PROMETHEUS

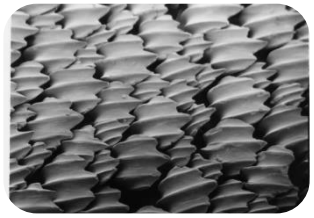
RAPID ULTRA-SHORT PULSE LASER SURFACE TEXTURING TECHNOLOGY

Laser textured surface functionalization for industrial applications

23.11.2021

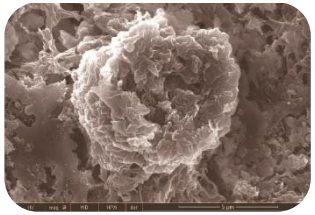
Surface microstructures – from nature to industrial application

Shark skin



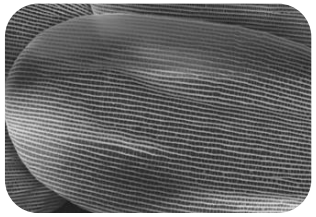
Drag reduction

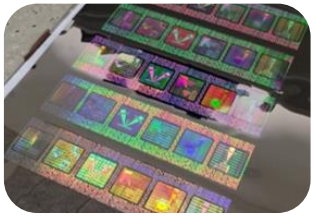
Rice leaf



Wettability

Butterfly wing





Decorative elements

P.Liu, Superhydrophobic and self-cleaning behavior of Portland cement with lotus-leaf-like microstructure, 2017
G. Bixler, Fluid drag reduction and efficient self-cleaning with rice leaf and butterfly wing bionisoired surfaces, 2013
D. Bechert, Experiments with three-dimensionaö riblets as an idelaized model of shark skin, 1999

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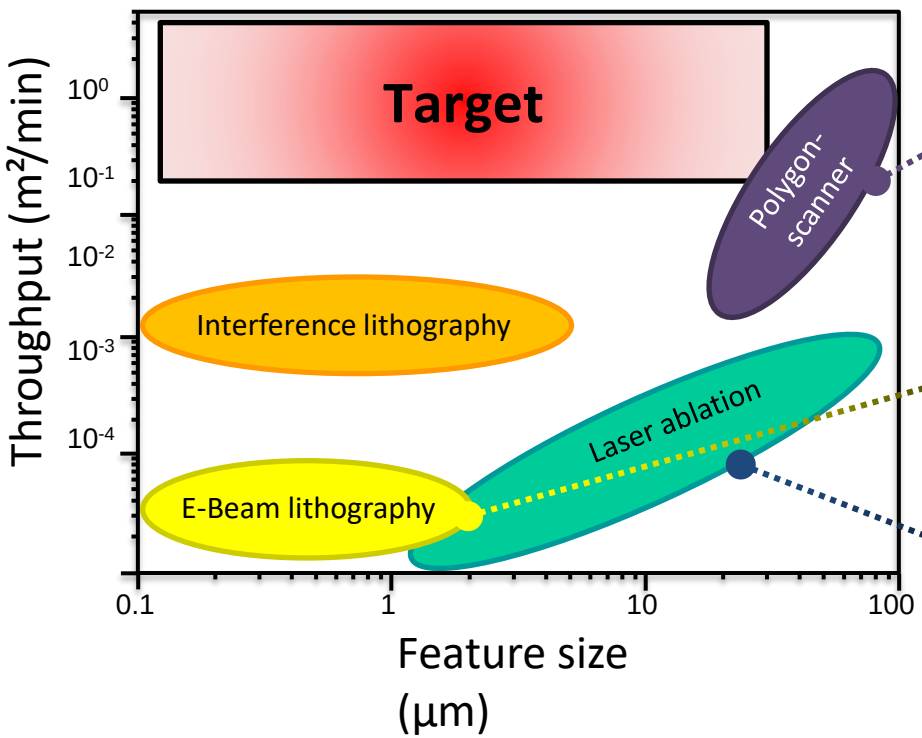
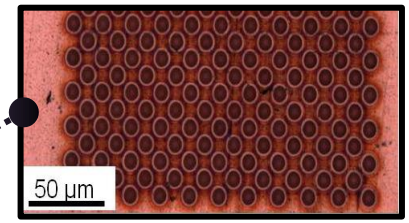
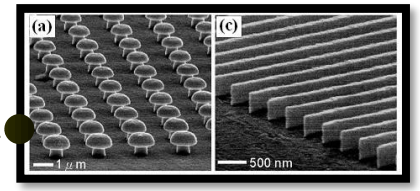
Surface microstructures – from nature to industrial application

