MATERIALS SCIENCE AND TECHNOLOGY NEWSLETTER

Vol. 16, No. 1 Winter-Spring, 2020

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NATURE'S SUBTLE METHODS FOR MOVING WATER:

EDITORIAL COMMENTS

Though the first paper on ultrahydrophobicity was published by Dettre and Johnson in 1964[1] the whole topic really started to catch hold with the work of Barthlott and Ehler in 1977[2] who described the self-cleaning and ultrahydrophobic properties of certain plant leaves as the “Lotus-Effect"® a name which Barthlott coined in 1992 after the remarkable self cleaning properties of the lotus leaf.

Prof. Barthlott has a rather interesting biography as related in the popular volume by Peter Forbes.[3] Currently the Director of the Nees-Institute for Biodiversity in Bonn Germany he apparently started out as a plant biologist with a keen interest in the evolution of plant species. While pursuing this work in the early 1960's he was obliged to do extensive microscope studies on plant anatomy, in particular micro-anatomy on things like pollen grains and the like. The critical juncture in this work came about with the commercialization of the scanning electron microscope (SEM) which allowed the researcher to study in detail the microstructure of surfaces in 3 dimensions at the level of one micron and lower. Studying the surfaces of various plant leafs and seeds with the SEM revealed a bizarre landscape of star and chimney shapes as well as pasta like waxy crystals and interlocking cells. Over time Barthlott came to realize that the self cleaning properties of certain leaves was closely correlated with the highly variegated morphology he observed with the SEM. Thus, as often seems to happen, an important discovery was made while looking for something quite different. In this regard I’m reminded of the work of Kamerlingh Onnes who set out to demonstrate that pure metals such as mercury and lead would cease to conduct electricity by cooling them to a very low temperature with liquid helium thus freezing out all electron motion only to discover that the metals instead became superconducting! From my point of view it is discoveries like this that make the scientific exploration of the natural world an exciting and rewarding pursuit.

SALVINIA EFFECT

Now some 40 odd years later Prof. Barthlott and his coworkers[4] have come up with an innovative scheme for employing the superhydrophobic properties of certain plant leaves and a number of textiles to remove oil slicks from a water surface. The proposed process depends on what has come to be called the Salvinia effect named after the floating fern Salvinia molesta which has the curious property of being able to trap air and exclude water in a thin layer just above the leaf surface. Figure (1) gives a schematic representation of what is going on. The surface of the leaf contains a forest of fine hairs which form a net hydrophobic surface which excludes the overlying water layer from reaching the surface and also contains a number of hydrophilic points on the tip each hair which further pin the water layer in place. The net effect is to

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[1] "Contact Angle Hysteresis. III. Study of an Idealized Heterogeneous Surface", Rulon E. Johnson Jr. and Robert H. Dettre; J. Phys. Chem. 68 (7) 1744 (1964).

[2] "Raster-Elektronenmikroskopie der Epidermis-Oberflächen von Spermatophyten”; Wilhelm Barthlott and N. Ehler, Tropische und Subtropische Pflanzenwelt, (19) 110 (1977).

[3] “The Gecko’s Foot”, by Peter Forbes (W. W. Norton & Company, New York - London, 2005)

[4] “Adsorption and Superficial Transport of Oil on Biological and Bionic Superhydrophobic Surfaces: a Novel Technique for Oil–water Separation”, W. Barthlott, M Moosmann, I. Noll, M. Akdere, J. Wagner, N. Roling, L. Koepchen-Thomš, MAK Azad, K. Klopp, T. Gries and M. Mail; Phil. Trans. R. Soc. A 2020, 378 : 20190447. (http://dx.doi.org/10.1098/rsta.2019.0447)

trap a thin layer of air next to the leaf surface. One application of this effect is to create a trapped air layer on the hull of a ship where the air layer serves as a slip agent significantly reducing the hydrodynamic drag on the ships hull.

However Prof. Barthelott and his colleagues had another application in mind. It turns out that the near surface of the leaf under the hairs is oleophilic and will thus have a tendency to suck in an oil layer as depicted in Figure (2). The oil is attracted to the oleophilic environment under the plant hair umbrella driving out the trapped air. This behavior immediately suggested that materials exhibiting the Salvinia effect could be used as sponges for selectively removing an oil layer from a water surface as depicted in Figure (3).

In this scheme a collection pan sits just below the water surface and a Salvinia style fabric is draped over the edge of the pan and one edge sits just under the oil layer and the other end drains into the pan. This elementary setup has been tested using abrasive papers, textile flocks and commercial textile oil adsorbents as the adsorbing film. Several different varieties of oil were used including mineral oil, Automobile waste oil, bilge oil and conventional heating oil. The rate of oil removal varied depending on the adsorbing fabric and the oil being observed. The authors estimate that in certain instances up to 1 kg of oil per hour could be removed from a lake surface using an adsorbing fabric 1m wide which would make the process of significant practical value in removing oil spills.

