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Multi-Scale Laser Surface Texturing for Low Ice-Friction Contacts

M-LUGE

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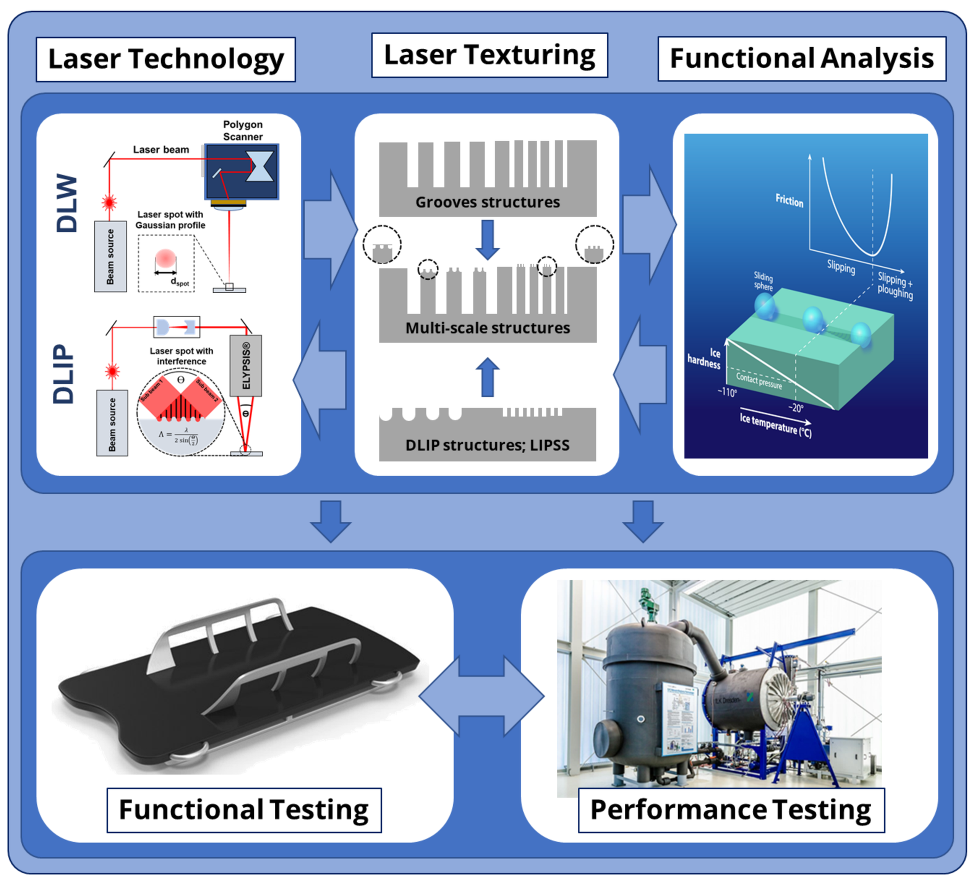
Introduction

Sliding on ice is primarily controlled by the micro topography at the metal-ice interface. This opens the door to design surfaces of different shapes, allowing to control ice-friction performance parts and real-life products. Three universities from Germany and Latvia have teamed up with two application partners to develop a flexible and environmentally friendly laser texturing method for surface functionalization. Laser texturing at three length scales from 200 nm to 100 µm is applied for reliable and long-stable multi-scale surface features. The goal of laser texturing is to provide low ice-friction and anti-icing functionality on large areas.

M-LUGE – Concept and approach



Objectives

- Develop laser-textured surfaces with microstructures at multiple scales for anti-icing and low ice-friction on metals.
- Create a hybrid laser process combining engraving, interference patterning, and fractal-like textures to enhance surface functionality.
- Scale up lab-scale laser texturing to large-area processing for high productivity and real-world applications.
- Establish a link between micro /nanostructure dimensions and low ice-friction performance for deeper understanding.
- Demonstrating new low ice-friction functionality in real-life applications in targeted industrial sectors