Surface patterning technologies

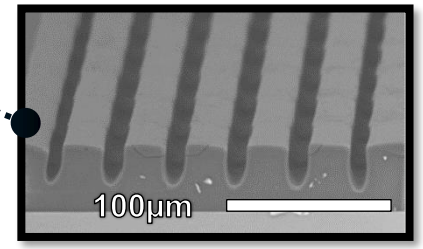




B.Jaeggi et al., Proc. SPIE 8243, LAMOM XVII. 2012.



Y.-W. Su et al., Advanced Materials, 15 **(2003)** 49.

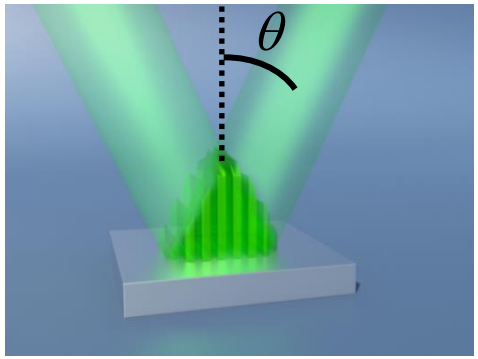


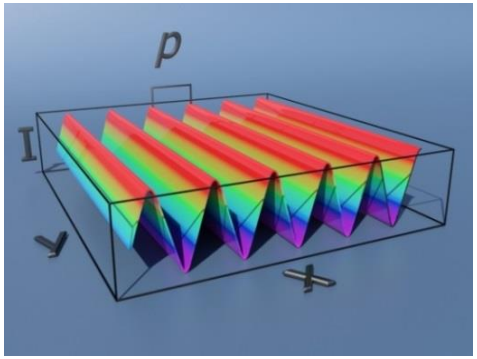
A. Singh et al., Micromachines 5 **(2014)** 472-485.

Laser texturing using Direct Laser Interference Patterning (DLIP)

Interference principle and key facts

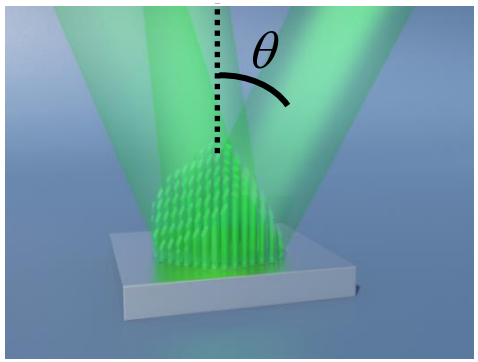
2-Beam Interference

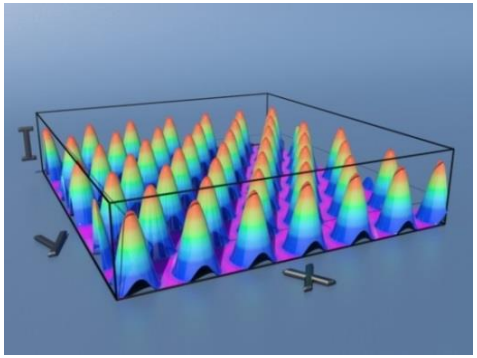




$$p = \frac{\lambda}{2\sin(\theta)}$$

3-Beam Interference





$$p = \frac{\lambda}{\sqrt{3}\sin(\theta)}$$

DLIP - Key facts

- Interference effects / patterns
- Facilitate pulsed laser sources: 1064 nm – 266 nm
- One-step process
- One laser pulse generates up to several millions of surface features
- Typical pattern dimensions: 180 nm – 30 µm
- Process speeds: up to ~ 1 m²/min

