NanoTurf: Nano-engineered Low Flow Friction Surfaces

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Flow friction on solid surfaces, whether it is inside small pipes or over large vessel surfaces, is determined by the shear at the wall. For all the practical purposes, the flow velocity at the wall surface is considered zero—the so-called "non-slip" condition. There have been efforts to defy the non-slip and reduce drag of liquid flow, for example, by generating bubbles on the surface. Our breakthrough is to use surfaces covered with nanometer-scale hydrophobic (i.e., non-wetting) posts, coined "NanoTurf". Skidding over the posts and mostly levitated from the wall, the liquid is expected to in effect "slip" over the solid surface. The concept can be demonstrated with micrometer-scale posts, made by conventional lithographic techniques (Fig. 1a). However, it is critical that the posts are of nanometer scale (Fig. 1b), because otherwise the liquid would lose levitation under a slight pressure. Nanotechnology makes the idea practical for the first time.

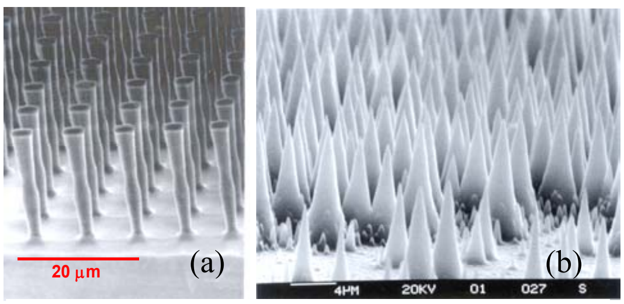

Fig. 1. SEM pictures of nano-structured silicon surfaces. (a) Micro-posts, (b) Nano-posts(Turf)

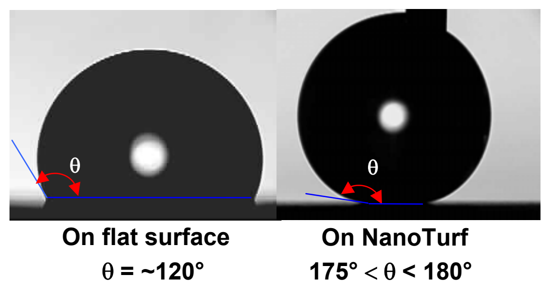

Fig. 2. Contact angles on flat surface and NanoTurf, both coated with very thin Teflon.

In Fig. 2, NanoTurf shows off its super-hydrophobicity, compared with a flat surface. Experiments with our current NanoTurf surfaces revealed that the resistance of *droplet flow* on open surfaces is less than 1% (i.e., over 99% reduction) and droplet flow inside channels is less than 5% (i.e., over 95% reduction) of the resistances of flat surfaces [1].

Drag reduction of liquid flows is fundamental in nature and has far-reaching consequences in numerous application areas from microfluidic devices all the way to chemical plants or marine transportation. Low flow resistance is a critical advantage in microfluidic systems, as liquid flows become exponentially lossy with size reduction. By addressing case-specific issues like surface scaling, NanoTurf can be further developed for large-scale applications as well. An extension of our project will involve exploiting the levitation of the liquid above the NanoTurf floor to selectively modify the tips of the NanoTurf. The long-range goal is to fabricate sensing patches that can be used to incorporate chemical analysis functions into NanoTurf-based devices.

References

[1] J. Kim and C.-J. Kim, "Nanostructured Surfaces for Dramatic Reduction of Flow Resistance in Droplet-based Microfluidics," *Technical Digest, IEEE Conference on MEMS,* Las Vegas, NV, Jan. 2002, pp. 479-482.