



Laser Processing of Materials for Improved Part Performance

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Dr. Ronan McCann, Dr. David Kinahan, Prof. Dermot Brabazon



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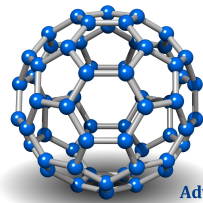
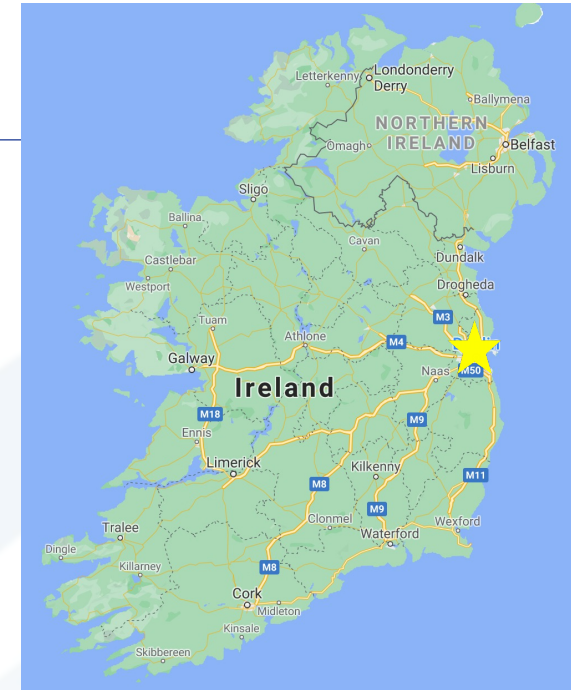
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Who we are – Dublin City University



Industry-focused research university in Dublin, Ireland



APT

Advanced Processing Technology Research Centre

- Production Technology
- Material Processing
- Product Design & Sustainability
- Micro/Nano Systems Technology

I-Form

Advanced Manufacturing Research Centre

- Additive Manufacturing
- Digitization & Industry 4.0
- Process Development & Modelling



Institiúid Uisce DCU
DCU Water Institute

- Energy
- Water & Health
- Marine

AEROSPACE

MEDICAL/PRECISION
ENGINEERING

SMART TOOLING

MATERIAL/
EQUIPMENT

SMART
MANUFACTURING

The Team



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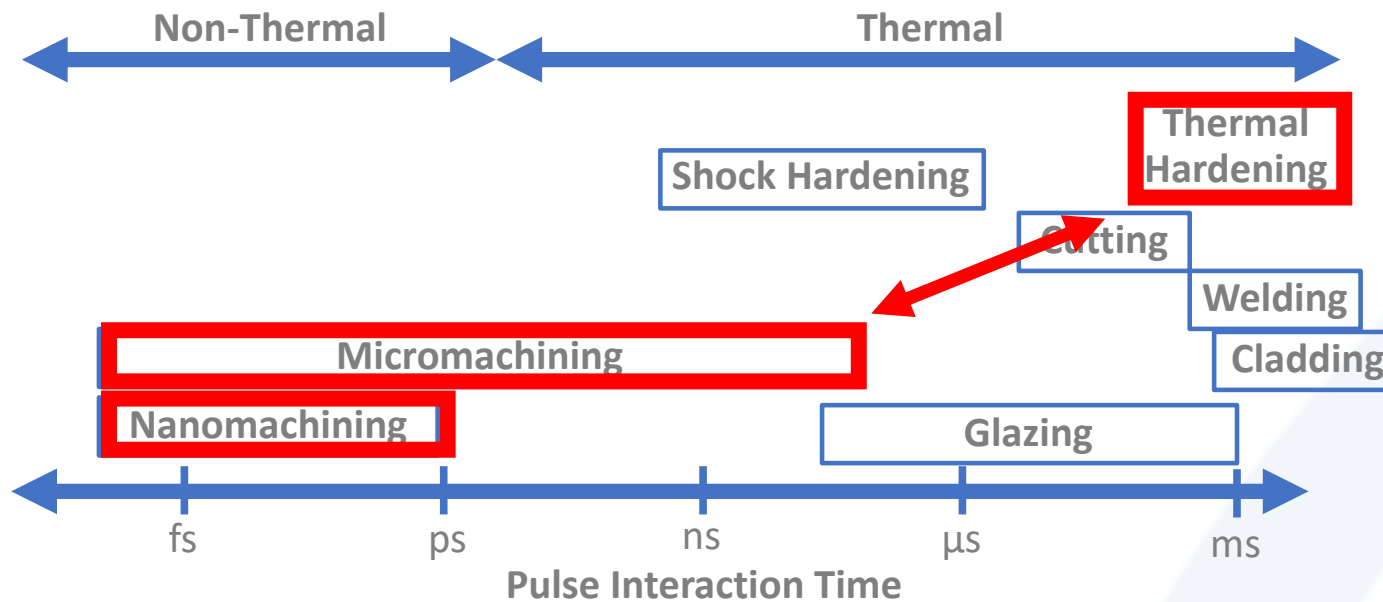


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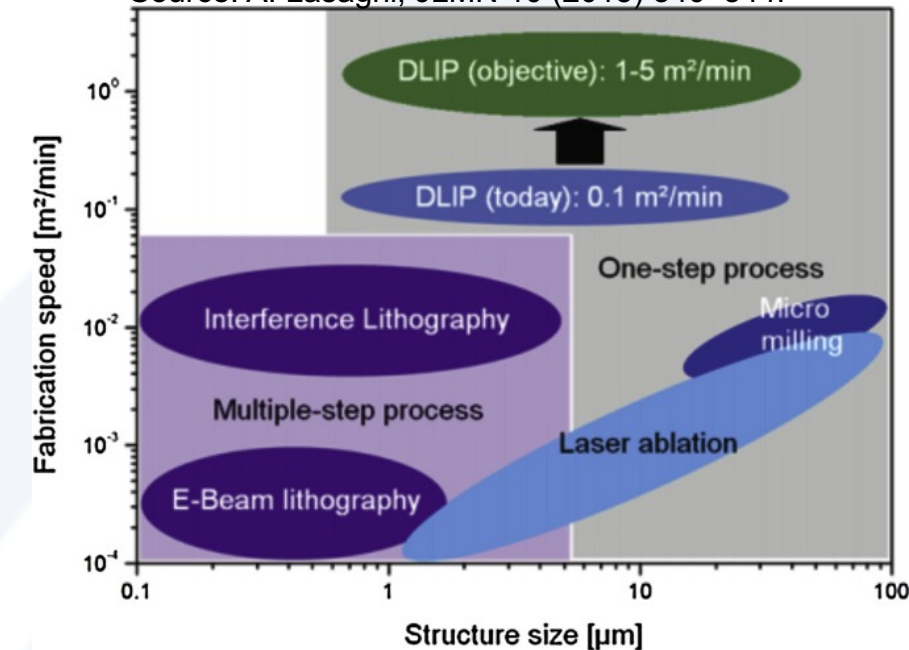
Laser Processing



- Direct application of lasers to surfaces for surface modification (structuring/bonding/chemical alteration)



