Laser Processes for Micro and Nano Scale Functionalisation of Surfaces

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HANNOVER MESSE

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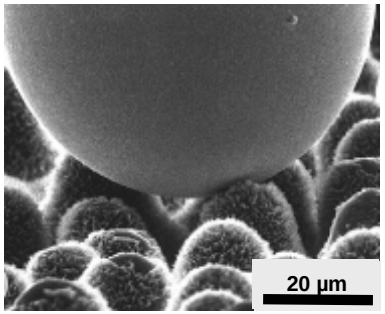
Outline

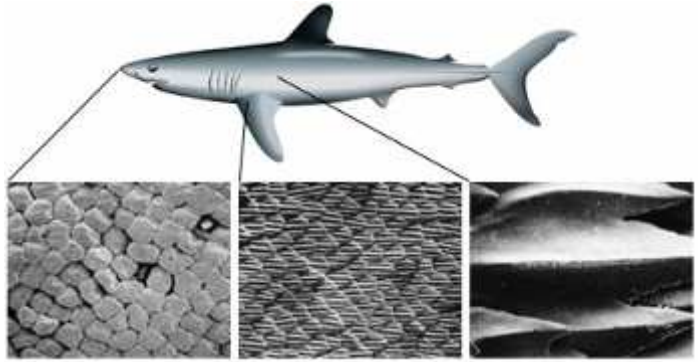
- Functional structures – examples from nature
- Ultra short laser pulse interaction with metals
- Laser micro structuring
- Laser nano structuring
- New developments

Functional structures in nature

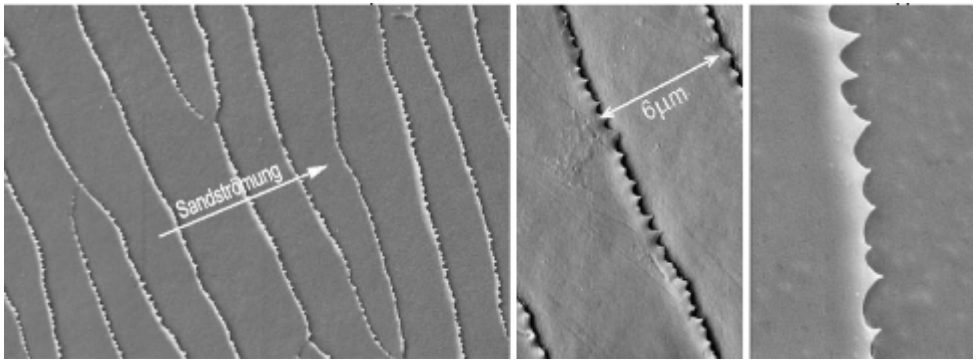


Lotus effect
Self cleaning,
water repellent

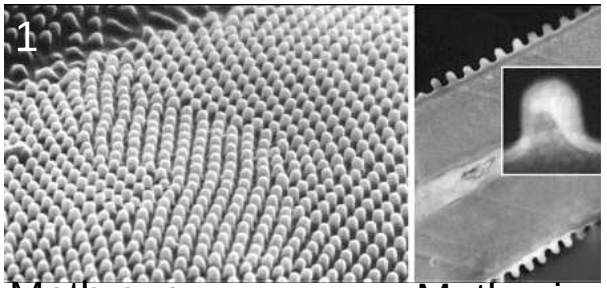
Gecko, self adhesive



Shark, low friction in fluidics



Sand fish, low friction with particles

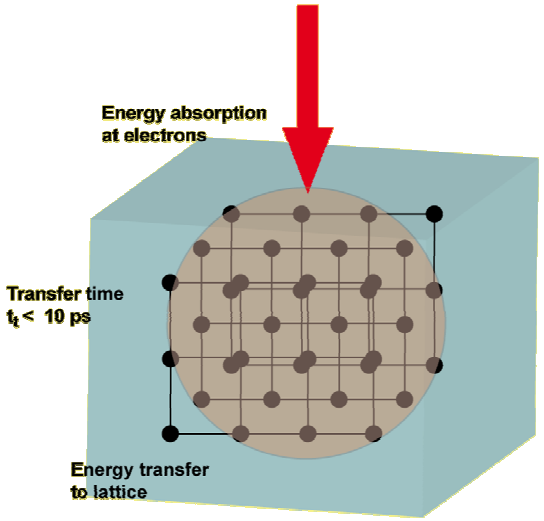


Moth eye Moth wing

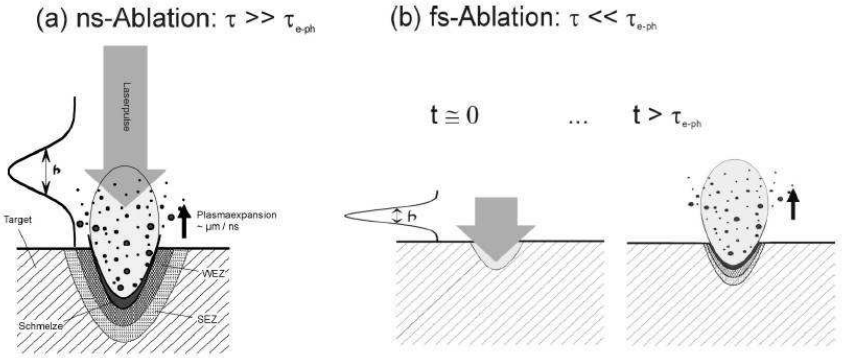
Moth eye, anti reflective

Ultra short laser pulse interaction with metals

- Energy absorption at electrons
- Transfer of energy to lattice within typical 10 ps
- Heating and melting after end of laser pulse



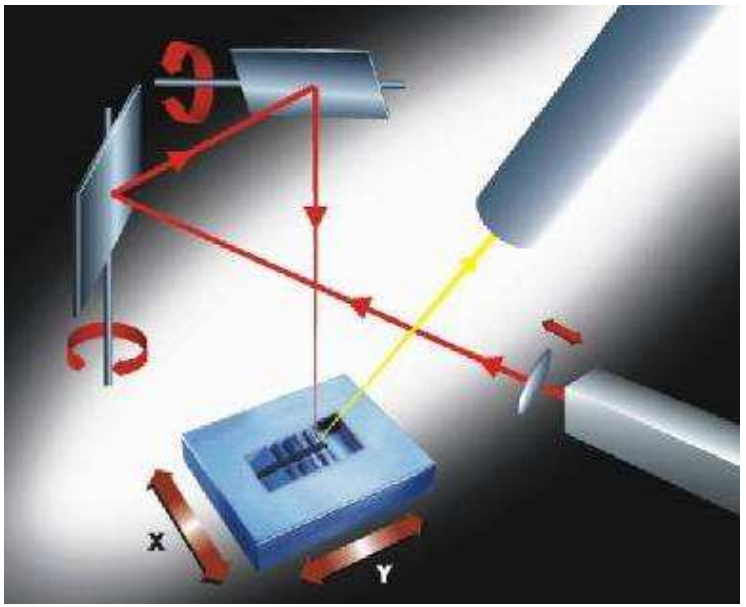
- No interaction of radiation with vapour and melt
- Ablation by vapourisation
- Minimal thermal influence

