

Preparation and Characterization of Super-Hydrophobic Surface

Y. Ohkubo^{(1)(2)*}, S. Onishi⁽¹⁾, Y. Asabe, H. Noriyasu⁽¹⁾ and K. Ogawa⁽¹⁾

- (1) Department of Advanced Materials Science, Graduate School of Engineering Kagawa University, 2217-20, Hayashi-cho, Takamatsu city, Kagawa 761-0396, Japan
e-mail: s06d552@stmail.eng.kagawa-u.ac.jp
(2) Development and Researching group, Kagawa Gakusei Venture Ltd., 1-28-4, Oh-gi-machi, Takamatsu city, Kagawa 760-0013, Japan

Abstract – A novel method for preparing and characterizing super-hydrophobic surface has been developed. Aluminum (Al) substrate was roughened by sandblasting and electrochemical etching to obtain micro and nano-sized morphologies, followed by immersing the Al substrate in the chemical adsorption solution. Thus, a chemically adsorbed monolayer (CAM) containing fluorocarbon groups were prepared, and super-hydrophobicity and oleophobicity were achieved. Additionally, the wettability was evaluated by three kinds of surface energies: solid, dispersive, and critical. All three kinds of surface energies became less than 1.0 mN/m. It may be the lowest surface energy in the world at present.

The super-hydrophobic surface was prepared by the combination of sandblasting, electrochemical etching, and chemically adsorbed technique through the schematic process, as shown in Figure 1 [1]. The FE-SEM image on the surface of the Al substrate roughened by sandblasting and electrochemical etching was taken for confirming nano-sized morphology, as shown in Figure 2(a).

The wettability of the surface was evaluated by the contact angles. Purified water, tetrabromoethane, methylbenzoate, hexadecane, and dimethyl silicone were used as mensurative solvents of the contact angles. Table I shows the list of liquid surface energies and contact angles of different solvents on the surface of the roughened Al substrate after covered with the CAM containing fluorocarbon groups. The surface of the Al substrate was clearly super-hydrophobicity, as shown in Figure 2(b).

In addition, the wettability of the surface was evaluated by not only the contact angles but also three kinds of surface energies: solid γ_s , dispersive γ_s^d , and critical γ_c . Solid surface energy γ_s was obtained from the equation (1) derived by Neumann and Li [2], where γ_l : liquid surface energy, γ_s : solid surface energy, θ : experimental contact angle, β : constant ($= 1.247 \times 10^{-4} \text{ m}^2/\text{mJ}$). These values became from 0.31 to 1.29 mN/m. The average solid surface energy $\text{Ave } \gamma_s$ was about 0.71 mN/m. Dispersive surface energy γ_s^d was obtained from the equation (2) called as Girifalco-Good-Fowkes-Young equation [2]. The liquid surface energy of each solvent and the experimental contact angles were assigned to equation (2). These values became from 0.08 to 1.19 mN/m. The average dispersive surface energy $\text{Ave } \gamma_s^d$ was about 0.52 mN/m. The critical surface energy γ_c was obtained from Zisman plot of contact angles [2]; such a plot of $\cos \theta$ against the liquid surface energy γ_l is a straight line. The extrapolation of γ_l to $\cos \theta = 1$ resulted in γ_c . The Zisman plots resulted in critical surface tension of 0.08 mN/m. Three kinds of the surface energies ($\text{Ave } \gamma_s$, $\text{Ave } \gamma_s^d$, and γ_c) were less than 1.0 mN/m.

$$\cos \theta = -1 + 2 \sqrt{\frac{\gamma_s}{\gamma_l}} \exp \{-\beta(\gamma_l - \gamma_s)^2\} \dots\dots\dots (1)$$

$$\cos \theta = -1 + 2 \sqrt{\frac{\gamma_s^d}{\gamma_l}} \dots\dots\dots (2)$$

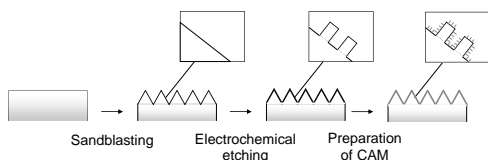


Figure 1: Experimental procedure for preparing the super-hydrophobic surface.

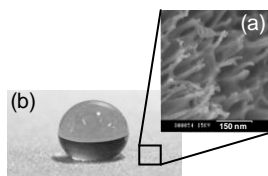


Figure 2: Photograph of the water colored by copper chloride on the super-hydrophobic surface.

Table I: List of liquid surface energy and contact angle on the super-hydrophobic surface.

| Solvent | γ_l [mN/m] | C.A. [°] |
|-------------------|-------------------|----------|
| purified water | 72.8 | 158.9 |
| tetrabromoethane | 47.5 | 142.9 |
| methyl benzoate | 37.6 | 141.6 |
| hexadecane | 27.6 | 139.6 |
| dimethyl silicone | 19.7 | 120.6 |

References

- [1] I. Tsuji, Y. Ohkubo, and K. Ogawa, Jpn. J. Appl. Phys. 48 (2009) 040205.
[2] A. F. Thunemann, U. Schnoller, O. Nuyken, and B. Voit, Macromolecules 33 (2000) 5665.