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Direct Observation of the Wetting Mode Transition during Evaporation of Water Droplets on Superhydrophobic Surfaces with Random Roughness Structure

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Abstract

Wetting mode and shape changes of ultrasmall water droplets (80 – 100 nL) were observed during evaporation on superhydrophobic surfaces with different random roughness sizes. Observation of droplets from a top view revealed that the nanometer-coating transition was from Cassie's mode to air-containing Wenzel's mode. For a sunny-side-up like state, flat liquid film formation around the droplet edge was observed on the superhydrophobic surface after the wetting mode transition. This state seems to depend on the relation of surface energy values between the solid surface and liquid.

Key-words: *Superhydrophobic, Contact angle, Wetting mode transition*

1. Introduction

A surface state for which the water contact angle is greater than 150° has commonly been designated as superhydrophobic. Chemical reactions and bonding formation through water are limited on such a surface because of the limited contact area between a solid and water. Accordingly, various functions such as snow removal, antifouling, anticorrosion, mold release, and electrical insulation have been expected on this surface.

Superhydrophobic state is not attainable merely by decreasing the surface energy of a solid. The combination of surface roughness with low surface energy is necessary to prepare superhydrophobic surfaces for enhancement of solid hydrophobicity. Wenzel modified Young's equation and the described contact angle using roughness factor, which is defined as the ratio of the actual area of a rough surface to the geometrically projected area. This mode implies that surface roughness enhances the wettability of the solid because of the change of the interfacial free energies of solid-liquid and solid-gas interface[1]. Therefore, a hydrophilic surface becomes more hydrophilic, and a hydrophobic surface becomes more hydrophobic.

Cassie proposed a model for a hydrophobic surface with large roughness. With increasing roughness scale of the surface, the air phase intrudes into the solid-liquid interface. Thus, the interface area is assumable as a composite surface of solid and air whose water contact angle is 180° [2]. It has been demonstrated experimentally that the contribution of Cassie's mode is dominant for a superhydrophobic surface with excellent water shedding properties[3]. To date, various processing methods have been reported for superhydrophobic surfaces by combining surface roughness and low surface energy[4-7].

Cassie's and Wenzel's modes do not always appear as the most stable state[8]. Cassie's mode appears as a metastable state even when Wenzel's mode is the most stable. The transformation phenomenon from Cassie's mode (**Fig. 1** (a)) to Wenzel's mode (Fig. 1(b)) is commonly defined as the wetting mode transition. It has been reported experimentally by evaporation[9], condensation[10-12], and vibration[13]. This transition commonly accompanies an increase of contact angle hysteresis[8,11]. The stability on each wetting mode has been evaluated from the perspective of surface structure and energy balance[14-26].

To date, most studies of wetting mode transition have been conducted using regular structures resembling pillars. Few investigations have examined this phenomenon using a surface with random roughness because of the difficulties in (1)

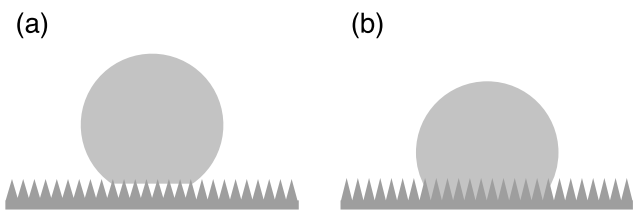

Fig. 1 Schematic illustrations of (a) Cassie's mode and (b) Wenzel's mode.