MATERIALS SCIENCE AND TECHNOLOGY NEWSLETTER

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CONTACT ANGLE, ADHESION AND THE STABILITY OF COATINGS

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EDITORIAL COMMENTS

This issue of the Newsletter is basically a followup on the very successful TENTH INTERNATIONAL SYMPOSIUM ON CONTACT ANGLE WETTABILITY AND ADHESION held July 13-15, 2016 at the Stevens Institute of Technology, Hoboken, New Jersey, USA. Some 52 topical papers were presented ranging from Numerical Studies of Dynamic Droplet Moving for Fluid Analysis to The Effect of Superhydrophobicity on the Bacterial Adhesion on Polymeric Surfaces. Notably absent, however, were any papers concerned with the effect of contact angle and surface tension on the stability of coating processes. The editorial essay in this issue will go into more detail on this mostly overlooked but highly important technology.

We would also like to bring every ones attention to the next session of the short course on:

THE CHEMISTRY, PHYSICS AND MECHANICS OF ADHESION SCIENCE

The course will be given again this coming May 17-19, 2017 at the Marriott Inn in Newburgh, NY and all readers of the NEWSLETTER are invited to join us this coming May in Newburgh or simply to pass the word along to colleagues or associates who might be interested. Further details available on the conference web site by clicking on

www.mstconf.com/AdhesionCourse.htm

EDITORIAL ESSAY:

Coating Flaws and Flow Instabilities

Those in the coating industry are likely familiar with at least one of the following defects which plague coating and film processes:

* Leveling
* Sagging
* Dewetting
* Film Retraction/Pinholes
* Orange peel
* Stress buildup
* Curling
* Delamination
* Cracking

All of the above failure modes are strongly controlled by the surface tension and wetting behavior of the coating material and the surface properties of the underlying substrate and, needless to say, they significantly impact film coating processes.

The above phenomena represent just a sample of conditions where fluid surface properties play a decisive role in coating applications. Figure 1 gives a schematic overview of three common coating defects which can occur if the fluid coating viscosity and surface tension are not in a proper range. We see that if the surface tension and viscosity are too low then sagging or dripping can occur. However if

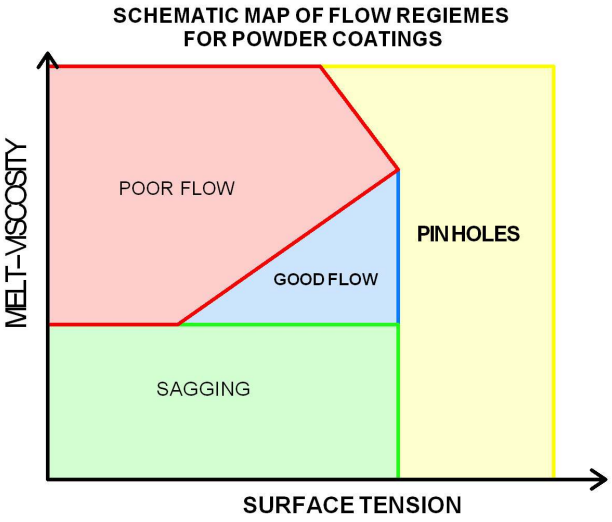

Figure 1 Map outlining effect of coating viscosity and surface tension on defect behavior. Low viscosity and surface tension give rise to sagging behavior whereas too high surface tension can lead to pin holes. From paper by Haroon Kheshgi, "Fate of thin Liquid Films after Coating" in(Liquid Film Coating: Scientific Principles and their Technological Applications, Ed. S. F. Kistler and M. Schweizer, Springer, 1997)

the surface tension gets too high then the fluid coating can strongly contract giving rise to pin holes. Thus knowledge and control of the coating surface tension is critical for the formation of acceptable films.

As the topic of coating failure mechanisms is rather enormous, we will restrict our attention here to the effect of surface tension on pin holes. Figure 2 presents a schematic diagram of how the coating surface tension and melt viscosity can give rise to pinhole formation for the case of powder coatings.

The process starts when a small isolated region of the wet coating develops a lower surface tension than the surrounding film. There can be a number of causes for this but most likely a contaminating particle or droplet containing a surfactant agent of some sort settles on the coating giving rise to the low local surface tension. The gradient in surface tension in the still liquid coating can now cause material to be pulled into the high tension surroundings. This can be very dangerous for thin films since the film may thin down to where molecular forces can give rise to what is called a disjoining pressure which can cause the liquid to separate entirely from the substrate leaving a dry patch. In essence the disjoining pressure arises when cohesive forces tending to hold the coating material in the bulk phase are larger than the surface forces which cause the material to spread over the surface leading to fluid contraction into the bulk as opposed to spreading over the surface.

