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Degradation Mechanisms of Fluorinated and Non-Fluorinated Anti-Soiling Coatings

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Presentation Objectives

- PV & Soiling
- Anti-soiling Coatings
- Samples & Experimentation
- Performance & Degradation
- Conclusion

The Challenge: PV & Soiling

...iling

Getty Images. *Istock*. [Online]. June 2022. [Accessed 05/06/2022].

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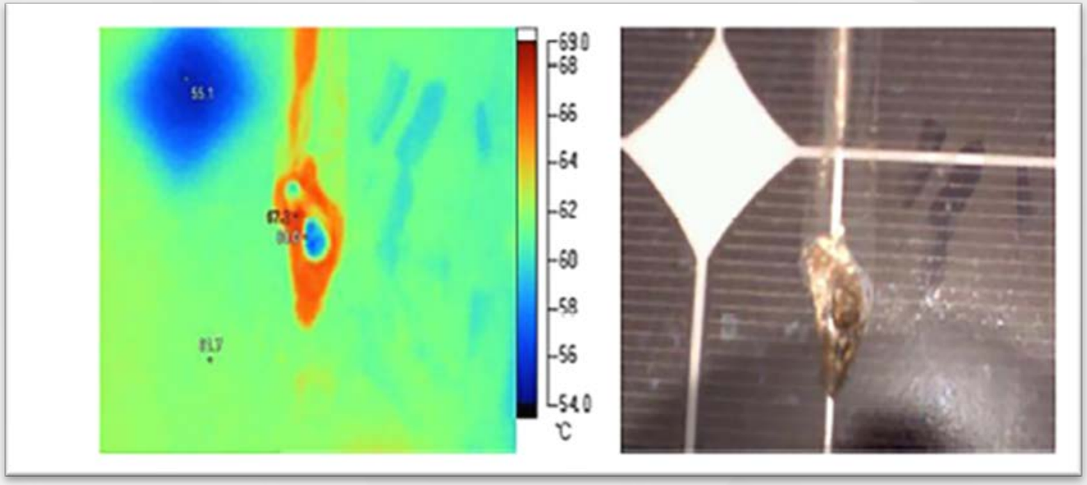
Effects of Soiling

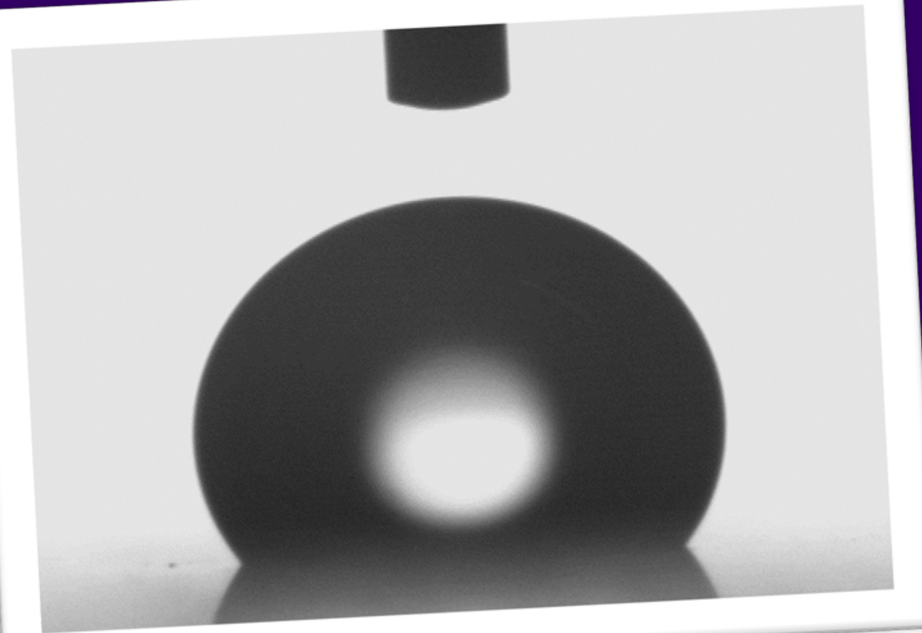
- Power Output Reduction
- Optical transmittance Reduction
- Localised Thermal Hotspots
- Abrasion and failure
- Economic Losses

"Accumulation of dirt, dust, debris and biological matter on light-collecting surfaces in solar panel systems."



V. Gupta et al. Comprehensive review on effect of dust on solar photovoltaic system and mitigation techniques. Solar Energy 191 (2019) 596–622

Anti-soiling Coatings & Hydrophobicity



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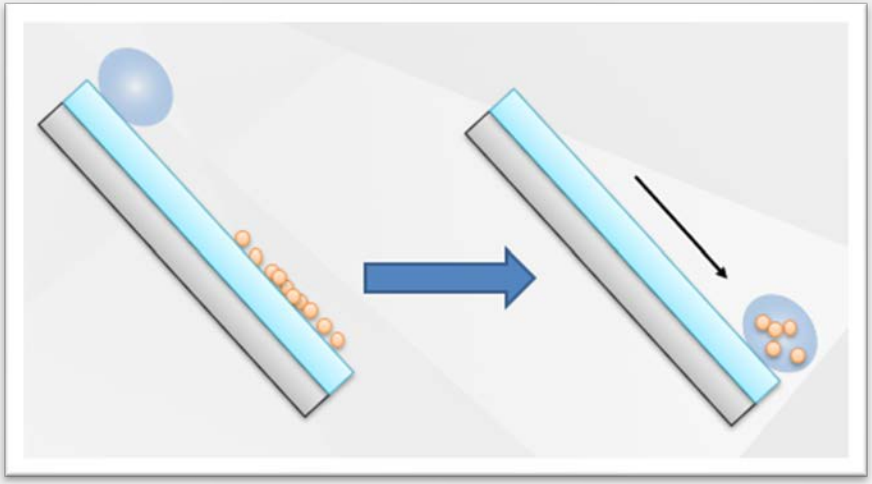
PV Hydrophobic, Anti-soiling Coatings

Oehler, G. et al. *Testing the Durability of Anti-Soiling Coatings for Solar Cover Glass by Outdoor Exposure in Denmark.* Energies **2020**, 13, 299.

Hydrophobic Coatings for PV

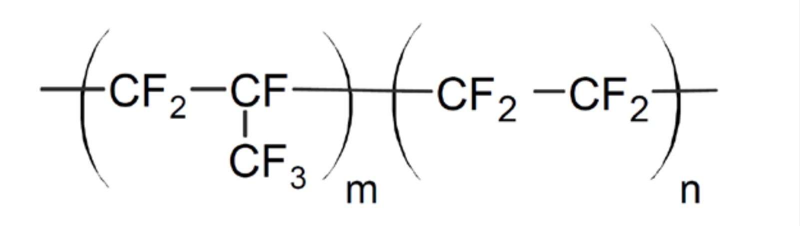


- Low surface energy materials.
- Water contact greater than 90° (hydrophobic), or greater than 150° (superhydrophobic).
- Low roll of angle, less than ~30° (for self cleaning effect).
- Chemically inert.
- Environment and mechanical resistant.