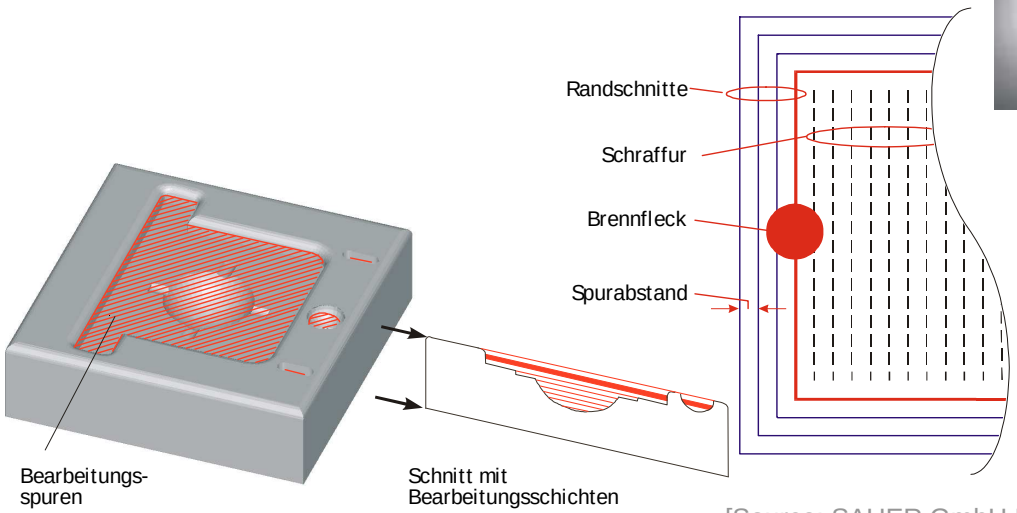


Process concept for laser micro ablation

Typical parameters

- Focus diamter: 5-40 µm
- Line distance: 5-15 µm
- Layer thickness: 0,1-2 µm

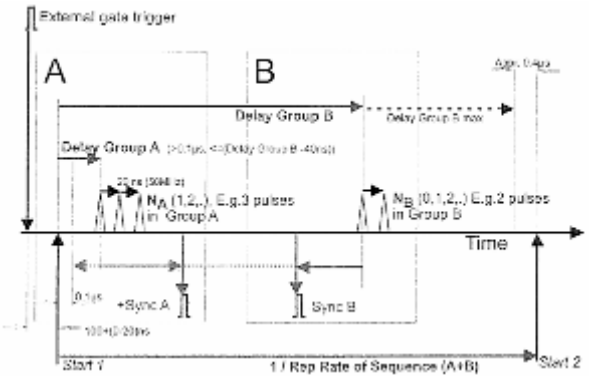




[Source: SAUER GmbH Lasertec]

Material ablation with ps-pulse-bursts

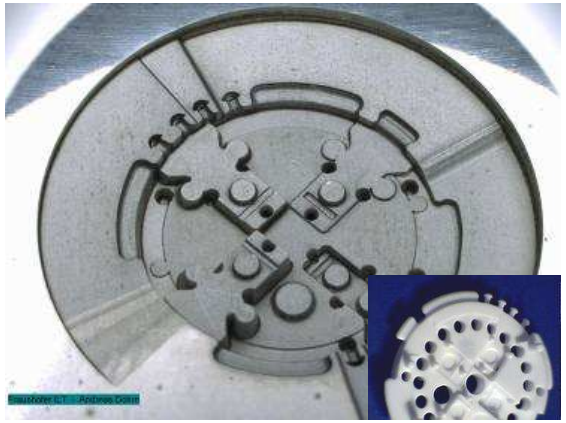
- Laser: SuperRapid (Lumera Laser)
- Puls duration t =12 ps
- Repetition rate $f \leq 500$ kHz
- Multi pulse option: yes
- Inter pulse-separation Δt = n x 20 ns
- Burst Energy E_{Bmax} 200 µJ



[Source: SAUER GmbH Lasertec]

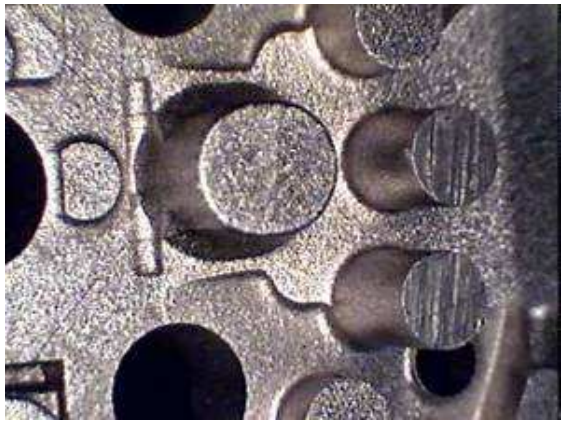
Comparison ns-Laser with ps-Laser

- Time for manufacturing 10 h
- Ablated volume 100 mm^3
- Quality of ablation comparable to EDM
- No tools needed



