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Biography

Professor Constantine Megaridis earned his Ph.D. (1987) in Fluid and Thermal Sciences from Brown University. He also holds a MS in Applied Mathematics from Brown. He is presently Director of the Micro/Nanoscale Fluid Transport Laboratory at UIC. His research interests focus on fluid/particle transport and interfacial phenomena relevant to micro and nanotechnologies. He is directing a number of research programs funded by the federal government and large industrial firms. He was awarded the 1997 Kenneth T. Whitby Award of the American Association for Aerosol Research for outstanding technical contributions to aerosol science and technology. He has been NASA-ASEE Summer Faculty Fellow, and is Fellow of the American Physical Society (APS), the American Society of Mechanical Engineers (ASME), and Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA). He was awarded the 2008 Annual Achievement Award by the Illinois Engineering Council, and the Faculty Research Award of the UIC College of Engineering.

Title:

Multifunctional Nanocomposite Liquid-Repellent Coatings/Films for the Electronics Industry

Executive Summary

Recent advances in polymer science and nanomaterials have fueled a frenzy of scientific activity in multifunctional coatings and films. This rich subject area encompasses several scientific disciplines, ranging from chemistry, physics and engineering, to biology and medicine. We present a polymer composite large-area coating method designed to impart desirable surface functionalities (such as super-repellency to liquids, or electrical conductivity) to substrates ranging from glass and metals, to porous or flexible materials. The wet-based approach relies on combining a polymer matrix in solvents with other materials to enhance adhesion and allow micro/nanoparticle filler dispersion. The advantage of the technique lies in its inherent ability to impart multiple functionalities by adding the proper ingredients to the solution, which is deposited on the target surface by spray, ink jet or other techniques. The approach combines tunable surface energy with micro-to-nano scale roughness, a necessary condition for super-repellent behavior towards water, oils and alcohols. In some coatings, super-repellency is combined with self-cleaning ability, which is effected by low droplet roll-off angles. We demonstrate thin coatings with controllable micro/nanostructure, liquid repellency, and electromechanical properties, combined with good mechanical or environmental durability. Several examples (including elastomeric, electrically conducting and icephobic coatings) demonstrate the potential of the method. We also discuss patterning of such coatings with spatial resolution approaching the micrometer regime. The present multifunctional nanocomposite coating technology appears well suited for the electronics industry; the coatings can be tuned for different functionalities and processed using large area deposition processes (e.g. ink jet and atomized spray). The coatings can be chemically designed to provide optimal adhesion to both rigid and flexible printed wiring boards.

Multifunctional Nanocomposite Liquid-Repellent Coatings/Films for the Electronics Industry

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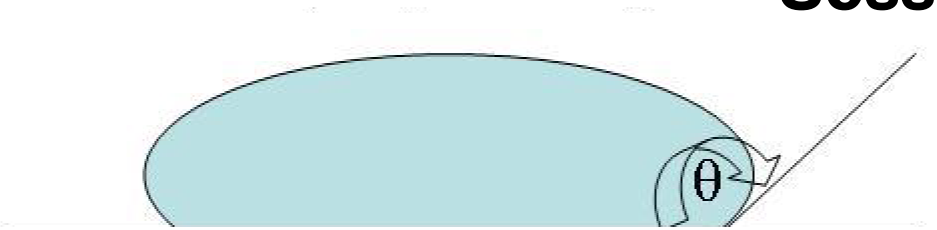
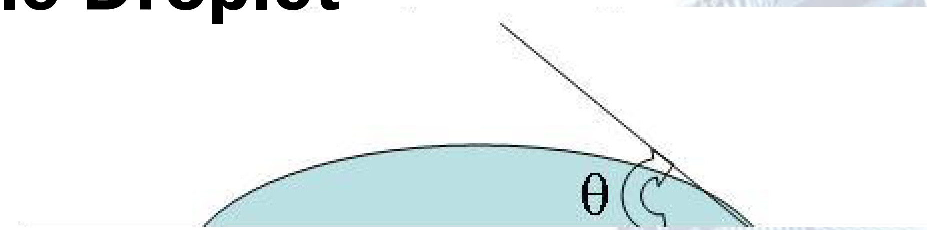
Outline

- Definitions and Background
  Hydrophobicity, Self-cleaning property
- Motivation and Objective
- Coating Synthesis and Characterization
- Add-on Coating Examples:
  - Electrically conducting coatings
  - Elastomeric (stretchable) coatings
  - Icephobic coatings
- Spatially patterned wettability: The future

Wettability, Contact Angle (CA), CA Hysteresis

Sessile Droplet





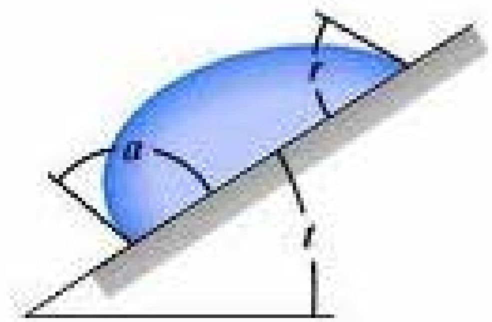
$\theta > 90^o$, Hydrophobic

Low Wetting

$\theta < 90^o$, Hydrophilic

High Wetting

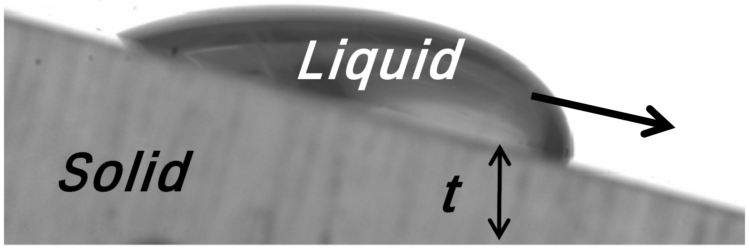
Moving Droplet



Advancing and Receding Contact Angles on tilted plate

CA Hysteresis = $\theta_a - \theta_r$

Sliding Angle, Self-cleaning

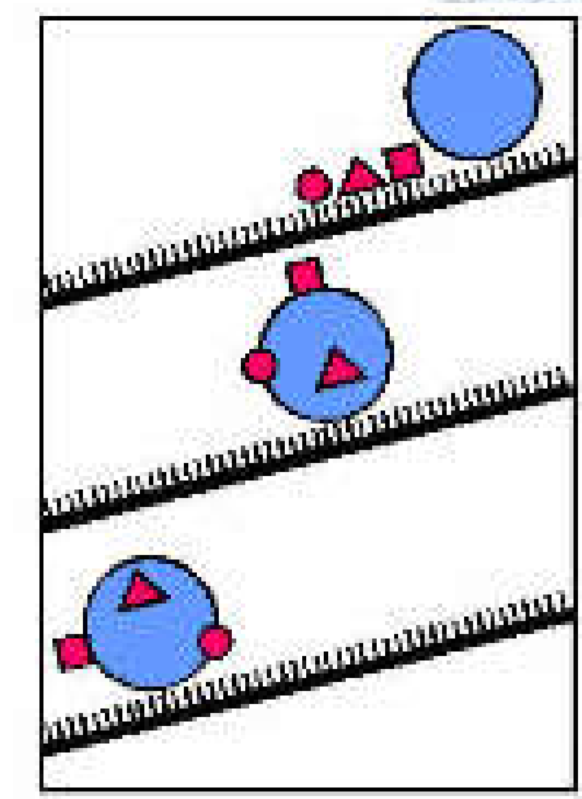


C.G.L. Furmidge, ***J. Colloid Sci.*** **17, 309-324 (1962)**

$$\boxed{\sin t = \frac{\sigma R k(\cos\theta_r - \cos\theta_a)}{mg}}$$

σ surface tension, R length scale,
k shape constant, m liquid mass

W. Barthlott



Low values of tilt angle *t* $\Rightarrow$ self cleaning surface (drop roll-off)

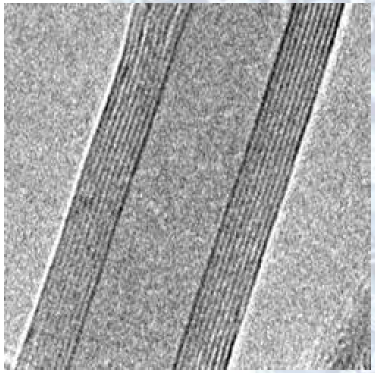
What's in a name?