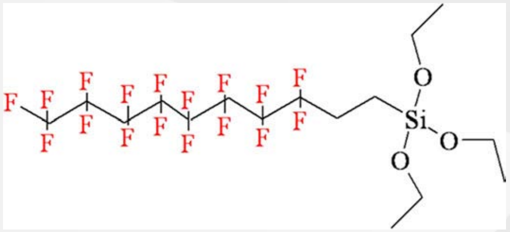
Hydrophobic Coating Chemistry

Fluorinated Polymers

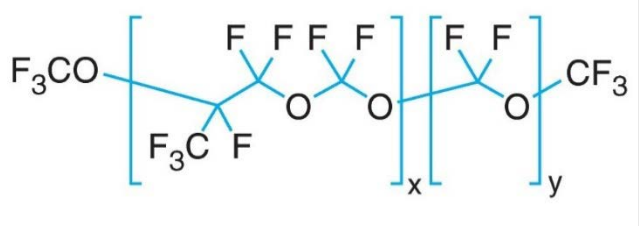
- Fluorinated-ethylene-propylene (FEP)



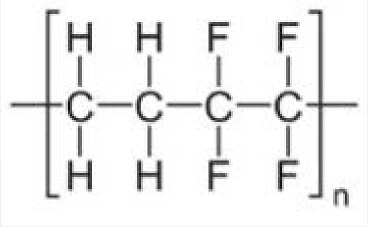
- Fluoroalkylsilane (FAS)



- Perfluoropolyether (PFPE).



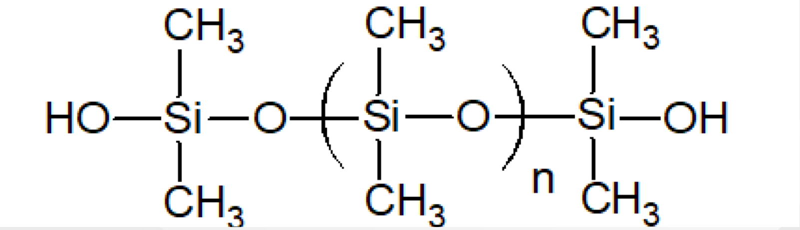
- Ethylene tetrafluoroethylene (ETFE)



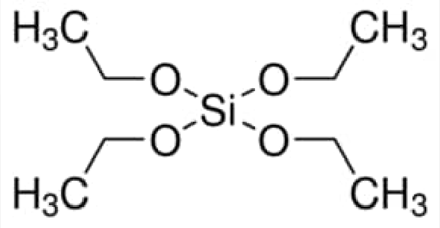
Hydrophobic Coating Chemistry

Non-fluorinated Polymers

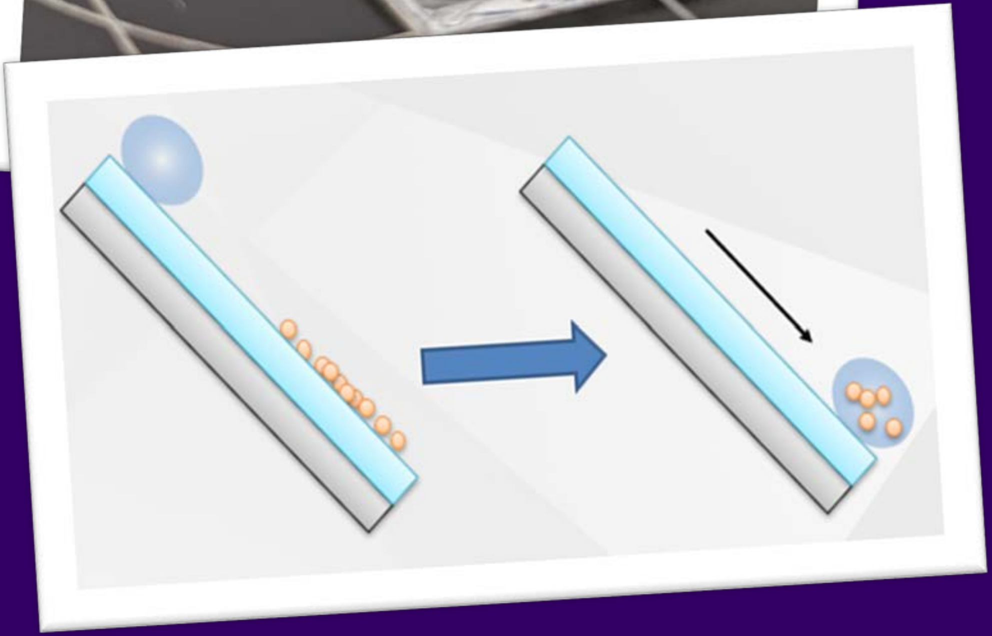
- Polydimethylsiloxane (PDMS)



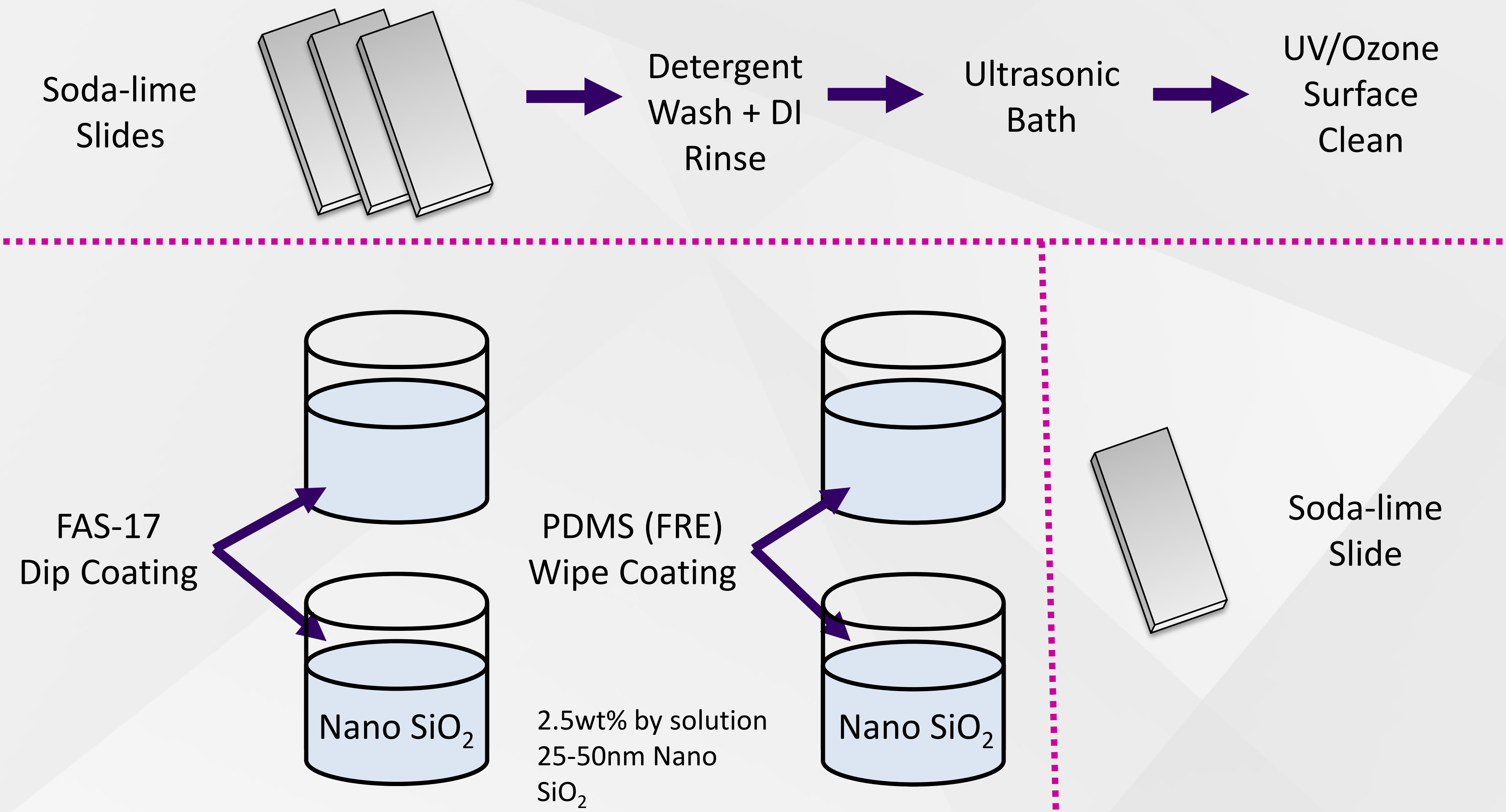
- Tetraethyl orthosilicate (TEOS)