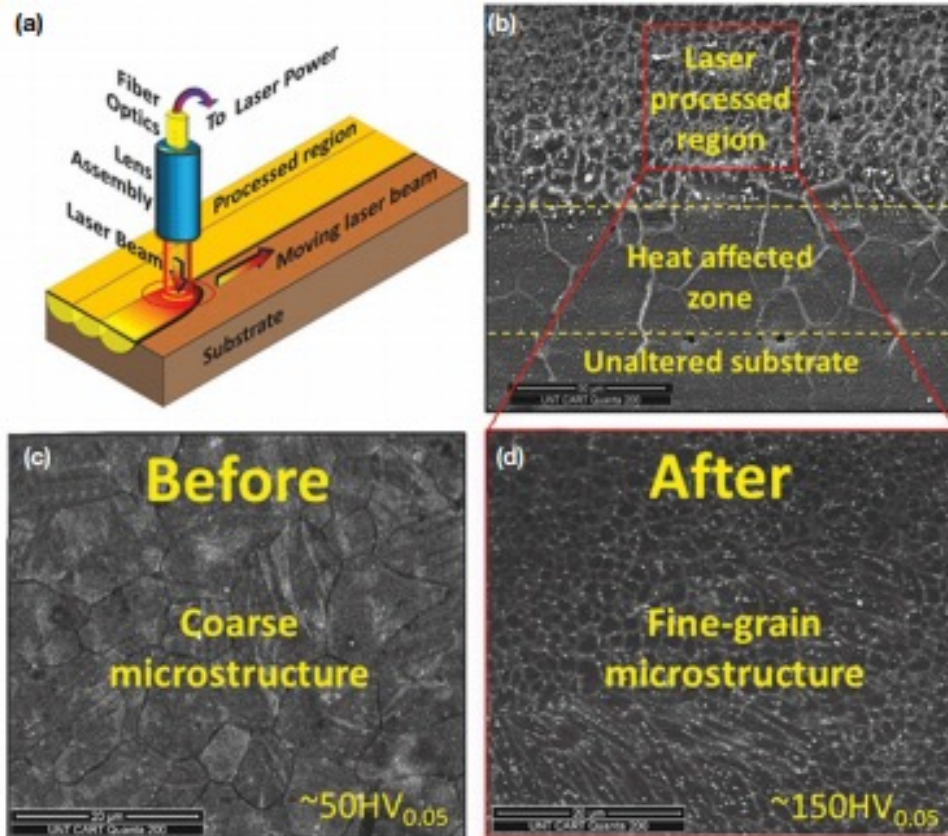
Source: A. Lasagni, JLMN 10 (2015) 340–344.



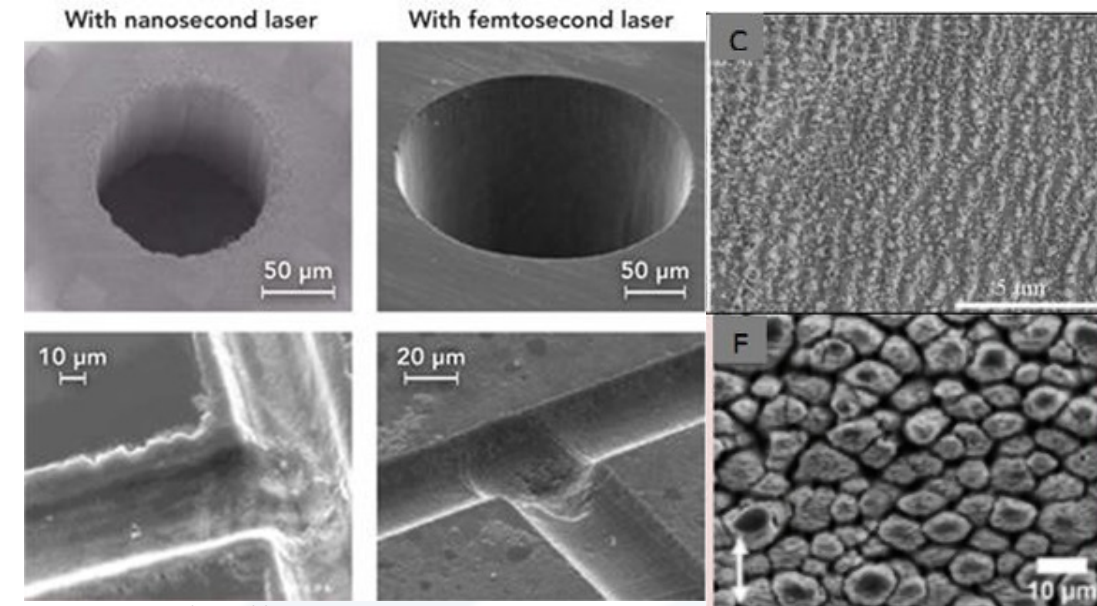
- Laser choice driven by applications
 - Micro/nanomachining and Hardening require two separate processes
- Use of a multi-modal approach needed for combination of techniques



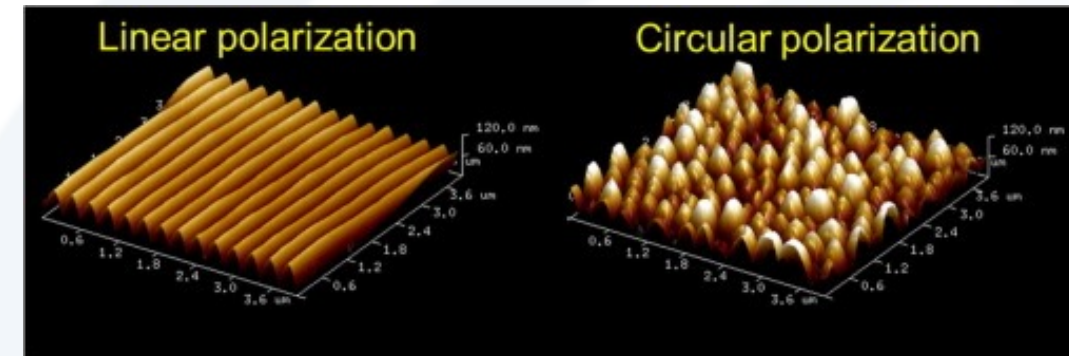
Multi-modal Laser Processing



H. Vora, N. Dahotre, *Advanced Materials and Processes* (2013) 171(11):45-47



Source:www.industrial-lasers.com



E. Rebollar, M. Castillejo, T.A. Ezquerro, *European Polymer Journal* 73 (2015) 162–174.

Combination of laser heat treatment and surface structuring



Use Cases for Laser Processing



- Three example Use Cases identified:
 1. Laser Textured Surfaces & Coatings
 2. Micro- and nano-structuring of membranes
 3. Bi-modal laser hardening and texturing
- Many other potential uses – NewSkin takes supplier/customer driven approach
- Laser process compatible with wide range of metals/ceramics/polymers/composites