Thus we see that in the plant world, lacking available physical pumps, nature makes use of surface free energy gradients to move liquids. This is exemplified by the lotus leaf which employs a low free energy surface to remove water and debris and also trees and other long stemed plants which employ osmosis and capillary forces

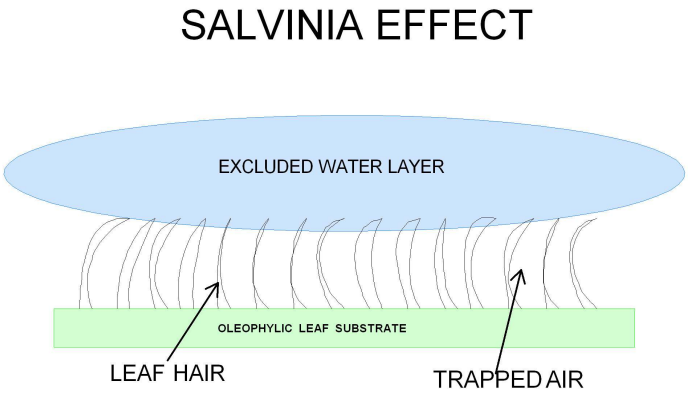

Figure 1 Schematic representation of the Salvinia effect

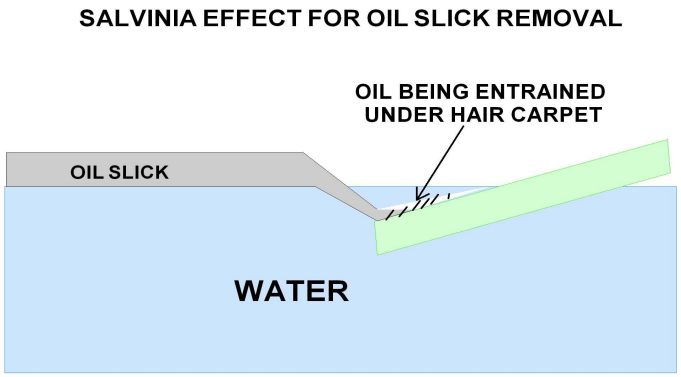

Figure 2 Schematic of Salvinia effect whereby an oil film is entrained by the oleophilic substrate

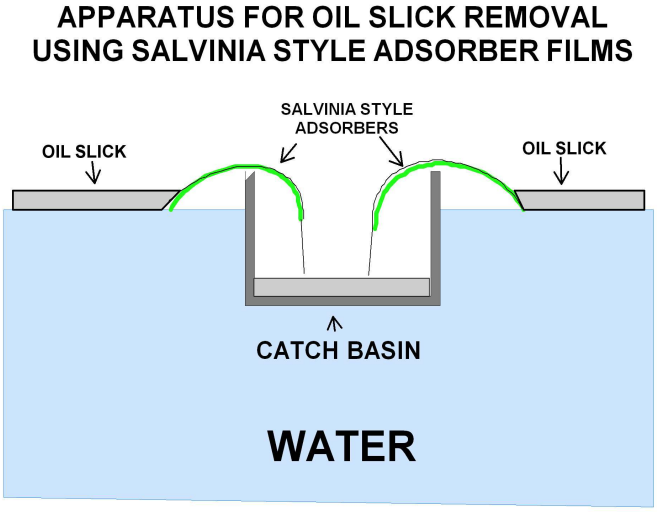

Figure 3 Simplified schematic of an apparatus using the Salvinia effect to remove an oil film from a water surface.

to move water from the soil up into the leaves.

All of this brings us to the next topic of this essay which is the announcement of the upcoming 12th in the symposium series on contact angle wettability and adhesion. Contact angle measurement is the simplest and most direct method for sampling the surface energy of a solid material. Though the first symposium in the series was held in 1992 the topic has not faded in the least since that first meeting but has in fact grown significantly as new situations arise which address applications not even dreamed of at the time of the first meeting. In the intervening years the contact angle method has been employed to investigate a wide range of practical phenomena ranging from ice adhesion to detecting fake collector coins (See for example Vol. 5 No 1 in the newsletter series available at (www.mstconf.com/Vol5No1-2008.pdf) and we suspect that a number of new applications will continue to turn up as the need to understand surface related phenomena becomes more and more critical in the development of new commercial products. In this regard we cordially invite all readers of the Newsletter to join us at the 12th in the Contact Angle symposium series to be held this coming June. Full details are given in the official symposium announcement reprinted below.

Finally, if you are not an expert on contact angle behavior and surface science but are nonetheless interested in learning more about these topics at an introductory level then you should have a definite interest in the upcoming:

3- Day Impact Course on the Chemistry, Physics & Mechanics of Surface Science and Adhesion to be held May 13-15, 2020 at the Anton Paar Technical Facility; 10215 Timber Ridge Dr, Ashland, VA USA .

