Icephobic Coating Associated with Low-power Electromechanical De-icers

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Low ice adhesion coatings have been fabricated and tested regarding wettability and erosion resistance. Structured samples have been scaled up to A4 size to reduce the energy consumption of de-icers. These coatings may be applied to protect outdoor and indoor surfaces from freezing.

Ice adhesion and accretion on surfaces such as aircraft present long-recognized problems with respect to safety, efficiency and operational costs. Current active ice removal methods, such as electromechanical de-icers, are often based on breaking already-formed ice layers. In addition to their undesired weight and design complexity, these active anti-icing approaches require substantial energy for their operation. Passive solutions such as icephobic coatings have also been evaluated with varying success. Recently, coatings preventing ice accretion have been the subject of more attention stimulated by the remarkable water repellent properties of superhydrophobic surfaces. If superhydrophobic coatings are also not able to fully prevent ice accretion, the development of highly efficient hybrid low power systems combining active electromechanical de-icers and passive icephobic coatings remains highly promising to reduce the ice adhesion. This development and the design optimization of a hybrid solution require a deeper understanding of the links between superhydrophobicity and anti-icing properties.

To this end, the ICEAGE project was aimed at evaluating superhydrophobic coatings regarding ice adhesion reduction and erosion resistance in combination with electromechanical de-icers. Two types of nanostructures (pillars and holes) with two lateral sizes (100 and 500 nm) were created with selected resins, regarding their elasticity and structurability (Figure 1). These nanostructures were generated by combining nanosphere lithography, etching, and replication techniques. Hydrophobization of the replicated nanostructures was then performed to confer them superhydrophobic property. Holey samples are expected a) to be more erosion-resistant than pillared ones, and b) to prevent the formation of strongly adhering 'Wenzel ice' (ice penetrating inside the structures).

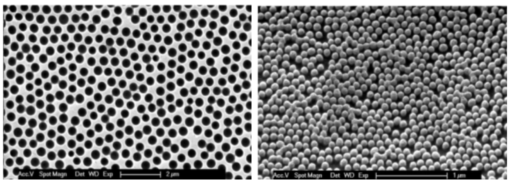

Figure 1: SEM pictures of structures of 500 nm large holes (left) and 100 nm pillars (right).

Produced samples have been tested regarding the ice adhesion, and the resistance to cracking and erosion. Based on agreed specifications, dedicated set-ups have been designed and fabricated by our partner WSL-SLF. The samples all exhibited good cracking resistance (no delamination), along with an exceptionally low ice adhesion (shear strength < 50 kPa), ten times lower than the ice adhesion of reference surfaces, i.e. aluminum and commercial coatings (Figure 2). Moreover, this ice adhesion of the ICEAGE samples remains low over a large temperature range down to –45 °C. Finally, the erosion test demonstrated that the holey samples with a large size (500 nm) exhibited the best erosion resistance of the structured samples. Nevertheless, erosion resistance may be improved by selecting a more appropriate resin. In addition to indoor tests, outdoor exposure and bombardment with a snow gun were carried out. Surprisingly, the small pillared sample (100 nm) showed a good resistance to this testing. In addition, all the nanostructured samples resisted very well to the snow gun test compared to the reference samples, confirming the ranking of the ice adhesion test.

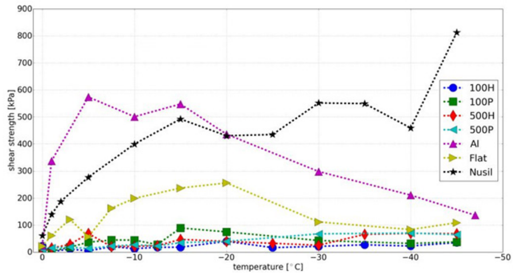

Figure 2: Dependence of adhesion strength on temperature between 0 and –50 °C. 100/500=structure size in nm; H=holes, P=pillars.

The low ice adhesion nanostructured layer is intended to be coated on the metallic surface of an electromechanical de-icer. Based on experimental conditions proposed by the industrial partner Zodiac Aerotechnics, vibration modes of a coated aluminum plate have been determined to shed the ice layer.

In order to prepare a more realistic ice wind tunnel test, large samples (A4 sized) were prepared with two highly promising nanostructures: 500 nm large holes (due to their higher resistance to abrasion) and 100 nm large pillars (due to their resistance to outdoor exposure). A step-and-repeat process was designed to form these large area samples from an elementary 7x7 cm^2 sized nanostructured block. After the hydrophobization step performed by MVD™, the samples produced exhibit a superhydrophobic behavior (Figure 3). These large area samples are expected to be evaluated in the icing wind tunnel to confirm the excellent anti-icing performance in the lab. These coatings will impact not only aeronautics, but will also benefit to outdoor (e.g. windmills, antennas, solar panels) and indoor infrastructures (e.g. freezers, condensers).

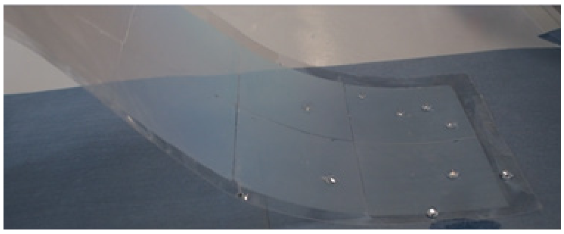

Figure 3: Picture of water droplets rolling off a large scale sample.

• WSL-SLF, www.slf.ch