MATERIALS SCIENCE AND TECHNOLOGY NEWSLETTER

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OBSCURE 19TH CENTURY EFFECT IMPACTS MODERN TECHNOLOGY

EDITORIAL COMMENTS

Just when you think you have discovered all of the impacts that surface effects have had on modern technology and commerce yet another phenomenon floats to the surface which makes you feel that somehow you have been out of touch. The effect in question was apparently first discovered by James Thomson in 1855 in regard to the so called “tears of wine” phenomenon whereby drops of liquid are observed to accumulate on the side of the glass surface substantially above the liquid level. The effect was later studied in more detail by the Italian Physicist Carlo Marangone who published his results in his doctoral thesis in 1865 and after who the effect acquired its name. You might think that this curious effect would sit on the shelf of scientific curiosities along with other quaint phenomena remaining of interest only to a small cadre of dedicated researchers. What catches you by surprise, however, is that the Marangoni effect has found applications in a number of important technologies including laser welding, crystal growth, electron beam melting and integrated circuits. More on this extraordinary curiosity in the lead essay of this newsletter.

This issue of the Newsletter will also announce the upcoming 11th in the MST symposium series on CONTACT ANGLE, WETTABILITY AND ADHESION. In this regard the second essay presents a summary of an innovative method for applying drops to surfaces using what is referred to as the “liquid needle approach”. Developed by the Krüss organization it provides an alternate and superior method of applying drops to surfaces which should be of significant interest to all who are active in the field of contact angle measurement.

Finally, as mentioned above this issue provides details on the 11th CONTACT ANGLE symposium scheduled to be held at the Stevens Institute June 13-15, 2018. We cordially invite all readers of the newsletter to join us at this event where not only will many of the latest research efforts on contact angle be discussed but also representatives from Krüss will be available to demonstrate the liquid needle method and our good friend and colleague Professor Bormashenko from Ariel University will give a most interesting paper on his latest investigations of the Marangoni effect.

THE MARANGONI EFFECT: A 19TH CENTURY SCIENTIFIC CURIOSITY EMERGES IN THE 21ST

As is well known, whenever you have a gradient of some kind there is also a corresponding flow of material. Common place examples include the flow of water in a pipe due to a pressure gradient, the flow of electrons in a wire due to a potential gradient and the flow of heat in a body due to a temperature gradient. With the Marangoni effect we get flow of liquid over a surface due to a gradient in the surface energy or surface tension.

An illustrative example is the case where alcohol and water are not completely mixed. The effect is driven by the fact that alcohol has a lower surface tension than water. If alcohol is mixed with water inhomogeneously, a region with a lower concentration of alcohol will pull on the surrounding fluid more strongly than a region with a higher alcohol concentration. The result is that the liquid tends to flow away from regions with higher alcohol concentration. A striking example of this phenomenon occurs when a drop of alcohol is placed on a thin film of water. The abrupt change in the surface tension of the liquid where the alcohol fell causes the liquid to rush out.

Tears of Wine Effect

Wine is another example where a gradient in a mixture of water and alcohol can occur.

Since wine is mostly a mixture of alcohol and water, with assorted sugars and other components there is the possibility of a gradient in the alcohol/water concentration. It turns out that wine sitting in a glass creates just the right opportunity since natural capillarity action will cause the wine to climb the sides of the glass. When this happens the alcohol in the ascending film evaporates faster than the water again causing a gradient in surface tension between the liquid adhered to the side of the glass and the rest. The resulting increase in surface tension on the side of the glass causes more liquid to be drawn up from the bulk of the wine, which has a lower surface tension because of its higher alcohol content. The wine moves up the side of the glass and forms droplets that fall back under their own weight mimicking the so called tear drop effect.

Marangoni and the Semiconductor Industry

Interestingly the Marangoni effect also finds applications in the semiconductor industry where there is a need to thoroughly dry silicon wafers after wet processing steps. Liquid spots left on the wafer surface can cause oxidation that can damage components on the wafer. Applying a mist of alcohol to the wet wafer sets up a surface tension gradient in the liquid allowing gravity more easily to pull the liquid completely off the wafer surface, effectively leaving a dryer wafer surface compliments of the Marangoni effect.

Marangoni and Nanotechnology

Quite unexpectedly the Marangoni effect also finds application in the nano-technology field. Apparently nano-technologists have found the effect useful in self-assembling nanoparticles into ordered arrays and in growing arrays of ordered nanotubes. The recipe is as follows. Nano-particles dispersed in an alcohol mixture are spread on a substrate, followed by blowing the substrate with a humid air flow. The alcohol is evaporated under the flow setting up concentration gradients which cause water to condense and form microdroplets on the substrate. Subsequently the nano-particles in the alcohol are transferred into the micro-droplets which then form the required self assembled arrays after drying.

Marangoni and Welding Technology

The more you look into the Marangoni effect the more curious it becomes. It certainly never would have occurred to me but surprisingly welding is a fabrication process where the Marangoni effect has to be accounted for. When the base metal during welding reaches its melting point, a weld pool forms. Marangoni forces within these pools can affect the flow and temperature distribution and modify the molten pool extension. This can potentially result in stresses within the material as well as unwanted deformations. An interesting consequence of this is that the resulting weld-seam geometry may vary significantly notwithstanding the use of constant process parameters and steels with the same material number. What apparently happens is that small variations in the concentration of sulfur, phosphorus, oxygen, and other chemical elements that are well within the tolerance of the standard of a specific alloy, can act as surfactants giving rise to the surface tension gradients which bring about the unwanted Marangoni forces which can give rise to unwanted stresses and deformations.