From this analysis it is clear that contact angle behavior and surface tension play a strong role in determining how thin a coating can be made without running into the problem of pin holes. This is of great concern in the microelectronics industry where polymer dielectric layers are coated down to a level of a few microns. Taylor

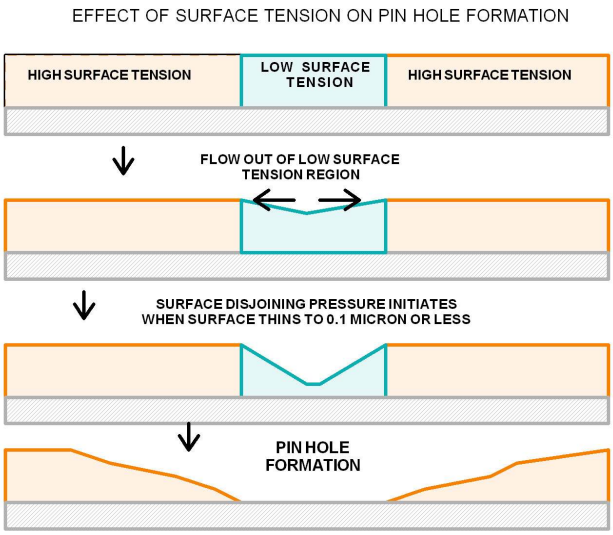

Figure 2 Steps leading to pinhole formation in a thin coating where a small island in the film develops a lower surface tension than the surrounding film possibly due to a surface active contaminant. (Adapted from Kistler&Schweizer from Fig.(1))

and Michael[1] have shown that the critical thickness below which pin hole formation sets in is determined by the competing forces of gravity and surface tension. For a thick film gravity dominates over surface tension in advancing the contact line thereby suppressing pin hole formation. However, the effect of gravity diminishes directly with the coating thickness and thus a point is reached where the surface tension dominates. Taylor and Michael calculate that the critical transition thickness is given by:

$$h_c = 2\left(\frac{\sigma}{\rho g}\right)^{1/2} \sin\frac{\theta}{2}$$

Where:

h_c = Critical film thickness for pin hole formation
σ = Surface tension
ρ = Coating density
g = Gravitational acceleration
θ = Coating contact angle

[1] "On Making Holes in a Sheet of Fluid", G. I. Taylor and D. H. Michael, J. Fluid Mechanics, 58, 625 (1973)

A further question arises as to how large a hole will be formed. Sharma and Ruckenstein[2] have calculated that the pin hole size is related to the critical film thickness and the contact angle as:

$$r_h = \frac{h_c}{1 - \cos\theta}$$

Where r_h is the pin hole radius and h_c and θ as listed above.

Thus we see that the contact angle and the surface tension of coatings play a key role in all aspects of pin hole formation.

Much more detail on the surface tension and contact angle behavior of liquids and liquid films is covered in the Adhesion Science short course. Details are given below and all readers of the Newsletter are invited to join us this coming May as we delve into the inner workings of the subtle material interactions that hold the world together and also cause it to fall apart and uncover the basic principles that determine which outcome will prevail.

SHORT COURSE ON THE CHEMISTRY, PHYSICS AND MECHANICS OF ADHESION SCIENCE

3- Day Impact Course
The Chemistry, Physics & Mechanics of Surface Science and Adhesion

May 17-19, 2017
Courtyard by Marriott, Stewart-Newburgh New York

[2] " Energetic Criteria for the Breakup of Liquid Films on Nonwetting Solid Surfaces", E. Ruckenstein and A Sharma, J. Colloid and Interface Science, 137, 433 (1990).

SCENIC HUDSON VALLEY

First discovered by Europeans in 1609 when Henry Hudson sailed his ship the Half Moon into Newburgh Bay, the HUDSON VALLEY has since been visited by a long list of remarkable adventurers, explorers and statesmen. These influential men and women determined the early history and culture of America from the 18th century onward. From the time of the Revolutionary war when George Washington established his headquaters in a stone fortress in Newburgh on through the tumultuous years of the 19th century which witnessed the revolutionary changes brought on by the industrial revolution, the Hudson Valley has been the scene of landmark developments in commerce, technology and American culture.

Topics to be Covered

I. Surface Contamination and Cleaning
II. Theories or Mechanisms of Adhesion
III. Contact Angle, Wettability and Adhesion
IV. Investigation of Interfacial Interactions
V. Surface Modification Techniques including Plasma
VI. Ways to improve Adhesion of Organic Coatings
VII. Silanes and Other Adhesion Promoters
VIII. Adhesion Aspects of Thin Films
IX. Adhesion Measurement of Films and Coatings
X. Basics of Adhesion Measurement
XI. Residual Stress and Material Mechanical Properties
XII. Setting Adhesion Requirements for Coating Applications
XIII. Adhesion Measurement at Atomic and Molecular Level
XIV. Practical Adhesion Applications

How You Will Benefit From This Course

You will be able to understand the advantages and disadvantages of a range of adhesion measurement techniques. You will be able to select the right surface cleaning technique including the use of atmospheric plasmas. You will utilize the concept of acid-base interactions in improving adhesion and acquire basic skills for addressing adhesion failure problems, analyze the alternatives and select the optimum technique for improving adhesion and structure durability. Know where help is available in emergency situations and learn how to select the best measurement technique for a given application.