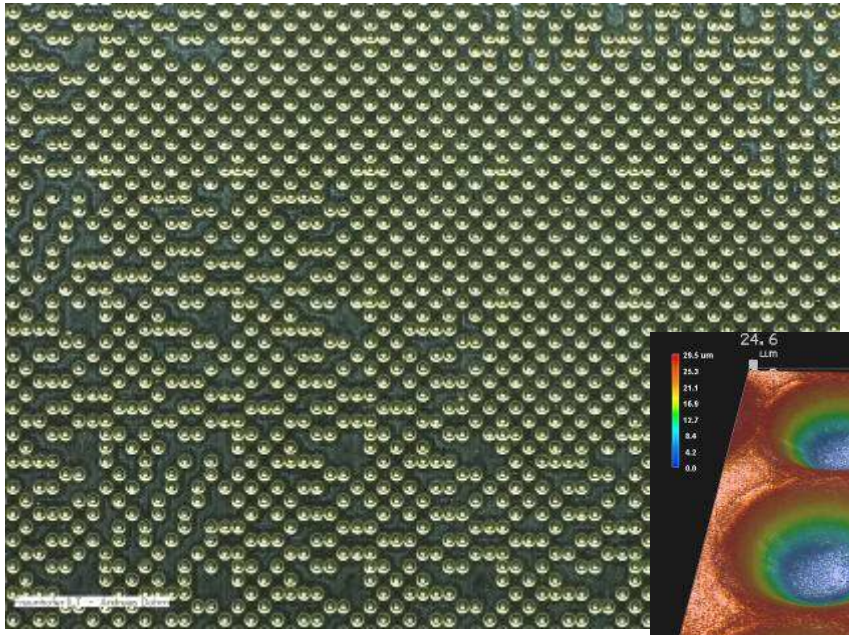
ns-Laser

ps-Laser

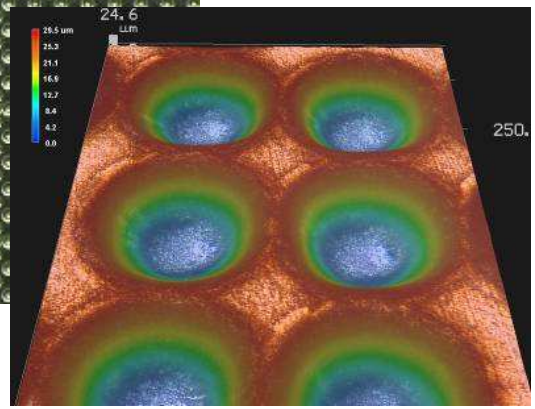


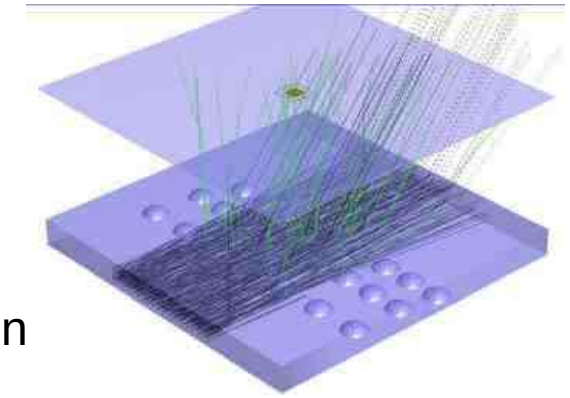
EDM

Micro injection moulding of lens arrays in PMMA



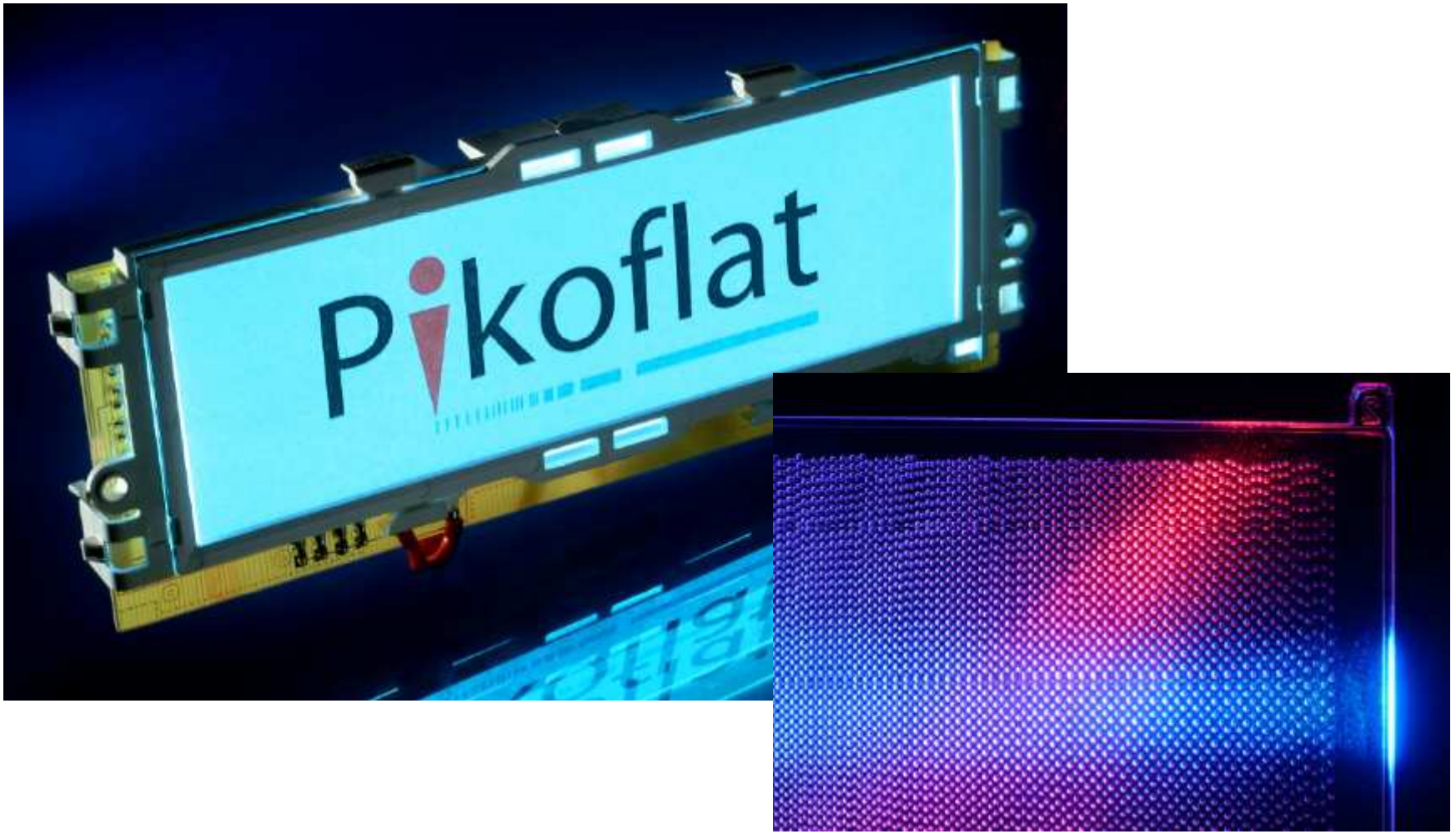
Micro moulding tool for surface structured parts



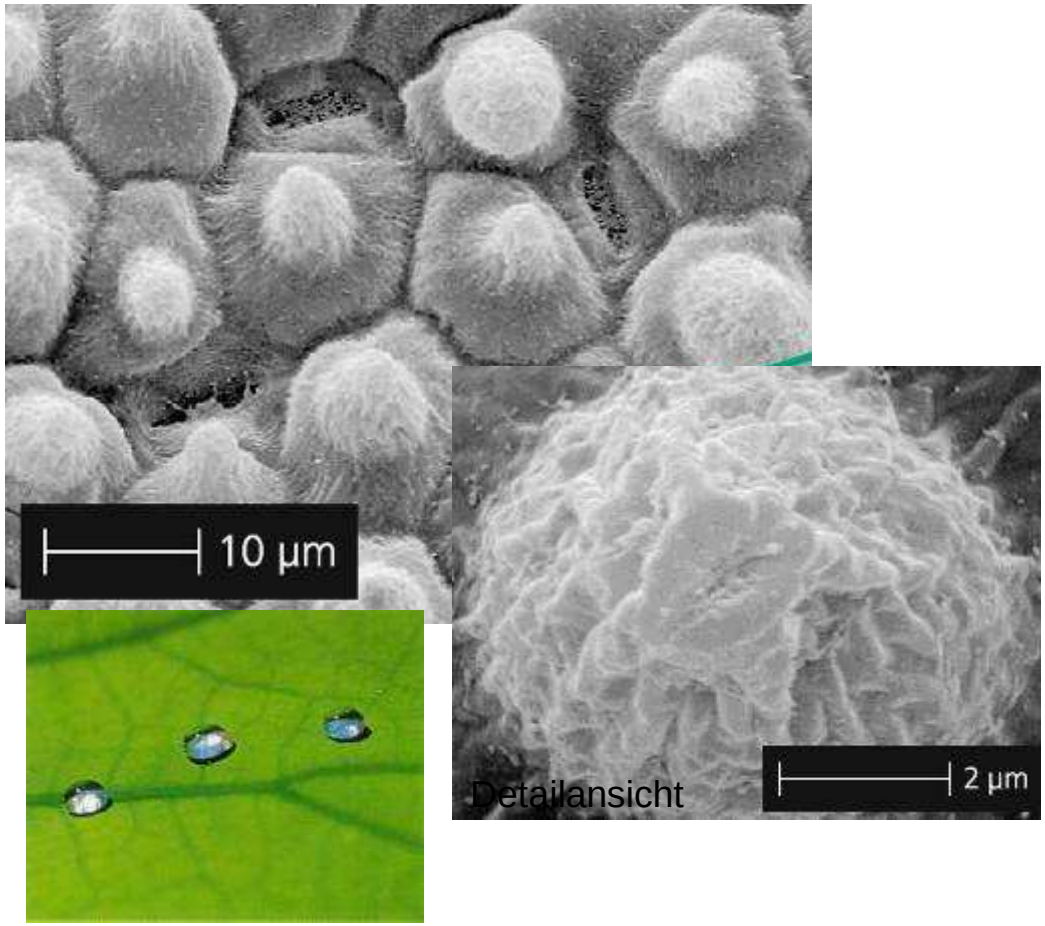


After tool polishing sufficien part quality with surface accuracy better than 100 nm

Light guiding element for LED illumination



Laser structuring for functional surfaces



Hydrophobic surfaces

Natural example:
Lotus leave

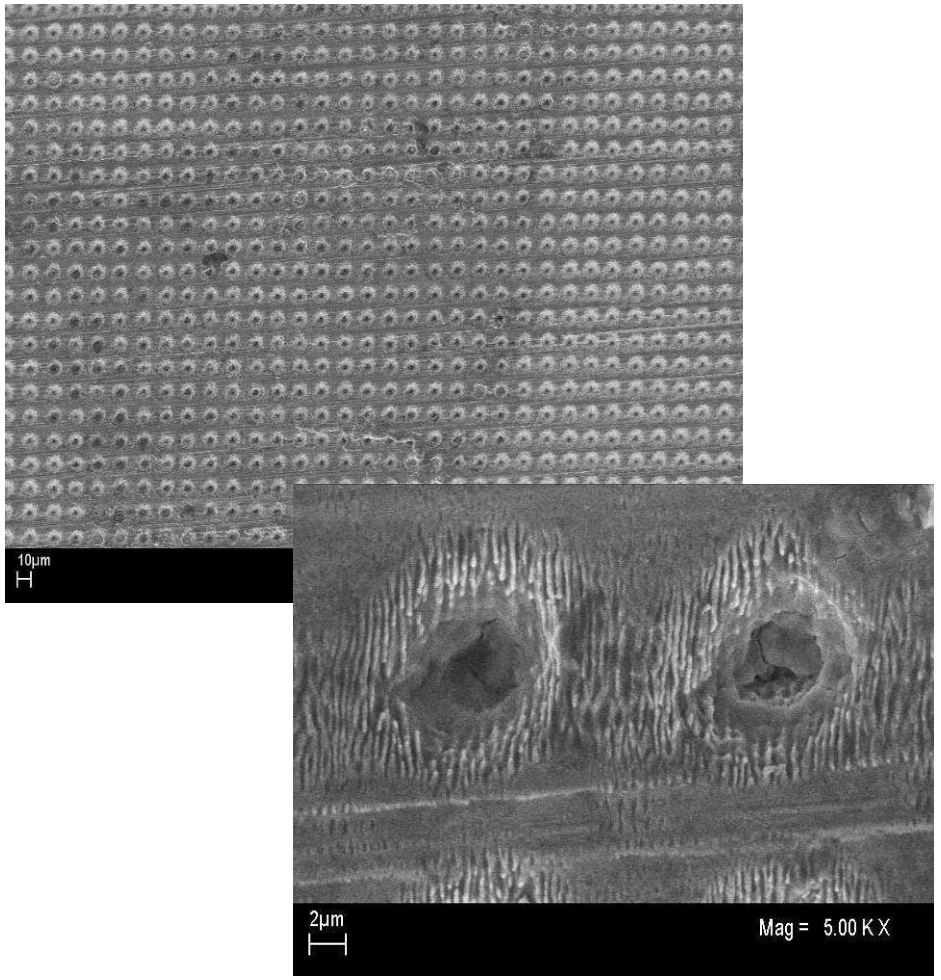
Applications:

- Medical technology
- Bio analytics
- Micro chemistry

Laser structuring of injection moulding tools

Structuring of injection moulding tool with Pikosecond lasers Lumera Rapid, λ = 355 nm

Generation of multiple structures
Structure size: 10 µm
Sub structure: 2 µm
Sub-Sub structure: 100 nm



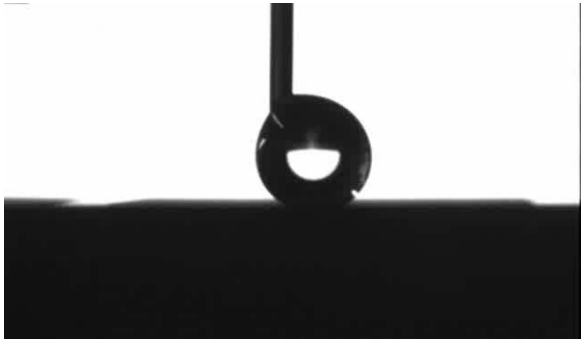
Replication of micro structures surfaces

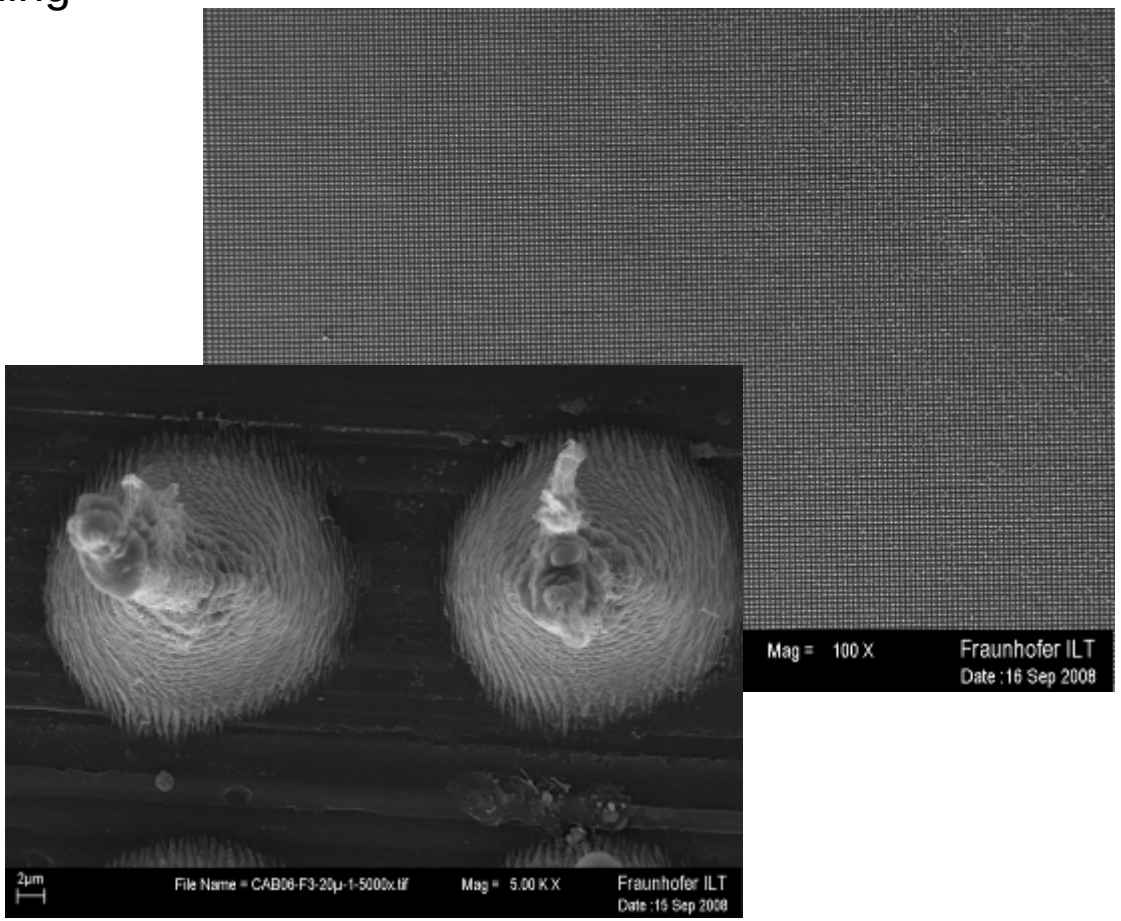
Replication by injection moulding

Material: Polypropylen

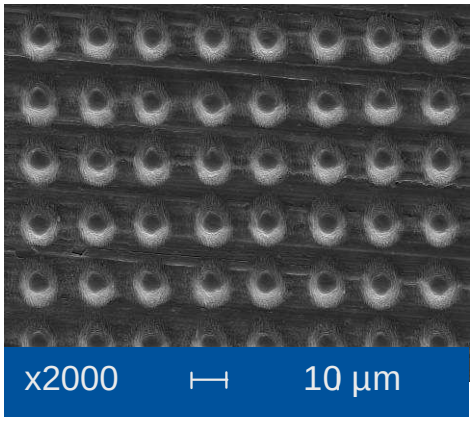
Contact angle 174°

Minimal Adhesion



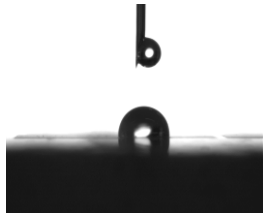


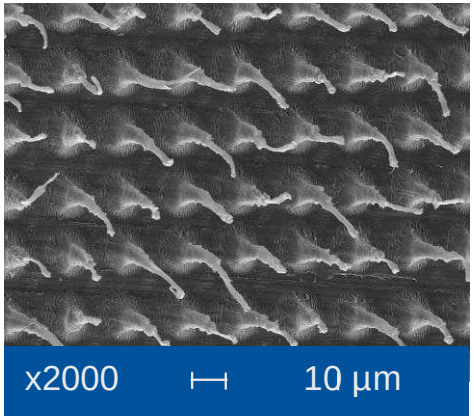
Replication of micro structures surfaces

