Hydrophilicity Enhancement of UV Cured Acrylic Materials

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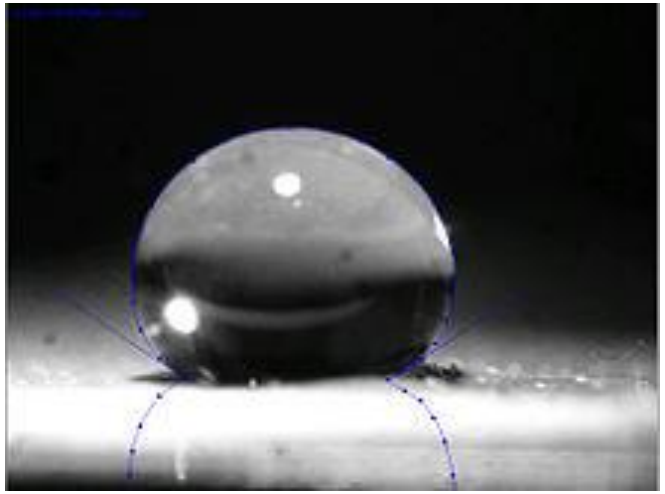
Outline

- Introduction
- Hydrophilicity and its measurement
- Hydrophilicity of UV cured formulations
- Possible solutions to enhance hydrophilicity
- Conclusions



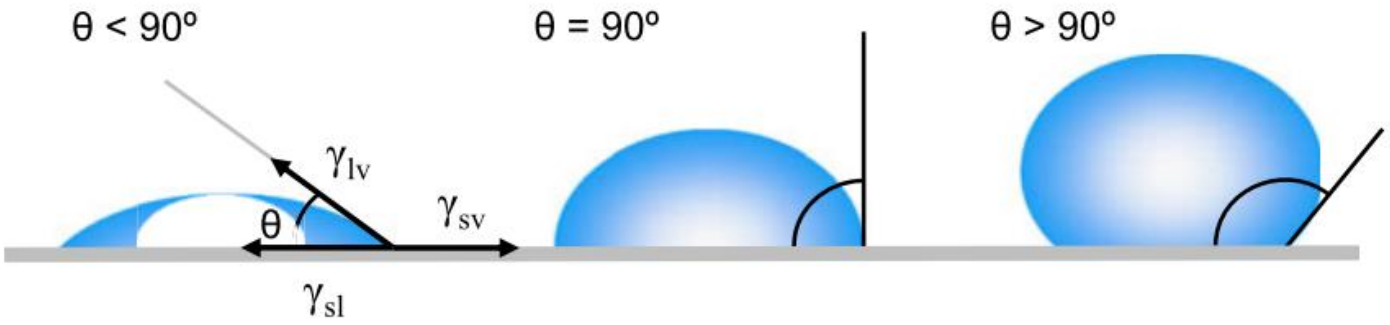
Water on lotus leaf (147º)

Why Hydrophilicity

- Some applications require hydrophilic coatings
  - Membranes
  - Lithography
  - Coatings
  - Special adhesives
  - To improve compatible with hydrophilic surfaces
  - Lubrication
  - Biocompatibility
  - Sensing
  - Spray quenching

Hydrophilicity

- Hydrophilicity is measured by the sessile drop contact angle of water on the desired surface using goniometer
- Contact angle of <30º is considered as hydrophilic in nature



