Wetting behavior on hybrid surfaces with hydrophobic and hydrophilic properties

Chun-Wei Yao\textsuperscript{a}, Jorge L. Alvarado\textsuperscript{b,\*}, Charles P. Marsh\textsuperscript{c,d}, Barclay G. Jones\textsuperscript{d}, Michael K. Collins\textsuperscript{c,d}

\textsuperscript{a} Dept. of Mechanical Engineering, Texas A\&M University, College Station, TX 77843, USA
\textsuperscript{b} Dept. of Engineering Technology and Industrial Distribution, Texas A\&M University, College Station, TX 77843, USA
\textsuperscript{c} ERDC – Construction Engineering Research Laboratory, 2902 Newmark Dr., Champaign, IL 61826, USA
\textsuperscript{d} Dept. of Nuclear, Plasma, and Radiological Engineering, University of Illinois at Urbana-Champaign, Champaign, IL 61801, USA

A R T I C L E   I N F O

Article history:
Received 2 September 2013
Received in revised form 28 October 2013
Accepted 30 October 2013
Available online 8 November 2013

Keywords:
Hybrid surface
Hydrophobic
Hydrophilic
Water condensation

A B S T R A C T

Hybrid surfaces consisting of a micropillar array of hydrophobic and hydrophilic sites were designed and fabricated to understand the effects of their unique surface morphology and chemistry on droplet condensation. Droplet impingement experiments have revealed that hybrid surfaces exhibit high contact angles, which is characteristic of purely hydrophobic surfaces. However, little is known about the wetting behavior of droplets that nucleate and grow on hybrid surfaces during condensation. In fact, condensed droplets display a distinct wetting behavior during the droplet growth phase which cannot be reproduced by simply impinging droplets on hybrid surfaces. In this study, hybrid surfaces with three different spacing ratios were subjected to condensation tests using an environmental scanning electron microscopy (ESEM) and a condensation cell under ambient conditions. For hybrid surfaces with spacing ratio below 2, droplets were observed to form on top and sides of the micropillars, where they grew, coalesced with adjacent droplets, and shed after reaching a given size. After shedding, the top surface remained partially dry, which allowed for immediate droplet growth. For hybrid surfaces with spacing ratio equal to 2, a different wetting behavior was observed, where droplets basically coalesced and formed a thin liquid film which was ultimately driven into the valleys of the microstructure. The liquid shedding process led to the renucleation of droplets primarily on top of the dry hydrophilic sites. To better understand the nature of droplet wetting on hybrid surfaces, a surface energy-based model was developed to predict the transition between the two observed wetting behaviors at different spacing ratios. The experimental and analytical results indicate that micropillar spacing ratio is the key factor for promoting different wetting behavior of condensed droplets on hybrid surfaces.