Samples & Experimentation



Coating Deposition



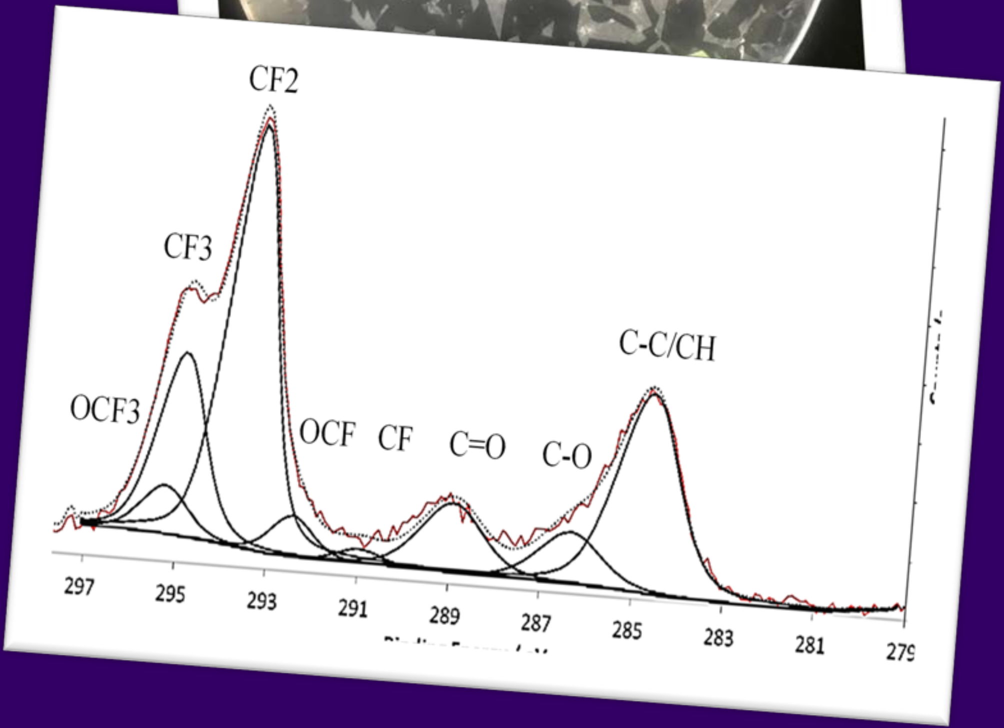
Testing & Characterisation

UV Test

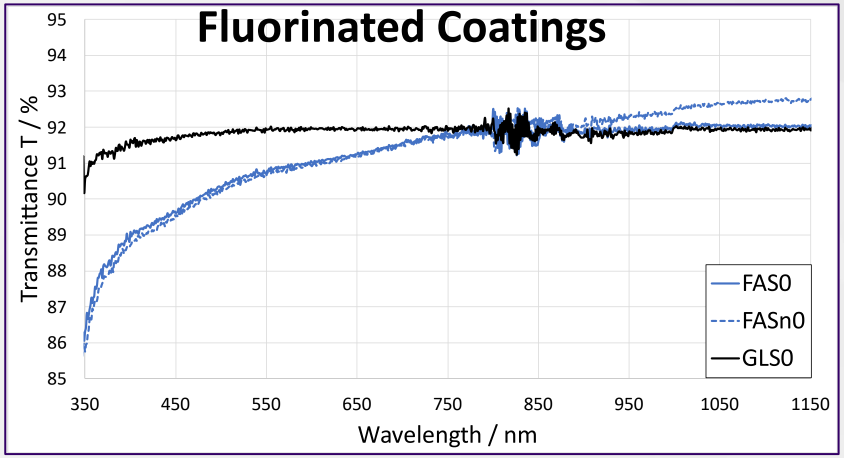
A minimum of 15 kWh/m2 of UV light, with 3% to 10% total energy in UVB light range (BS EN 61215-2) for 1000 hours.

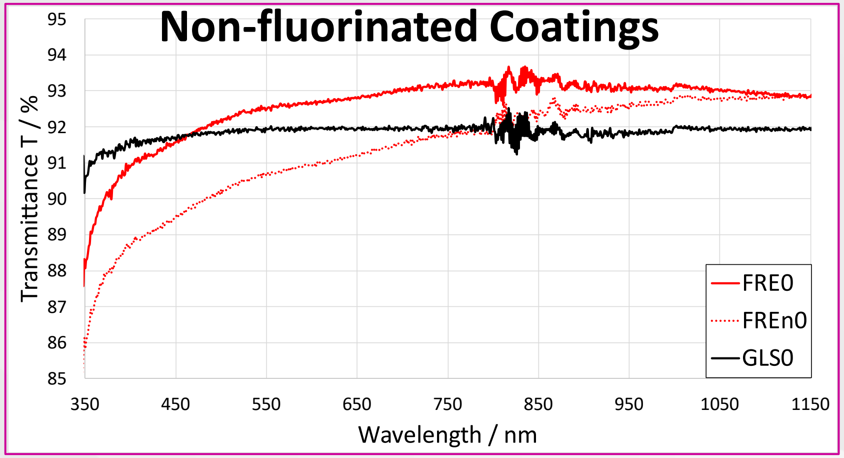
- Optical Transmittance & Reflectance
- Water contact angle (WCA)
- X-ray Photoelectron Spectroscopy Analysis (XPS)