"Superhydrophobic"

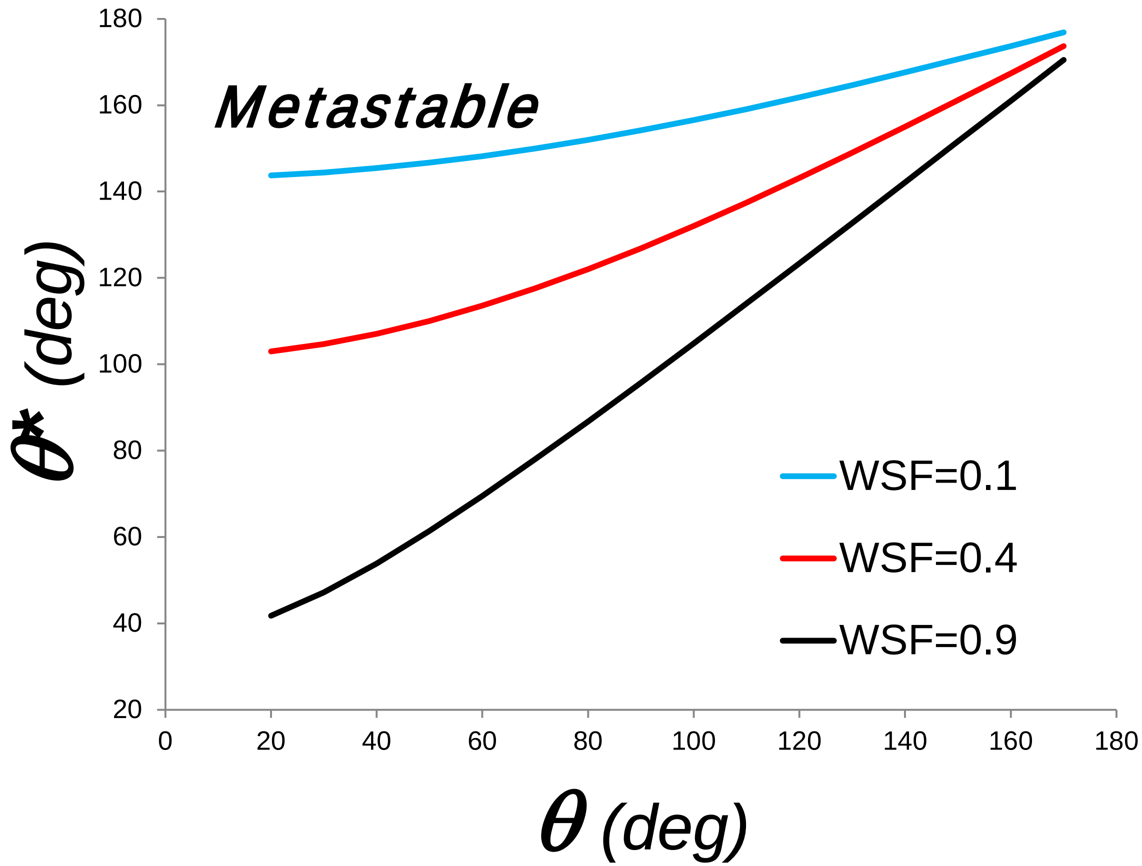
Year	Number of ISI indexed papers
1989-2000	20
2005	87
2011	790

"Carbon Nanotube"

Year	Number of ISI papers
1992	10
1996	225
2000	1,021
2011	17,770



Underlying Science and Practical Importance



+ Can design **metastable** superphobic surfaces by adding texture to philic substances ($\theta < 90^{o}$)

- How do we create **durable** superphobic surfaces?

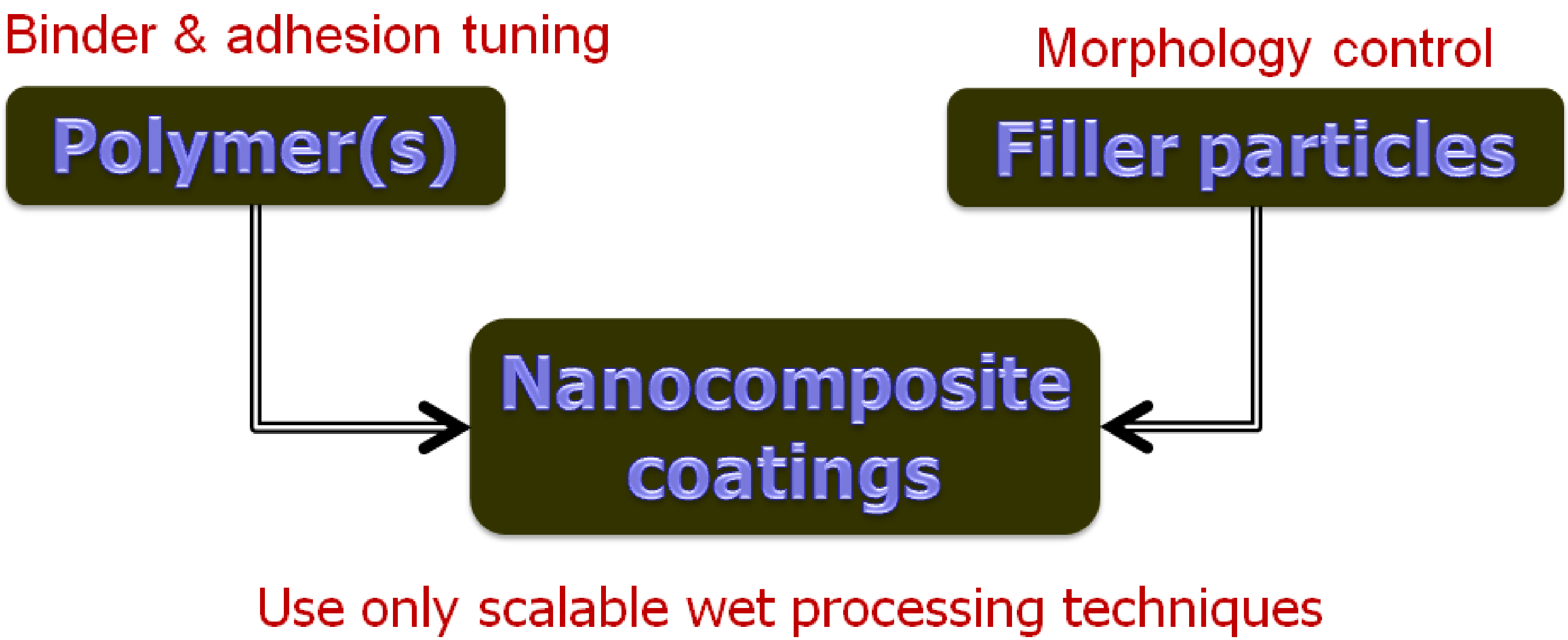
Our Technology

Motivation and Objective: Synthesize and evaluate scalable (i.e., large-area) strongly-adhering, mechanically durable coatings with high repellency to water and/or other liquids (alcohols, oils).

Approach: Solution-processed polymer composite coatings containing one or more micro/nanomaterials, each contributing specific functionality: mechanical or chemical durability, adhesion enhancement, electromagnetic function, antibacterial/antimicrobial action, etc.