Texturing catalog – Multi-scale topographies

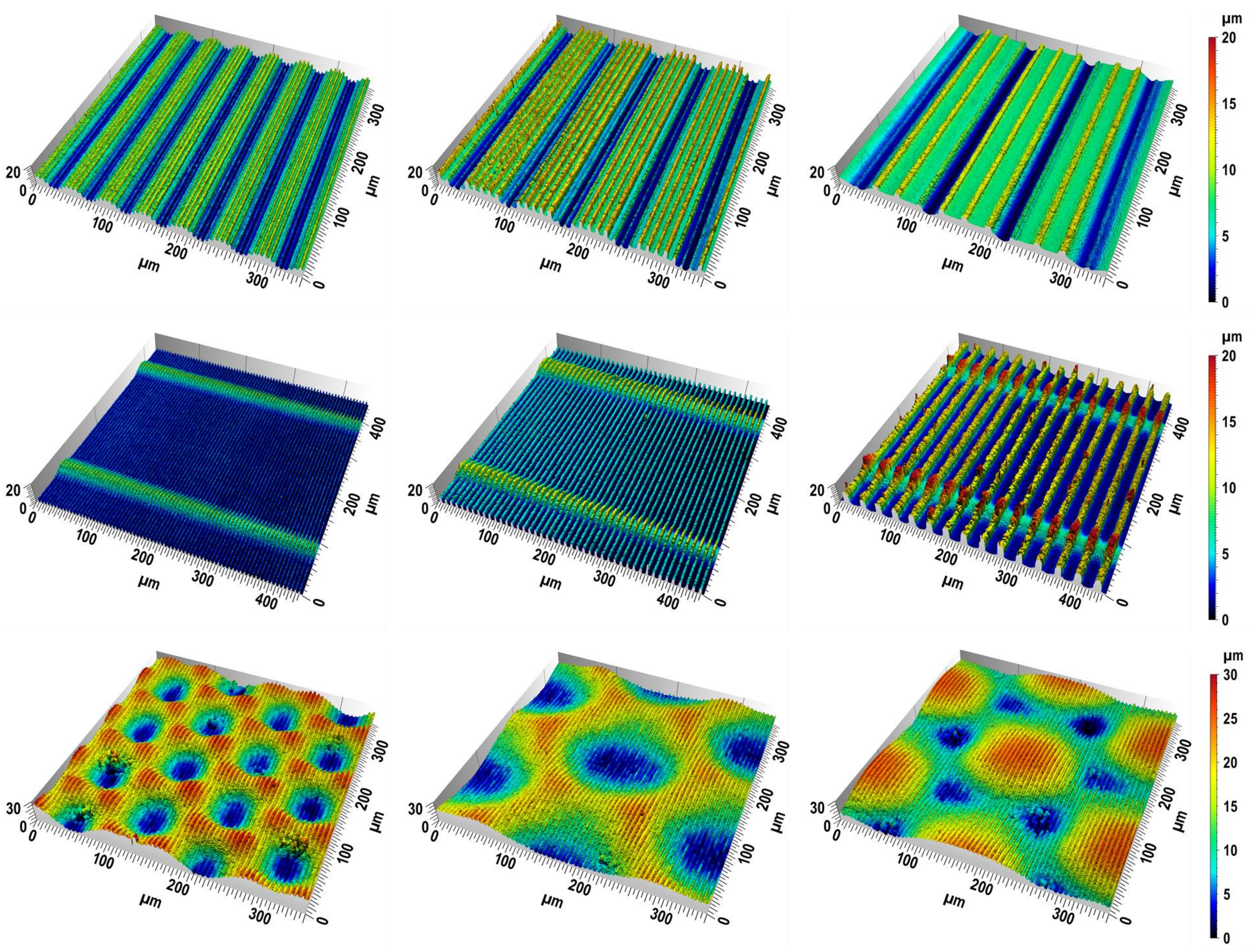


Fig. 1: exemplary 3D topography images of multi-scale periodic microstructures consisting of linear DLIP textures with spatial period of 6.0, 10.0, 30.0 µm and underlying trench and crater-shaped DLW structures with varying trench spacing and crater diameter.