Performance & Degradation



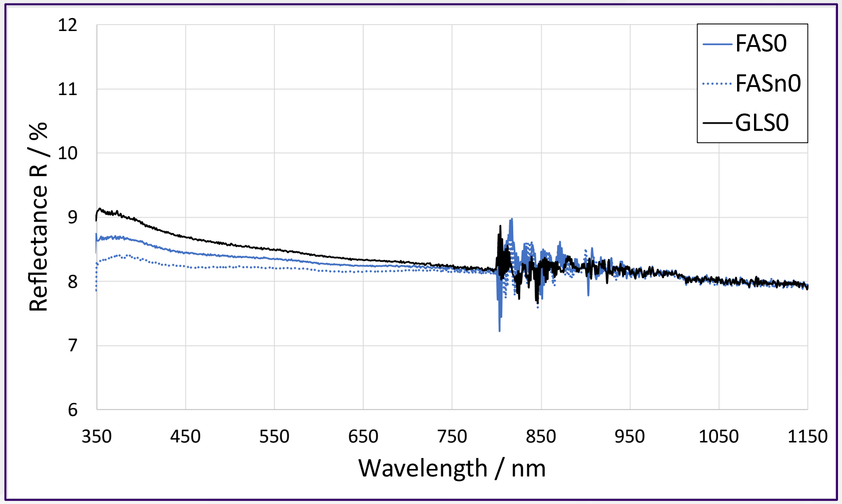
Optical Transmittance & Reflectance

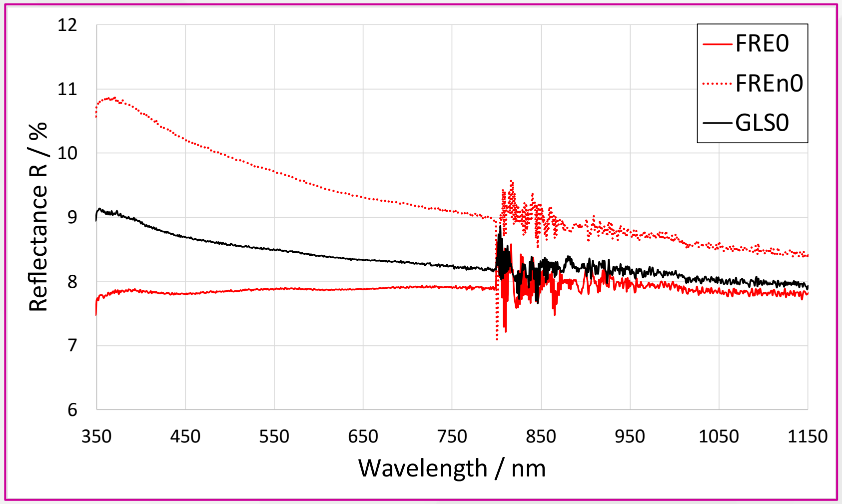




(Above) UV/Vis transmittance / (below) reflectance data of as deposited fluorinated coatings on soda-lime glass between 350-1150nm.

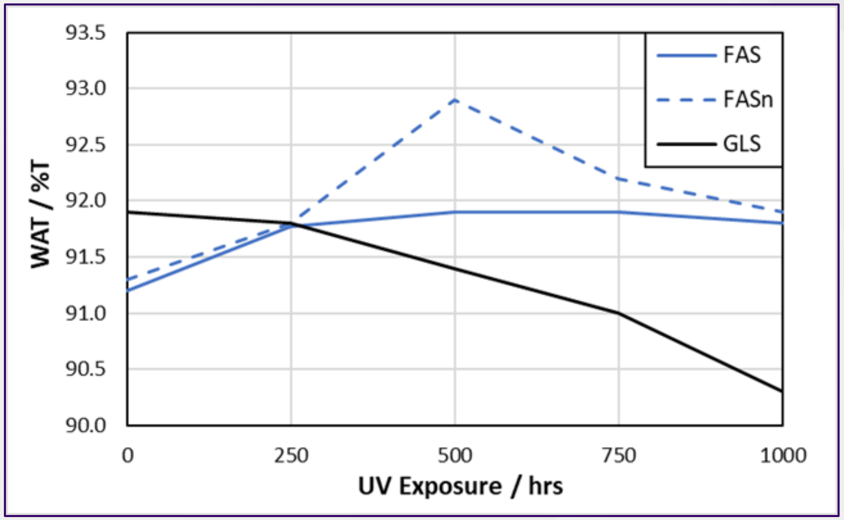
(Above) UV/Vis transmittance / (below) reflectance data of as deposited non-fluorinated coatings on soda-lime glass between 350-1150nm.





Optical Transmittance & Reflectance

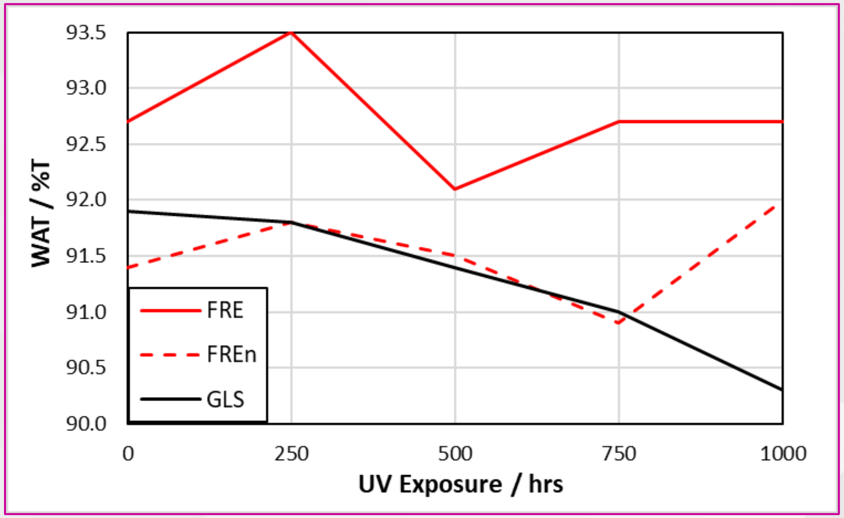
Fluorinated Coatings



(Above) UV/Vis weighted average transmittance of fluorinated coatings on soda-lime glass between 0 and 1000 hours of UV exposure.

WAT/R%	As Deposited		UV Exposed 1000 hrs	
FAS	91.2	8.2	91.8	8.2
FASn	91.3	8.2	91.9	8.1
GLS	91.9	8.3	90.3	8.3

Non-fluorinated Coatings

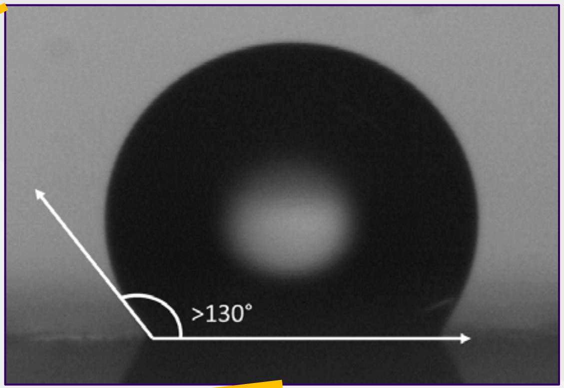


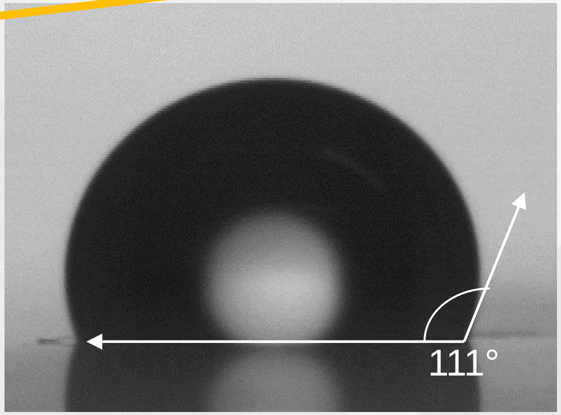
(Above) UV/Vis weighted average transmittance of non-fluorinated coatings on soda-lime glass between 0 and 1000 hours of UV exposure.