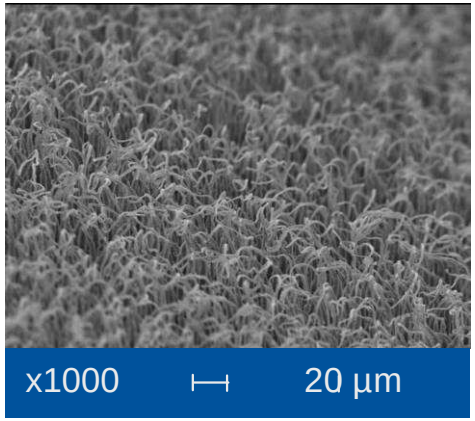


Normal injection moulding

- Micro structures are not filled completely

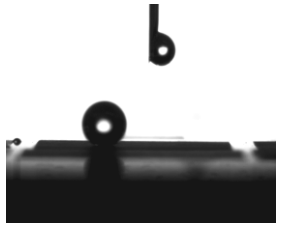




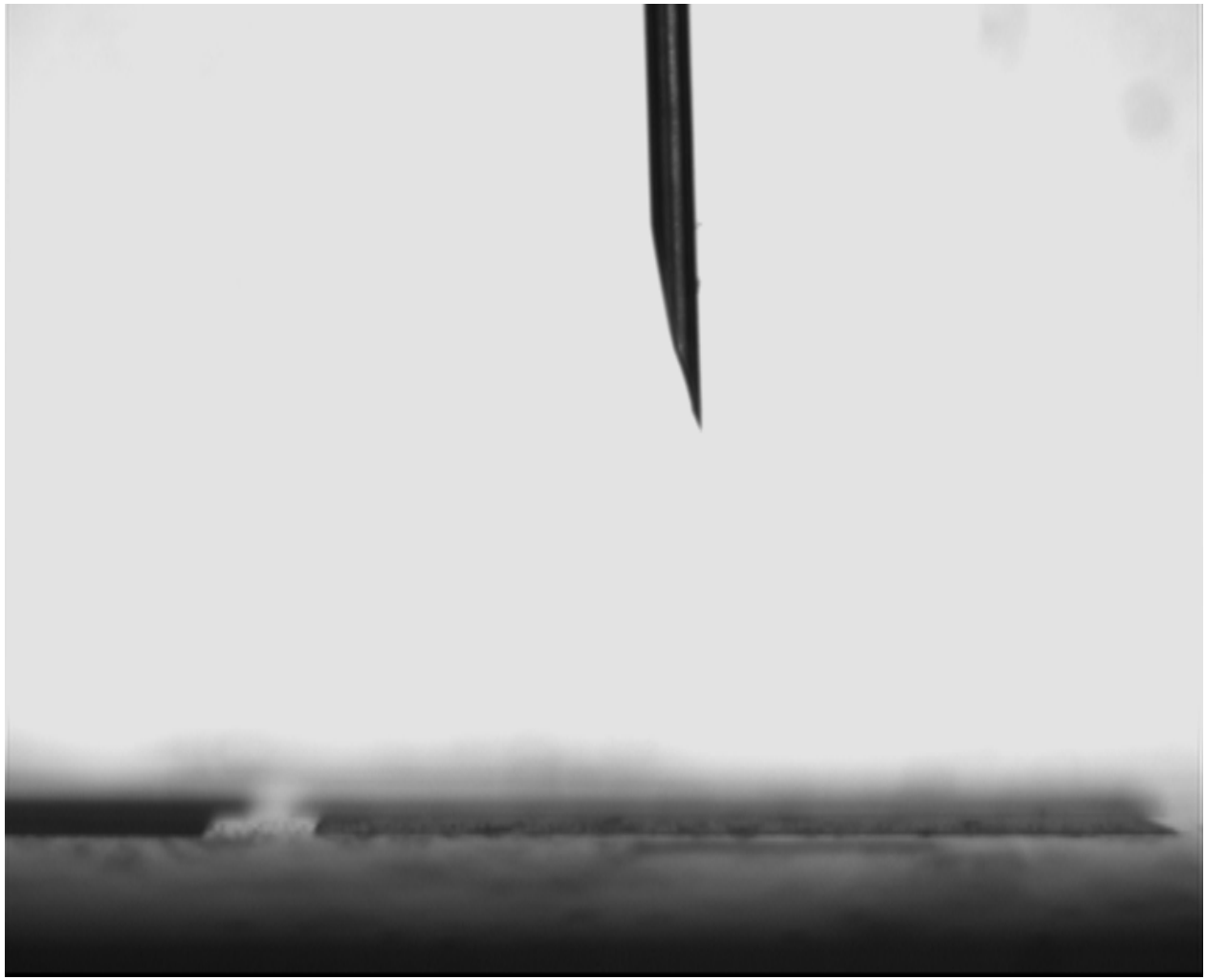


Vatiothermal injection moulding

- Micro structures are filled completely
- The structures get stretched during demoulding



Contact angle

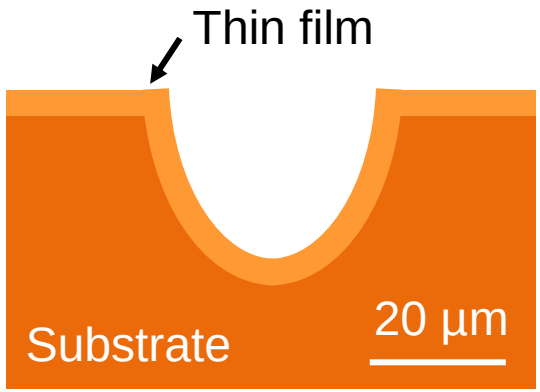


Wear resistant layers

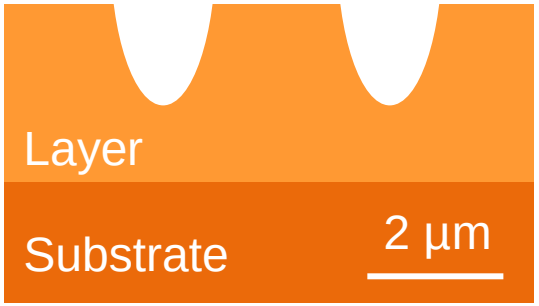
Wear protection of tools due to PVD layers

Two tool concepts are possible

- Deposition of thin film on structured tool
  (“big” structures (depth: >10 µm))
- Structuring of coated tool
  (“small” structures (depth: <5 µm))



Coated micro structures



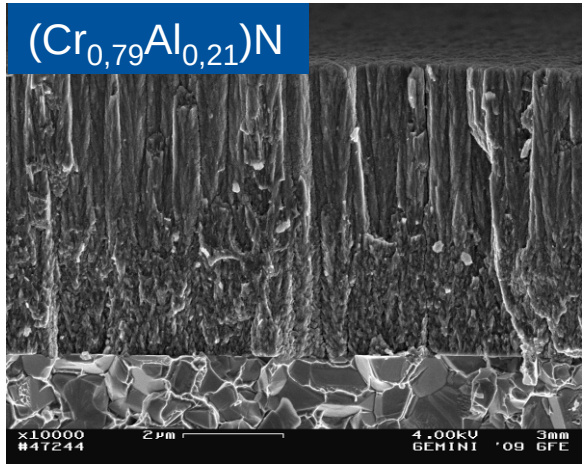
Micro and nano sturctures
in a PVD thin film

Characterization of the PVD-layers

Characterization regarding:

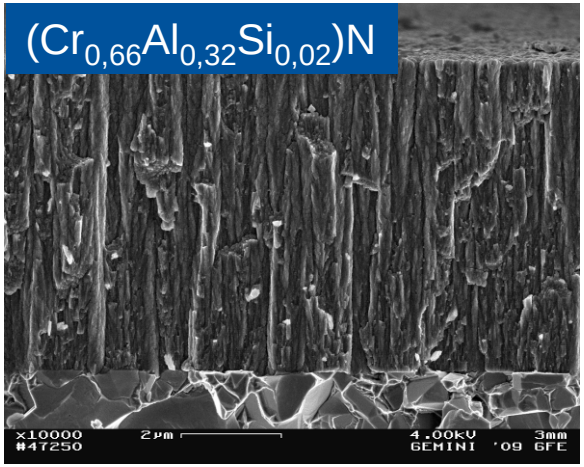
- Film thickness, morphology (SEM) & chemical composition (at-%) (EDS)
- Hardness & Young's modulus (Fischerscope HM2000; penetration depth 0.5 µm)
- Adhesion – test / Rockwell indentation (VDI 3198)

$(Cr_{0,79}Al_{0,21})N$



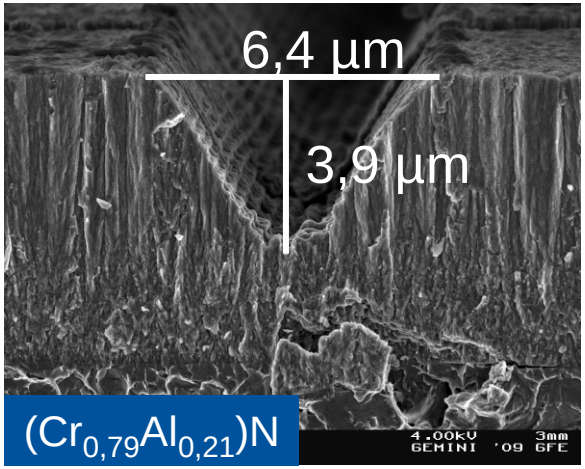
- Columnar film growth
- Thickness: 5.7 µm
- Hardness: 1026 ± 47 HV
- Young's modulus: 201 ± 5 GPa
- Adhesion class: 1

