Developing Bioinspired Slippery Coating on Industrial Steels

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Introduction:

Creating an omniphobic coating on industrial metals that can repel various liquids and solids would have numerous industrial and medical applications, yet the development of such a coating has been very challenging. Conventional approaches utilizes the lotus effect to create liquid-repellent coating, which capitalizes the idea of trapped air pockets within micro/nanotextures to create low-friction and low-adhesion surfaces As these surfaces cannot sustain its property under extreme conditions such as high temperatures and pressures, another lesson was learned from nature to develop novel liquid/solid repellant mechanism. Inspired by the insect trapping mechanism of a pitcher plant, a novel repelling surface was developed, which was termed as "Slippery Liquid-Infused Porous Surfaces" (SLIPS) [1]. SLIPS is consisted of chemically functionalized micro/nanostructured substrate and infused with a lubricating liquid. In this project, the protocol to apply SLIPS to industrial steels was explored.

Fabrication:

First micro/nanotextures were created on steel surface through chemical etching. Then the surface was chemically functionalized through oxygen plasma cleaning and silanization processes. At last, lubrication was applied to the functionalized micro/nanotextured surface.

Results and Discussion:

The resulting SLIPS-treated metal showed excellent liquid repellent properties against a broad range of fluids, including both water and oils, as well as complex fluids, such as blood. Figure 1 shows the change in surface repellency to octane after the SLIPS treatment.

First, the etched surface was investigated through field emission scanning electron microscope (FESEM) to ensure the existence of micro/nanoscale textures, as shown in Figure 2. Second, the repellent property of the surface was studied by measuring sliding angles with a goniometer. A droplet of 10 μL and a CSS camera were used to capture pictures of droplet's movement at each second. Those pictures were used to determine the sliding angle. Significant decrease of sliding angle was observed for various liquids in Figure 3 as a result of SLIPS treatment. The sliding angle of 90° was decreased to below 3° after the SLIPS coating.

Since the micro/nanoscale textures are mono-lithographically integrated with the metal surfaces, our SLIPS coatings demonstrate excellent robustness against multiple physical damages. The physical damage was demonstrated by applying adhesive tape on the etched metal surface with 500 gram of weight to add an extra force to the tape. The tape was removed and the sliding angle was measured to observe the change in surface repellant properties after the physical damages. Additionally, the application of SLIPS on metals of any geometries was succeeded including a flat surface, sphere, and pipe tube as shown in Figure 4.

The ability to apply omniphobic slippery coatings on industrial steels would enable a broad range of industrial and medical applications including multi-functional coatings for anti-icing, anti-corrosion, anti-scaling, friction reduction, and anti-fouling purposes [2, 3].

Future Work:

SLIPS will be applied to different metals to explore various industrial and medical applications of SLIPS.

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References:

[1] Wong, T.-S., et al. "Bioinspired self-repairing slippery surfaces with pressure-stable omniphobicity", Nature 477, 443-447 (2011).

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[3] Epstein, A. K., et al." Liquid-infused structured surfaces with exceptional anti-biofouling performance", PNAS, 109, 13182-13187 (2012).

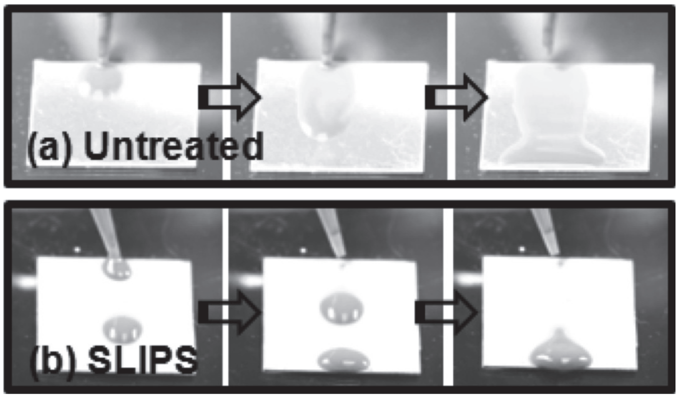

Figure 1: The surface repellency of stainless steel 304 to octane;
(a) Untreated steel, (b) SLIPS-coated steel. (See full-color version on inside cover.)

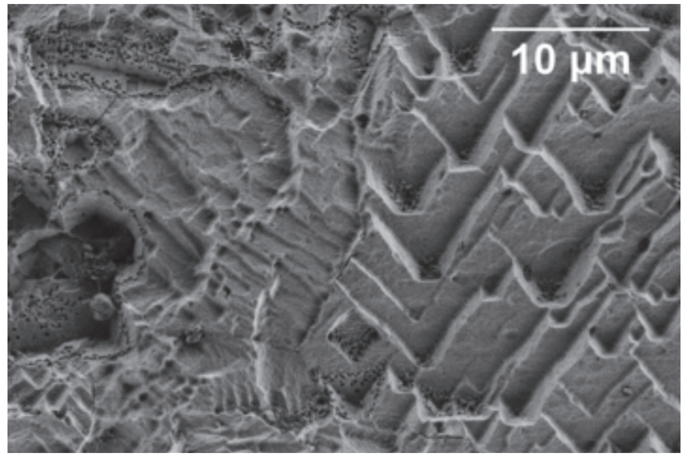

Figure 2: FESEM image of etched stainless steel 304 surface.

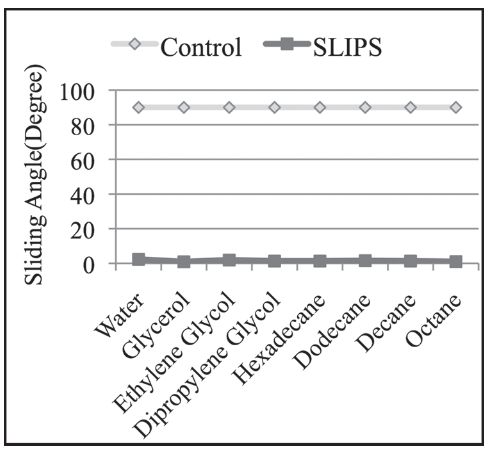

Figure 3: Sliding angles of various fluid droplets on untreated and SLIPS-coated stainless steel 304. The sliding angle before SLIPS treatment resulted in 90°, which decreased to less than 3° after SLIPS treatment against broad range of liquids.

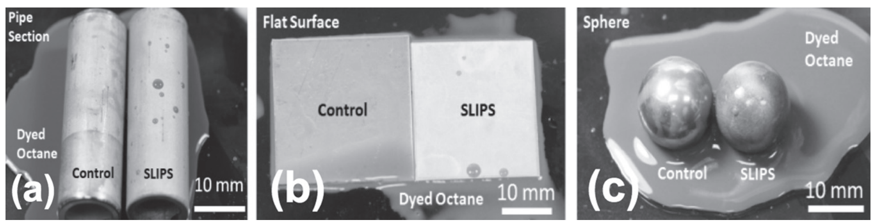

Figure 4: SLIPS was applied on different geometries of stainless steel 304 and the surface repelled octane (dyed in yellow-orange color). In each picture, the left sample is untreated steel and the right sample was SLIPS-treated steel. (a) pipe tube, (b) flat surface, and (c) sphere. (See full-color version on inside cover.)