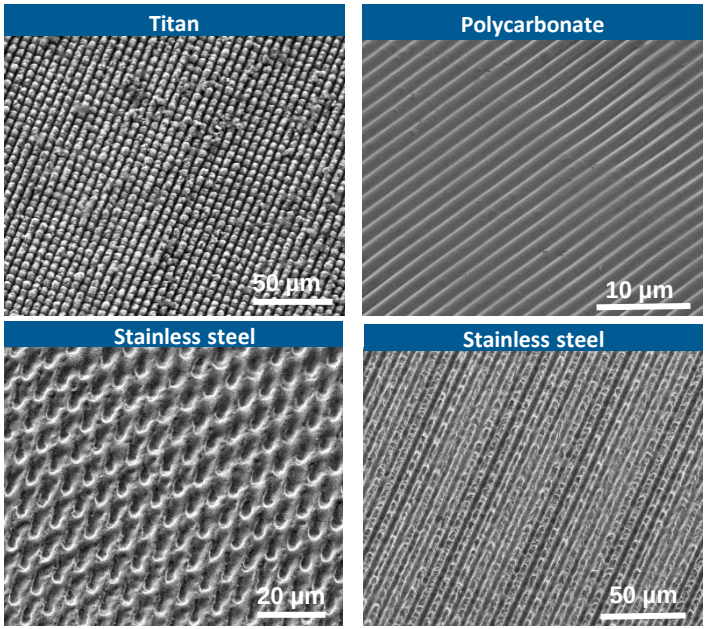
Laser texturing using Direct Laser Interference Patterning (DLIP)

Interference principle and key facts

What influences the DLIP structure?

- Laser wavelength (spatial period)
- Laser fluence (structure height)
- Pulse duration (structure quality)
- Angle of the beams (spatial period)
- Number of sub-beams (pattern geometry)
- Structuring strategy (homogeneity)
- Thermal properties of the material (structure quality)

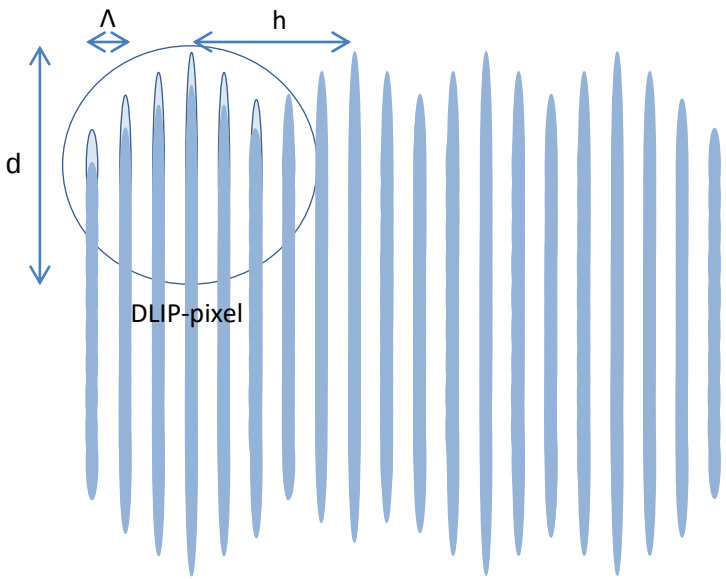
Examples of DLIP surface structures



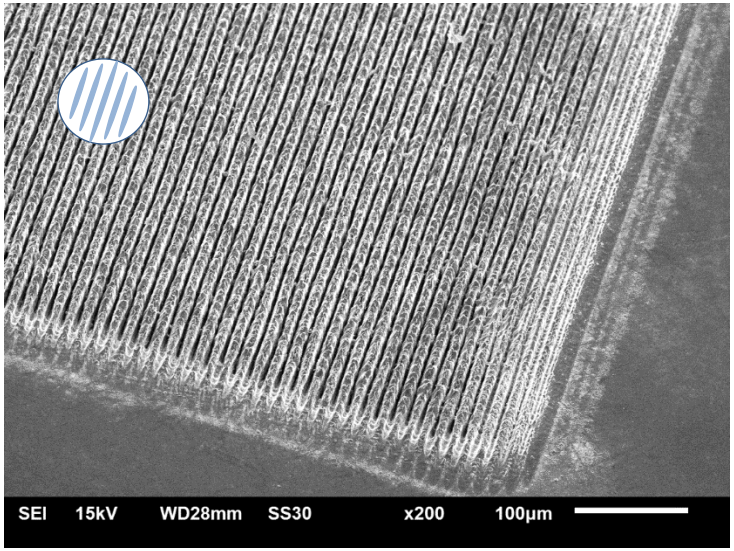
Laser texturing using Direct Laser Interference Patterning (DLIP)