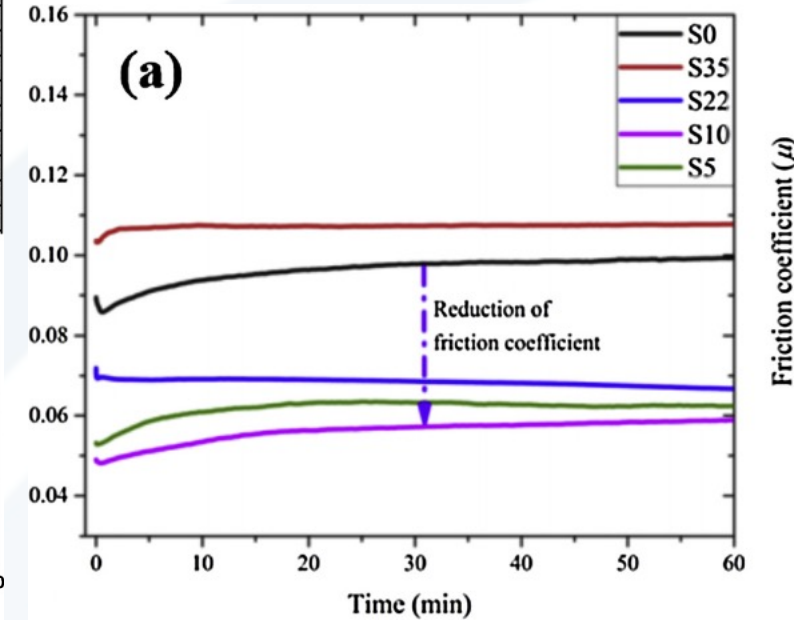
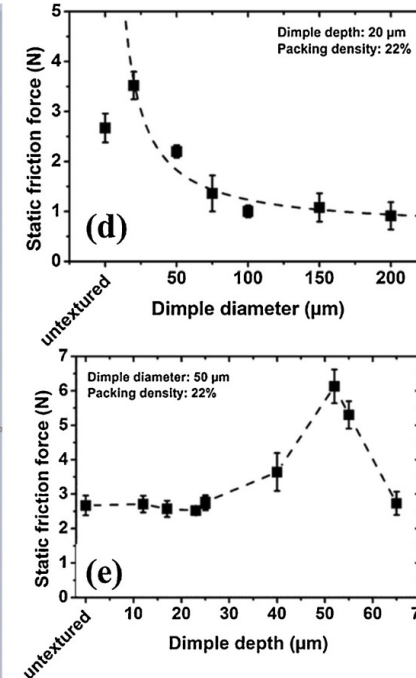
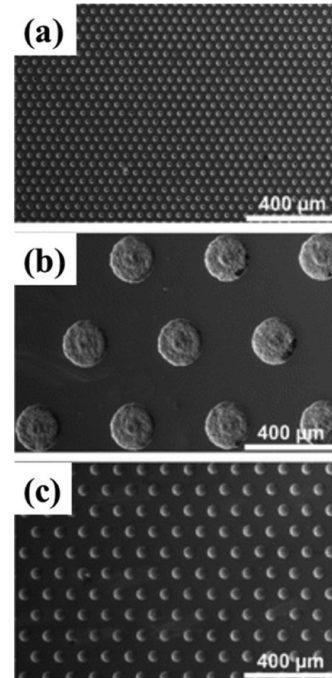
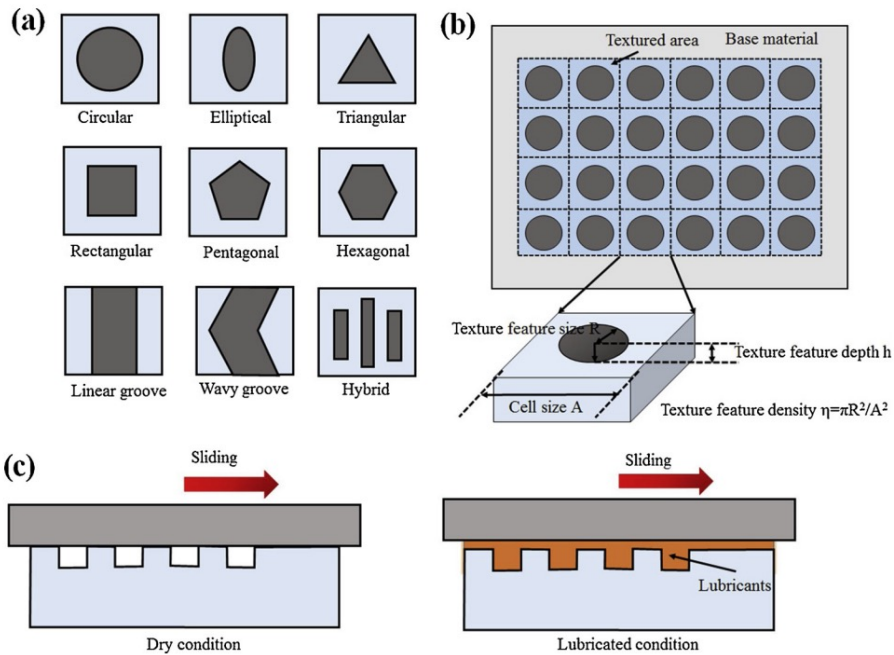
Use Case 1: Laser-textured Materials/ Coatings



- Laser-induced textured surfaces with nano/micro scale roughness which reduces attachment of liquids and microorganisms
- Fine control over tribological properties through defined surface texturing
- Application areas:
 - Components working in **immersed conditions**
 - Marine, water treatment, heat exchangers, chemical/bioreactors.
 - **High-friction** environments
 - **Anti-icing** (construction/aerospace)
 - **Anti-corrosion** (bioprocessing/chemical engineering)
 - Prosthesis and **medical components**.
- Unique Selling Point:
 - Enhanced lifetime of high-friction or water-facing surfaces
 - Reduced cleaning requirements



Use Case 1: Laser-textured Materials/ Coatings

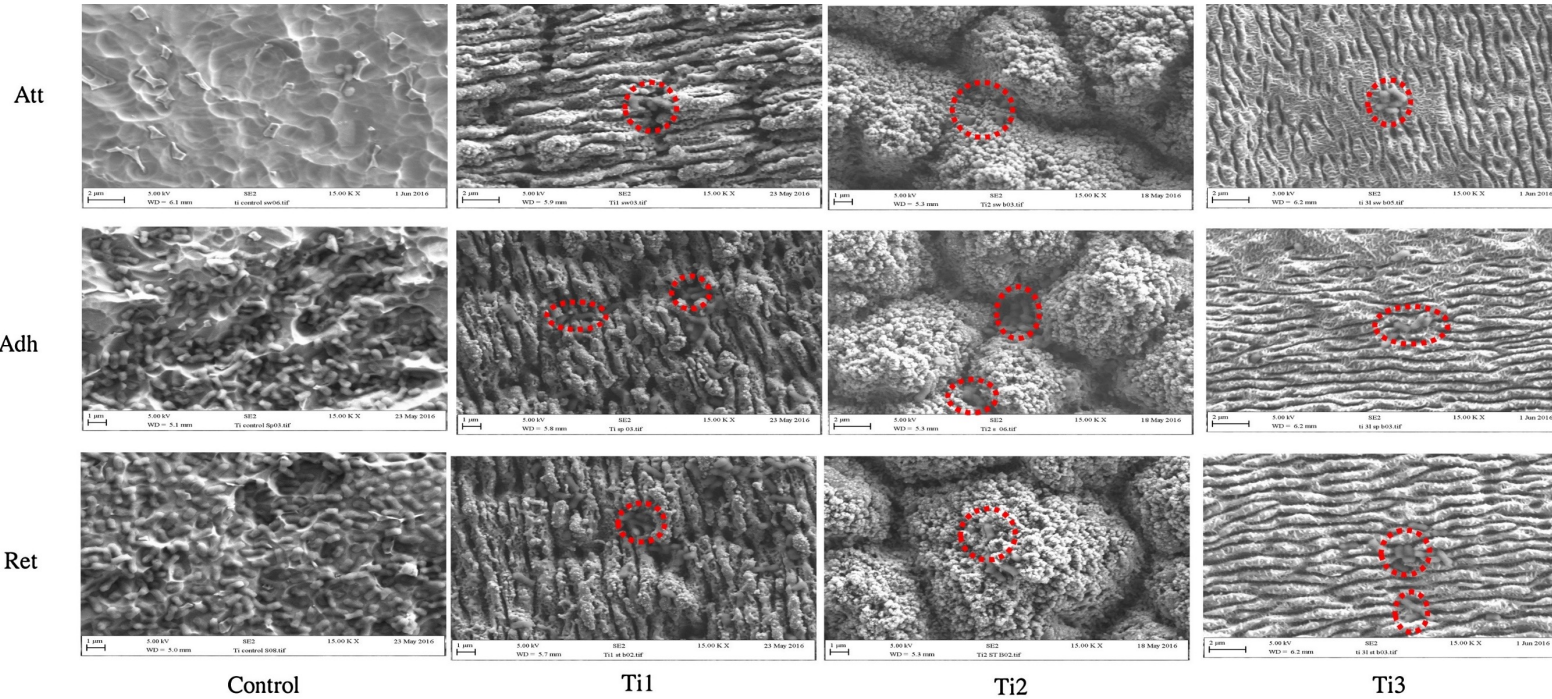


Micro/nano morphologies scaled to large areas or complex geometries for tribological improvements