WAT/R%	As Deposited		UV Exposed 1000 hrs	
FRE	92.7	7.3	92.7	7.3
FREn	91.4	7.9	92.0	8.0
GLS	91.9	8.3	90.3	8.3

Surface Hydrophobicity

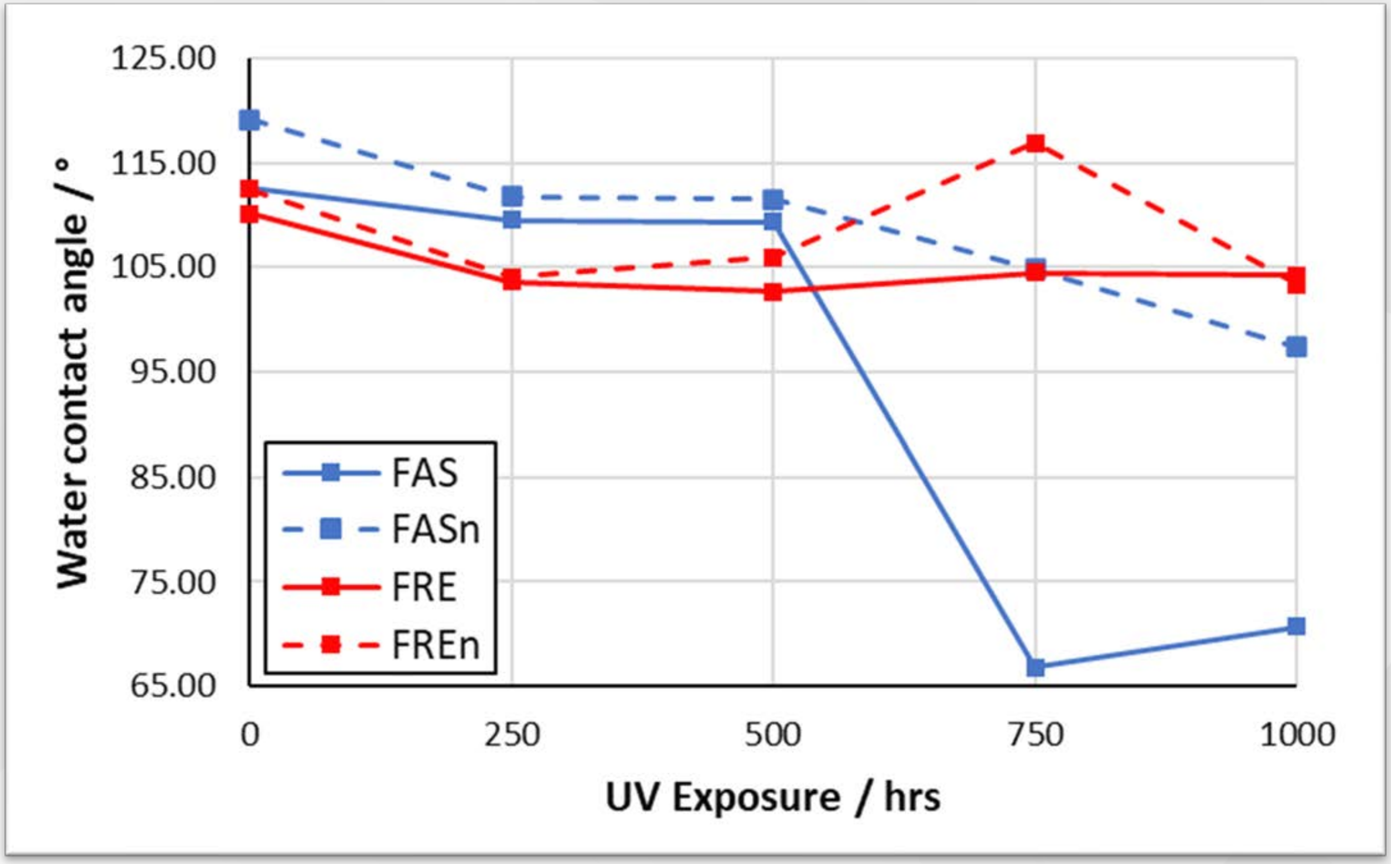
WCA	As Deposited		UV Exposed 1000 hrs
	θ	σ	
FAS	112.5	1.7	
FASn	119.2	2.1	
FRE	110.2	0.5	
FREn	112.4	1.9	
GLS	14.2	2.0	





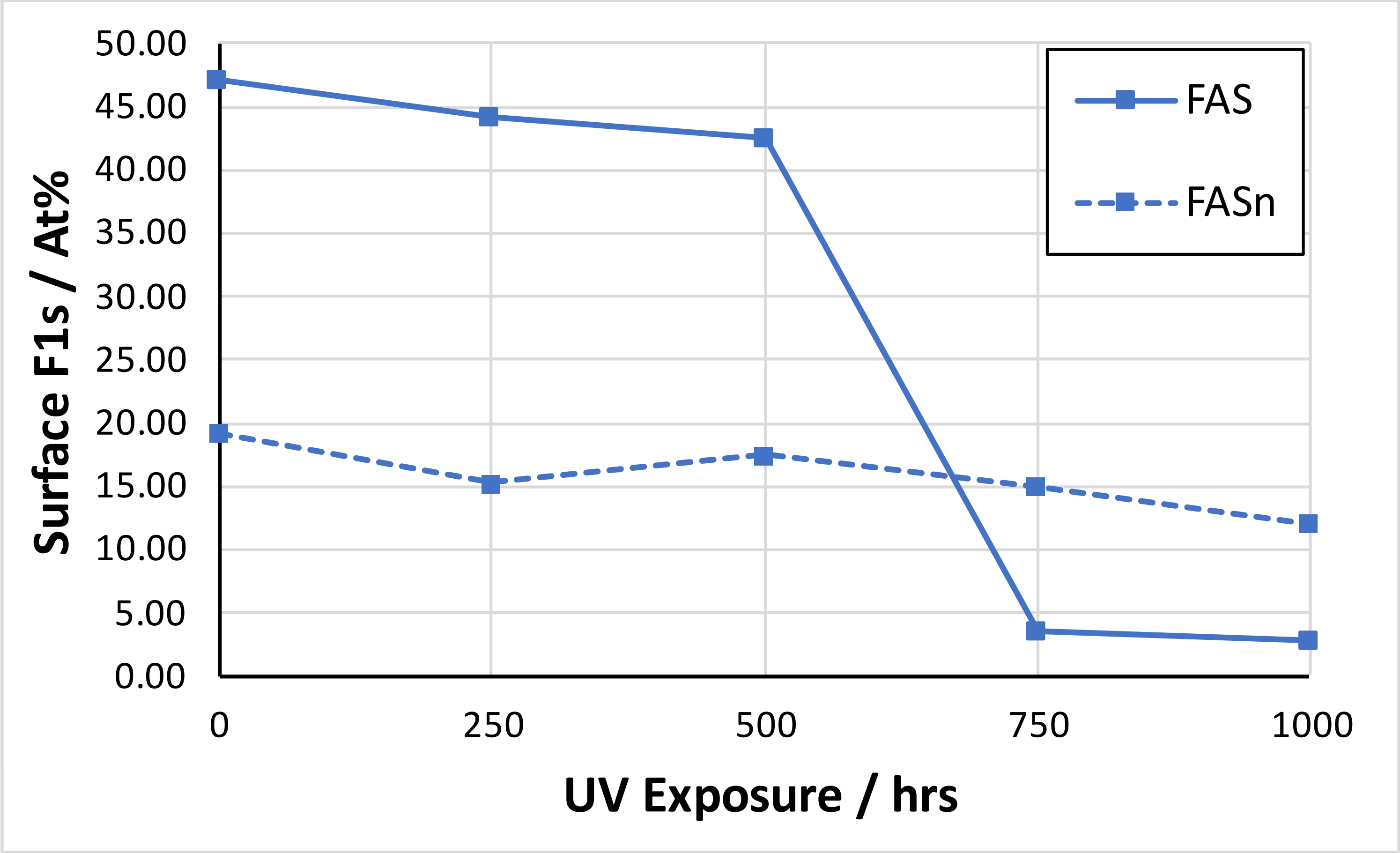
WCA measurements of (top) as deposited FASn, WCA 131.0°, and (bottom) as deposited FRE, WCA 111.0°.