DLIP process strategy

Two beam interference process strategy



Two beam interference final sample



Laser texturing using Direct Laser Interference Patterning (DLIP)

Large-area surface functionalization

High speed laser surface texturing

Laser parameters:

- Frequency
- Laser power
- Laser fluence

Process parameters:

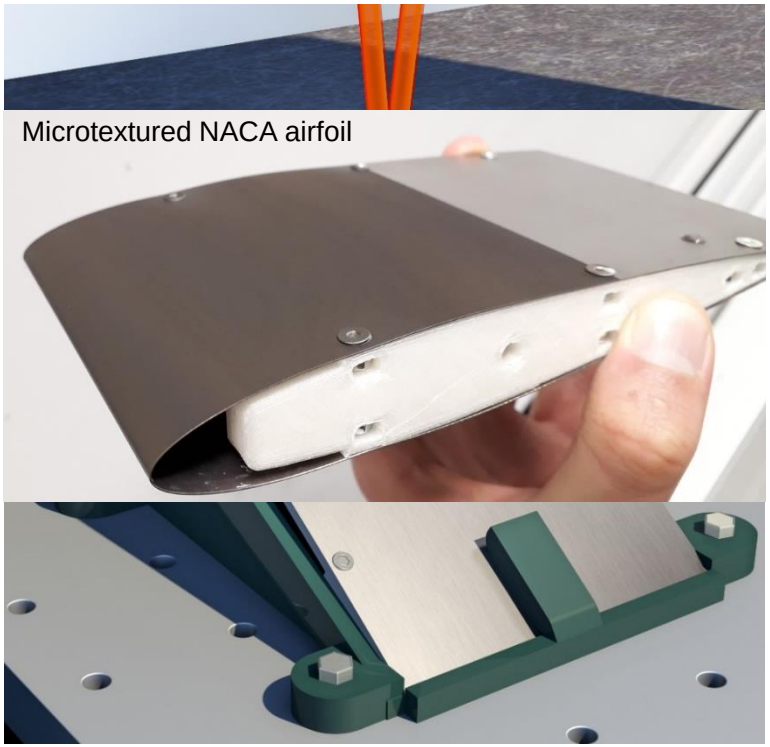
- DLIP pixel size and beam shaping strategy
- Pulses per pixel
- Linear axis or scanner systems for structuring process
  - Linear axis speed: up to 2 m/s
  - Galvo-scanner speed: up to 12 m/s