Approach

Superhydrophobicity is obtained by imparting micro/ nanoscale roughness to a hydrophobic material



- **I.S. Bayer, M.K. Tiwari, C.M. Megaridis, *App. Phys. Letters* 93, 173902 (2008)**
- **M.K. Tiwari, I.S. Bayer, G.M. Jursich, T. Schutzius, C. M. Megaridis, *ACS Appl. Mater. Interfaces* 2:1114-1119 (2010)**

Choice of Polymer as Main Matrix

Poly(vinylidene fluoride) (PVDF)

Poly(methyl methacrylate) (PMMA)

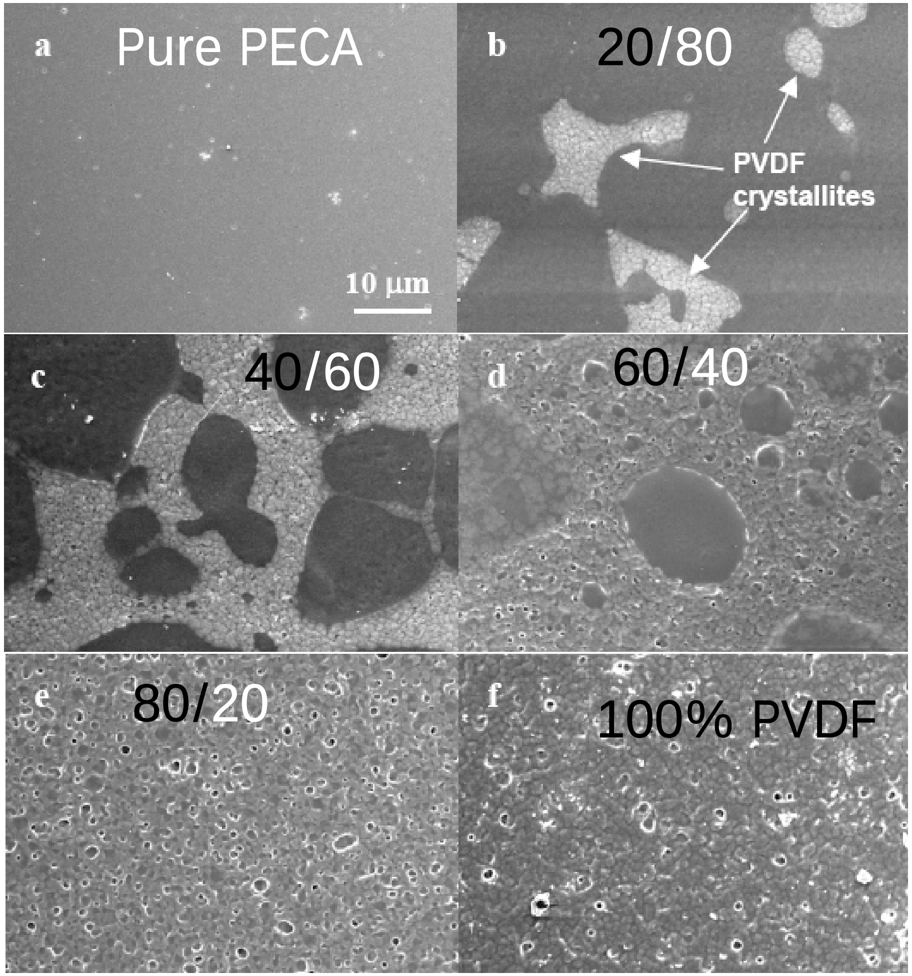
Cyanoacrylates (CA): Esters of 2-cyano-acrylic acids

Nitrile Rubber (NBR)

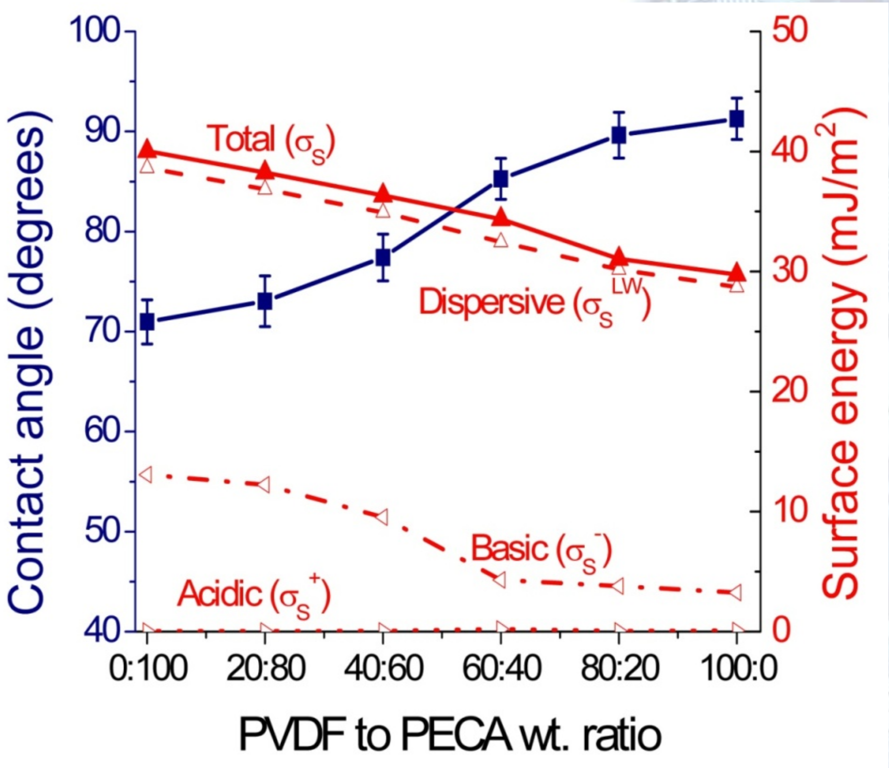
Fluorinated acrylics (PMC)