B. Mao, et al, J. Manuf. Process. 53 (2020) 153–173.

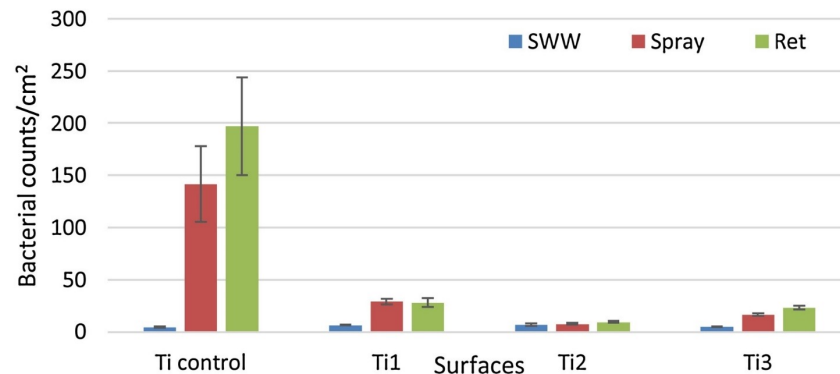


Use Case 1: Laser-textured Materials/ Coatings



Anti-fouling texturing of Ti6Al4V via direct-write laser processing

a)

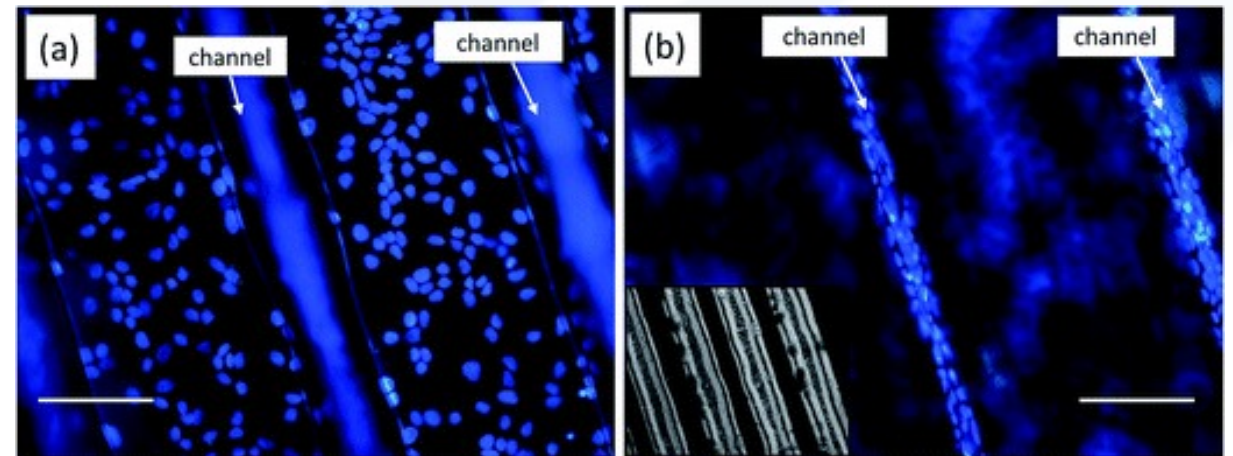
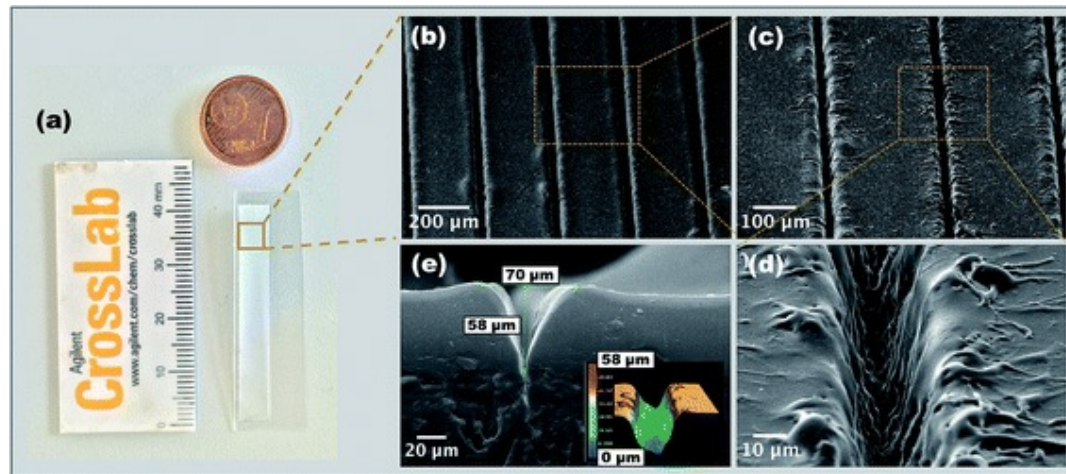
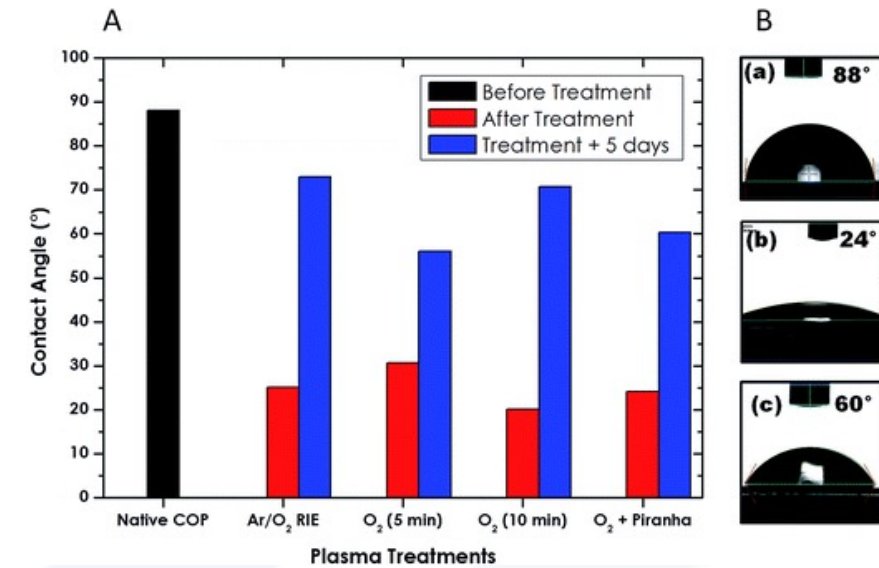
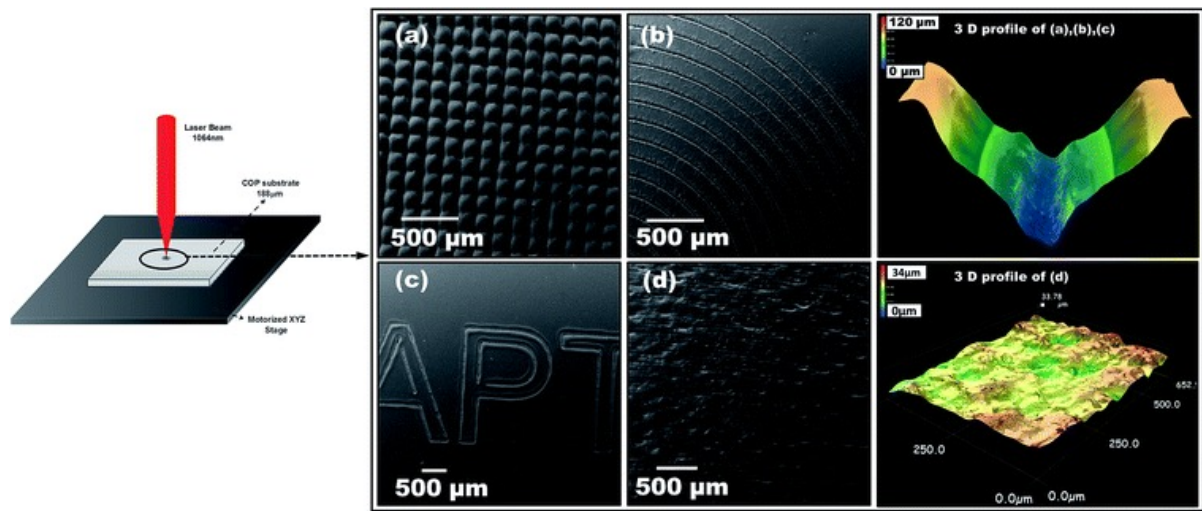