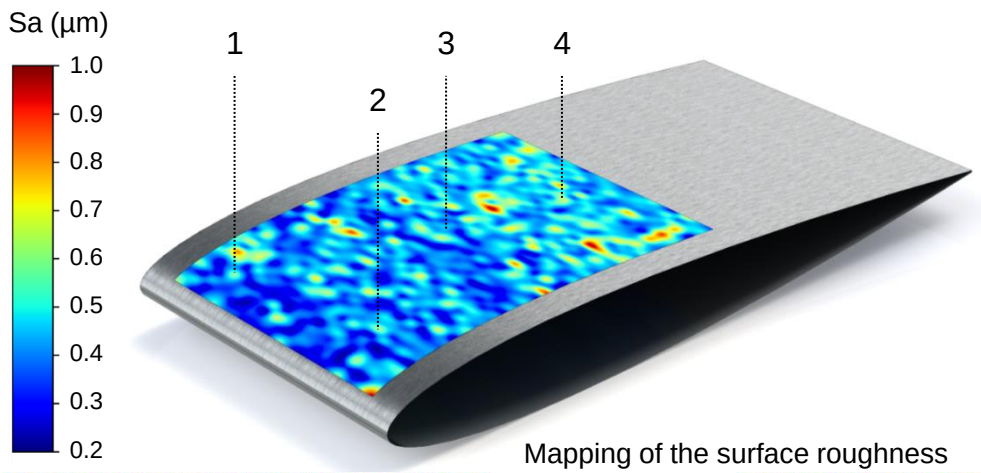
Fraunhofer IWS

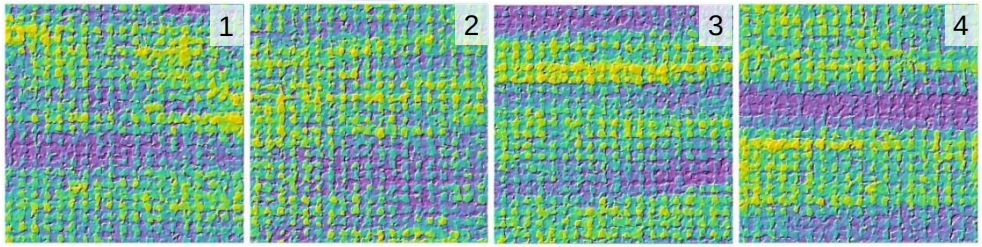
Can surface texturing **reduce ice formation**?
Can de-icing be improved?