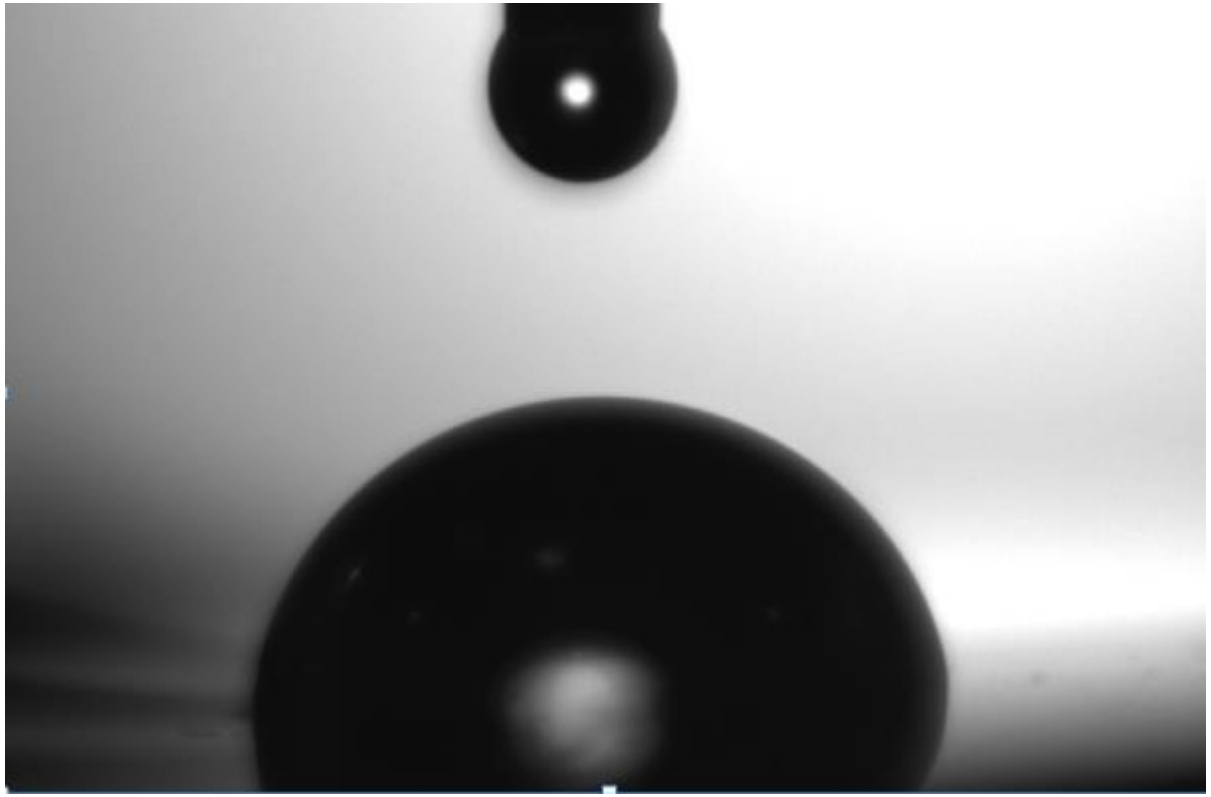
Contact angle (º)	Definition of hydrophobicity/hydrophilicity
>150	Superhydrophobic
30-150	Hydrophobic
<30	Hydrophilic
0	Superhydrophilic

Preparation of UV cured film

- UV curable formulation is prepared with acrylic/methacrylic monomers and photoinitiators
- In general 125 micron layer is coated with doctor blade
- Cured with 2 passes in Heraeus UV curing station at 35% intensity (24 mJ/cm2)
- Dry to touch
- Smooth and bubble free flat film is made (rough surface can trap air that can mislead the results)
- Immediately CA was measured

LC6B Heraeus Noblelight Benchtop Conveyor

Behavior of typical UV cured materials

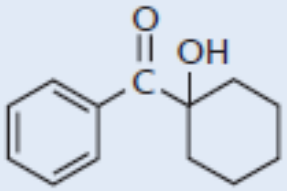


Water contact showing the hydrophobic nature

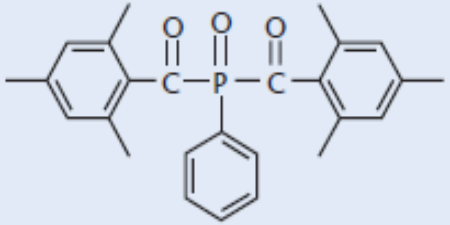
Reasons for hydrophobic nature of UV cured films