……

PVDF/PECA Blend Properties

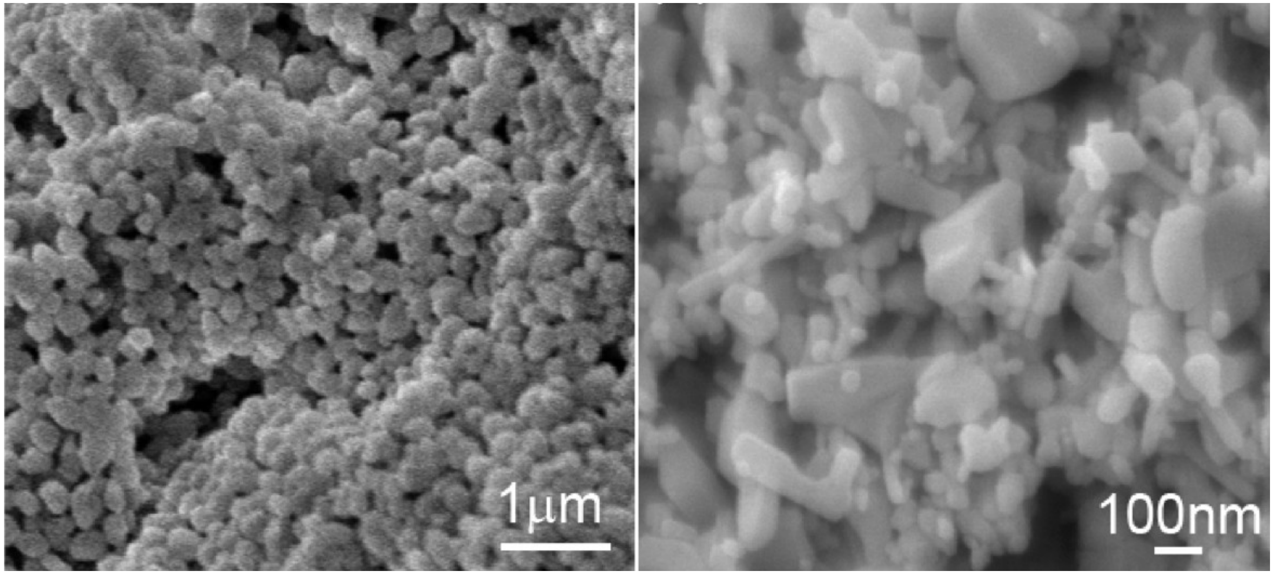


$$\sigma_S = \sigma_S^{LW} + 2(\sigma_S^{+}\sigma_S^{-})^{1/2}$$



M. K. Tiwari, I. S. Bayer, G. M. Jursich, T. M. Schutzius, C. M. Megaridis, *Macromol. Mater. Eng* 294: 775-780 (2009)

Add Particle Fillers

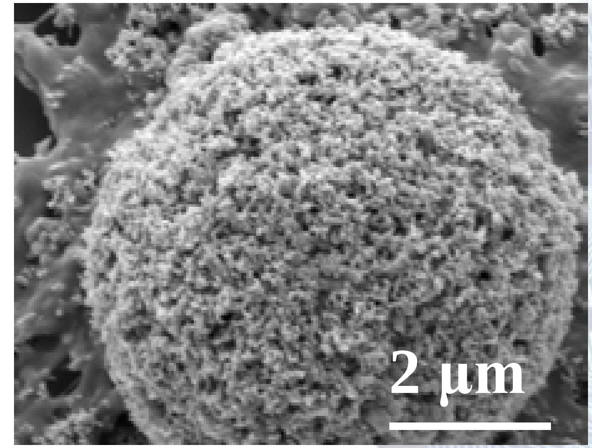


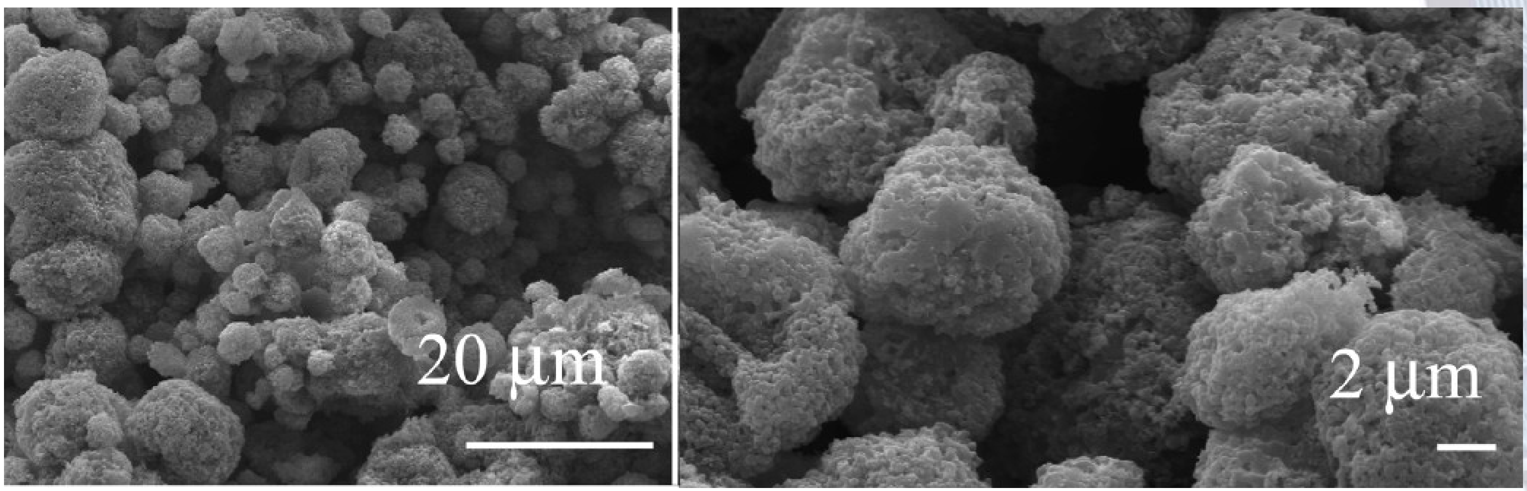
PTFE
Non-wettable

ZnO
Wettable

…. Apply by Spray, and Dry

Hierarchical Micro/Nanoscale Roughness

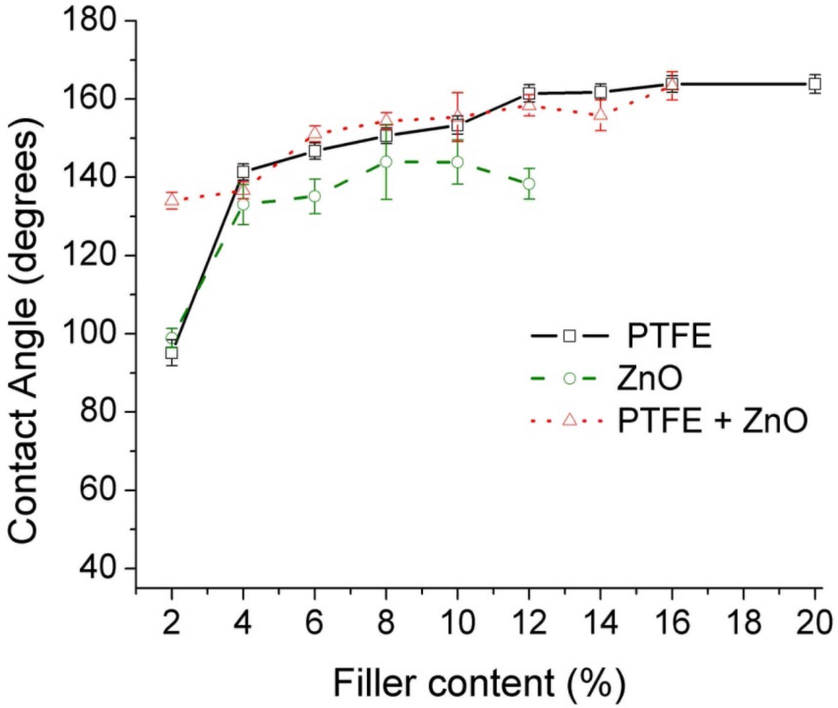




PVDF/PECA + PTFE + ZnO particles (1:1 wt. ratio)

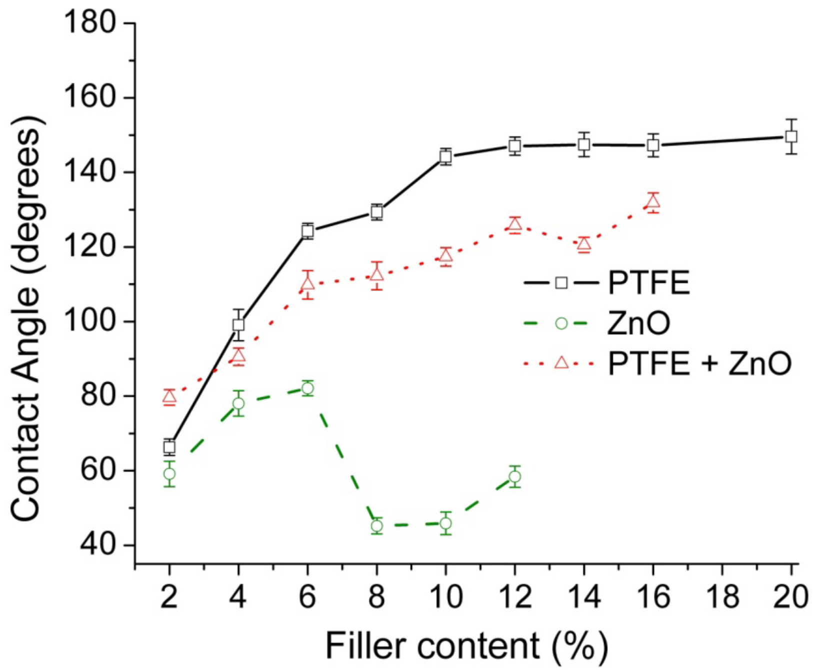
M. K. Tiwari, I. S. Bayer, G. M. Jursich, T. M. Schutzius, C. M. Megaridis,
***ACS Appl. Mater. Interfaces* 2: 1114-1119 (2010)**

