Observation of thin film wetting by a total reflection and interference fringe method

［課程博士・論文博士共通］

博士学位論文内容要旨
Abstract

専　攻 Major	応用環境システム学	氏　名 Name	李　賀
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When a droplet is placed on a substrate, wetting behavior will occur. No matter in natural systems or man-made systems, wetting behavior is important in large scale and small scale. For example, in oil recovery, coating, friction, printed electronics and printing, hydrophobicity and hydrophilicity play significant roles. The super-hydrophilicity is desirable for self-cleaning and antireflective coatings applied in glasses, flexible electronics, and solar cells protective panels. In particular, in the printed electronics technology, high-definition thin film patterns such as semiconductors and metals are formed using printing technology for drawing characters and photographs, and these are combined to manufacture electronic devices, and in the process it requires ink droplets mixed with other materials. But there are some unclear problems on the thin film growth occurs near the surface of the ink droplet. And it is also a subject to be solved that whether such thin film growth is possible for various ink combinations. So that, measurement and observation for the wettability and wetting behavior of the inks which have super-hydrophilicity is necessary. Since the tendency for the liquid to spread has relation to contact angle. Hence, the contact angle is a useful measure of wettability. The contact angle located at contact line, is the angle formed by the liquid-gas interface and the solid or immiscible liquid surface. The contact line, defined to be the locus of points that are simultaneously in contact with the gas, liquid and solid phases.

There are some methods applied to measure the contact angle. But for the side view method, it is difficult to determine the position of the contact line precisely, especially in super-hydrophilic surface with very small contact angle. And for the fringe method with top-down incident laser, there is a problem when the liquid is located between two planes that have a narrow gap or when an object on the liquid, observation cannot be performed because the light for interfering is blocked.

In this paper, in order to study the wetting behavior of a liquid film on a super-hydrophilic surface without considering the existence of objects above the liquid blocking the laser, the interference fringe method with oblique upward laser is developed.

The features of the method used in this experiment are that: This method allows to detect the position of contact line precisely and observe the surface profile of very thin film. And due to the total reflection, the contact line can also be measured accurately at the same time. Through the verification experiment, the applicability of the calculation equation and observation method used in this experiment has been verified. The contact angle measurement is verified from 0.007° to 3°.

By using this experimental method, the spreading behavior, wetting behavior of liquid and changes of liquid wetting behavior in liquid bridge experiment are observed. Experiment of observing the spreading behavior confirmed the factors affecting spreading, and measured the *n* values of several liquids. In the experiment of observing the wetting behavior, the three stages of liquid diffusion are identified, and the performance characteristics of different stages are observed. The spreading phenomenon of the liquid film is found in the liquid bridge experiment.

In the experiment of observing the spreading behavior, due to the total reflection area and partial reflection area, it is easy to determine the position of the contact line from the brightness-position curve, so that the

wetting radius can be measured. The liquids used in this experiment are octane, decane, ethanol, silicon oil (1cSt and 10cSt) and water. The Tanner's law expresses the relationship about liquid wetting radius, time, surface tension, dynamic viscosity and volume of the liquid in the spreading process. After Tanner's law is simplified, the wetting radius is proportional to the n-th power of the wetting time. And in the equation of Tanner's law, the power n=1/10 found for the viscous spreading of small droplets has been well corroborated by many experiments. However, this value is not applicable to all liquid's spreading, the value of n between 1/10 and 1/7 was reported in some other experiments. In this experiment, the wetting radius-time of octane, decane, ethanol, silicon oil (1cSt and 10cSt) and water are fitted to Tanner's law. The value of n is found that: n of octane, decane and silicone oil 10cSt is 1/6, n of ethanol, silicone oil 1cSt and water are 1/3, 1/4 and 1/10, respectively. When comparing the surface tensions of the 6 liquids, it will be found that except silicone oil 1cSt and water, the others have similar values. Obviously, the surface tension cannot directly determine n. But the surface tension and volume are found to affect factors other than the time parameter in the equation of Tanner's law.

In the experiment of observing the wetting behavior, the wetting behavior of silicon oil 1cSt droplet on a glass substrate is observed precisely. By measuring the spacing of the adjacent interference fringes which are produced by the curvature of the air-liquid interface, the surface profile of the liquid film can be calculated. In the experiment, when measuring the contact angle, there are two continuously changing angles around the contact line. Both of the angles can be used to characterize the progress of wetting. For the two angles, one is contact angle at the contact line and the other one is contact angle near the contact line. During the wetting process, for the contact line, three stages can be found. They are advancing, stable and receding stage, respectively. In the advancing stage, the contact line keeps advancing, and there is no big fluctuations in the contact angle at the contact line. When entering the stable stage, the position of the contact line does not change significantly. However there are some big fluctuations in the first fringe, which leads some fluctuations in contact angle at the contact line, and the two contact angles have opposite variations in trend. The wetting behavior is firstly observed that there are some reciprocating changes in the two angles and the thickness of the liquid film near the contact line during the stable stage, like the edge of the surf. For the receding stage, the contact line recedes continually and there are no big fluctuations in the contact angle at the contact line.

In the experiment of liquid bridge, the wetting status between the liquid and glass substrate is observed by using the same experimental facility. At the same time, a device for measuring the pulling force is added to measure the change in force during the process of cross-link and breakage of the liquid bridge. Through the liquid bridge experiment of water, decane and ethanol, the pulling force curve and wetting behavior are observed. When the liquid is ethanol, different with water and decane, the ethanol liquid forms a very thin liquid film on the glass substrate which cannot be observed from the side. By calculating Laplace pressure and pulling force, it is found that the thin liquid film has little effect on the adhesive force.