Surface Hydrophobicity



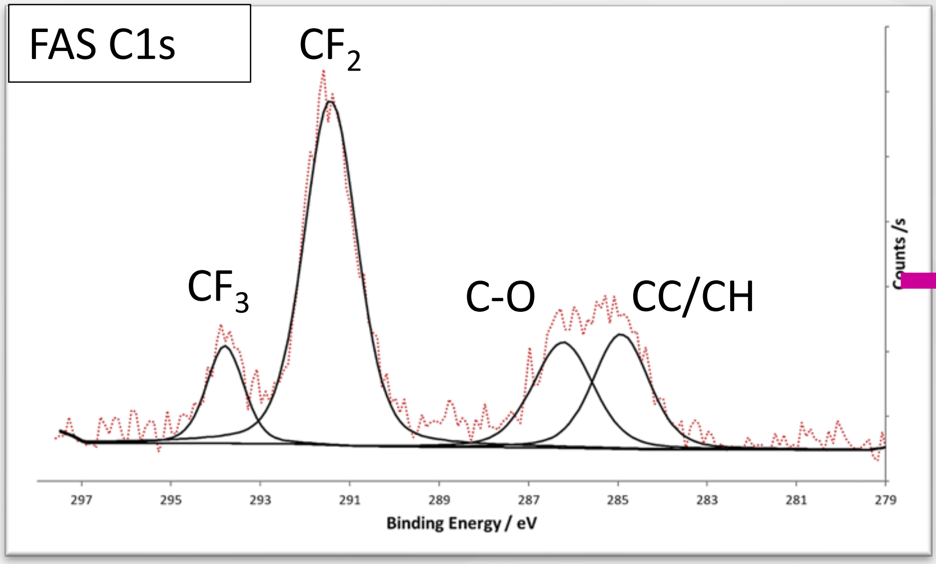
WCA measurements of FAS, FASn, FRE and FREn coatings during UV exposure from as-deposited to 1000 hours of UV exposure.

Hydrophobic Fluorine Loss

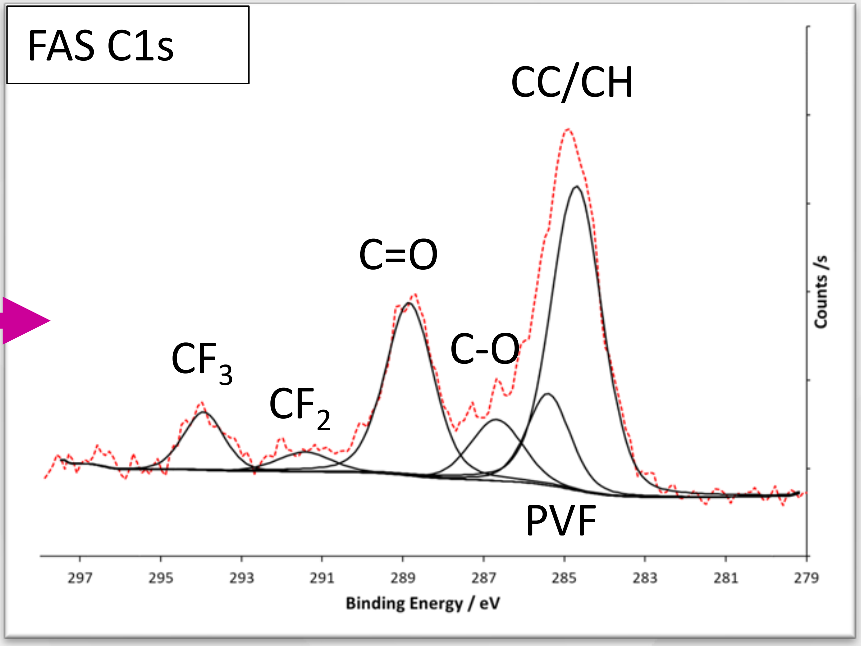


Comparison of F1s content on surface of FAS and FASn coating from 0 to 1000 hours of UV exposure.

Loss of Hydrophobic Functional Groups



C1s XPS Spectra of as deposited FAS Coating on soda-lime glass substrate.