Full details on short course available at:

www.mstconf.com/Chem-Phys-MechImpactSprng2020.pdf

CALL FOR PAPERS: TWELFTH INTERNATIONAL SYMPOSIUM ON CONTACT ANGLE, WETTABILITY AND ADHESION

Homewood Suites by Hilton, at Newburgh Stewart International Airport,
180 Breunig Rd., New Windsor, NY 12553 USA
JUNE 17-19, 2020

SYMPOSIUM HISTORY AND MOTIVIATION

In his opening remarks at the first symposium in this series Professor Robert Good pointed out that Galileo in the 17th century was quite likely the first investigator to observe contact angle behavior with his experiment of floating a thin gold leaf on top of a water surface. Since that time contact angle measurements have found wide application as a method for determining the energetics of surfaces. This, in turn, has a profound effect on the wettability and adhesion of liquids and coatings to surfaces.

This symposium will be concerned with both the fundamental and applied aspects of contact angle measurements. Issues such as the applicability and validity of various measurement techniques and the proper theoretical framework for the analysis of contact angle data will be of prime concern.

In addition, a host of applications of the contact angle technique will be explored including but not limited to: wettability of powders, fibers, wood products, paper, polymers and monolayers. Further focus will be on the use of contact angle data in evaluating surface modification procedures, determining relevance of wettability to adhesion, the role of wettability in bioadhesion, ophthalmology, prosthesis and in the control of dust in mining and milling applications.

AUDIENCE AND PARTICIPATION

The primary focus of this symposium will be to provide a forum for the discussion of cutting edge advancements in the field and to review and consolidate the accomplishments which have been achieved thus far.

SUBMITTING A PAPER

This symposium is being organized under the direction of Dr. K. L. Mittal, Editor, Reviews of Adhesion and Adhesives and by MST Conferences. Please notify the conference chairman of your intentions to present a paper as early as possible. An abstract of about 200 words should be sent by April 31, 2020 to the conference chairman by any of the following methods:

E-mail: rhl@mstconf.com
FAX: 212-656-1016
Regular mail:

Dr. Robert H. Lacombe
Conference Chairman
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Full conference details and registration via the Internet will be maintained on our web site:

www.mstconf.com/Contact12.htm

SYMPOSIUM TOPICS:

Factors Influencing Contact Angle Measurements:

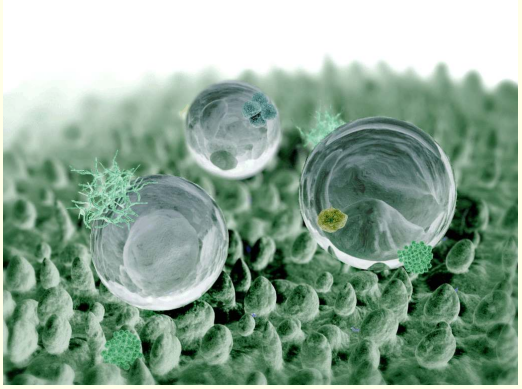
- Static and dynamic contact angles, effect of surface flaws and surface roughness on wetting.
- Effect of pore size distribution
- Effects of velocity and viscosity of liquid on solid-liquid interfacial behavior.
- Interaction forces including: van der Waals, Acid-Base, Hydrogen bonding, ...etc

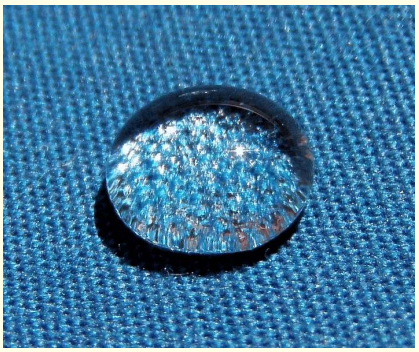
Wettability Behavior and Surface Characterization of Various Materials:

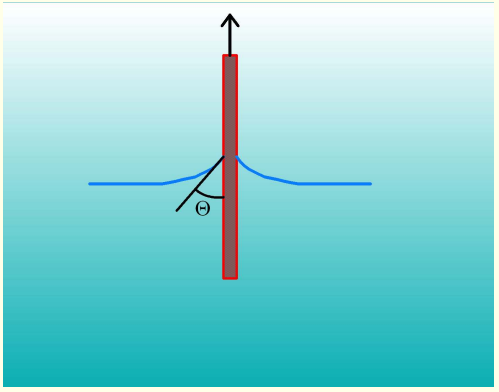
- Contact angle interpretation and hysteresis.
- Wettability of various material surfaces including but not limited to: wood, elastomers, silicon wafers, pharmaceutical powders, metals, polymers, paper, particles, fibers... etc.
- Surface treatments to modify wettability behavior.
- Superhydrophobicity
- Electrowetting

Wettability, Adhesion and Applied Aspects of Contact Angle Measurements:

- Effect of surface energetics on adhesion.
- Biological applications including protein and bacterial adhesion.
- Fine particle adhesion and control of dust.
- Other technological applications including: printing, agriculture, pharmaceuticals, textiles and paper.







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