- Photoinitiators are required for UV curing (Typical photoinitiators are shown below)
- 1-5% are added
- Sometimes surface cure additives are also added to make sure top surface is cured well (dry to touch – no finger impressions)
- These are all hydrophobic compounds
- Most of the UV cured materials are hydrophobic in nature (exhibit water CA of 50 to 90º)
- Photoinitiator and its fragments can migrate to the surface
- Strong contribution from the photoinitiator caused higher contact angle

IRGACURE 184



IRGACURE 819



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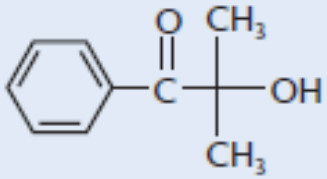

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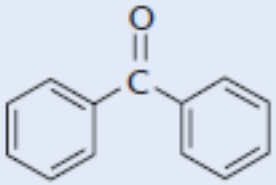

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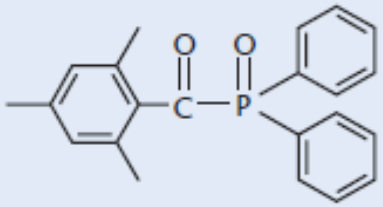
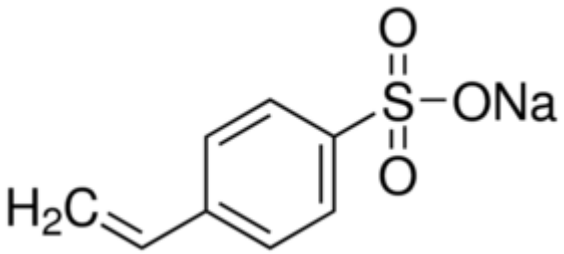
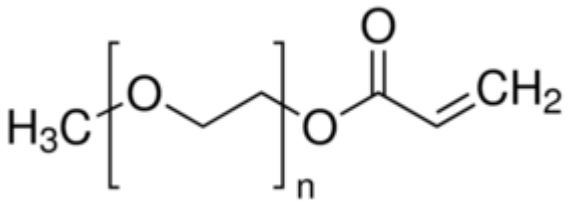


Additives to increase hydrophilicity

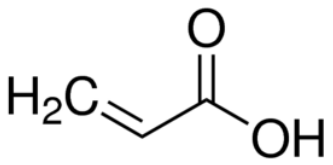
- Styrene sulfonate (solubility is a serious concern)
- Other typical monomers: Polyethylene glycol acrylates
- Incorporation of such monomers did not increase hydrophilicity
- Acrylic/methacrylic acid was not tried because of their acidic nature
- None of these additives enhanced hydrophilicity substantially (CA remains >50º)
- Up on contact with water, water CA actually increased (+25º) suggesting the theory of migration of components to the surface