Particle Filler Effects on Coating Wettability



Water (72 mN/m)

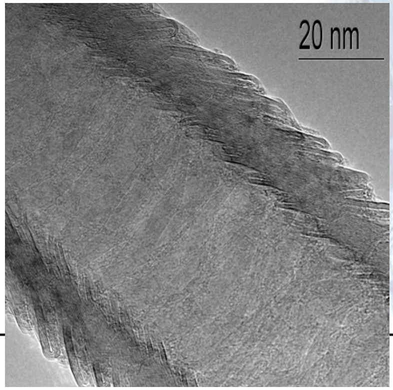
Water + IPA mixture (9:1 wt. ratio) (~ 40 mN/m)



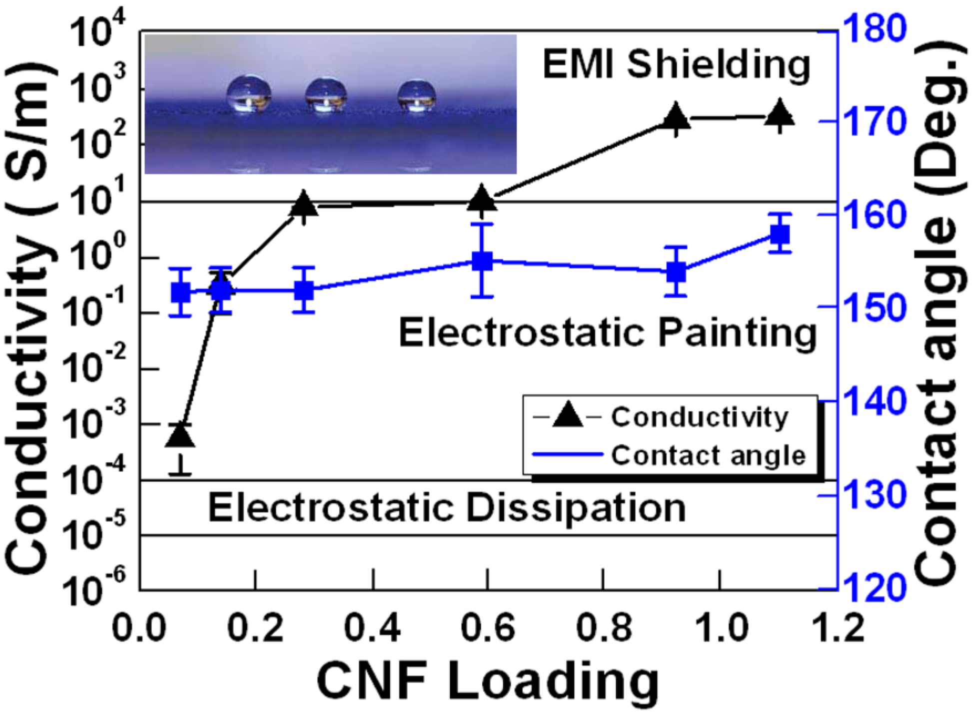
M. K. Tiwari, I. S. Bayer, G. M. Jursich, T. M. Schutzius, C. M. Megaridis, *ACS Appl. Mater. Interfaces* 2: 1114-1119 (2010)

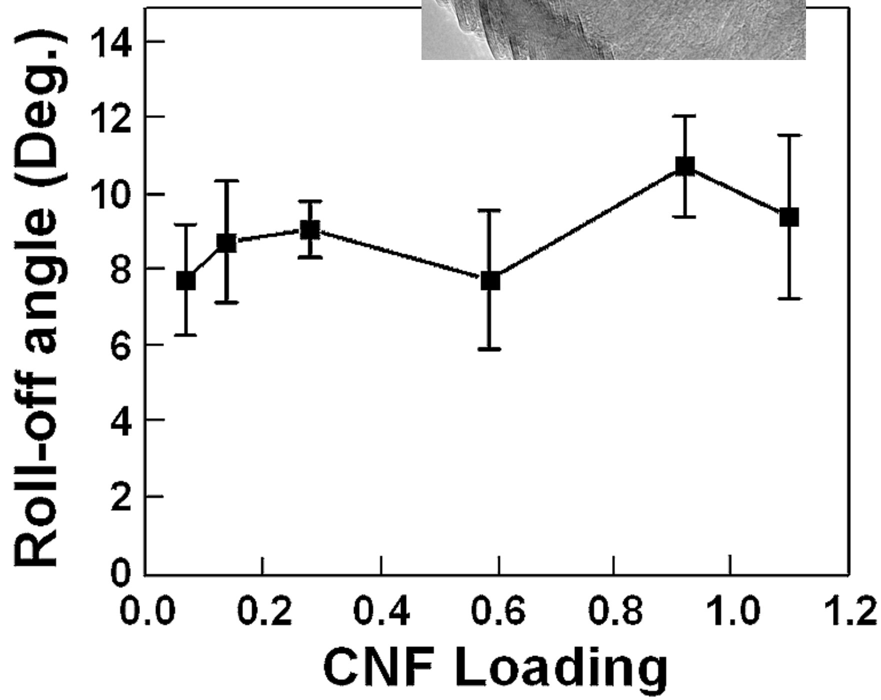
Example I: Electrically Conducting Coatings

