

Fabrication Controlled Droplet Transport on Femtosecond-Laser Microstructured Metal Surfaces

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Femtosecond-laser micro/nanofabrication enables coating-free functionalisation of metallic surfaces, offering a robust route to passive liquid manipulation on industrially relevant materials¹. Our team has demonstrated that it is possible to create coating-free superhydrophobic surfaces on aluminium, as well as wetting gradients that promote spontaneous motion of microlitre droplets².

Building on this work, we extended the approach to other metallic substrates, including titanium and stainless steel, and to different types of surface patterning. On all metals, superhydrophobicity was achieved for fixed-pitch structures without applying any additional coatings, relying solely on the naturally occurring oxidation process (Figure 1). On variable-pitch surfaces (gradients), spontaneous droplet motion was demonstrated without coatings (Figure 2). The observed transport behaviour is directly linked to fabrication parameters and is consistent with a force-balance model developed by our team³. Process optimisation using long-range optics and accelerated scan paths significantly reduced fabrication time while preserving resulting functional performance.

Complementary droplet impact experiments on fixed-pitch concentric microgrooves revealed that structure curvature imposed solely by fabrication (Figure 3) can bias droplet recoil even in the absence of an explicitly designed wetting gradient (Figure 4), highlighting geometry as an independent control parameter.

These results establish curvature and pitch as independent, fabrication-controlled parameters for passive droplet manipulation, offering new avenues for fluid management and system design on metal surfaces for microfluidics, condensation control, and thermal-management applications.

¹ P. Sinha Mahapatra *et al.*, Chem. Rev. acs.chemrev.2c00045 (2022).

² K. Misiuk *et al.*, Langmuir **38**, 1954 (2022).

³ K. Misiuk *et al.*, Physics of Fluids **35**, 024108 (2023).

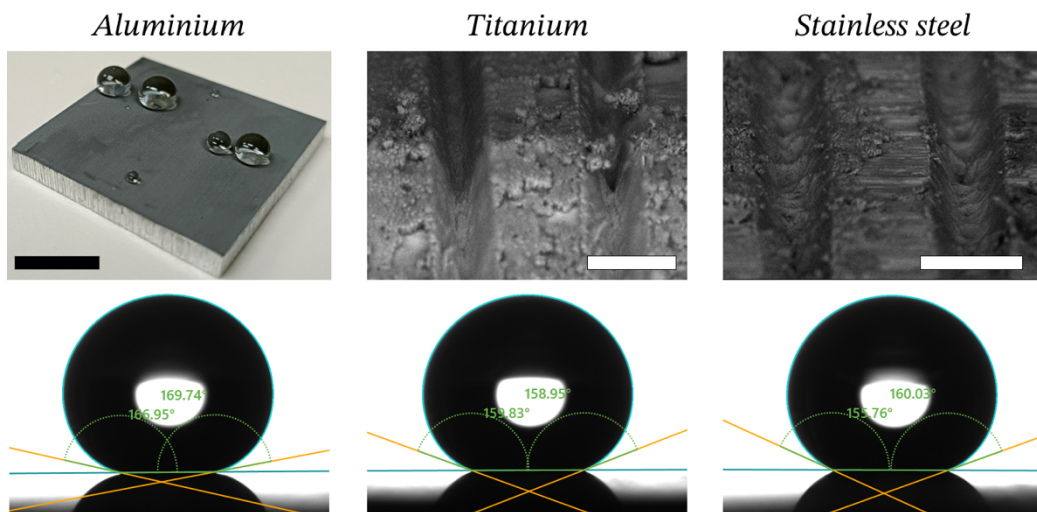


Figure 1: Top: Al sample overview (black bar is 10 mm) followed by SEM images of the manufactured channels on Ti and Stainless Steel (white bar is 30 μm); bottom: goniometric measurements on processed samples.



Figure 2: Droplet motion on coating-free Al wetting gradient (green line between start and finish locations is 3.95 mm).

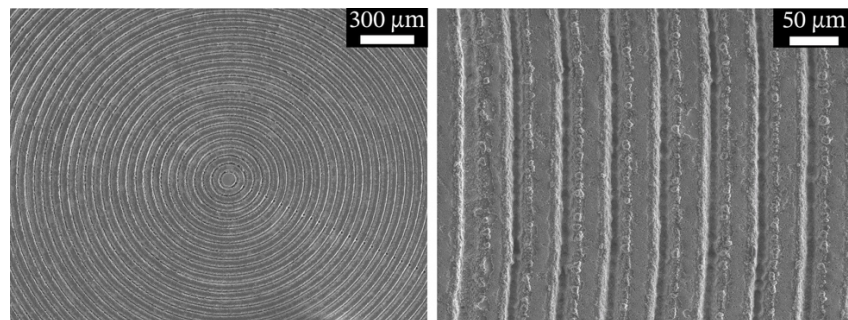


Figure 3: SEM images of the radial pattern on Al

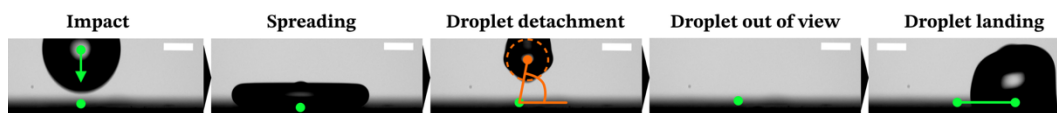


Figure 4: Directional droplet rebounding/motion on coating-free Al radial pattern due to the curvature of the channels (white bar is 1 mm).