b)

F.H. Rajab, C.M. Liauw, P.S. Benson, L. Li, K.A. Whitehead, Colloids and Surfaces B: Biointerfaces 160 (2017) 688–696.



Use Case 1: Previous Work – Biomimetic Surfaces



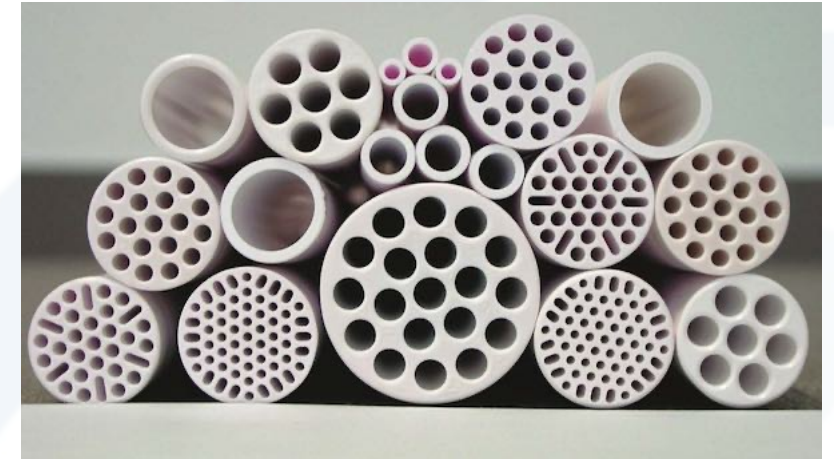
K. Bagga, R. McCann, F. O'Sullivan, P. Ghosh, S. Krishnamurthy, A. Stalcup, M. Vázquez, D. Brabazon, RSC Adv. 7 (2017) 8060–8069.



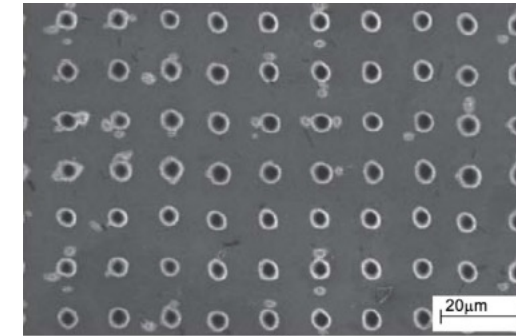
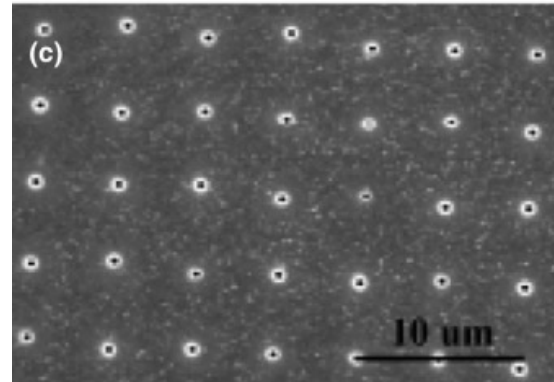
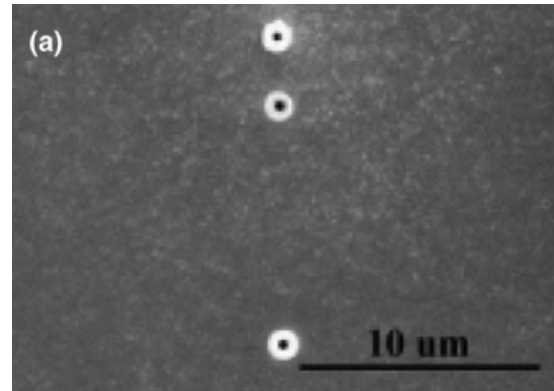
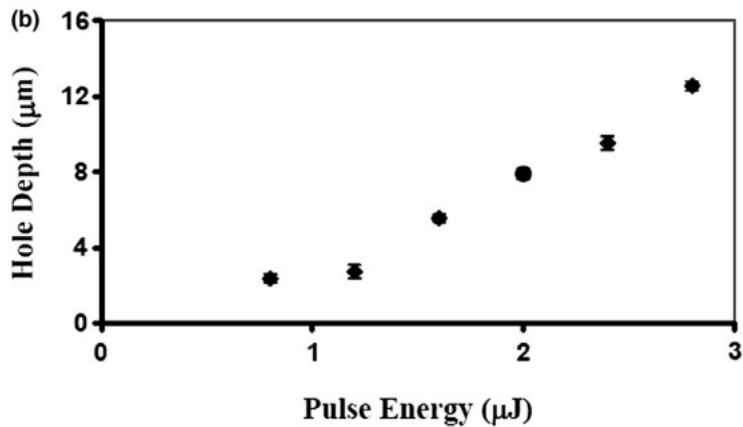
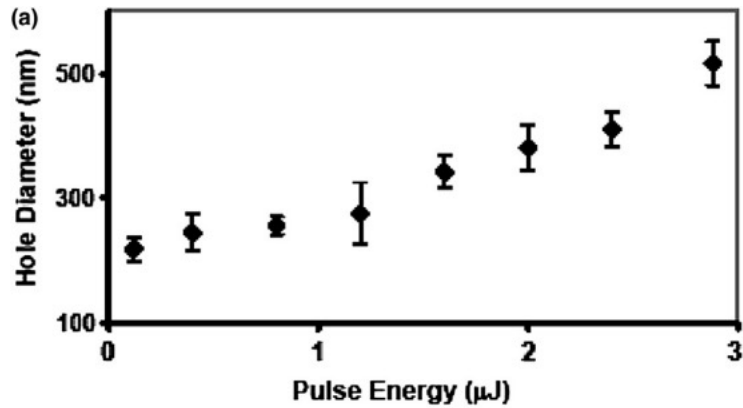
Use Case 2: Micro/Nano structuring of ceramic membranes



