

Frontiers of Mechanical Engineering and Materials Engineering III

Part 1

Edited by
Wen-Pei Sung and Jimmy (C.M.) Kao



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Frontiers of Mechanical Engineering and Materials Engineering III

PART 1

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Frontiers of Mechanical Engineering and Materials Engineering
(MEME 2014),
November 21-23, 2014, Xiamen, China

Edited by

Wen-Pei Sung and Jimmy (C.M.) Kao



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Preface

2014 the 3rd International Conference on Frontiers of Mechanical Engineering and Materials Engineering (MEME 2014) will be held in Xiamen, China during November 21-23, 2014. The aim is to provide a platform for researchers, engineers, academicians as well as industrial professionals from all over the world to present their research results and development activities in Mechanical Engineering, Materials Engineering and Control Engineering.

In this conference, we received more than 600 submissions from email and electronic submission system, which were reviewed by international experts, and about 227 papers have been selected for presentation, representing 10 national and international organizations. I think that MEME2014 will be the most comprehensive Conference focused on the Mechanical Engineering, Materials Engineering and Control Engineering. The conference will promote the development of Mechanical Engineering, Materials Engineering and Control Engineering, strengthening the international academic cooperation and communications, and exchanging research ideas.

We would like to thank the conference chairs, organization staff, the authors and the members of International Technological Committees for their hard work. Thanks are also given to Trans Tech Publications.

We hope that MEME 2014 will be successful and enjoyable to all participants. We look forward to seeing all of you next year at the MEME 2015.

November, 2014

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CHAPTER 1:

Materials, Technologies for Processing and Chemical Engineering

Hydro-oleophobic Property of Butterfly Wing Surface and Biomimetic Fabrication of Hydrophobic Silver Film

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Keywords: Hydrophobicity, Oleophobicity, Methanol, Butterfly wing, Bio-template.

Abstract. The hydrophobicity and oleophobicity (methanol repellency) of butterfly wing surfaces were measured by a video-based contact angle (CA) meter. The multi-dimensional microstructure of the wing surfaces was characterized by a scanning electron microscope (SEM) and an atomic force microscope (AFM). The wing surface exhibits superhydrophobicity (water CA 150.4~159.2°) and low adhesion (water sliding angle 1~3°). Meanwhile, the wing surface displays high repellency against methanol. The critical concentrations for wetting and spreading-wetting of methanol solution on the wing surface are 60% and 80%, respectively. The butterfly wing surface is of hydro-oleophobicity. The wing surface possesses complicated hierarchical microstructures. Using the butterfly wing as a bio-template, the hydrophobic silver films were prepared. Water CA increases from metal silver's intrinsic CA 63.0° maximally to 139.2° (*Speyeria aglaja*, 5 nm silver film). The microstructures on the wing surface result in the transition of metal silver from hydrophilic to hydrophobic. The butterfly wing can be used as a template for design of smart interface and functional surface.

Introduction

After millions of years of evolution, many creatures have possessed peculiar body surfaces which are superhydrophobic, self-cleaning, anti-adhesive, drag reducing, self-healing, anti-wearing and so on [1]. In the last few years, more and more researches have been focused on fabrication of materials with special properties and functions using biological surfaces as templates. The special functional surfaces with complex wettability, such as amphiphilicity (i.e. hydrophilic-lipophilic properties), hydro-oleophobicity (i.e. water-oil repellency), hydrophilic and oleophobic properties, hydrophobic-lipophilic properties, are often needed in engineering domain [2]. Butterfly wing is one of the most complicated three-dimensional periodical substrates in nature [3]. In this paper, the hydrophobicity and oleophobicity (methanol repellency) of butterfly wing surfaces were measured. Using the butterfly wing as a bio-template, hydrophobic silver films were fabricated. The results may provide evidence for preparation of special functional surface used in harsh industrial environments, as well as enlightenment for biomimetic design of superhydro-oleophobic surface.

Materials and Methods

Materials. The specimens of ten butterfly species were collected in Changchun City. The wings were cleaned, desiccated and flattened, then cut into 5 mm × 5 mm pieces from discal cell (Fig. 1). The reagents used were of analytical reagents (AR) grade and purchased from Tianjin Pharmaceuticals Group Co. Ltd., China. The volume of water droplet for CA and sliding angle (SA) measurements was 5 µl.

