

Forced spreading over superhydrophobic and copper surfaces

Dmitry Feoktistov^{1,*}, Konstantin Ponomarev¹, and Kseniya Batishcheva¹

¹National Research Tomsk Polytechnic University, Tomsk, Russia

Abstract. Dynamic spreading over superhydrophobic and copper surfaces was studied experimentally under the condition of contact line movement with speed greater than 1 mm/sec. Three modes of spreading of distilled water drop over copper surfaces with sufficient typical roughness (0.591, 5.190 and 6.210 μm) were detected. The first one is drop formation when the contact line speed and dynamic contact angle increase sharply. The second mode is spreading of a drop, which is characterized by a monotonic decrease in the contact line speed and dynamic contact angle. The third one is a formation of an equilibrium contact angle at a constant wetted area (the contact line speed tends to zero, and spreading of a drop occurs as long as the driving force is greater than zero). Some features in spreading were detected on superhydrophobic surface with parameter roughness of 0.751 μm compared to other substrates. During drop formation after sharp increase in the contact line speed and dynamic contact angle, there is a mode which is accompanied by a decrease in the contact line speed and monotonic increase in the advancing dynamic contact angle.

1 Introduction

Superhydrophobic surface is not a unique phenomenon in nature, and it is common to many plants and insects. Prospects for the use of superhydrophobic surfaces in everyday life and in industrial processes in virtually all areas of the industry are huge [1-8]. For example, superhydrophobic treatment of buildings allows to reduce dirtying of windows and panes. A similar effect can be obtained in automobile manufacturing at treatment of car body by superhydrophobic coating. In the textile industry hydrophobe processing of clothes will allow to make them waterproof, anti-dirtying in contact with coloring food and drinks. Moreover it can be achieved without change in color, texture properties of clothes. In the power industry there are several examples of using superhydrophobic surfaces: design of filters for cleaning of fuels and oils. The use of such filters allow to separate water-oil emulsions with high efficiency in a wide range of compositions of dispersion systems and the particle size of the dispersed phase. Moreover, such surfaces have a great potential in aviation when creating anti-icing surfaces.

* Corresponding author: fdv@tpu.ru

Currently several methods of creating such surfaces are known: deposition techniques, sublimation, controlled polymerization, nanorod growth, templating and lithographic techniques. However there are no scientific bases [9-12] to control the wetting process. It happens due to the lack of available registration equipment of fast processes of wetting and spreading. In the last decade scientific and technological progress in the field of microelectronics has allowed to create a relatively inexpensive photo and video devices allowing by research groups [13-19] to record the physical mechanisms of fast processes. It should be noted that changes in the dynamic contact angle (DCA) during wetting surfaces (including super hydrophilic) by advancing and receding drops were studied only at slow movement of the three-phase contact line (up to 1 mm/sec). The dynamics of wetting at three-phase contact line speed greater than 1 mm/sec is poorly understood. So the purpose of this work is to study change in the dynamic contact angle of drops spreading over superhydrophobic and copper surfaces at high contact line speeds.

2 Experimental methods

The shadow and Schlieren systems were implemented for conducting experimental studies. The operational principle of the experimental setup is described in detail in [12,19].

According to results of preliminary experiments the main influencing factors were defined (Table 1).

Table 1. Main influencing factors.

Liquid volume	0.3 mL
Flow rate of distilled water	0,005; 0,01; 0,02; 0,04; 0,08; 0,16 mL/sec
Material of substrate	Copper, surface with superhydrophobic coating
Roughness parameter (Ra) of surfaces	flexible copper Ra=0,591 μm ; copper Ra=5,190 μm ; copper Ra=6,210 μm ; surface with superhydrophobic coating Ra=0,751 μm
Wetted liquid	distilled water

3 Results and discussion

According to results of experimental series (Fig. 1 (a-c)) three modes of spreading of the water drop over copper surfaces with typical roughness (0.591, 5.190 и 6.210 μm) were detected [19].

The first mode is characterized by the drop formation; the contact line speed and dynamic contact angle increase sharply. The second one is drop spreading; the contact line speed and DCA decrease monotonously. The third mode is formation of an equilibrium contact angle when the wetted area is constant; the contact line speed tends to zero, and spreading of a drop occurs as long as the driving force is greater than zero.

Duration of modes in the experiments is 1-2% from overall time of spreading for the first mode, 39-50% for the second one, and 48-60% for the third one.

