From drop impact to fog harvesting using hydrophobic meshes

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Abstract

Due to global water shortage crisis, the demand for water resources intensifies, particularly in Iran, Italy and China. Extracting water from fog, particularly in humid regions is a promising solution. This research aims to enhance fog collection efficiency by studying the critical factors of surface structure and wettability. Our approach involves creating superhydrophobic meshes through electrodeposition of copper on steel meshes, followed by a silica-sol modification to boost hydrophobicity. The fabrication strategy imparts to the mesh high surface roughness which, together with the silanization, leads to high advancing and receding contact angles of >145° and >130°, respectively, low hysteresis (<20°), and a sliding angle of <15° for a 2.5 mm drop. Single drop impact experiments with millimetric drops reveal that while hydrophobicity marginally affects the initial penetration stages, increased hydrophobicity aids in breaking down drops after penetration through the mesh. The result of this study suggests that highly hydrophobic meshes can enhance collection in moderately windy areas ($1 < U < 2\, m\, s^{-1}$). Additional proof-of-concept tests were conducted in a fog chamber, where a microdroplet spray with an average drop diameter of $\sim 5 - 10\ \mu m$, generated from a humidifier and mimicking fog, were blown onto the mesh surface mounted at the front of a wind tunnel with $\sim 0.3\, m\, s^{-1}$ wind speed. The fog collection and the wetting durability of the samples experiments reveals that copper-coated meshes without a silane layer experience clogging, reducing wetting durability and fog collection efficiency which was not observed in single droplet impact experiments. Conversely, copper coated meshes with an extra silane thin layer demonstrate a fog collection efficiency of $\sim 600\ mg/cm^2h$, marking a 40% improvement compared to an uncoated stainless steel mesh. This advancement holds promise for addressing water scarcity challenges through innovative and efficient fog water harvesting technologies based on surface property design and control.

Keywords: Surfaces; Wetting in liquid-solid interfaces; Water collection from fog; Hydrophobic mesh; Electrodeposition of copper; Silica–sol surface modification.