Carbon Nanofibers (CNF) add electrical functionality



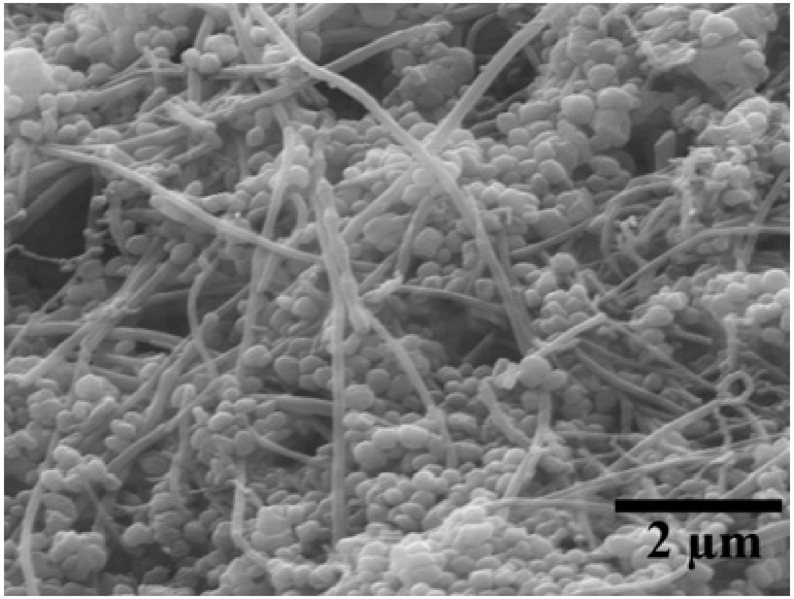
PVDF + PMMA + CNF on paper

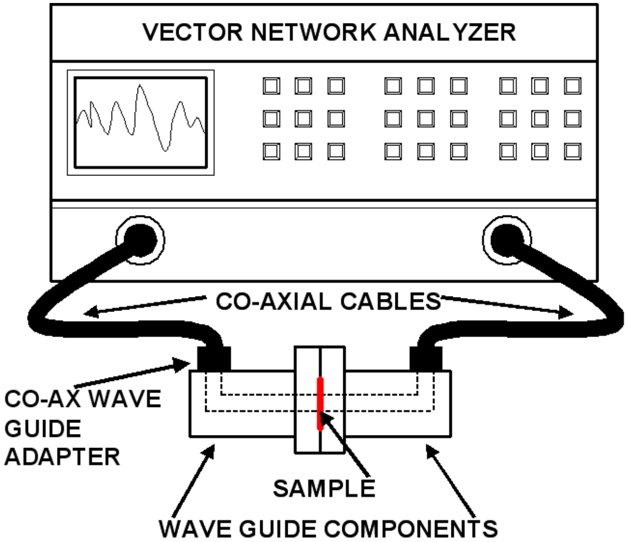




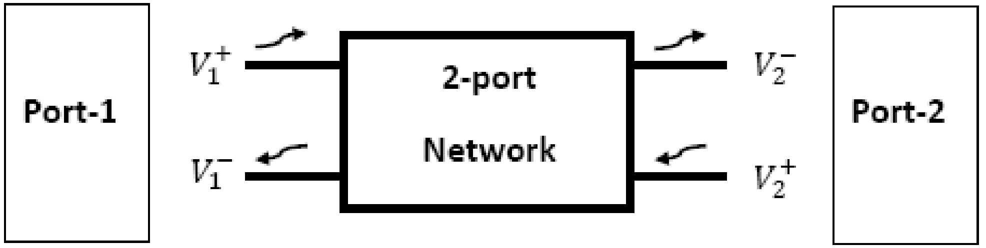
A. Das, H.T. Hayvaci, M.K. Tiwari, I.S. Bayer, D. Erricolo and C. M. Megaridis, *J. Colloid Interface Science* 353: 311-315 (2011)

Example I: EMI Shielding in GHz Freq. Range





X-band (8.2GHz -12.4GHz)

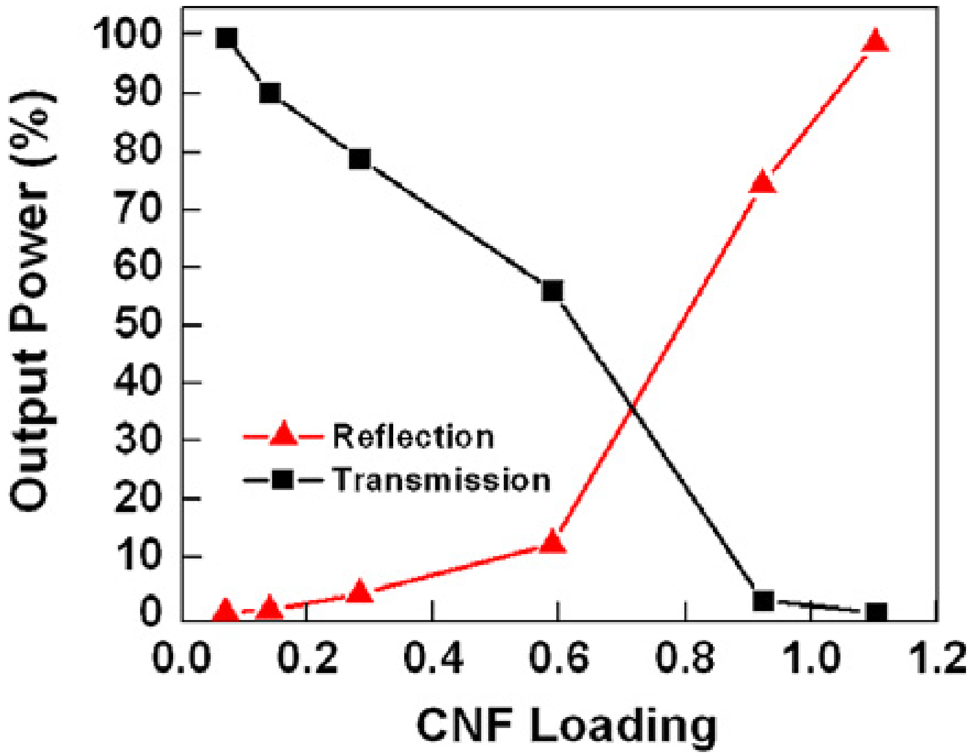


EMI Shielding Effectiveness quantified by

S_{11} [dB] = $20\ \log |V_1^- / V_1^+|$ and S_{21} [dB] = $20\ \log |V_2^- / V_1^+|$

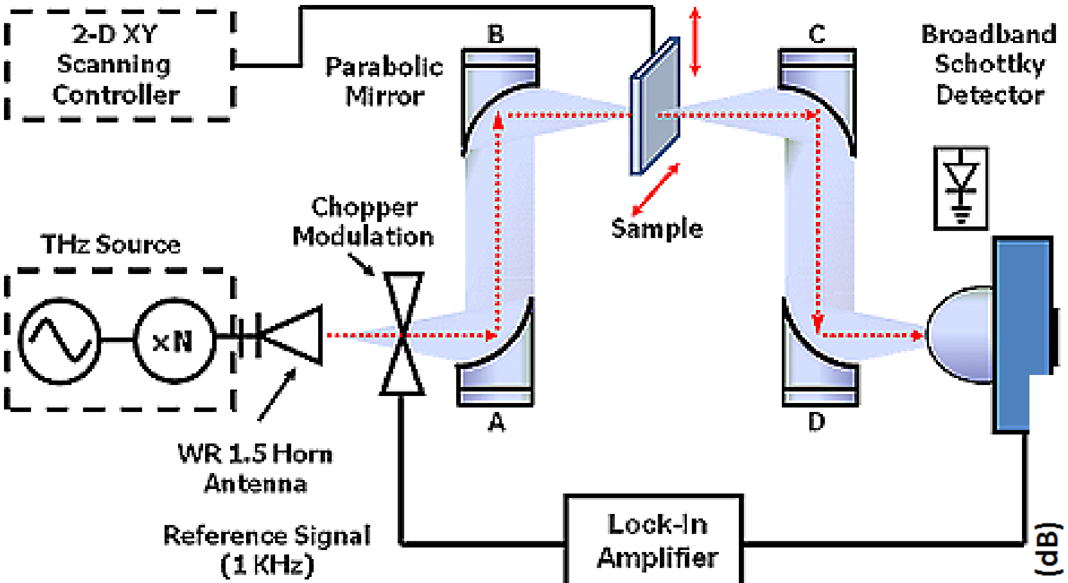
Reflection **Transmission**

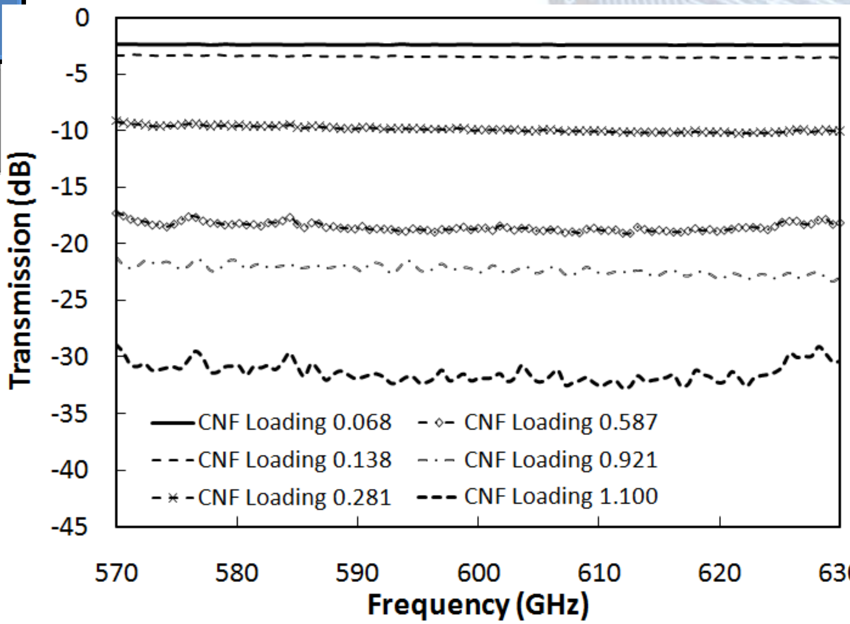
Example I: EMI Shielding in GHz Range



A. Das, H.T. Hayvaci, M.K. Tiwari, I.S. Bayer, D. Erricolo and C. M. Megaridis, *J. Colloid Interface Science* 353: 311-315 (2011)