Audience: Scientists and professional staff in R&D, manufacturing, processing, quality control/reliability involved with adhesion aspects of coatings and adhesion sensitive applications.

Level: Beginner- Intermediate; introduction/overview

Prerequisites: Elementary background In chemistry, physics or materials science.

Duration: 3 days

Course fee and materials: $1,295, includes break refreshments, complete set of lecture notes and copy of handbook and reference guide ADHESION MEASUREMENT METHODS: THEORY AND PRACTICE, (CRC PRESS, 2006)

INSTRUCTORS AND CONTACT INFORMATION

Dr. K. L. Mittal & Dr. R. H. Lacombe
3 Hammer Drive
Hopewell Junction, NY 12533
Tel. 845-897-1654 & 845-592-1963
E-mail: klm@mstconf.com ; rhl@mstconf.com

For detailed information and registration: www.mstconf.com/AdhesionCourse.htm

REGISTRATION INFORMATION

DATES: May 17-19, 2017: SHORT COURSE ON CHEMISTRY, PHYSICS AND MECHANICS OF ADHESION SCIENCE

www.mstconf.com/AdhesionCourse.htm

LOCATION:

Courtyard By Marriott
Newburgh Stewart Airport
4 Governor Drive.
Newburgh, New York 12550 USA.

Phone: 1 845 567 4800
Fax: 1 845 567 9550

Register by phone:

Call 1-866-237-5979 and ask for MST Adhesion course block

Web Site:

www.marriott.com/hotels/travel/hpnnb-courtyard-newburgh-stewart-airport

Course Fee and Materials:

$1,295, includes break refreshments, complete set of lecture notes and copy of handbook and reference guide ADHESION MEASUREMENT METHODS: THEORY AND PRACTICE, (CRC PRESS, 2006)

TRANSPORTATION:

Area Airport

Stewart International Airport - SWF
Phone: 1 845 564 2100
Hotel direction: 1 mile(s) NE

Driving directions:

Follow Rte 207 from airport. Turn left on Rte 300 (Union Ave.). Follow to Rte 17K, turn left. Hotel is on left 2 miles. Courtesy phone available

Alternate transportation: All Family Taxi; fee: 17 USD (one way) ;on request

Airport shuttle service, on request, complimentary

Other Transportation

Bus Station: Shortline Trans Center (4 mile(s) E)

http://www.coachusa.com/shortline/

Car Rentals:

Nearby:Hertz
49 Route 17 K
Newburgh, New York 12550
Phone: 1-845-561-7479

Parking

* Complimentary on-site parking

TO REGISTER FOR COURSE

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Hotel and Nearby Attractions

Courtyard by Marriott Newburgh, redesigned for the way you travel. Our new lobby features inviting, flexible spaces to work or relax, free Wi-Fi throughout the hotel and easy access to the latest news, weather and airport conditions via our GoBoard. The highlight of our new lobby experience is The Bistro - Eat. Drink. Connect., which provides healthy offerings in the morning, dinner service with beer or wine selections in the evening and Starbucks® coffee each day. In addition to the new lobby, you'll find redesigned guest rooms, fitness facility and meeting space. Nestled in the heart of the Hudson Valley, we are just minutes from Stewart International Airport, West Point Military Academy and Woodbury Commons Premium Outlets. For your convenience, we provide complimentary airport shuttle service on request, daily from 7am to 11pm.

Highlights

* West Point Military Academy
* Paul Jr. Designs
* Orange County Choppers
* Stewart International Airport
* Woodbury Common Premium Outlets
* Washington's Headquarters State Historic Site
* New York Military Academy
* Mount Saint Mary College
* Newburgh Waterfront

CANCELLATIONS: Registration fees are refundable, subject to a 15% service charge, if cancellation is made by April 15, 2017. NO refunds will be given after that date. All cancellations must be in writing. Substitutions may be made at any time without penalty. MST Conferences reserves the right to cancel the short course if it deems this necessary and will, in such event, make a full refund of the registration fee. No liability is assumed by MST Conferences for changes in program content.

REGISTRATION FORM: FILL OUT AND SEND TO DR. LACOMBE BY REGULAR MAIL, FAX OR AS EMAIL ATTACHMENT AT THE ADDRESS/PHONE NUMBER/E-MAIL ADDRESS GIVEN ABOVE

SHORT COURSE ON CHEMISTRY, PHYSICS AND MECHANICS OF ADHESION SCIENCE: MAY 17-19, 2017, Newburgh, New York	$1295
Deduct 10% if more than 1 participant from same institution	
TOTAL REGISTRATION FEE	

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(As it appears on card)

[3] As an extra security measure card companies require that the address given be the billing address for the card. The street address and zip code are required inputs.

[4] On most cards this is a 3 digit number on back of card to right of last 4 digits of card number