Supporting Information

Porous Superhydrophobic Surface with Active Air Plastron Control

for Drag Reduction and Fluid Impalement Resistance

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Fig. S1. Ti particles of different grain sizes for powder sintering the porous Ti medium of different porosity. (a) Particles of small grain size used for Ti-S, (b) particles of medium grain size used for Ti-M, and (c) particles of large grain size used for Ti-L.



Fig. S2. SEM images of pristine porous Ti samples of different grain sizes or porosities. (a), (d) and (f): oblique side view for the pristine Ti-S, Ti-M and Ti-L sample respectively, showing the existence of micro-channels and interconnected micro-pores through the thickness for active supplying air through the porous medium. (b), (e) and (h): top surface of the pristine power-sintered Ti-S, Ti-M, and Ti-L sample respectively. (c), (f) and (i): cross-sectional SEM image of the pristine Ti-S, Ti-M, and Ti-L sample respectively. As for the porosity \emptyset , the fraction of void space in the porous medium, it was characterized as the ratio (by measuring sample weight and volume): $\emptyset = V_{\text{void}}/V_{\text{total}} \times 100\%$, where V_{total} is the measured sample volume, and V_{void} is the volume of void space. $V_{\text{void}} = V_{\text{total}} - m/\rho$, *m* is the measured sample weight, ρ is the density of titanium (4.506 g/cm³). Sample weight *m* was measured with an analytical weighing balance (resolution: 0.01 mg); sample volume V_{total} was acquired by measuring the sample length/weight/thickness with a digital caliper (resolution: 10 µm). Porosity for Ti-S, Ti-M and Ti-L was measured to be 29.7 ± 1.3\%, 30.3 ± 1.2\%, and 35.0 ± 1.0\%, respectively (averaged over 4 measurements).



Fig. S3. (a) Schematic setup for electrochemical etching and anodization. Pt was used as the cathode, and the Ti sample was the anode. (b) Illustration of different methods used for processing the pristine porous Ti samples: no treatment, electrochemical etching with NaCl followed by PFOTS silanization, and electrochemical etching & anodization followed by PFOTS silanization.



Fig. S4 Cross-sectional view of the Ti-S, Ti-M and Ti-L samples after micro-etching, anodization and PFOTS coating. (a-b) The pseudo-SHP Ti-S sample; (c-d) The SHP Ti-M, and (e-f) the hydrophobic Ti-L sample.



Fig. S5. SEM images of the Ti-M surface after electrochemical etching in NaCl solution at 15 V DC for 15 minutes. Etching was found to preferentially occur at interfaces between fused particles as shown in (c).



Fig. S6 Durability test results for the SHP Ti-M. (a) CA and SA for droplets of different pH. (b-c) WCA and WSA for the SHP Ti-M samples after soaking in solutions of different (b) pH and (c) salinity for 24 hours.



Fig. S7. Drag reduction test. (a) Summary of the friction force on SHP Ti-M with active air control; without air control (0 psi), increased drag was observed on SHP Ti-M at jetting speeds higher than 4 m/s; with active air control, the drag force was evidently decreased; the drag reduction ratio was larger at a higher pressure. At low jetting speeds (< 4m/s), the pressure exerted on the surface by the water jetting was small thus the drag reduction at 20 psi was nearly the same as that at 40 psi; at higher jetting speeds (>4 m/s), the friction force at 20 psi was larger than that at 40 psi, due to the increased external pressure exerted by the high speed water jetting; therefore, a higher pressure would be desired to counter the increased external pressure in order to maintain the drag reduction performance at high jetting speeds. (b) Summary of the friction force on the pristine Ti-M surface with active air control; active air control lead to increased drag on the hydrophilic Ti-M surface; the drag force at 20 psi on pristine Ti-M was larger than that at 40 psi, possibly due to the interaction between hydrophilicity and turbulent flow.



Fig. S8. Droplet impact onto the pristine hydrophilic Ti-M surface at a high air pressure of 80 psi; violent bubbling was observed on the surface.



Fig. S9. Droplet impact on the SHP Ti-M at a higher Weber number of We = 80 ($P_2 = 80$ psi). Complete bouncing was observed at 2.2 ms with a complete air layer formed beneath the droplet; the droplet continued to bounce in a pancake shape at 2.8 ms; after the maximum spreading 4.5 ms, the droplet started to retract.