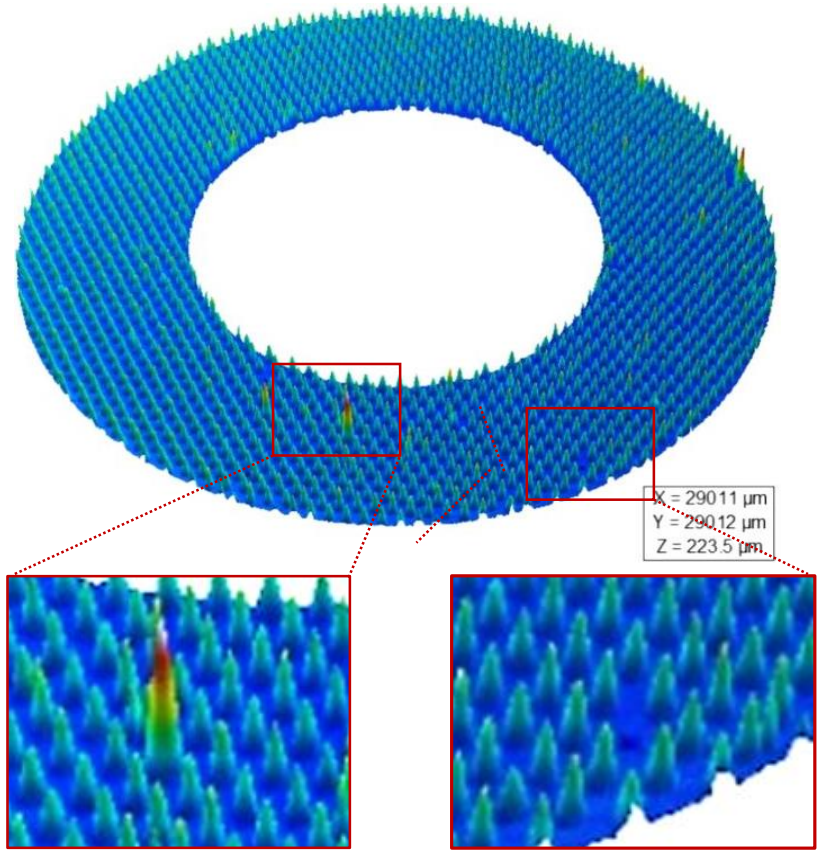


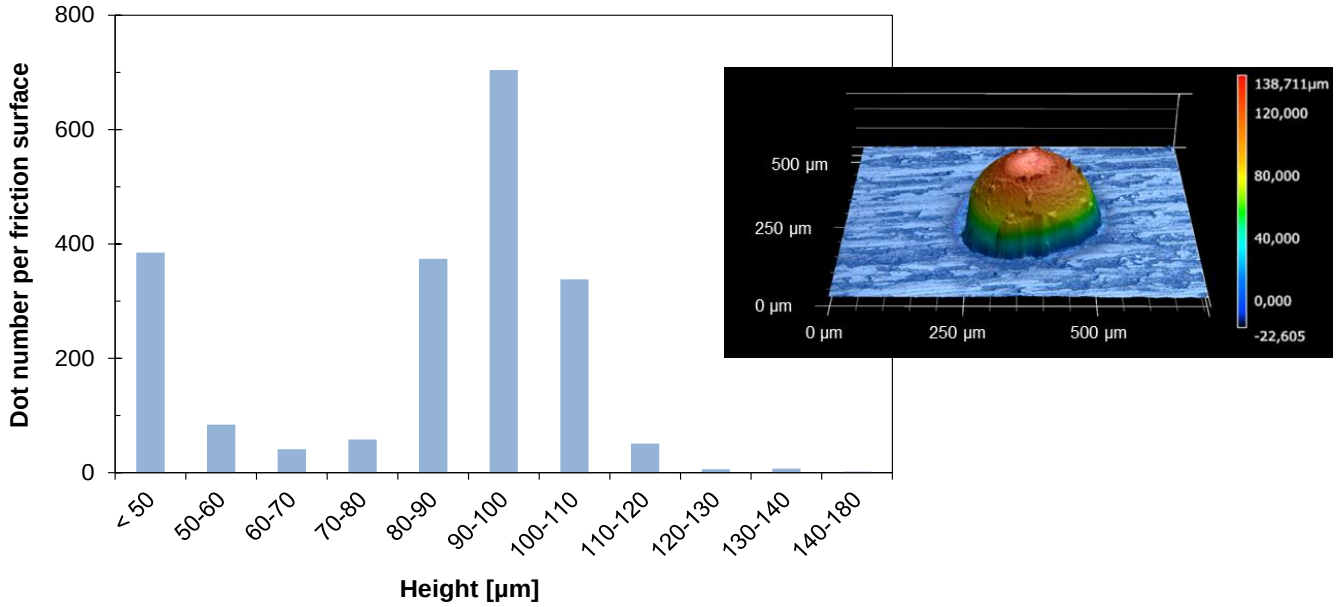


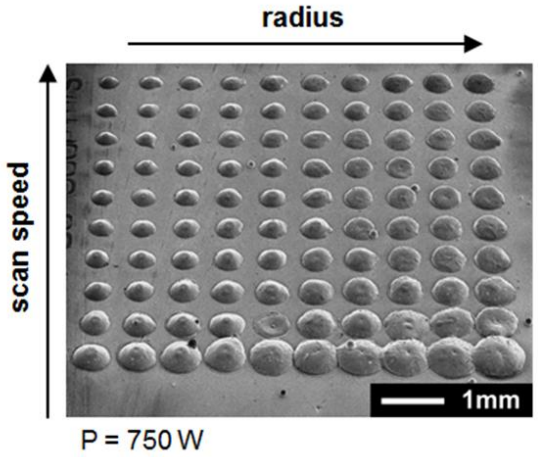


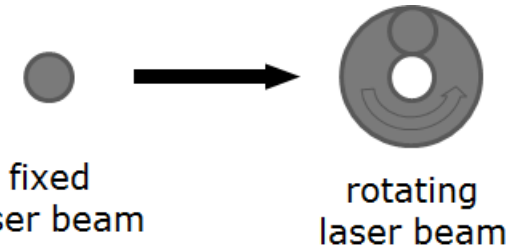
Deep penetration welding dots (kinetic CoF)

