

ACS AMA: Hi Reddit! I am Neelesh Patankar, Associate Chair of Mechanical Engineering at Northwestern University. Ask me anything about rough surfaces for non- or super-wetting, or other novel phase change properties!

AmerChemSocietyAMA¹ and r/Science AMAs¹

¹Affiliation not available

April 17, 2023

Abstract

ACS AMA Hi Reddit! My name is Neelesh A. Patankar, and I am the Charles Deering McCormick Professor of Teaching Excellence and Associate Chair of the Department of Mechanical Engineering at Northwestern University. Following my Ph.D. in Mechanical Engineering at University of Pennsylvania, I was a post-doctoral associate with Prof. Daniel D. Joseph at the University of Minnesota until 2000. I then joined the Department of Mechanical Engineering at Northwestern University as an Assistant Professor in 2000, and have been a Professor since 2011. My research area is developing computational methods for immersed bodies in fluids and applying them to problems in biology (fish swimming, esophageal transport, rat whiskers) and engineering (vehicle aerodynamics). I have also been active in designing rough surfaces for non-wetting, super-wetting, anti-icing, and novel phase change properties. My group has published a series of papers on the thermodynamics of phase change on rough surfaces. Topics include keeping surfaces dry under water (see a short video [here](#)), restoring underwater superhydrophobicity, changing the boiling curve by extending or delaying the Leidenfrost regime, and the thermodynamics of sustaining vapor, “non-condensable” gases, and superheated liquids in roughness pores. I also recently acted as a scientific consultant for an ACS Reactions video on the Leidenfrost effect. The broader research vision is to engineer metasurfaces, that is surfaces that exhibit novel interfacial interactions during heterogeneous phase transition (e.g. condensation, boiling, freezing). Potential application areas include boiling and condensation heat transfer (e.g. in power plants), anti-icing, anti-fouling, and atmospheric water harvesting, among others. I will be answering your questions on the topics of rough surfaces for non-wetting, super-wetting, or novel phase change properties at 11am EDT (10am CDT, 8am PDT, 3pm UTC) -ACS edit text formatting 08:45 ET

[REDDIT](#)

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[ACS AMA](#)

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CORRESPONDENCE:

DATE RECEIVED:

July 19, 2017

DOI:

10.15200/winn.150038.82261

ARCHIVED:

July 18, 2017

CITATION:

Will your work give us better batteries? Improvements in charging speeds, storage capacity, cost, degradation conditions or anything else I might not have thought about?

[whativebeenhiding](#)

I am not a battery expert. However, I would note that if there is any application that involves surface interactions where phase change is relevant, then the ideas in our work could be applied there.

Manipulating phase change of materials in roughness geometries could be used to store/retrieve latent heat.

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Winnower* 4:e150038.82261 ,
2017 , DOI:
[10.15200/winn.150038.82261](https://doi.org/10.15200/winn.150038.82261)

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I was working for a company a few years ago developing superhydrophobic coatings for countertops. We had great difficulty protecting against vinegar's acid etching. We thought the problem was that these superhydrophobic coatings would hold a bubble of the vinegar above the surface and over time, the surface tension would lessen and the vinegar would seep down and etch the surface of the countertop.

Have any of your studies helped you come up with a potential solution to this issue? I was very impressed by keeping surfaced dry under water.

[nestaa51](#)

Here we are talking super-liquid-hating (rheustophobic??) properties. I will loosely use the term superhydrophobic for it. Chemical, thermal, and mechanical robustness are indeed challenges that are still being researched.

In your example, if for some reason the surface tension is changing that causes the liquid-substrate interaction to be inherently more “philic”, then indeed what you observed could happen. This would occur if the roughness has predominantly “pillar” or “ridge” type geometry. To improve robustness against this effect one would have to use “reentrant” roughness geometry (imagine nail head) like several researchers have demonstrated. Even in this case, it is likely that condensation within roughness grooves (which is facilitated on inherently hydrophilic surfaces) could lead to a wetting transition. We have demonstrated this in molecular dynamic simulations but I am not aware of corresponding experimental results. If wetting transition by condensation within the roughness were to happen, then we don’t have an answer to this problem unless perhaps some active method (e.g. electric fields, heating, vibration) is used to cause dewetting. Of course, typically, passive superhydrophobicity is desired as in your example.

