

## **Introduction**

Wetting affects chemical and physical properties. In aluminum, superhydrophobic surfaces keep fog, ice, and corrosion at bay. Biomimicry replicates natural processes. The high surface energy of aluminum limits its intrinsic dewetting properties. Existing surface modification methods have disadvantages such as hazardous chemicals, high costs, and harsh processing conditions. This work is environmentally friendly and overcomes traditional limitations.

## **Methods**

Aluminum alloy plates (AA5083) of commercial grade (ASTM-B-209M) were used in the study. Stationary Friction stir processing (sFSP) was carried out on a universal milling machine focused solely on surface characteristics using transition metal powders (99% purity). The prepared samples were polished with abrasive papers to 1000 grit after processing. In the microwave hot water treatment (mHWT), processed and unprocessed samples were processed for 10 min at 800 W. A silanization agent was vapor-deposited on the samples following mHWT at 55°C for 60 minutes.

## **Results**

A low strain rate sFSP of the aluminum alloy results in substantial grain refinement, reaching  $\sim 1 \mu\text{m}$  for processed samples and  $\sim 30 \mu\text{m}$  for unprocessed samples. The refined grains have a dense and networked nanostructure after mHWT. Post-silanization, the samples exhibit excellent contact angles ( $>155^\circ$ ), low tilt angles ( $<10^\circ$ ), and low contact angle hysteresis ( $<5^\circ$ ). The processed samples, featuring highly refined grains, demonstrate low water adhesion ( $\sim 16 \mu\text{N}$ ) compared to unprocessed samples ( $\sim 50 \mu\text{N}$ ), attributed to the high interfacial energy of the Cassie state, effectively entrapping air. These processed samples exhibit remarkable dewetting properties and mechanical resilience, owing to the strong negative capillary pressure ( $>1100 \text{ kPa}$ ) generated by highly dense networked nanostructures.

## **Conclusions**

In conclusion, the research contributes to the development of sustainable and durable superhydrophobic aluminum surfaces. The environmentally friendly and cost-effective strategies explored have far-reaching implications for industrial applications, emphasizing opportunities for advancements and practical utilization across various industries.