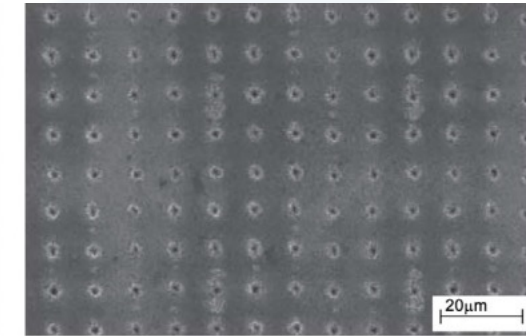
- Creation of micron or nanometre-sized sized pores on functional materials
- Application Areas: Ceramic membranes manufacturers
 - Environmental and water treatment
 - Chemical and bioprocessing industries
 - Chromatography/Separation Science
 - Laser treatments of existing products
- Unique Selling Point
 - Enhanced separation/filtration efficiency than previous generation of filters.
- Benefit for customers
 - Longer filter life, better filter performance



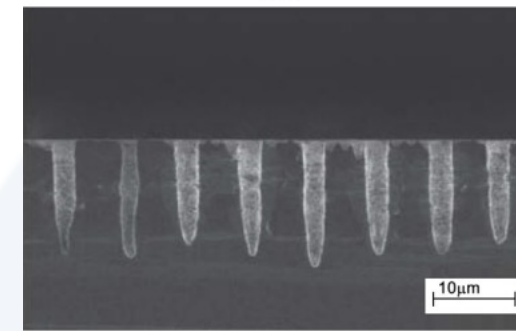
Use Case 2: Micro/Nano structuring of ceramic membranes



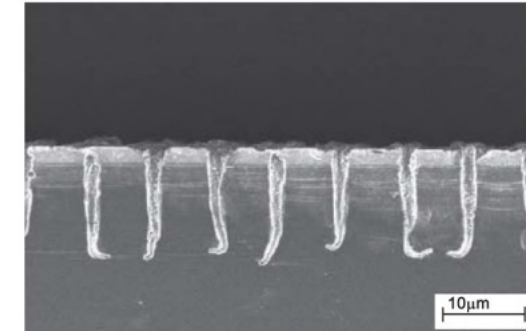
(a)



(b)



(c)



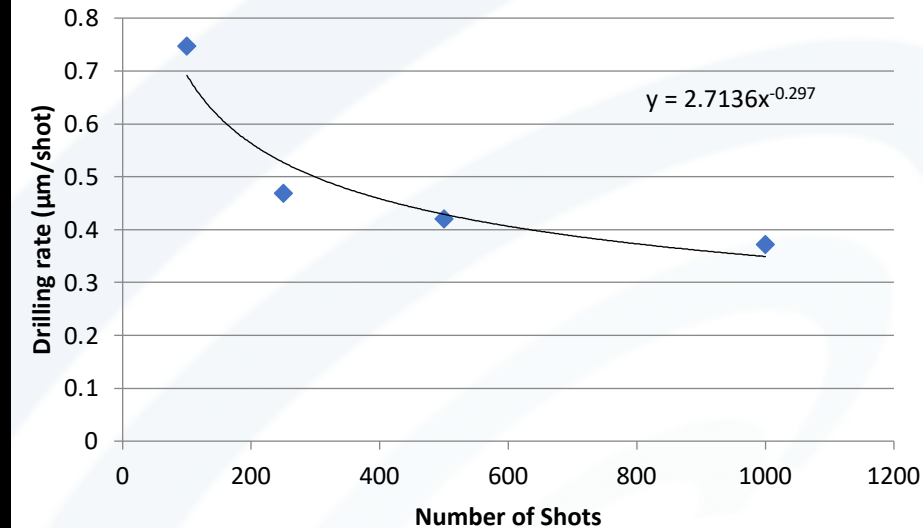
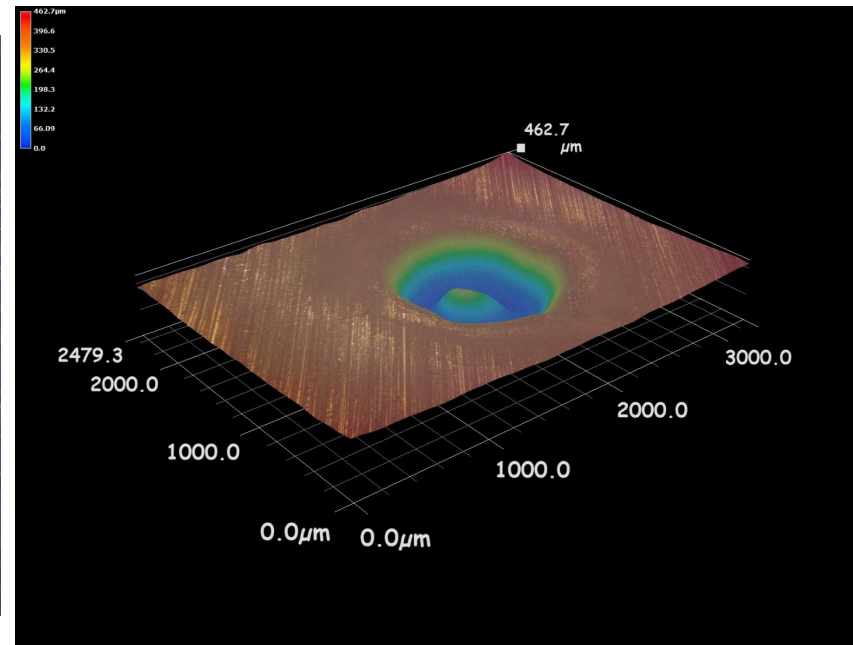
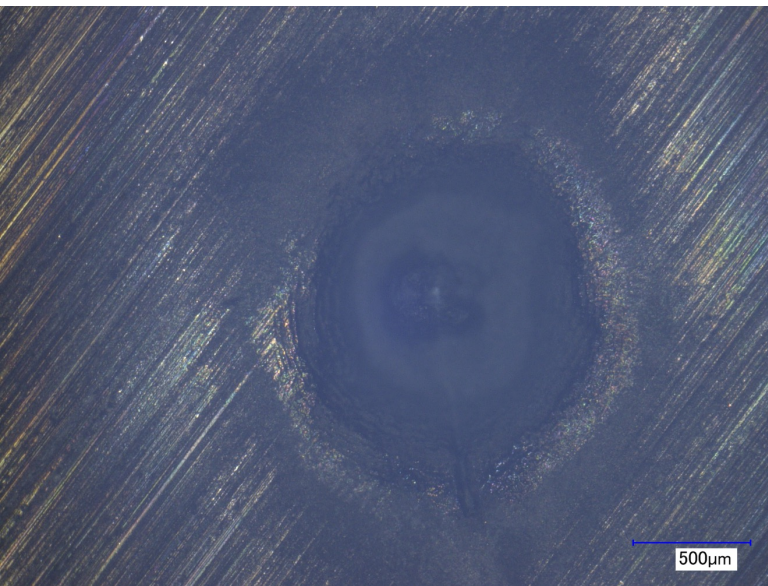
(d)

Micron and sub-micron scale holes on chrome-coatings (left) and silicon (right)

Source: A.K. Nath, in: Comprehensive Materials Processing, Elsevier, 2014, pp. 115–175.