Microtexturing of a NACA 0012 airfoil

Three-dimensional Direct Laser Interference Patterning



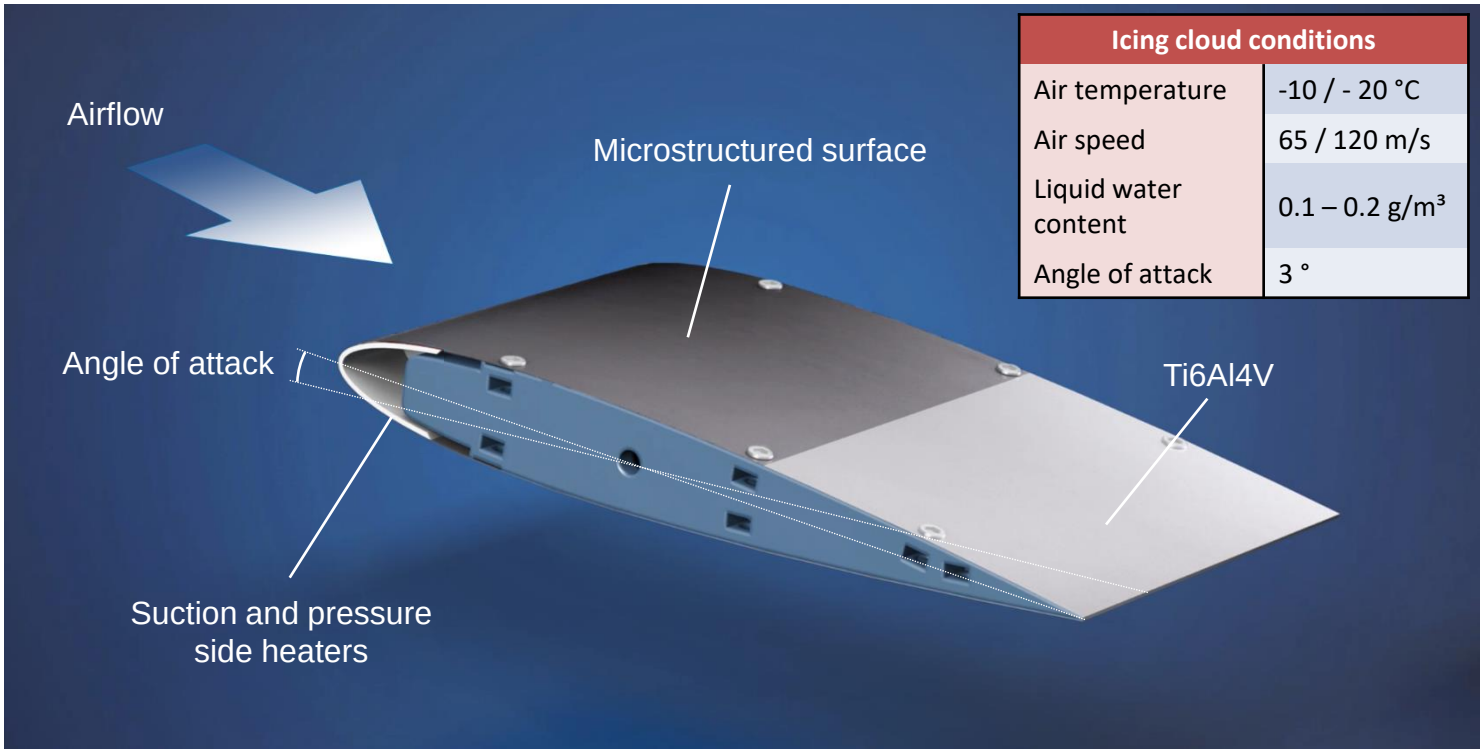




S. Alamri et al., Advanced Materials Interfaces 2001231 (2020) 1-10

Icing wind tunnel: ice accretion tests

Experimental setup



Icing cloud conditions	
Air temperature	-10 / - 20 °C
Air speed	65 / 120 m/s
Liquid water content	0.1 – 0.2 g/m³
Angle of attack	3 °

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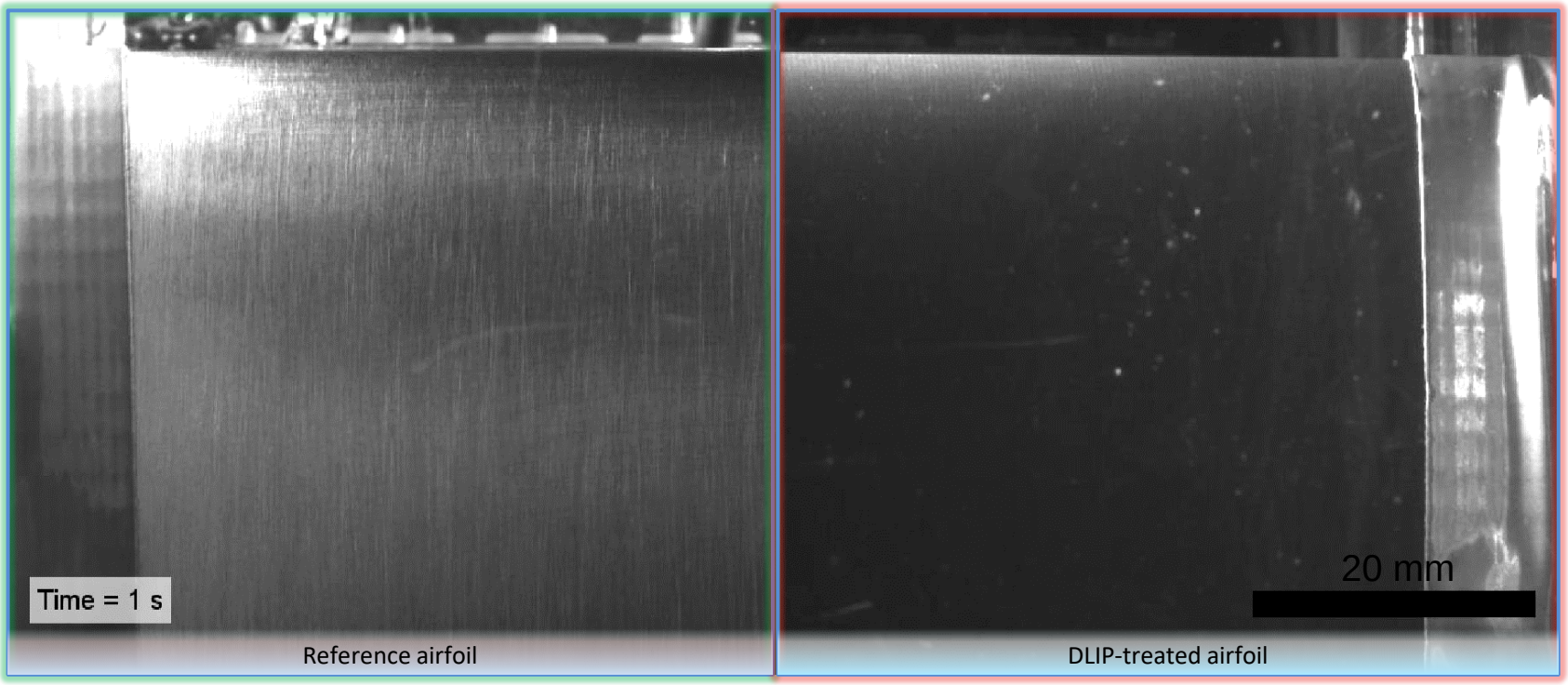
Icing wind tunnel: ice accretion tests

How does ice accrete on a microtextured surface?