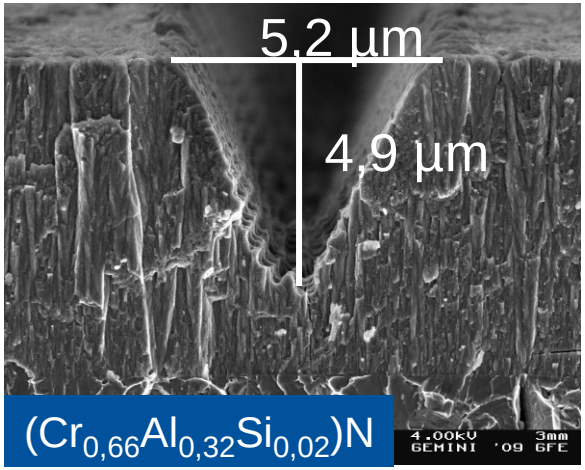
$(Cr_{0,66}Al_{0,32}Si_{0,02})N$



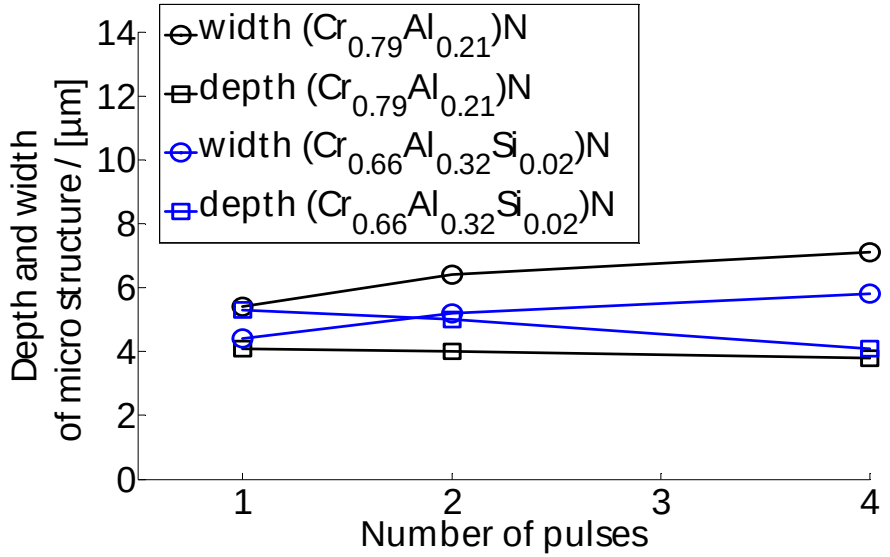
- Columnar film growth
- Thickness : 6.0 µm
- Hardness : 975 ± 86 HV
- Young's modulus: 175 ± 8 GPa
- Adhesion class: 1

Micro structuring of the PVD-layers



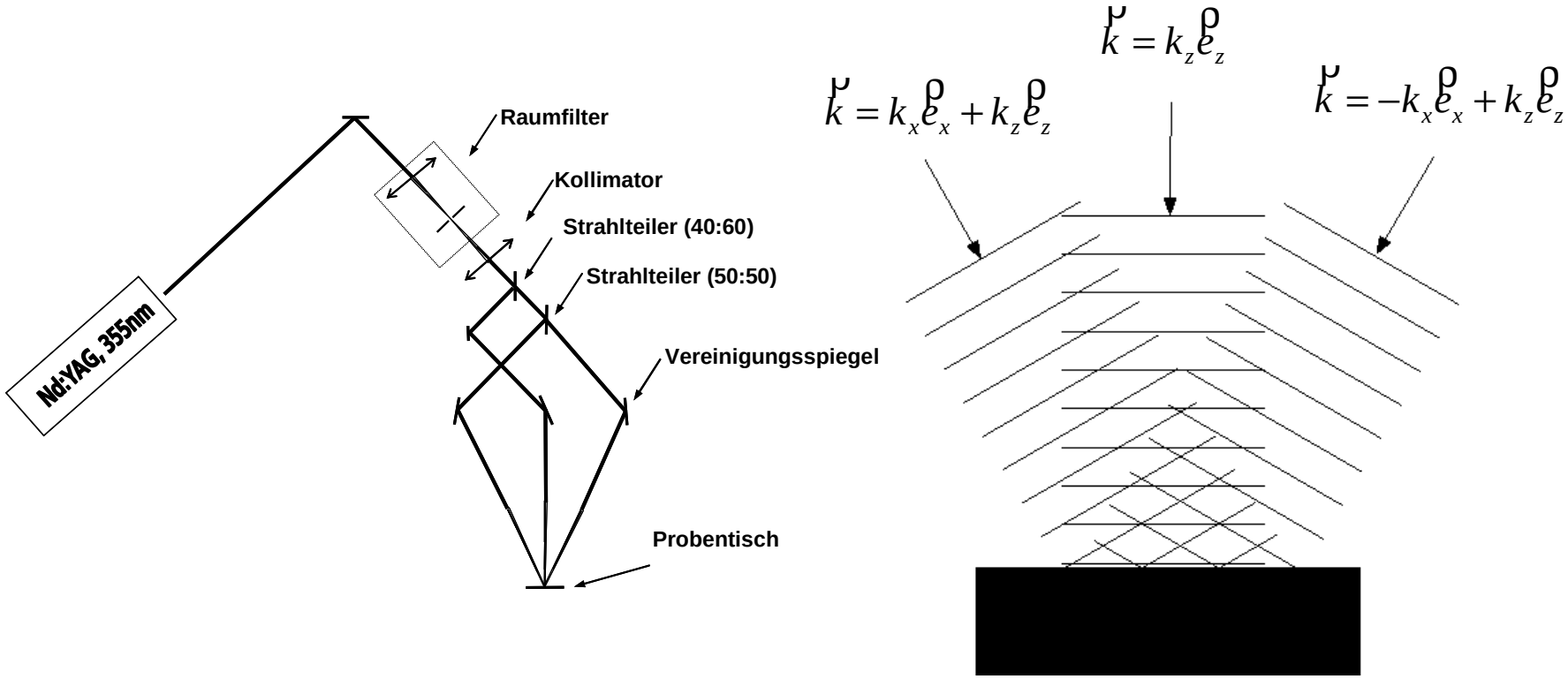


λ = 355 nm
E_{burst} = 0.4 µJ
double pulses
v = 100 mm/s
10 passes



λ = 355 nm
E_{pulse} = 0.2 µJ
E_{burst} = 0.2, 0.4, 0.8 µJ
v = 50,100, 200 mm/s
10 passes

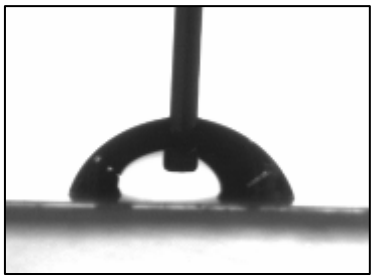
Interference structuring with laser radiation



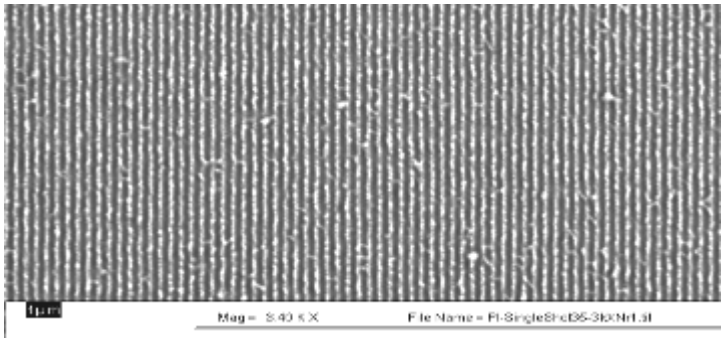
Three beam interference in a plane

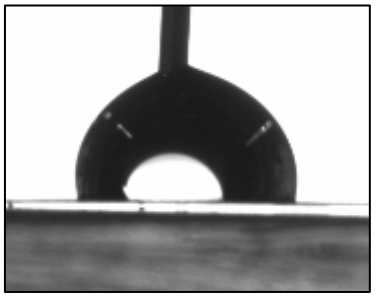
Nano structuring for surface functionalisation of polymers

Contact angle of unstructured polyimid θ_{H_2O} = 70°

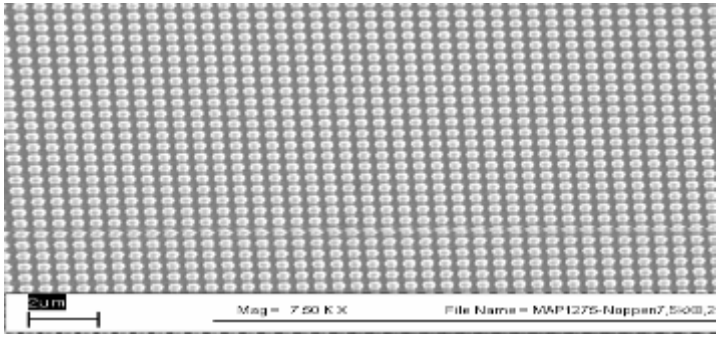


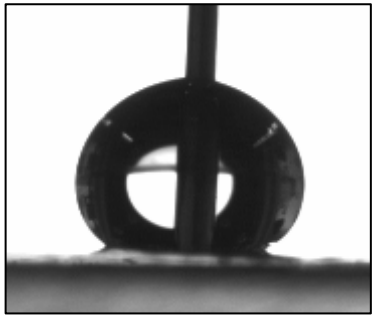
Polyimid with nano scales
Structure size: 100 nm
θ_{H_2O} = 110°