Styrenesulfonate



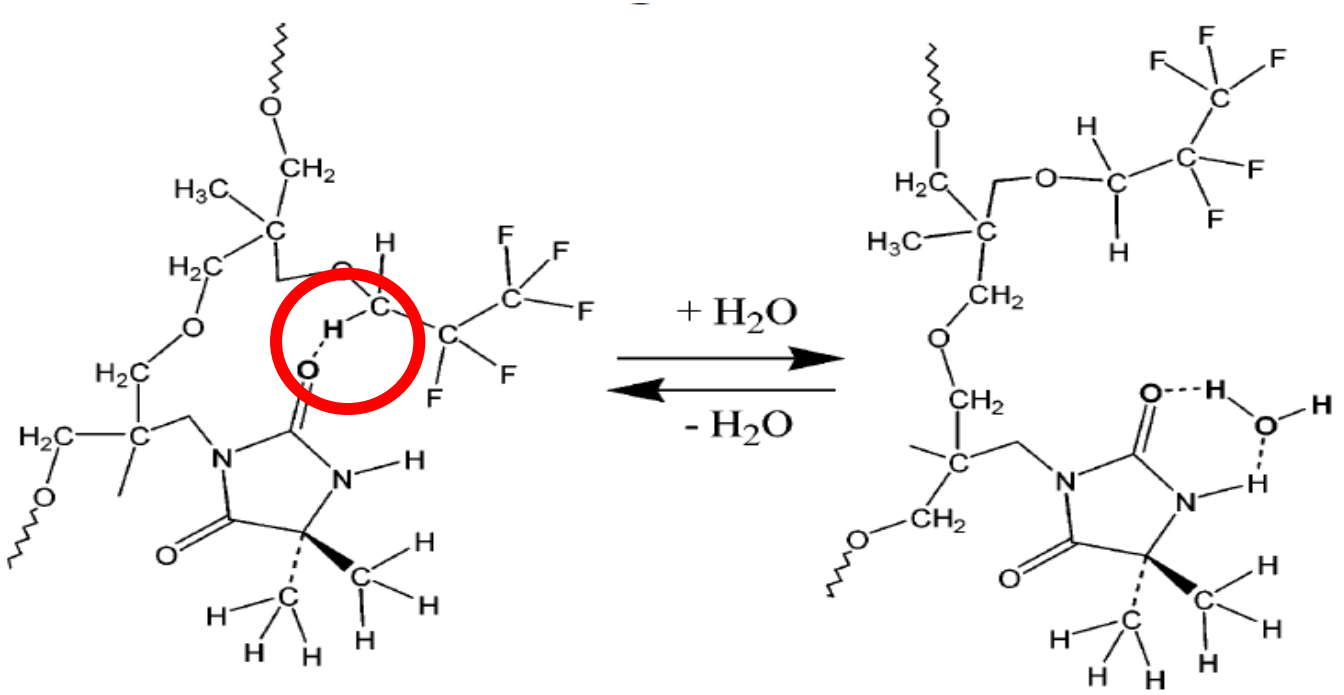
Poly(ethylene glycol) acrylate



Acrylic acid

Reorganization of polymer surface

- Only poly(ethylene-acrylic acid) exhibit increased hydrophilicity with acrylic acid content
- Polymer surface groups reorganize in response to contact medium in most cases
- Occurs through hydration and swelling
- Reorientation of the polymer backbones, segments or pendant groups
- Different molecular moieties at the surface

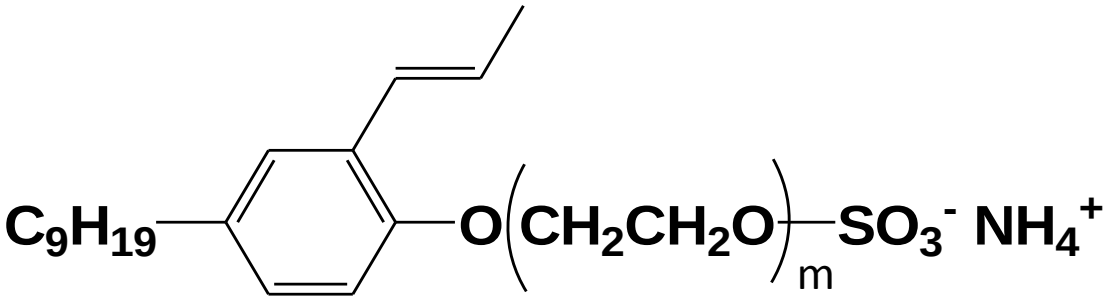


83º (dry state) 108º (wet state)