S. Alamri et al., Advanced Materials Interfaces 2001231 (2020) 1-10

Can surface texturing improve the **usability & reliability of electrical connectors?**

Application examples: Automotive

Usability & reliability of electrical connectors

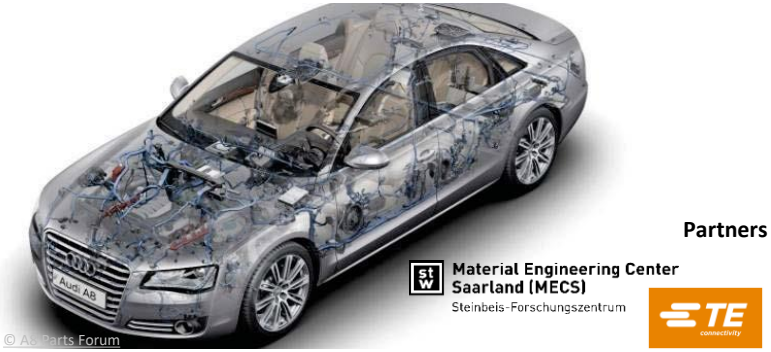
- **Target:**
  Development of next generation of electrical connectors for more reliable & manageable electrical systems (due to electrification, autonomous driving)

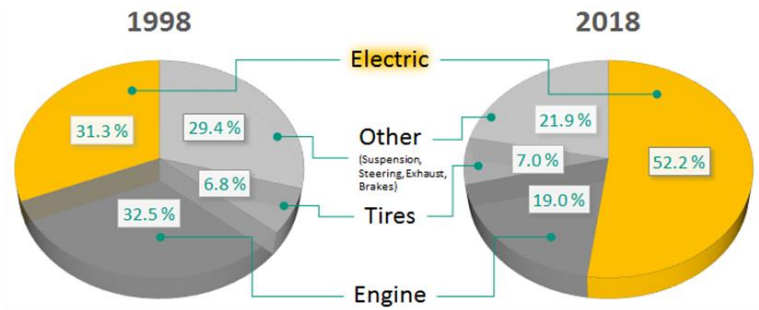
- **Challenges:**
  High-speed structuring of electrical connectors

Results of pre-tests:

- Oil-film encapsulation lead to reduced plug force (up to 30 %)
- Reduction of electrical resistance up to 80 %

https://industrieanzeiger.industrie.de/technik/fertigung/high-speed-laserstrukturierung-fuer-funktionale-oberflaechen/





Reasons for car failure (ADAC 2018)

Application examples: Automotive

Usability & reliability of electrical connectors

Industry transfer

- Development of completely new prototype employing DLIP technology
- Lead Partner:
  Material Engineering Center Saarland
- End user:
  TE Connectivity
- **Result:**
  On-the-fly structuring of connectors
  (> 80,000 connectors/h)

DLIP prototype for functionalization of connectors

https://www.steinbeis.de/de/steinbeis/transferpreis/preistraeger/2019-neue-generation-elektrischer-steckkontakte-optimale-performance-durch-high-speed-laserstrukturierung.html

Application examples: *Conclusions*

Enhanced usability & reliability of connectors

- **Target:** Next generation of electrical connectors
- Oil-film encapsulation lead to reduced plug force
  (up to 30 %)
- Reduced plug forces enable up to 30 % more contacts in electrical housings (approx.)
- High-speed (on-the-fly) processing using DLIP

Ice adhesion on DLIP-treated cantilevers

- Hierarchical microstructures fabricated
- Superhydrophobic behaviour achieved
- Ice accretion tested in icing wind tunnel
- Ice adhesion up to 70 % less for different icing conditions
- De-icing power saving up to 80 %
- Anti-icing power saving up to 60 %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Questions?