There are some features in spreading modes for superhydrophobic surface with Ra=0.751 μm (Fig. 1 (d)) compared to another surfaces [19]. During drop formation after sharp increase in the contact line speed and dynamic contact angle, there is a mode which is accompanied by a decrease in the contact line speed and monotonic increase in the advancing dynamic contact angle. not allow to use optical methods of processing.

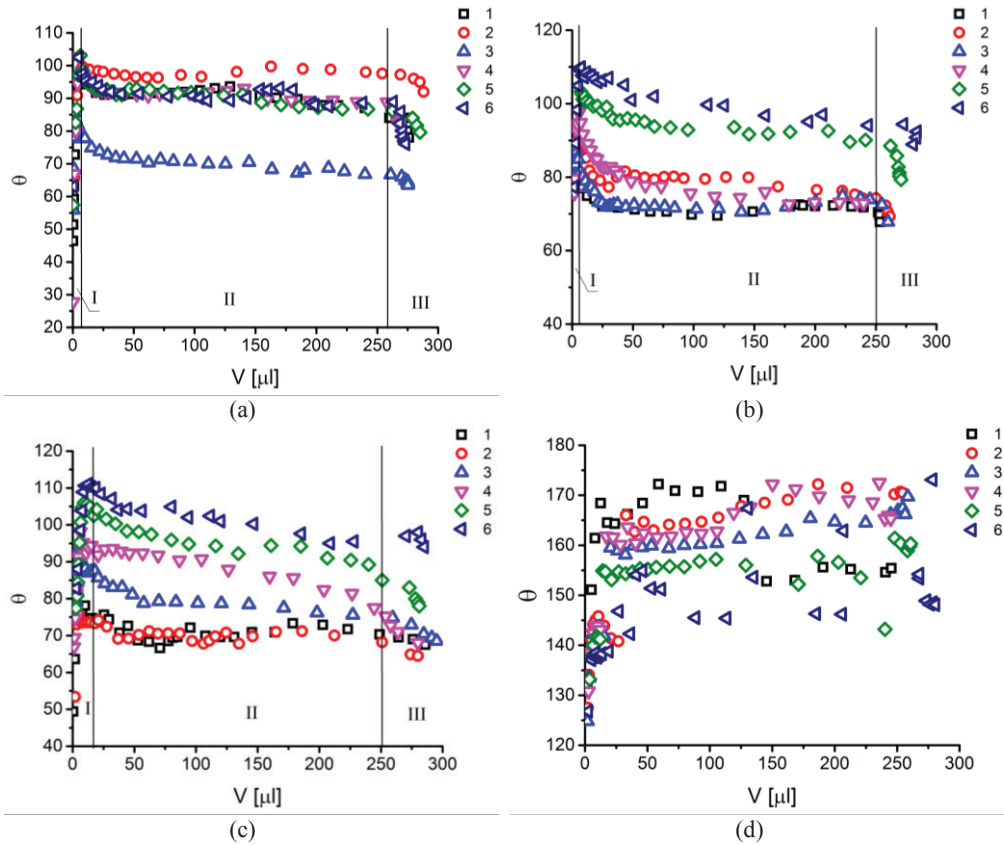


Fig. 1. Dynamic contact angle versus liquid volume during spreading of distilled water drop over surfaces: (a) flexible copper ($Ra=0.591 \mu\text{m}$); (b) copper ($Ra=5.190 \mu\text{m}$); (c) copper ($Ra=6.210 \mu\text{m}$); (d) superhydrophobic surface ($Ra=0.751 \mu\text{m}$).

It should be noted that analyses of the contact angles values were conducted for the second and third modes. It is found that the maximal value of advancing contact angle increased by 30 % with increasing volumetric flow rate of distilled water from 0.005 mL/sec to 0.16 mL/sec at spreading over copper surface with $Ra=5.190 \mu\text{m}$, and the angle increases by 37% at spreading on surface with $Ra=6.210 \mu\text{m}$. Increase in the volumetric flow rate on flexible copper surface has not led to an increase in the value of the advancing contact angle. Advancing DCA in the range of volumetric flow rate from 0.04 mL/sec to 0.16 mL/sec is independent of the drop volume. Wetting replaces by nonwetting during drop spreading on such surfaces. DCA decreases during contact line movement, and after a certain time, which depends on the volumetric flow rate, material of substrate and surface microrelief, becomes less than 90° .

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