Conclusions

In the frame of the M-LUGE project the implementation of novel laser-based surface texturing technology based on Direct Laser Writing (DLW) and Direct Laser Interference Patterning (DLIP) was successfully applied for the energy-efficient production of multi-scale surface textures. The fabricated surfaces displayed enhanced wettability with self-cleaning characteristic and long-term stability. The ice-friction of the generated surface features were evaluated using an ice-tribometer and a novel measurement technology based on nano-indentation. The candidate surface features for low ice-friction and anti-icing performance were scaled-up and successfully transferred to large areas up to 300 x 300 mm².

Wettability and anti-Icing analysis

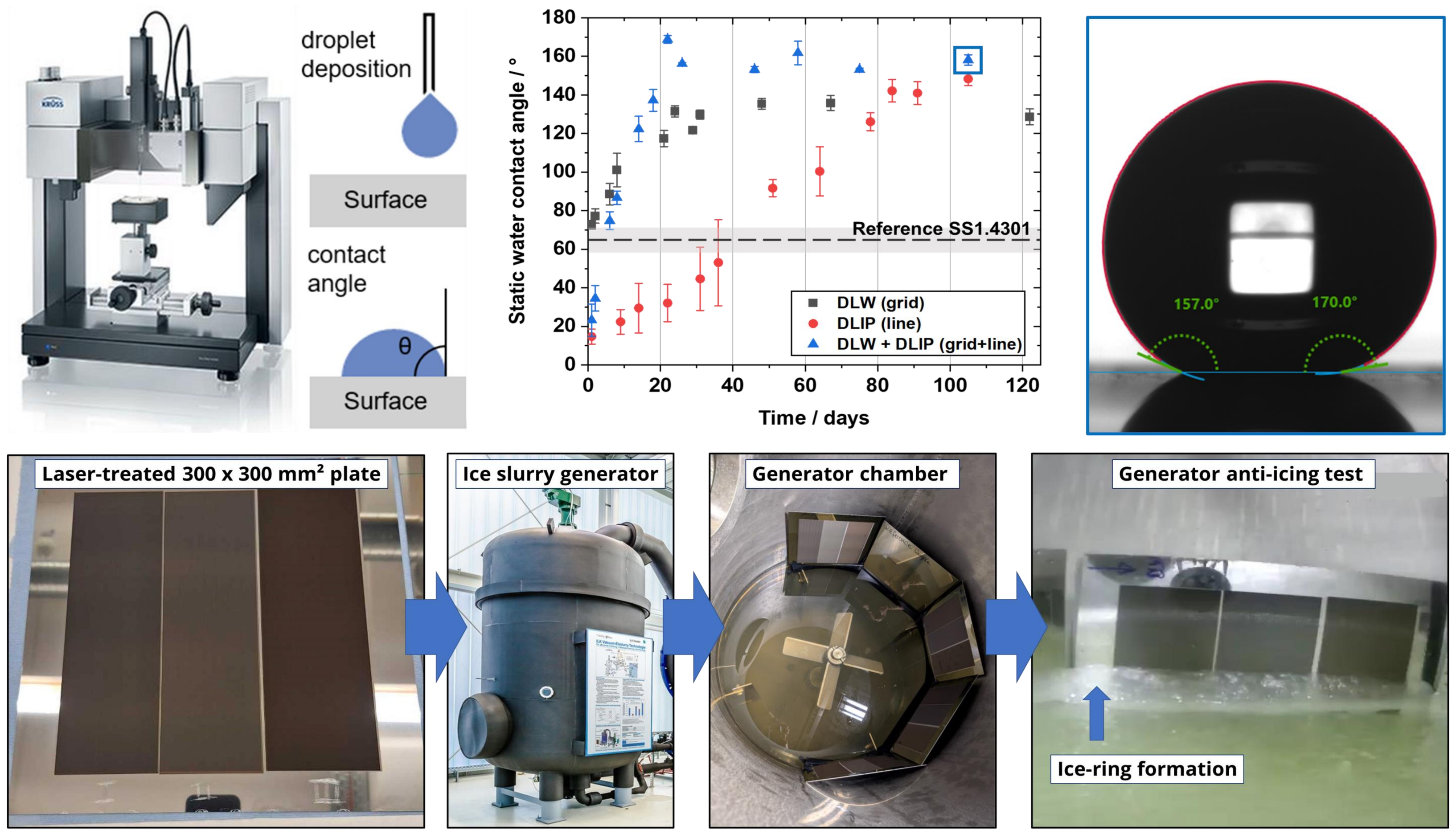