Example I: EMI Shielding in THz Regime



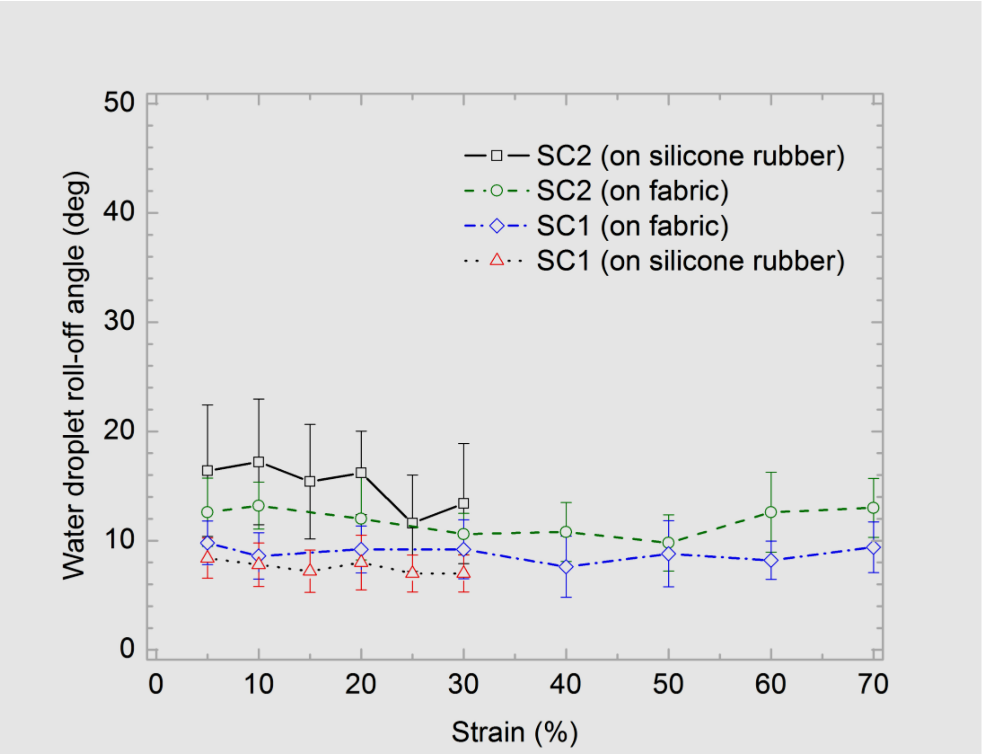


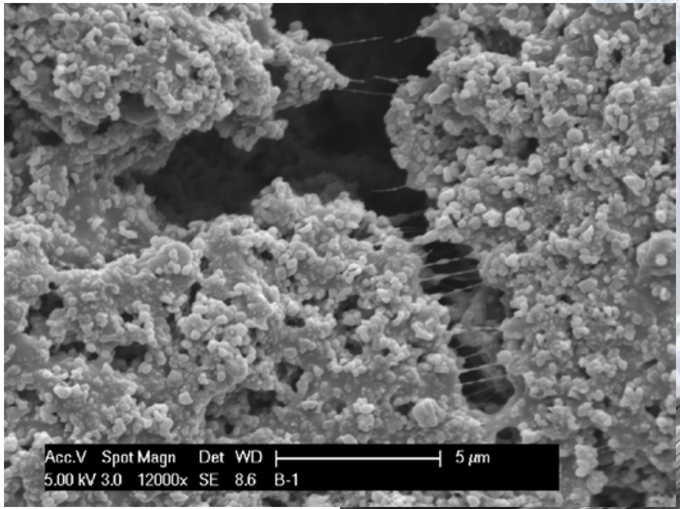
A. Das, C. M. Megaridis, L. Liu, T. Wang and A. Biswas, *Appl. Phys. Lett.* 98, 174101 (2011).

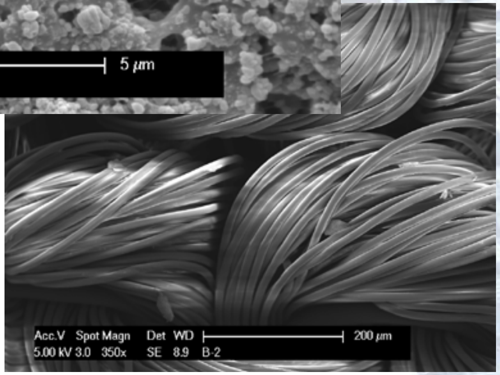
Example II: Elastomeric Coatings

Solutions of Nitrile rubber (NBR) in acetone and PTFE-CB suspensions in acetone mixed.

Sprayable solutions applied on silicone rubber or polyester fabric substrates and dried at 80°C for ~1 hr.