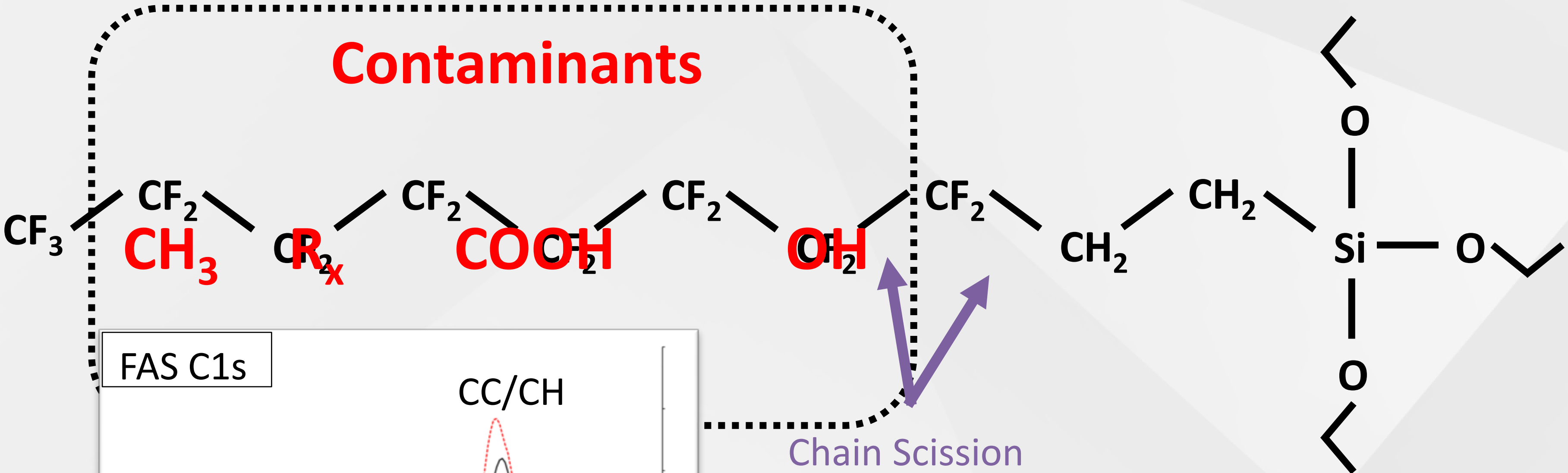


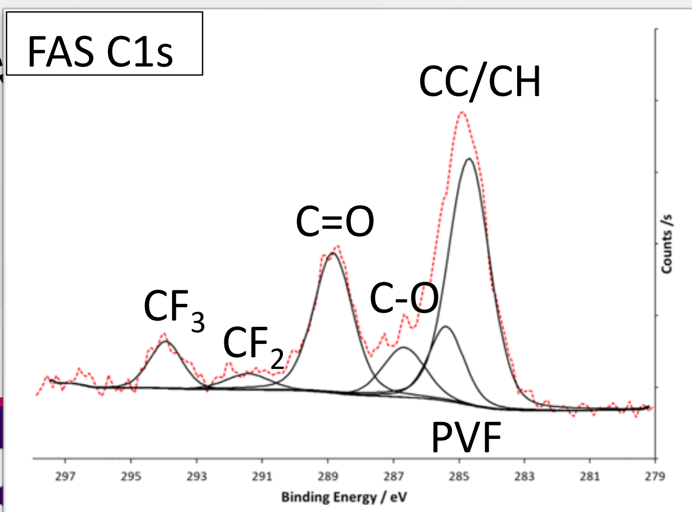
C1s XPS Spectra of FAS Coating on soda-lime glass substrate after 1000 hours of UV exposure.

- ~40% reduction in surface Fluorine and ~50° reduction in WCA.
- Fluoromethyl groups detached and replaced by oxygen-containing functional groups.