Fig. 2: Drop shape analyzer for water contact angle measurements with schematic drawing of the procedure for contact angle measurements; Time-dependent development of static water contact angle over a period of 100 days for single- and multi-scale textures. Image of resulting water droplet for multi-scale texture. Images of test procedure for testing anti-icing performance in ice-slurry generator.

Low ice friction – Functional analysis

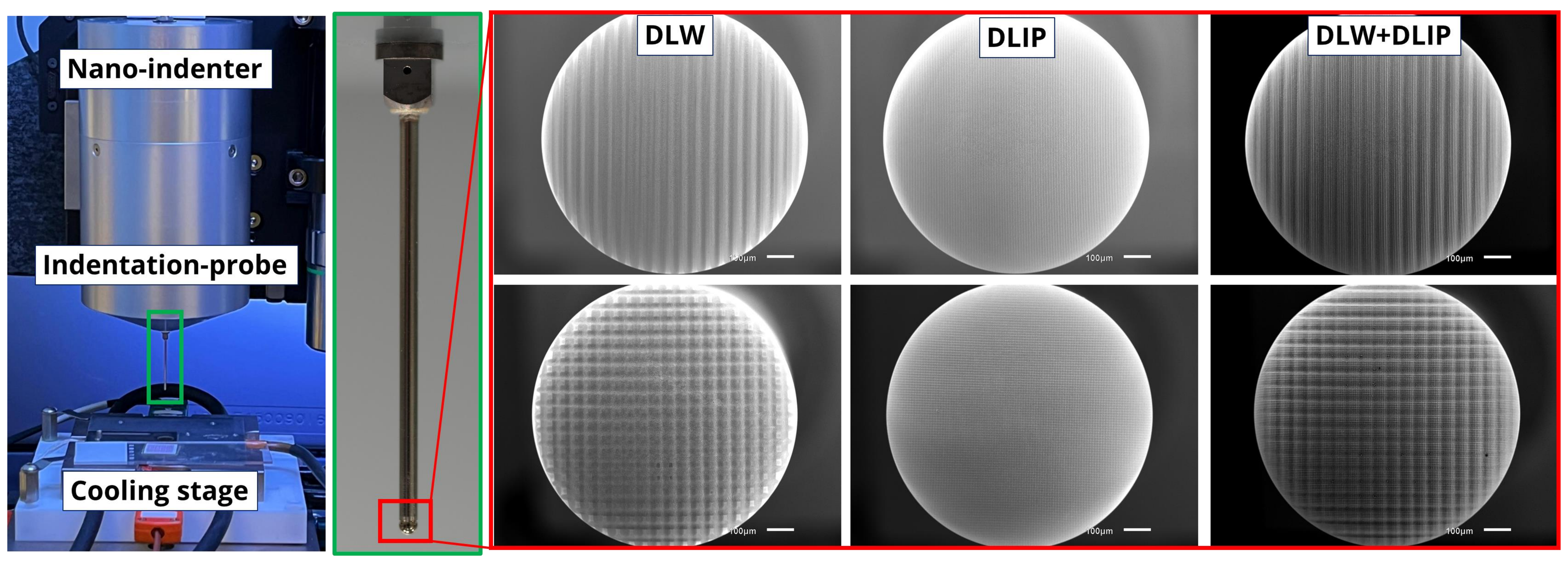


Fig. 3: Developed measuring system based on nano-indentation to determine the ice friction coefficient. Designed nano-indenter with 1 mm sphere as tip (highlighted in green). SEM images of laser-structured indenter tips (highlighted in red) with single-scale DLW trench/cross structures with a structure spacing of 50.0 µm and DLIP line/cross-like structures with a spatial period of 6.0 µm, as well as the combined multi-scale textures.

