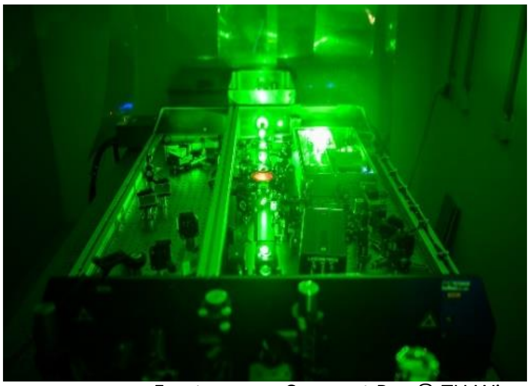
Klima- und Energiefonds, FFG-Project „NICE“ (871733)

Reduction of ice formation by structuring of surfaces with ultrashort laser pulses.

Consortium lead: TU Wien, Institute for Production Engineering and Photonic Technologies

Industry partner: Energiewerkstatt



Femtopower Compact Pro © TU Wien

Motivation for the wind energy sector:

- Ice throw is a serious public safety issue.
- Turbine icing may cause mechanical stress and lifetime reduction due to dynamic imbalance.
- Icing can induce substantial production losses of up to 30% through decreased aerodynamic efficiency and turbine shutdowns during icing events.

Project Objectives:

Development of laser structured anti-ice surfaces to increase energy production efficiency of wind turbines in cold climate.

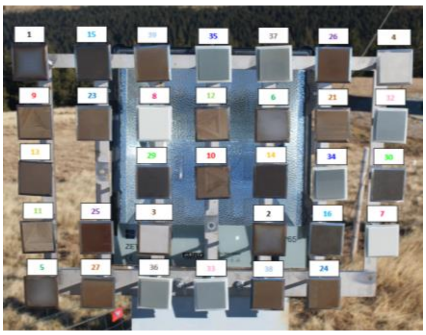
- Reducing shutdown times due to icing prevention and low ice adhesion.
- Increasing aerodynamic efficiency through icing mitigation.
- Increasing water repellency (super-hydrophobic surfaces).
- Replacing active IPS (ice protection systems) with passive anti-ice surface structures.
- Reducing the operational and health & safety risks caused by icing.

Implemented Tasks:

- Development of a wide range of super-hydrophobic structures.
- Characterization of femtosecond laser application and the resulting structures in regard to the surface wettability and the ice adhesion for different materials.
- Field tests in cold climate conditions with differently structured surfaces and materials investigated the
  - delay and reduction of icing as well as increased deicing capability (static test)
  - durability of samples attached to rotor blades of a small wind turbine (dynamic test)

Field test setup in the Austrian Alps © Energiewerkstatt

Static icing/deicing test © Energiewerkstatt



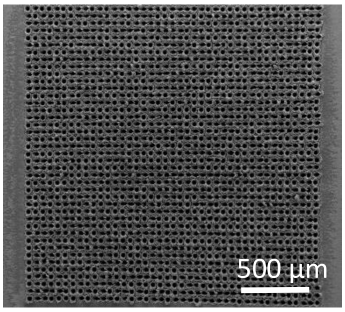
Static icing/deicing test with 50 x 50 mm samples © Energiewerkstatt

This project is funded by the Climate and Energy Fund and carried out as part of the 2018 Energy Research Program.

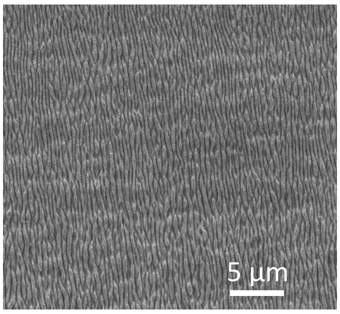
- Icing wind tunnel experiments to investigate surface properties under calibrated dynamic icing conditions.
- Development of a CFD simulation model that takes the surface chemistry and surface structure into account when calculating the wettability of a surface. Integration of the model in TU Wien's existing multi-phase-laser-solver.

Project Results

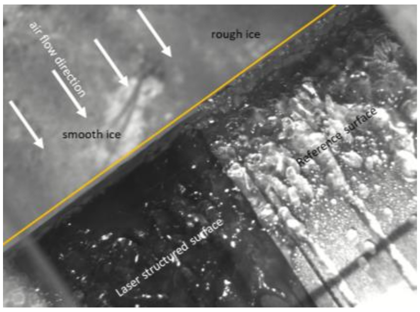
- Generation of superhydrophobic surfaces, contact angle > 160°, roll-off-angle < 5°.
- Reduction of ice adhesion from 800 kPa to 200 kPa via post-laser hydrocarbon treatment.
- Delay of ice accumulation in icing wind tunnel tests.
- Better aerodynamic properties due to reduced ice roughness on the leading edge.
- Static ice/deicing performance tests have been performed to compare the ice accumulation on laser structured samples and reference surfaces (for steel and gelcoat). LIPSS and micro hole arrays showed significantly reduced/delayed ice accumulation and better deicing.



Micro-hole array © TU Wien

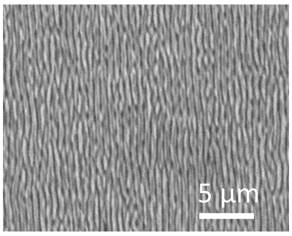


Laser induced periodic surface structures (LIPSS) © TU Wien

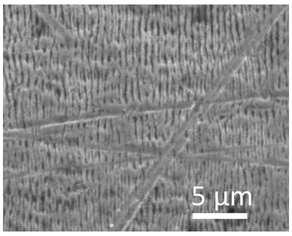


Wind tunnel test of laser structured (left) and unstructured reference sample (right) © TU Wien

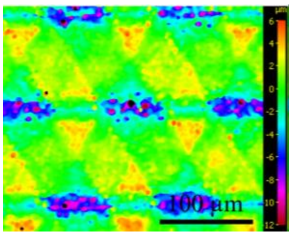
- Dynamic field tests showed an acceptable erosion resistance of micro- and nanostructures on stainless steel foils. After 6 months of testing under harsh environmental conditions the structures were still intact (with some erosion marks). LIPSS nanostructures suffered particle impact resulting in scratches, microstructures showed a reduction of structure height.



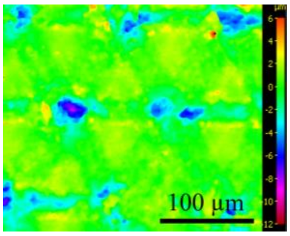
SEM image of LIPSS before field test © TU Wien



SEM image of LIPSS after field test © TU Wien



False color 3D surface scan image of triangle structure before field test © TU Wien



False color 3D surface scan image of triangle structure after field test © TU Wien

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