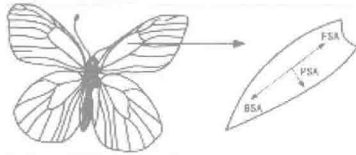


Fig. 1 The experimental area and the sliding angles in various directions on the butterfly wing

Measurements of Wetting Angles. Using an optical CA measuring system (DataPhysics OCA20, Germany), the CAs of water and methanol solution on the wing surface were measured via sessile drop method at ambient temperature of $25\pm1\text{ }^{\circ}\text{C}$. The SA of water droplets was measured along three different directions, including forward SA (FSA, the SA of droplet from wing base to wing terminal end), backward SA (BSA, the SA of droplet from wing terminal end to wing base), and perpendicular SA (PSA, the SA of droplet perpendicular to the major axis of wing) (Fig. 1).

Characterization of Micro/nano-structure. After gold coating by an ion sputter coater (Hitachi E-1045, Japan), the wing pieces were observed and photographed by a SEM (Hitachi SU8010, Japan) and an AFM (Bruker Dimension Icon, USA).

Biomimetic Fabrication of Hydrophobic Silver Film. A vacuum vapor coating machine (OLED300D, Shenyang Scientists Friend Vacuum Technology Company, China) was used for coating of silver film on the wing surface. The thickness of silver film was determined as follows:

$$\Delta H = \frac{\rho \times d}{0.1329}$$

(1)

where, ρ is the density of metal (g/cm^3), d is the thickness of metal film coated (nm), ΔH is the change in excitation frequency (Hz). For metal silver, $\rho_{\text{Ag}}=10.5\text{ g}/\text{cm}^3$. The thicknesses of silver films coated on the wing surface were 5, 10, 20, 40, 60, 80, 100 nm, respectively, meanwhile the silver films of the same thicknesses were coated on glass slides as contrast.

Results and Discussion

Water and Methanol Repellency of the Wing Surface. The wing surfaces of the ten butterfly species are superhydrophobic (CA $150.4\sim159.2^{\circ}$), the average value is 154.0° . Meanwhile, the butterfly wing surfaces have low adhesion, the water SA is extremely small (FSA $1\sim3^{\circ}$, BSA $4\sim12^{\circ}$, PSA $3\sim7^{\circ}$). The butterfly wing surface is of low adhesive superhydrophobicity. There are significant differences between the water SAs in various directions ($p<0.01$), $\text{FSA}<\text{PSA}<\text{BSA}$ (Table 1). The sliding behavior of a droplet on the wing surface shows remarkable anisotropic property. Even a very slight tilting ($1\sim3^{\circ}$) of the wing is sufficient to cause the water droplet to roll off readily and take away the contaminating particles efficiently [4].

Table 1 Contact angle and sliding angle of water, the minimum (critical) concentrations for wetting and spreading-wetting of methanol solution on the butterfly wing surfaces

Butterfly species	Water CA ($^{\circ}$)		Water SA ($^{\circ}$)			The minimum concentrations for wetting and spreading-wetting of methanol solution (%)	
	With scale	Without scale	FSA	BSA	PSA	Wetting (CA< 90°)	Spreading-wetting (CA $\rightarrow 0^{\circ}$)
<i>Aporia crataegi</i>	150.4	106.7	2	7	5	60	85
<i>Brenthis ino</i>	152.5	123.6	3	9	7	60	80
<i>Coenonympha amaryllis</i>	154.6	112.4	3	8	6	65	90
<i>Gonepteryx mahaguru</i>	153.1	114.2	2	4	5	60	95
<i>Lycaeides argyrognomon</i>	159.2	119.8	2	5	6	65	95
<i>Nephargynnis anadyomene</i>	153.8	114.5	2	6	5	60	80
<i>Neptis rivularis</i>	154.3	120.1	2	12	5	60	85
<i>Papilio maackii</i>	158.0	118.3	1	6	4	65	90
<i>Polygonia c-aureum</i>	152.4	109.1	1	5	3	65	95
<i>Speyeria aglaja</i>	151.7	127.9	3	8	7	60	90
Average	154.0	116.7	2	7	5	62	88

The droplet of methanol solution presents three kinds of states on the wing surface: (1) As the concentration is lower than 60%, the CAs of droplet on the wing surface of the ten species are