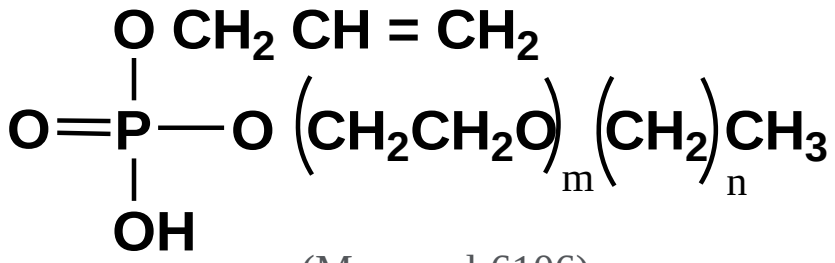
Ref.: Water induced hydrophobic surface by U. Makal and K.J. Wynne, *Langmuir* **2005**, *21*, 3742-3745

Additives to increase hydrophilicity

- Unusual additives explored in this study
- Some surfactants have unusual properties
- Contains hydrophobic components to have compatibility with the formulations (non-polar) and hydrophilic components (ionic)
- Sluggishly reactive olefinic groups
- Requires higher energy to effect polymerization (>50 mJ/cm^2 for 125 micron thickness)
- Amount required 5 to 10% by weight
- >10% can affect other properties of the cured material

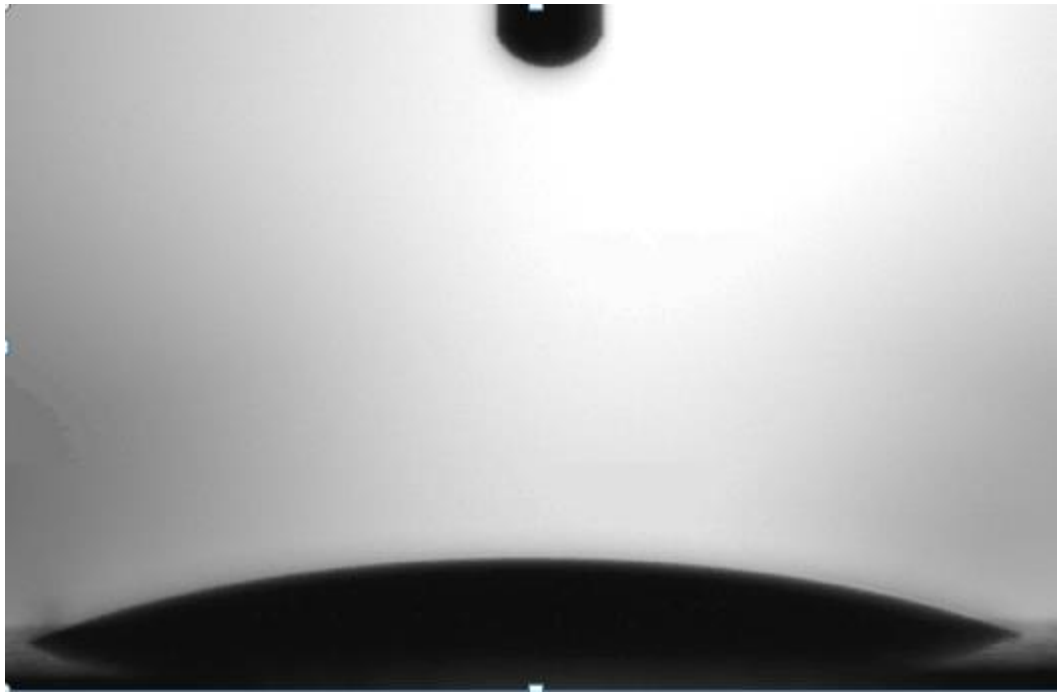


Structure of Hitenol BC-10 (m=10)



(Maxemul 6106)
(predicted structure)

Behavior of UV cured materials with reactive surfactants



Water contact showing the hydrophobic nature

Conclusions

- UV cured films are mostly hydrophobic in nature
- Addition of standard hydrophilic materials did not influence much in increasing hydrophilicity
- Reactive surfactants have significant effect on increasing hydrophilicity
- Addition of such materials did not affect the properties of UV cured materials much if used within 5-10% range

Acknowledgements

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