J. Micromech. Microeng. **20** (2010) 055021 (5pp) doi:10.1088/0960-1317/20/5/055021

The evaporation and wetting dynamics of sessile water droplets on submicron-scale patterned silicon hydrophobic surfaces

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Received 1 March 2010, in final form 22 March 2010
Published 23 April 2010
Online at stacks.iop.org/JMM/20/055021

Abstract
The evaporation characteristics of 1 μl sessile water droplets on hydrophobic surfaces are experimentally examined. The proposed hydrophobic surfaces are composed of submicron diameter and 4.2 μm height silicon post arrays. A digital image analysis algorithm was developed to obtain time-dependent contact angles, contact diameters, and center heights for both non-patterned polydimethylsiloxane (PDMS) surfaces and patterned post array surfaces, which have the same hydrophobic contact angles. While the contact angles exhibit three distinct stages during evaporation in the non-patterned surface case, those in the patterned silicon post array surface case decrease linearly. In the case of post array hydrophobic surfaces, the initial contact diameter remains unchanged until the portion of the droplet above the posts completely dries out. The edge shrinking velocity of the droplet shows nonlinear characteristics, and the velocity magnitude increases rapidly near the last stage of evaporation.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Evaporation, one of the most important droplet behaviors, has recently received a great deal of attention in the field of micro-fluidics and regarding micro-system applications, including mechanical, electronic and biological engineering [1–4]. The characteristics of an evaporating sessile droplet vary with its surface contact conditions. Simple hydrophobic characteristics of surfaces can be defined by measuring contact angles of water droplets. Furthermore, analysis of evaporation characteristics of droplets is of use in evaluating surface characteristics. Surface modification is of increasing interest for a variety of purposes in a wide range of fields, including mechanical and electronic devices, bio-synthetic structures and water-repellent surfaces [5, 6].

In particular, to improve evaporation characteristics of the surface, such as contact angle variations, total evaporation times and droplet edge shrinking velocities [10], millimeter- and micron-scale patterned hydrophobic surfaces are currently in use, and non-patterned hydrophobic surfaces have also been developed. Various materials are currently being used to achieve this end, most notably PDMS [7], polymethylmethacrylate (PMMA) [8], poly(α-methyl styrene) (PAMS) [8] and silicon [6, 9]. It is well known that the evaporation of water droplets on hydrophobic surfaces has three distinct regimes: constant contact area mode, constant contact angle mode and mixed mode [8, 10]. These three modes have been observed for non-patterned hydrophobic surfaces and for patterned hydrophobic surfaces at larger-than-micron scales, but much less investigation has been reported with regard to these modes on submicron-scale patterned surfaces.

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