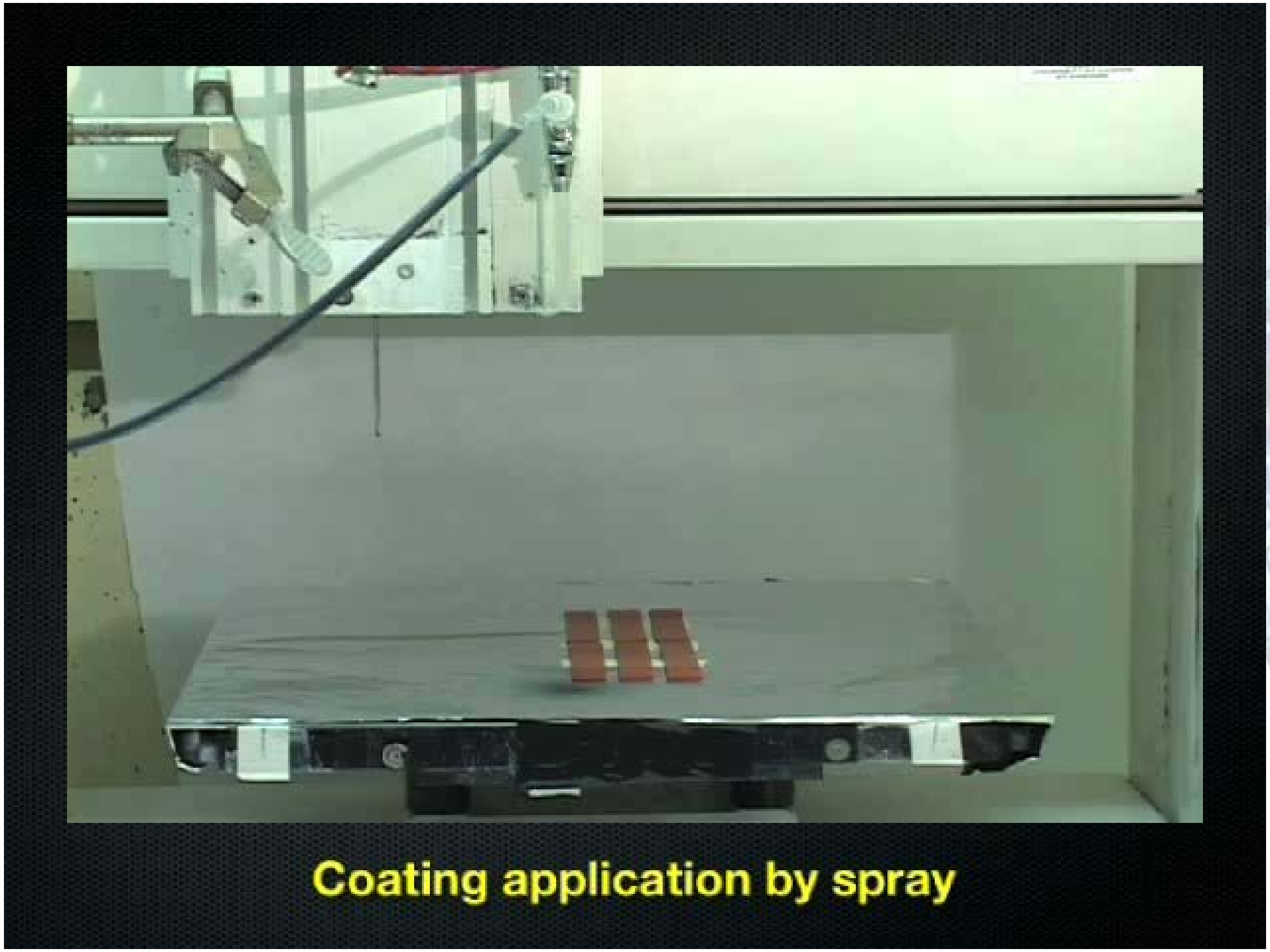






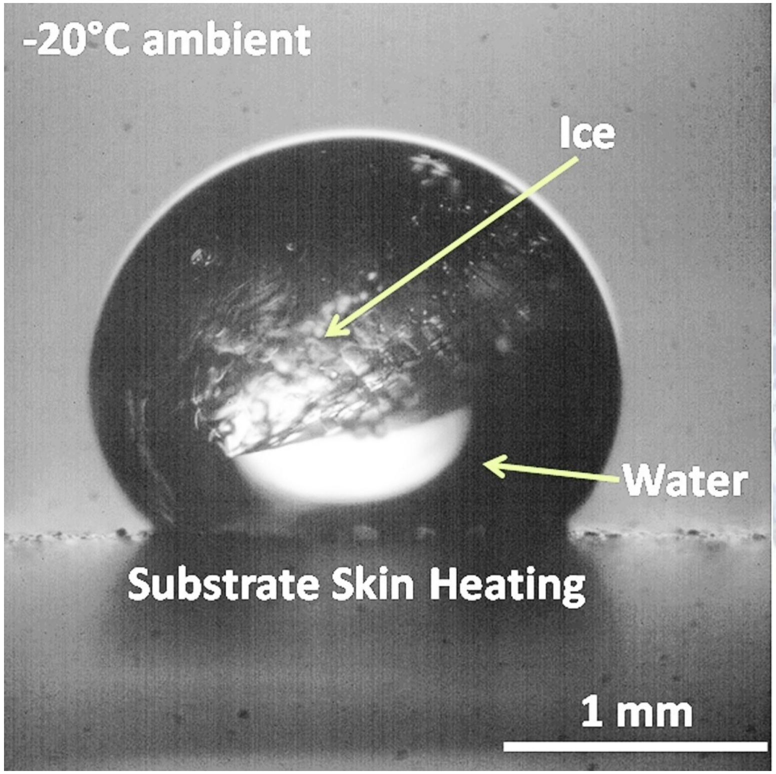
Schutzius et al., *J Composites A* 42, 979-985 (2011)

Example II: Elastomeric Coatings



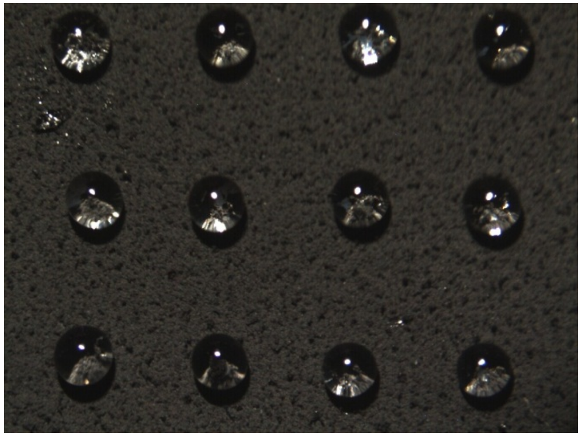
T. M. Schutzius, M. K. Tiwari, I.S. Bayer, C. M. Megaridis,
J. Composites A 42, 979-985 (2011)

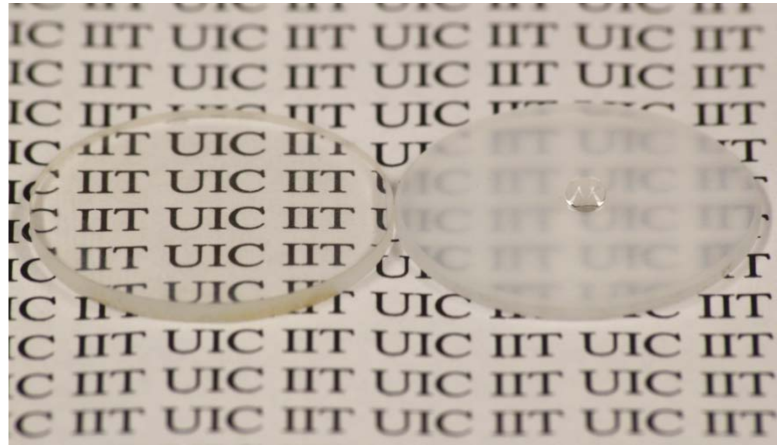
Example IV: Icephobic Coatings

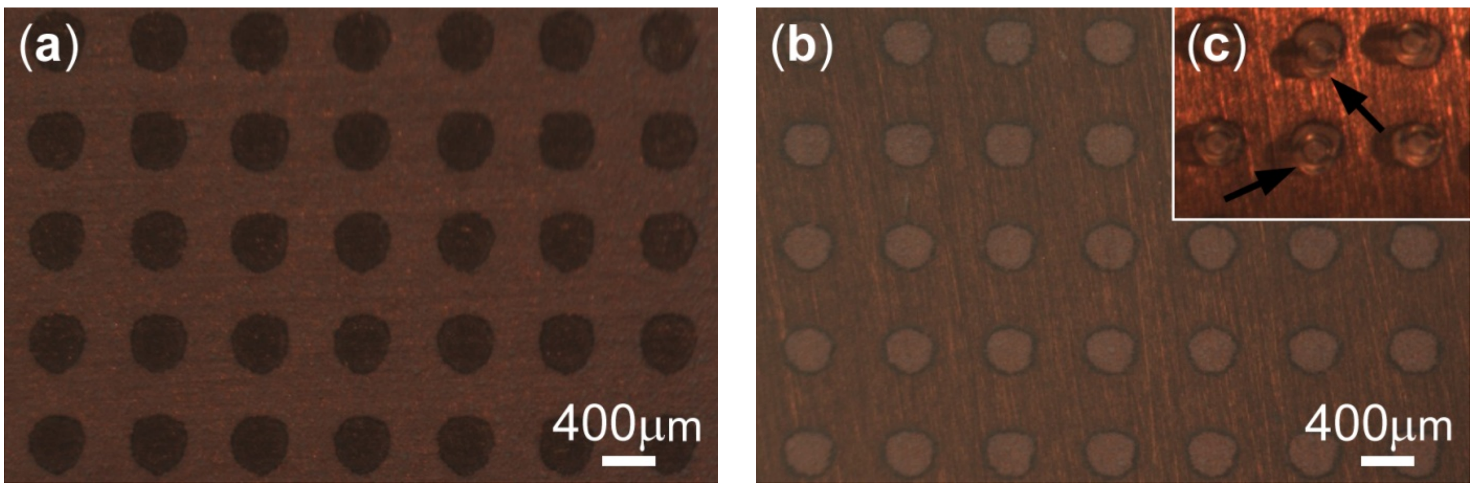


Active Anti-Icing Control

Examples of Patterned Wettability







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