A Versatile Method for Controlling the Wettability of Stainless Steel Meshes for High-Efficiency Fog Harvesting

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Addressing global water scarcity requires innovative fog harvesting solutions. While stainless steel meshes are durable and cost-effective, their intrinsic hydrophilicity often leads to pore clogging, reducing collection efficiency. This study presents a systematic experimental framework designed to precisely control the wettability of stainless steel meshes by modulating surface morphology and chemistry.

The framework employs copper electrodeposition to engineer surface roughness [1][2], followed by chemical functionalization with fluoro-silanes to lower surface energy. We demonstrate that the effectiveness of the silanization reaction, and the resulting macroscopic wetting state, is critically dependent on the presence of copper surface oxides. Using XRD analysis, we show that the extent of this oxidation can be systematically tuned through diverse surface treatments, including natural aging, accelerated thermal aging, and plasma treatment. This allows for the reproducible fabrication of superhydrophobic meshes with advancing contact angles above 150° and low hysteresis below 5°.

Sinlge drop impact experiments were conducted on the following mesh configurations: (i) hydrophilic (advancing contact angle (ADV) < 100°, receding contact angle (REC) < 5°), (ii) superhydrophobic (ADV > 150°, REC > 145°), and (iii) double-layer, with one superhydrophobic and one hydrophilic mesh. The drop impact experiments, using millimetric water drops, were conducted across a Weber number range of 5 – 500, spanning two orders of magnitude. Results indicate that a superhydrophobic impact surface minimizes pore clogging, while the combination with hydrophilic mesh promotes droplet penetration and retention.

Among the studied cases, the double-layer configuration exhibited the highest water retention capacity across impact velocities spanning from 0.4 m/s to 3.6 m/s, suggesting that "Janus" configurations exhibit superior performance under varying wind speeds. This surface preparation and testing method provides a precise strategy to better understand wetting behavior and droplet dynamics, offering a significant step forward in the development of high-efficiency fog harvesting technologies based on fundamental surface property control.

Keywords:
fog-harvesting, wettability, functionalized meshes, stainless steel meshes

References:

[1] Sartipizadeh, P., Mohammadizadeh, M. R., Antonini, C., & Akbari, R. (2025). Enhanced fog water harvesting on superhydrophobic steel meshes. *Advanced Engineering Materials* , *27* (13), 2402378.
[2] Akbari, R., Wei, Y., Bagni, A., Ruffo, R., Thoraval, M. J., Chen, L., & Antonini, C. (2024). Outcomes from water drop impact on hydrophobic meshes. *Physics of Fluids* , *36* (2).