Hi Dr. Patankar, fascinating research. One question, do you think surface patterning can also work against moisture absorption from atmosphere and not just reduce water absorption when dipped in water?

[gujjar_ravaiyya](#)

Yes.

Let me consider the opposite problem first. Imagine super-water-loving (superhydrophilic) rough surface. Such surfaces promote formation of the liquid phase, which could be used in condensers or for atmospheric water harvesting (dew formation).

On the flip side if you make the surface inherently liquid-phobic (superhydrophobic) then it would promote the vapor phase next to itself. This is true with those surfaces that remain dry under water. The same surfaces, even if not dipped in water, would avoid/delay getting moist (I am defining “getting moist” as getting wet with the liquid phase).

Considering the impact passive condensation of fresh water would have in drought stricken areas, what are the current rates of production of water for these materials in ideal atmospheric conditions? What are the minimum conditions needed currently and do you see those conditions being lowered to the point of passive condensation is extremely arid environments? What avenues are being explored and how long would you estimate before it becomes commercially viable, in particular in third world countries?

[poon-is-food](#)

Thanks for the questions. We have looked into these questions and will soon be publishing our analysis in a journal article. Here I provide a “brief” answer – an excerpt if you will.

Typical drinking water need per day of one person is 3 liters (L), whereas 8 L is needed for drinking and cooking per person per day and 33 L is needed for all personal needs per day. The individual water need underlying these estimates is indeed not for luxurious living. Typical domestic water use in USA is around 384 L per person per day (maximum in the world for any country) while it is 137 L per person per day in Israel. For reference, total water consumed by the world is 25 trillion L per day, which is around 3,800 L per capita per day.

To estimate the volume of air that has same the amount of water as required for individual needs, consider two locations: Kutch, India, which is an arid region in western India, and Sahara desert in Africa. Non-summer-time condition in Kutch is typically 30 deg C with 50% relative humidity. There is 16 g of water in 1 m³ of air in these conditions. At night the temperatures are lower and this amount of water brings air to close to 100% relative humidity. In Sahara, the daytime temperatures during certain times of the year are similar but the relative humidity is around 25% giving 8 g water per m³ of air. It can be calculated that a 5.7 m × 5.7 m × 5.7 m cubic box of air in Kutch will contain sufficient water for daily drinking water need of one person (3 L), while a 12.7 m × 12.7 m × 12.7 m cubic box of air will contain sufficient water for all daily needs of one person (33 L). Twice the volume will be needed for same needs in Sahara (sides of the cubic boxes estimated above would be 1.25 times greater).

The above estimates for air volume represent a static scenario. In reality if air is drawn by way of fan and water is extracted while flowing, much greater amount of water could be available per day. To get a better sense of this consider a duct with 1 m² cross-sectional area. Consider air flowing through it at a velocity of 2 m/s, which is typical for residential air conditioning air ducts. The volumetric flow rate would be 2.4 m³/s. It will take 78 s for the amount of air (Kutch conditions) that contains enough water for daily drinking need of one person (3 L) to pass through a given cross-section in the duct. This would mean air containing drinking water for 1,100 people passing the duct in one day. Similarly, air (Kutch conditions) with water for all daily needs (33 L/person) of 100 people will pass a given duct. Note that for domestic water need in USA (384 L) this would mean air (Kutch conditions for comparison) with water for 9 people.

There are several fine points one needs to carefully think through in the above feasibility, but it should give an idea for now.

In terms of avenues being pursued – keep an eye on the Water XPRIZE competition (<http://water.xprize.org/>).