Use Case 2: Previous Work – Ceramic Texturing



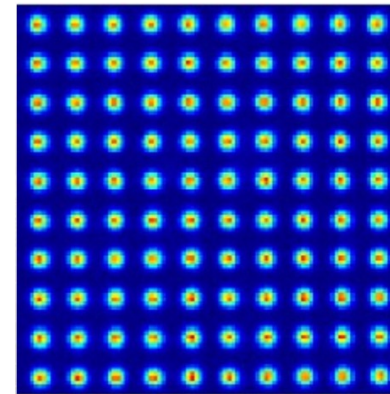
High aspect hole drilling on alumina ceramic materials



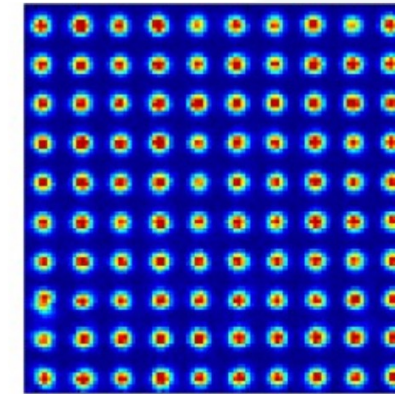
Use Case 2: Micro/Nano structuring of ceramic membranes



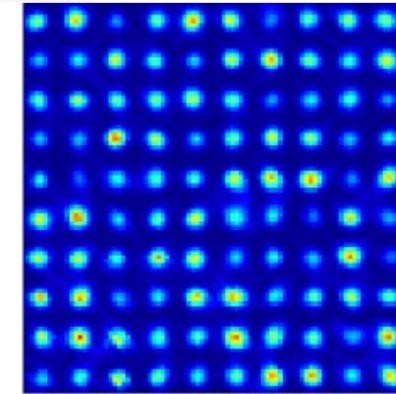
Resolution: 1920 x 1080
Pixel Pitch: 8.0 μm
Fill Factor: 93 %



100 spots



2500 spots



10000 spots

NewSkin Project - large-area upscaling using Selective Light Modulation

Source: Holoeye Photonics AG



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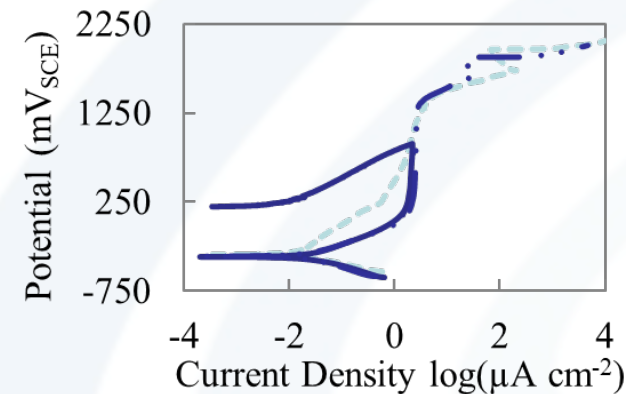
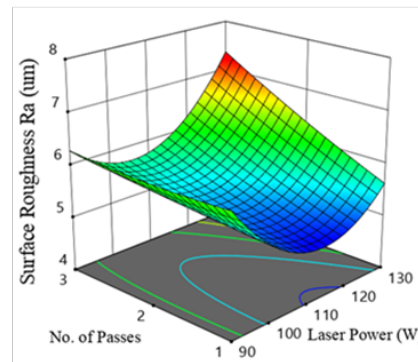
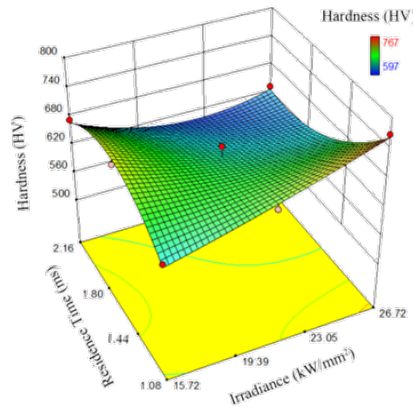
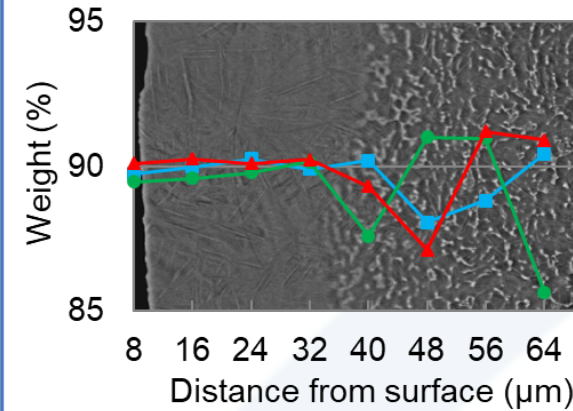
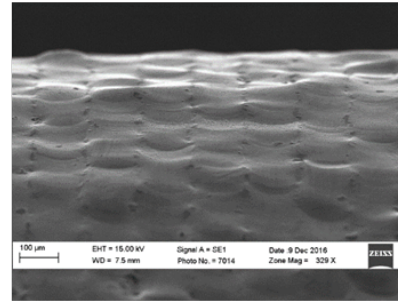
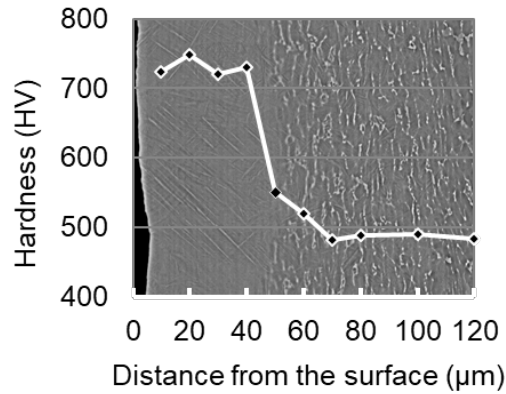
Use Case 3: Laser hardening and texturing for performance improvement



- Combination of laser texturing and laser hardening
 - Reduced cavitation/bubble generation of propellers in liquid environments.
 - High wear environments in energy/mining sector
- Unique Selling Point:
 - Increased part lifetime
 - Reduced cavitation damage of propeller blades, bearings and motor components.
 - Low friction applications
 - High wear resistance
- Benefit for customers:
 - Lower part maintenance, enhanced reliability, lower energy requirements



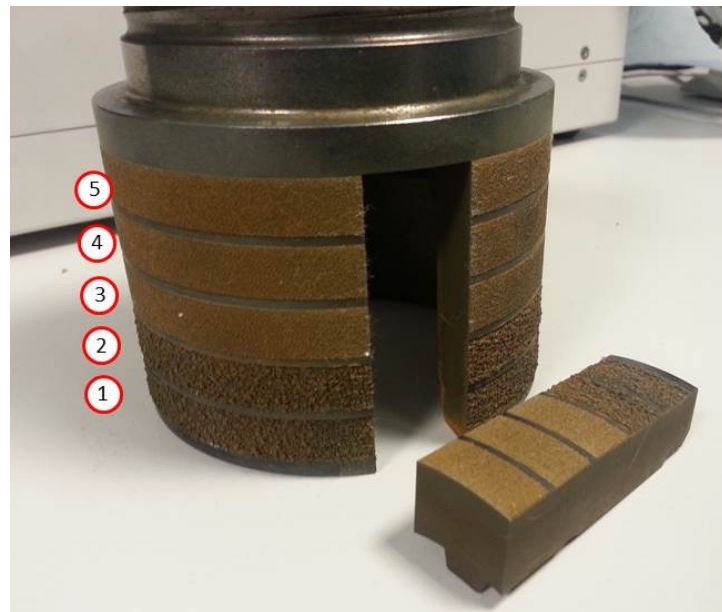
Use Case 3: Laser hardening and texturing for performance improvement (316L Steel)