Polyimid mit Nano pits
Structur size: 300 nm
θ_{H_2O} = 145°

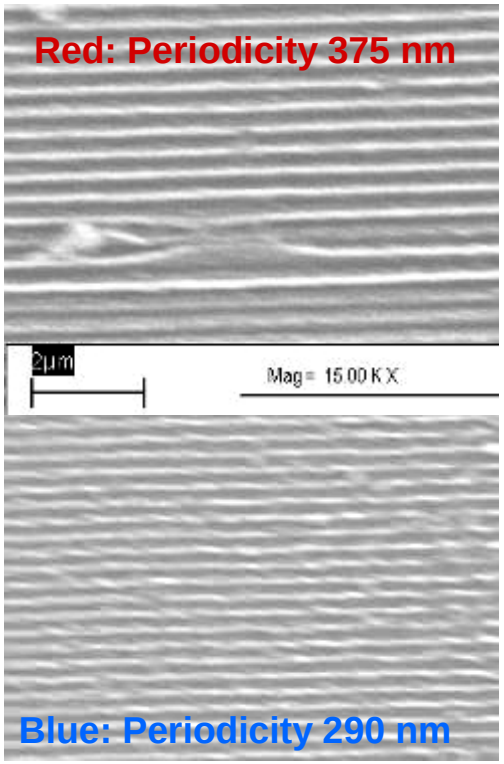


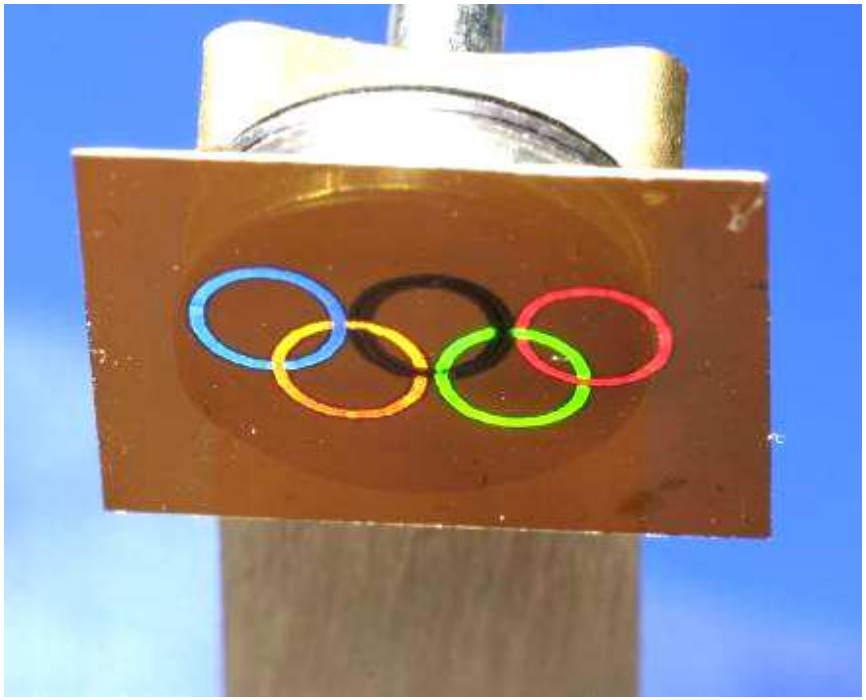


Laser based nano structuring for direct patterning of diffractive structures

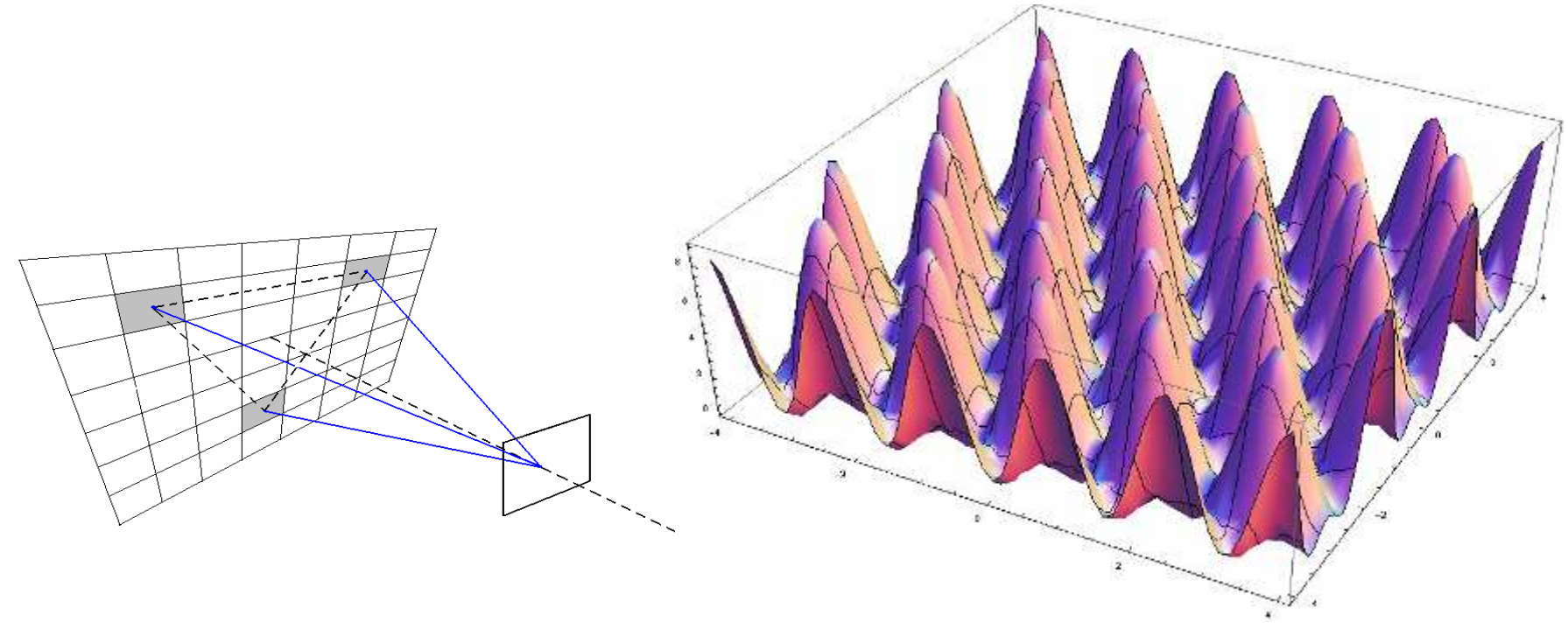
Two beam interference

Nd:YAG, 355nm, PI-Folie, d = 50 µm





Interference structuring with laser radiation



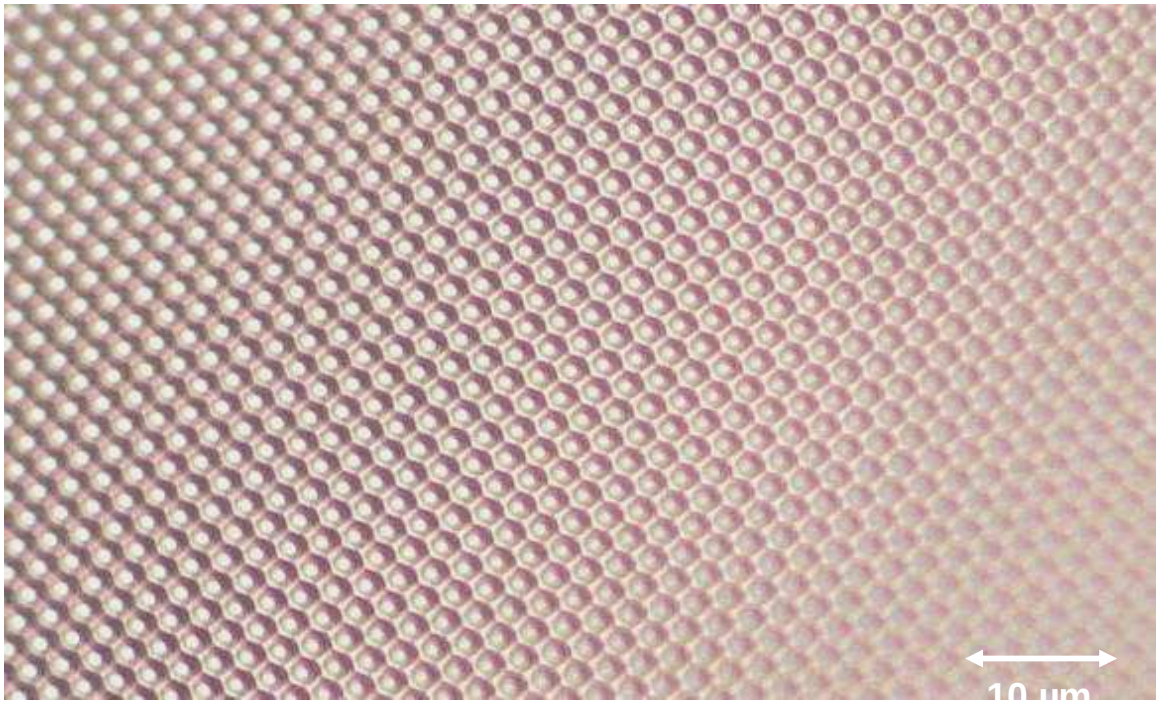
Out of plane three beam interference

Interference structuring with laser radiation

Periodic structure
with negative
illumination
in photoresist

(AR-P 5350)

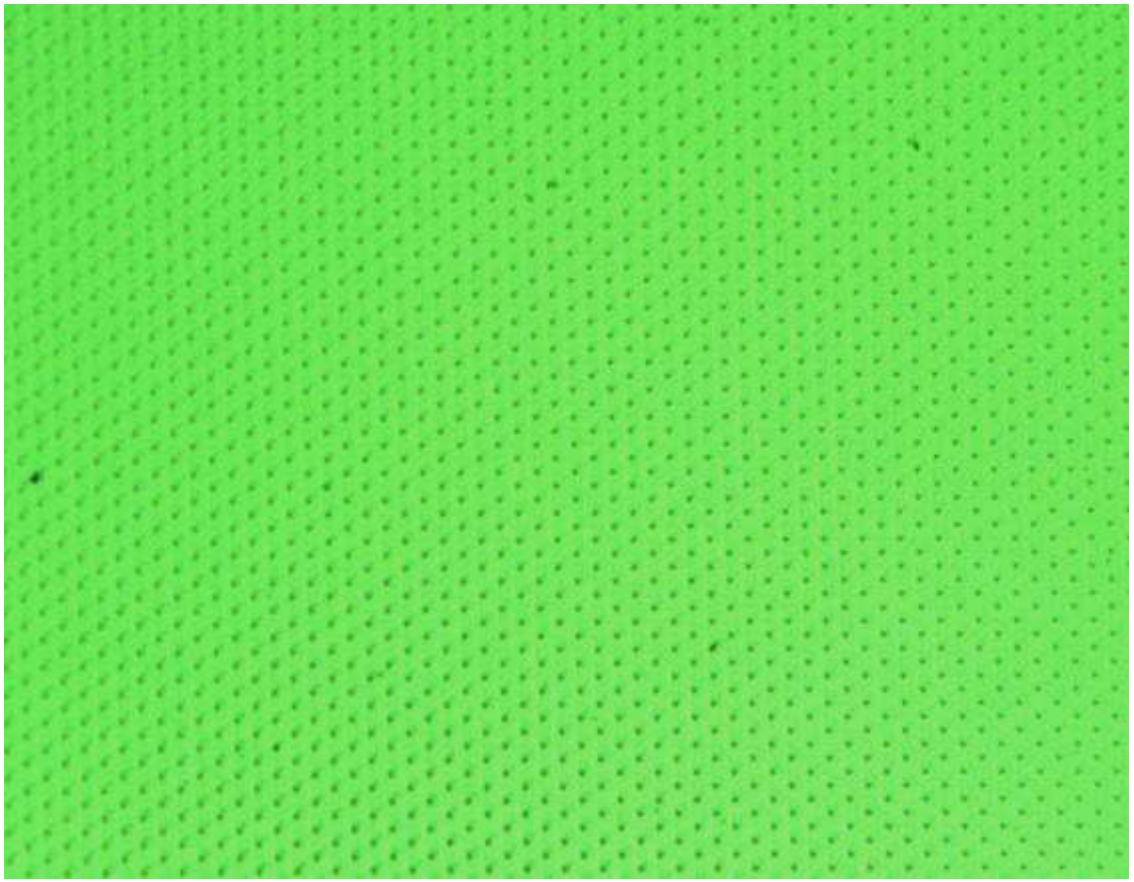
Periodicity 2µm



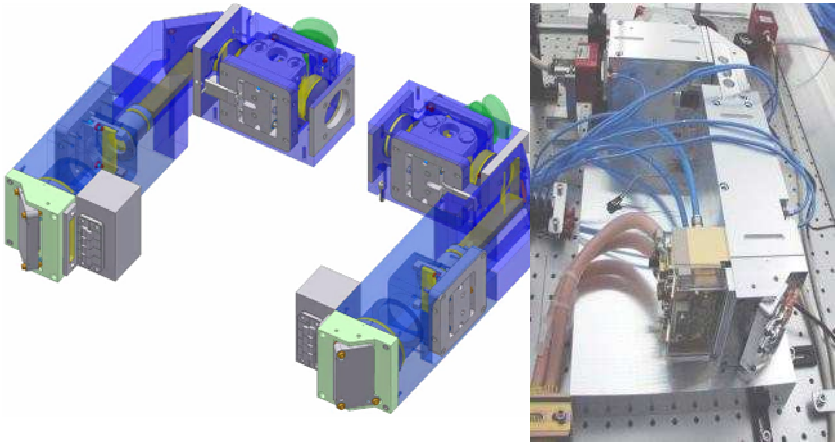
Interference structuring with laser radiation

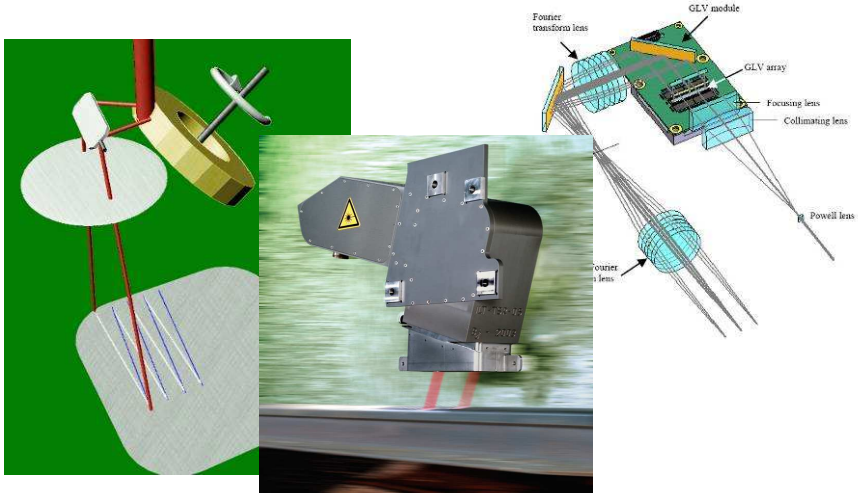
Hexagonal
pattern
of 1µm holes in
Polyimide-Foil

(100.000 Holes with
one shot)



High power ultra short pulsed lasers and fast scanners





Development of high power ultrafast lasers

- 10 ps-Laser with 20 MHz Rep-Rate and P = 200 W
- 500 fs-Laser with 80 MHz Rep-Rate and P = 300 W

Development of process adapted high speed optical systems for ultrafast laser ablation

- High speed scanner systems
- Multiple beam optics for increase of ablation rate

- Founded by German Research Foundation (DFG)

- Cluster of Excellence (CoE)
  „Integrative Production Technology for High-Wage Countries“

- CoE sub project C-3.2
  "Functional Surfaces via Micro and Nano Scaled Structures"

Thank you for your attention

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