- ***Topography analysis***





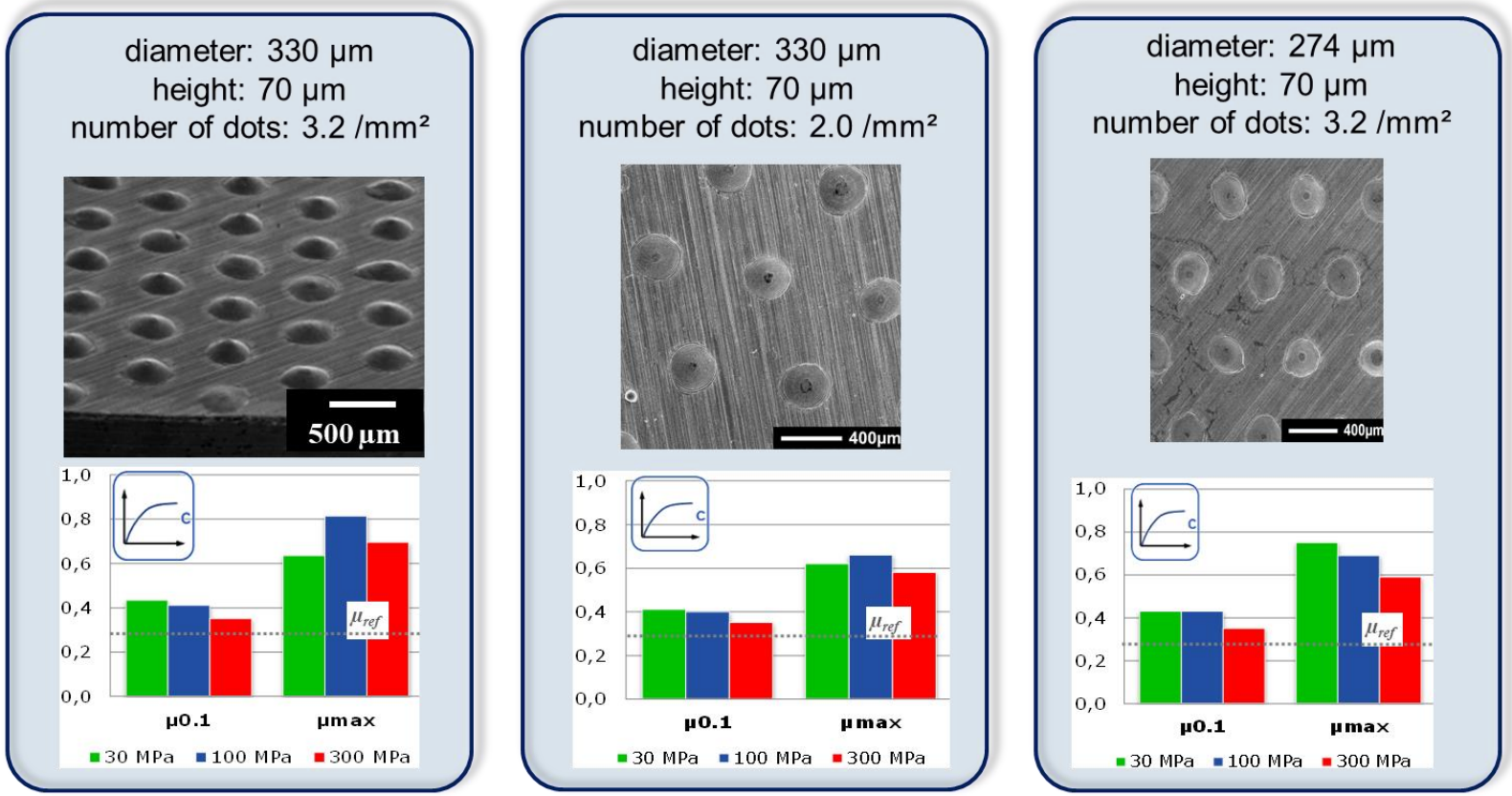


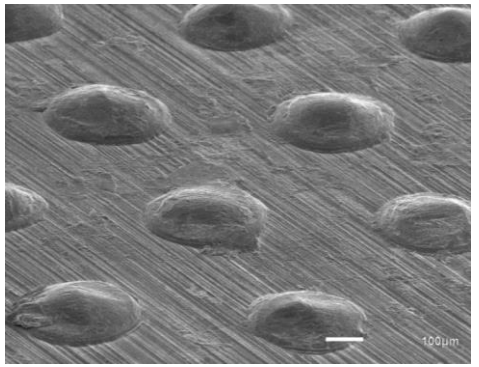


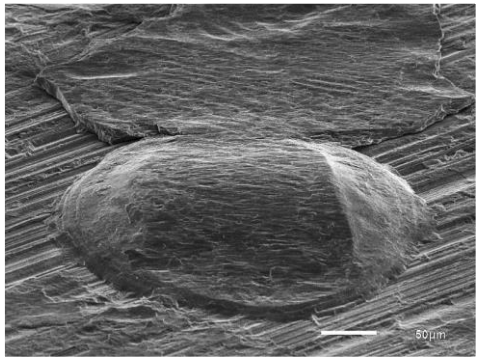
h/Ø: 0.23 **0.18 … 0.32**

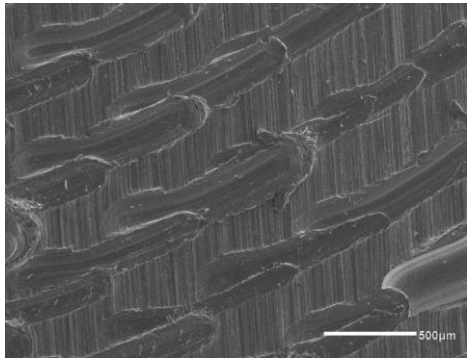
Deep penetration welding dots (kinetic CoF)