Digging further into the literature one finds that the Marangone effect also has significant consequences for further technologies as varied as crystal growth and electron beam melting. Rather than go into further details we can only suggest that the interested reader join us at the upcoming CONTACT ANGLE symposium where further developments on this most curious phenomenon will be discussed.

ADVANCES IN CONTACT ANGLE TECHNOLOGY

One of the important steps in making contact angle measurements is the application of the test fluid to the substrate in the form of a small drop. This is normally carried out using a hollow needle. However, an alternate method with significant advantages has recently been developed by KRÜSS GmbH using what they call the Liquid Needle dosing technique. The pressure-based method significantly accelerates the dosing process compared with classic needle dosing. Here, dosing units arranged in parallel can produce two drops at the same time and enable measurements of the surface free energy to be carried out within one second. A current scientific study in the journal Colloid and Polymer Science verifies that contact angles measured by this method are perfectly accurate in spite of this high dosing speed.

During this study, contact angles were measured on 14 different materials using the new pressure dosing method and also the classic needle dosing technique. A wide range of hydrophobic and hydrophilic, rough and smooth, chemically pure and technically contrived surfaces were investigated. The results show without exception a good accord between the contact angle results of the two dosing methods(Full details on this work available online at: DOI 10.1007/s00396-015-3823-1).

Alternatives to needle dosing have previously failed due to the region outside the contact area of the drop being pre-wetted as the dynamics were too high. This falsified the contact angle resulting in values which were too small. In contrast, with the Liquid Needle method, drops are formed in a controlled manner and with low dynamics with the help of a continuous jet. The jet is so thin compared with the final drop size that the contact area does not spread to any greater extent than with needle dosing. This is clearly shown by the results of the study. Both techniques are therefore basically distinguished by careful dosing. However, this is not always the case with classic needle dosing. The user can inadvertently increase the dynamics and thus falsify the value by an unsuitable choice of depositing speed or dosing distance. This is ruled out technically with the new dosing method. The Liquid Needle is also particularly beneficial with liquid-repellent samples. While smaller drops with needle dosing are difficult to deposit on such hard-to-wet materials, dosing with the Liquid Needle presents no difficulties. Overall, the study shows that the Liquid Needle combines speed with high accuracy, reliably prevents unwanted pre-wetting, and furthermore greatly simplifies dosing on liquid-repellent samples.

Interested readers are encouraged to join us at the upcoming CONTACT ANGLE symposium where they will be able to get a real time demonstration of this innovative method.

CALL FOR PAPERS: ELEVENTH INTERNATIONAL SYMPOSIUM ON

CONTACT ANGLE, WETTABILITY AND ADHESION

Stevens Institute of Technology,
Hoboken, New Jersey, June 13-15, 2018

SYMPOSIUM HISTORY AND MOTIVIATION

In his opening remarks at the first symposium in this series Professor Robert Good pointed out that Galileo in the 17^{th} 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 February15, 2018 to the conference chairman by any of the following methods:

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Regular mail:

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Full conference details and registration via the Internet will be maintained on our web site:

www.mstconf.com/Contact11.htm

SYMPOSIUM TOPICS:

Factors Influencing Contact Angle Measurements:

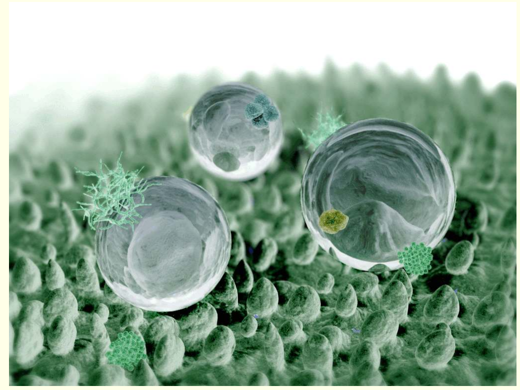
- Static and dynamic contact angles, effect of surface flaws and surface roughness on wetting.
- Effect of pore size distribution
- Effects of velocity and viscosity of liquid on solid-liquid interfacial behavior.
- Interaction forces including: van der Waals, Acid-Base, Hydrogen bonding, ...etc

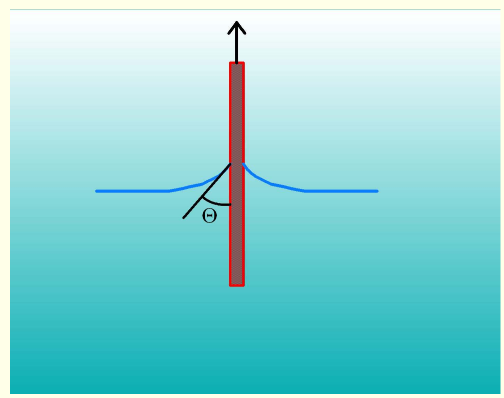
Wettability Behavior and Surface Characterization of Various Materials:

- 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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