Low ice friction – Functional testing

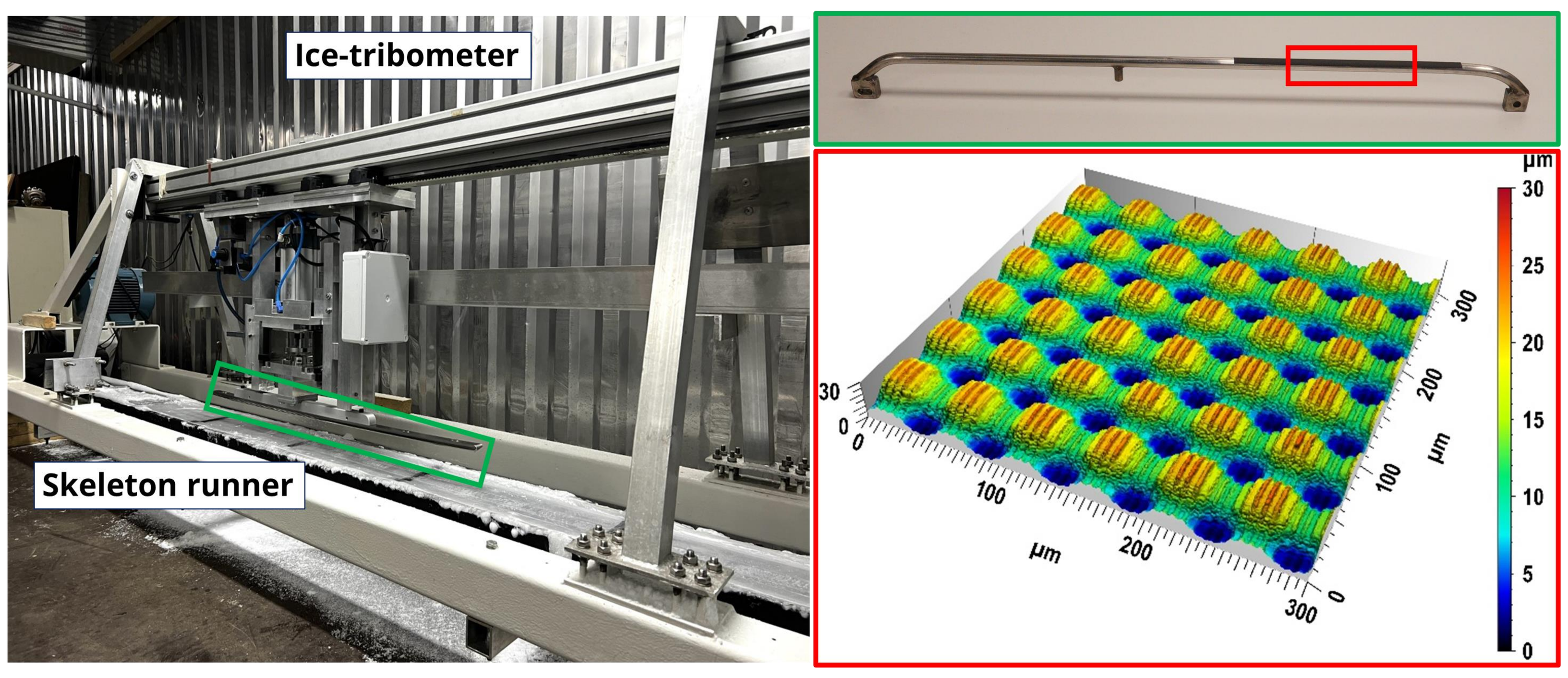


Fig. 4: Large scale ice tribometer for the functional testing of laser-structured skeleton runners (highlighted in green). Skeleton runner with laser-treated surface area (highlighted in red). The generated periodic microstructure consists of an underlying columnar DLW texture (distance between features 50.0 µm, column depth 15.0 µm) and a superimposed line-like DLIP pattern with a spatial period of 6.0 µm and a structure depth of 3.0 µm

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DRESDEN concept Exzellenz aus Wissenschaft und Kultur