- ***Friction analysis (fine-grinded counter parts)***



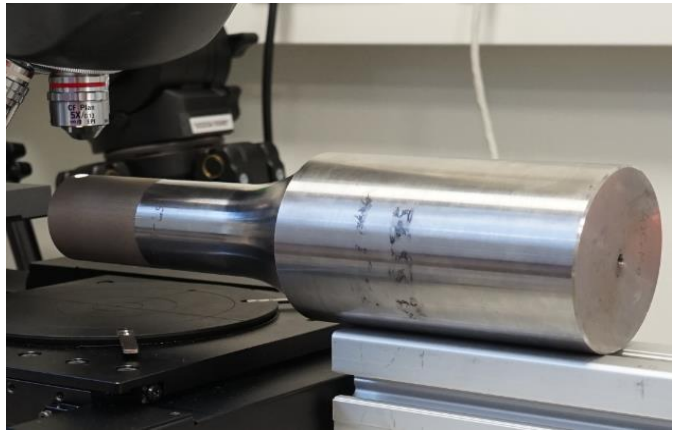


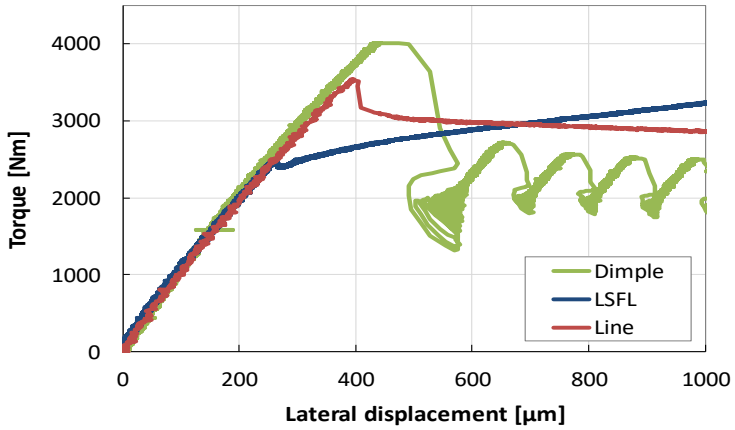


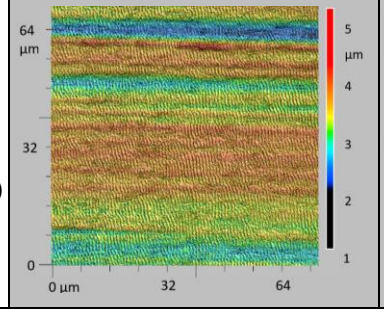
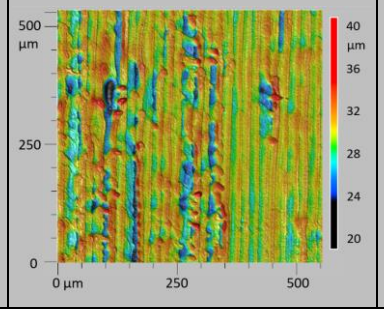
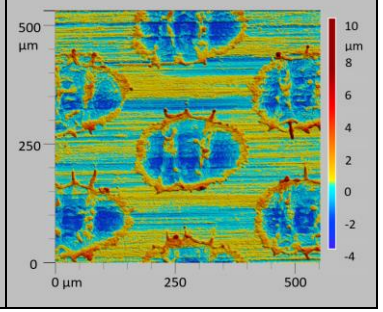


Schille et al.: Experimental Study on Laser Surface Texturing for Friction Coefficient Enhancement. Journal of Laser Micro/Nanoengineering 10 (2015), Nr. 3, 245-253

Shaft-hub connection





Tribological characteristic			
Laser texture	LSFL	Line pattern	Dimple-shaped texture
Surface pressure	85 ± 2 MPa	92 ± 9 MPa	84 ± 2 MPa
COF type	B	A	A
μ_{20}	0.24 ± 0.01	0.34 ± 0.02	0.32 ± 0.01
$\Delta\ \mu_{20}$	+ 20 %	+ 70 %	+ 60 %
μ_{max}	0.24 ± 0.01	0.35 ± 0.01	0.40 ± 0.02
$\Delta\ \mu_{max}$	+ 20 %	+ 75 %	+ 100 %
Processing rate	14.4 cm²/min	21.0 cm²/min	14.0 cm²/min
Topography measurements (before testing)			

Schille et al.: High-Rate Laser Surface Texturing for Advanced Tribological Functionality. *Lubricants* **2020**, *8*, 33.

Laserinstitut Hochschule Mittweida

AiF-Project: „Entwicklung von Tribomaps für reibwerterhöhende Laserstrukturen“

Werkstoffkenngrößen

Werkstoff	Härte	Rauigkeit	Materialdicke
W1			
W2			
W3			

Technologieparameter

Laserparameter	①	1	1	②	2
Betriebsart	pw	pw	pw	pw	pw

Strukturkenngrößen

Laserstruktur	①	1	1	②	2
Struktur	Aufschmelzungen				
Wallhöhe	3	5	7	9	15
Punktdichte	10	10	15	15	20
Inselanzahl	123	456	789	2468	3489
P-Abstand X	250	250	200	200	200
P-Abstand Y	300	300	300	250	250

HOCHSCHULE MITTWEIDA

Vielen Dank

Dr. Jörg Schille

Laserinstitut Hochschule Mittweida
Technikumplatz 17 | 09648 Mittweida

+49 (0) 3727 58-1838
schille@hs-mittweida.de
www.laser.hs-mittweida.de

Laserinstitut Hochschule Mittweida | Raum 42-208
Schillerstraße 10 | 09648 Mittweida

HOCHSCHULE MITTWEIDA
University of Applied Sciences

www.laser.hs-mittweida.de