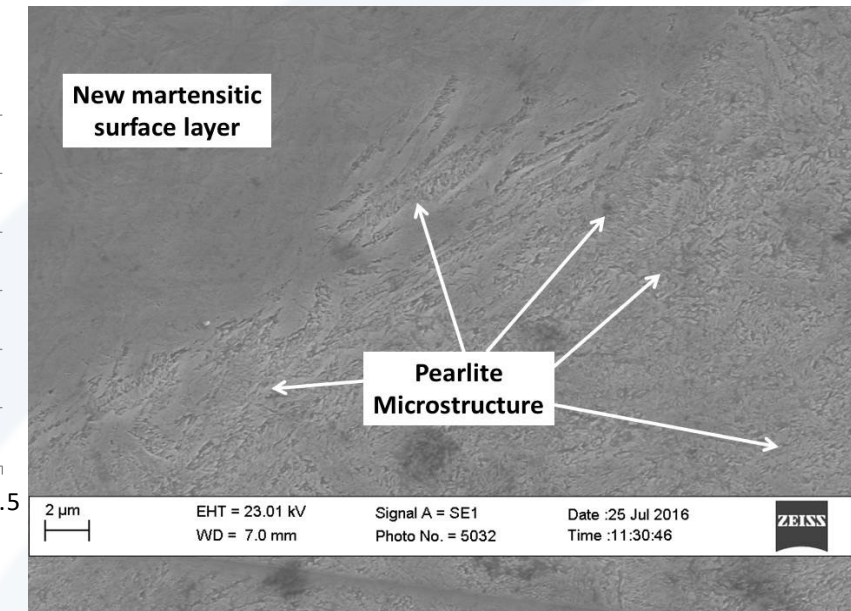
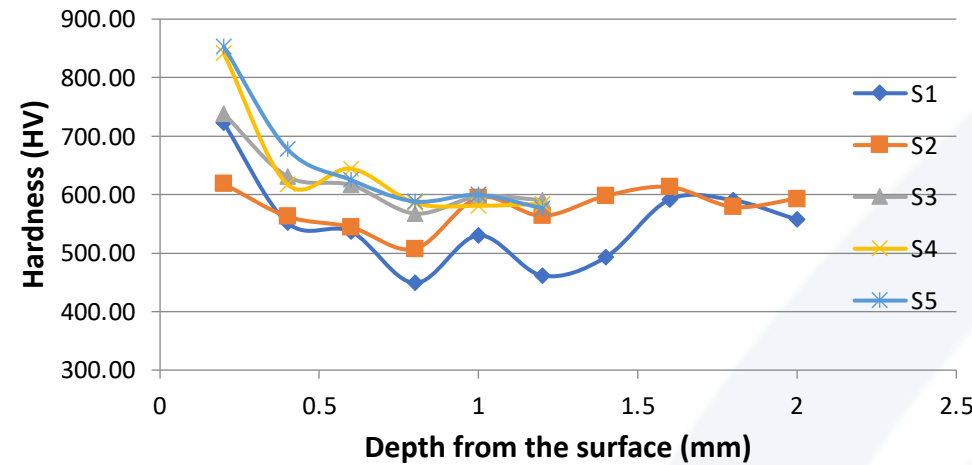
Improved wear resistance via laser thermal hardening



Use Case 3: Laser hardening and texturing for performance improvement



316L Steel laser nitriding



Combination of laser hardening and laser nitriding for improved wear resistance and corrosion resistance



NewSkin Open Innovation Test Bed

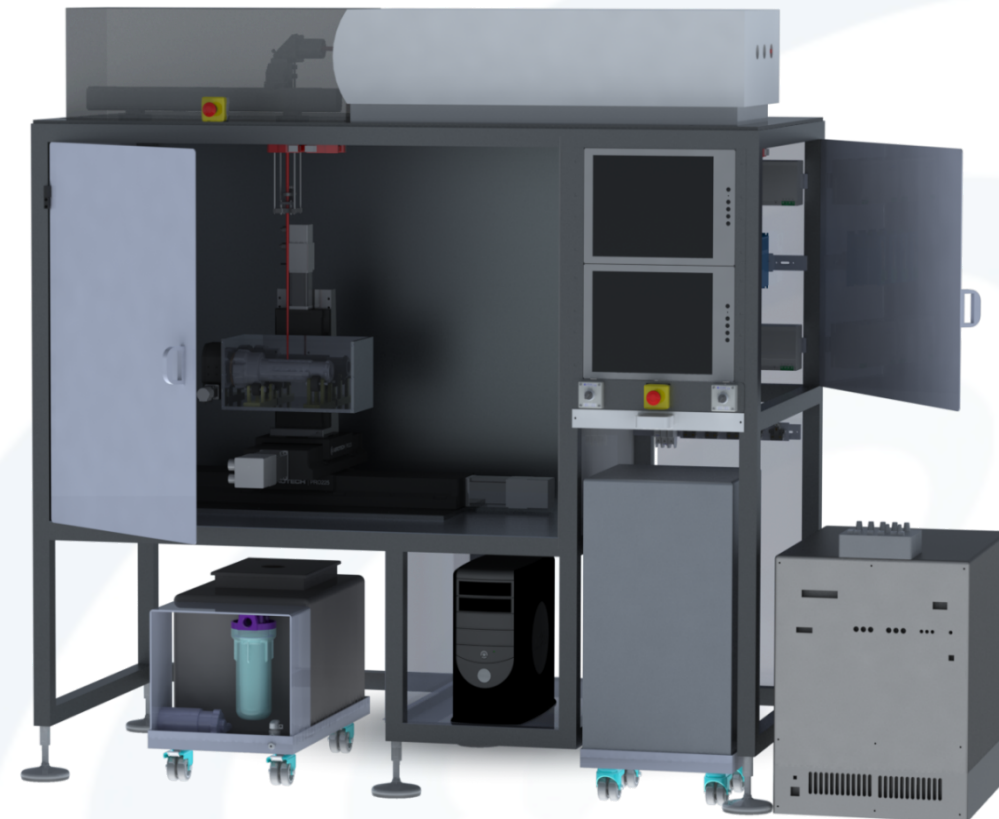


Integrated multi-modal micro/nano machining and surface hardening

- **Heat-treatment** laser (IPG YLR 1kW CW) w/ Welding Head
- **Femtosecond micro/nano machining** laser (NKT OneFive Origami 10XP)
 - Controllable pulse width (400 fs – 4 ps)
 - Optical Setup for LIPSS and Optical Phase Modulation
 - In-situ metrology (Interferometry/IR Pyrometry)
- 4-axis Aerotech Motion and part handling system
 - Max substrate size: 0.5 m × 0.9 m flat or \varnothing 0.4m × 0.3 m

Applications:

- Nano surface structuring/drilling
- Heat treatment/surface hardening
- Laser shock peening, laser polishing, high aspect ratio piercing





Thank you

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