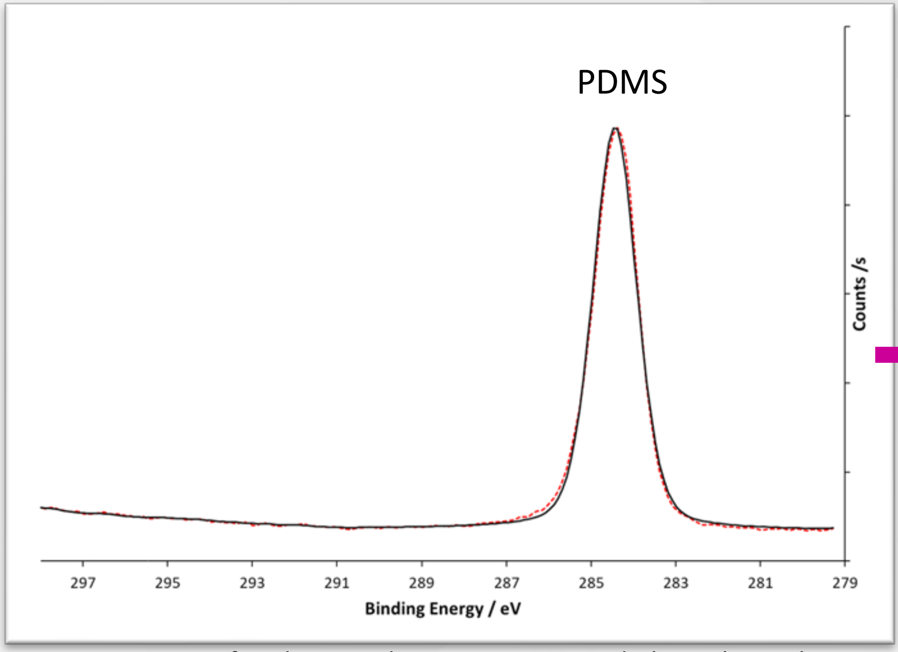
Loss of Hydrophobic Functional Groups

FAS-17 Polymer Chain

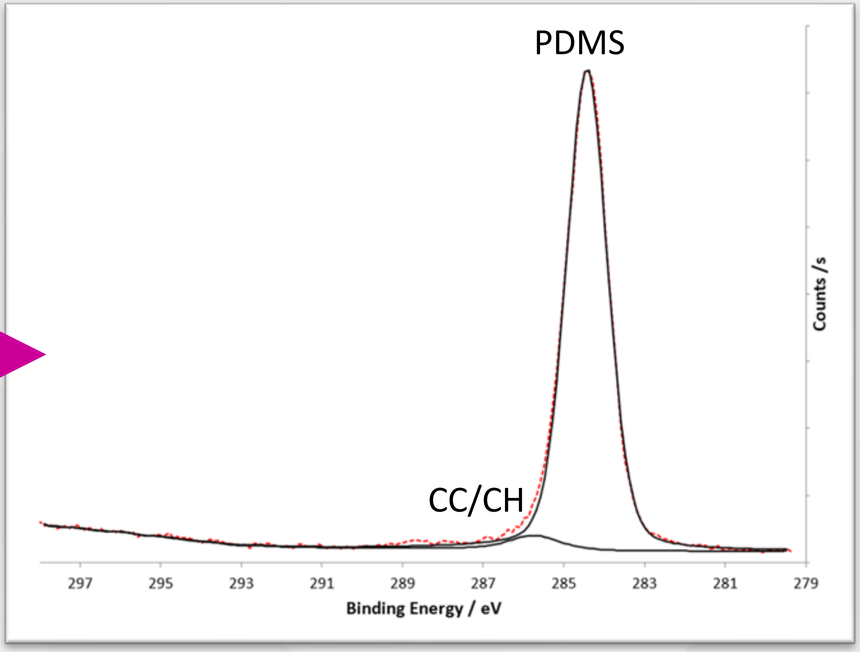




Stable Functional Groups



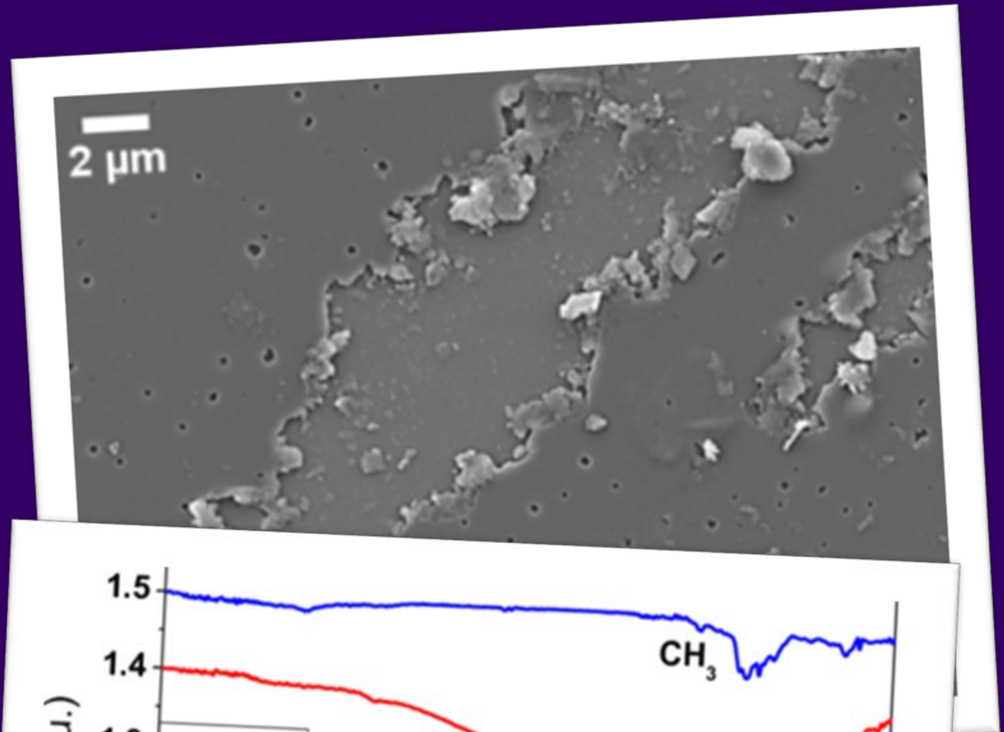
C1s XPS Spectra of as deposited FRE Coating on soda-lime glass substrate.

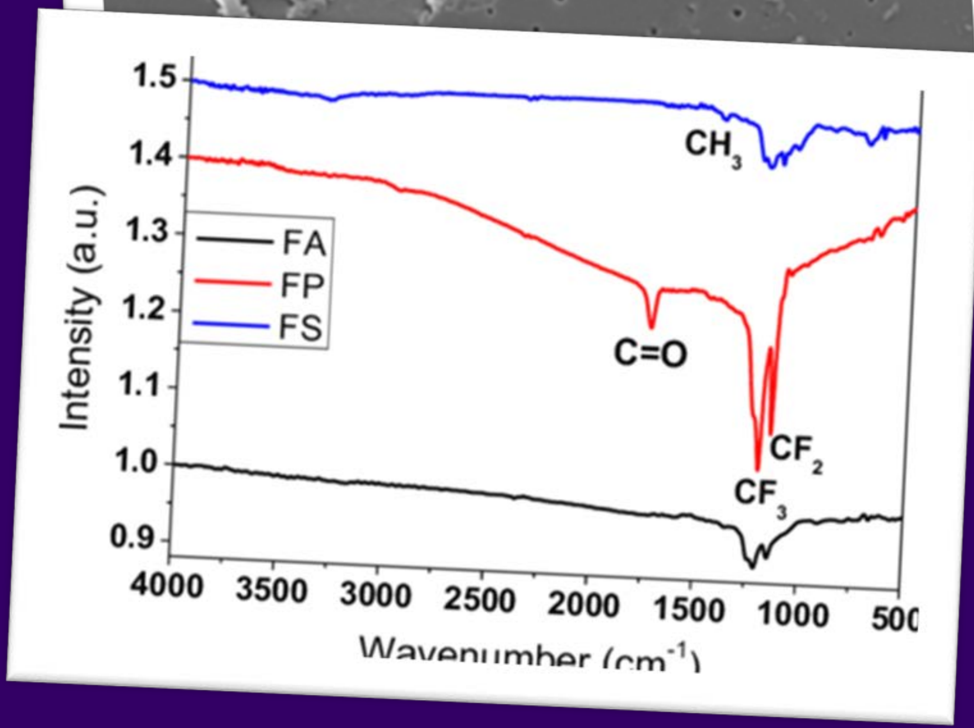


C1s XPS Spectra of FRE Coating on soda-lime glass substrate after 1000 hours of UV exposure.

- Maintained strong presence of surface PDMS C1s peak.
- Hydrocarbons, and oxygen-carbon bonds either from surface contamination or degradation.

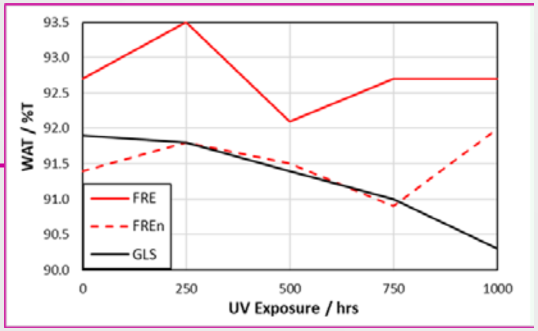
Conclusions & Further Work

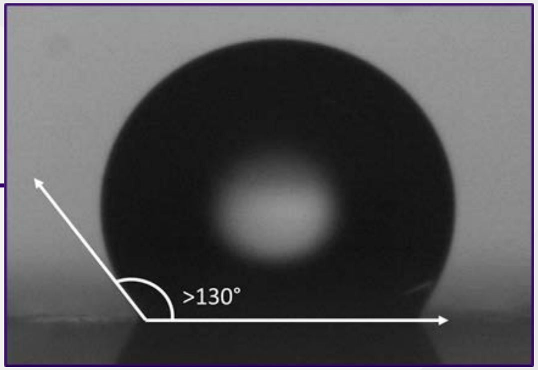


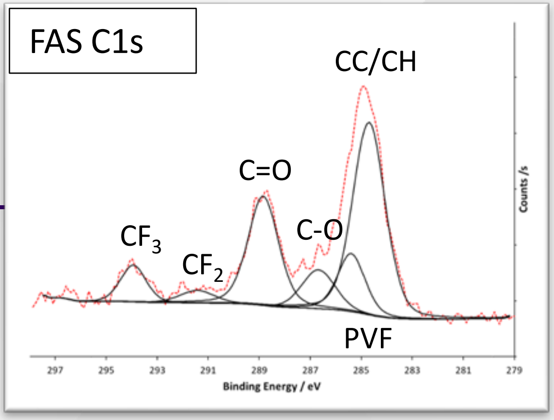


Conclusions

- Fluorinated and non-fluorinated coatings exhibited comparable optical properties (~92 T% and ~8 R%), with a difference in T% and R% of less than 1%.
- FAS coatings exhibited initially higher WCA values (~120°). PDMS coatings demonstrated high WCA (111°) but crucially, maintained hydrophobicity throughout UV exposure.
- Loss of fluorine content can be brought on by UV exposure, leading to reduced performance in fluorine-based chemistry.







Further Work

- Increase variance in hydrophobic materials
  - FEP and TEOS coatings
  - Improve deposition process (dip, wipe, spray)
- Increased degradation testing
  - Damp Heat (DH), Abrasion, Outdoor
- Additional characterisation techniques
  - Hydrophobicity (Diiodomethane, roll of angle)
  - Chemistry (XPS, FTIR, TOF-SIMS)
  - Microscopy (SEM, optical)

Acknowledgements

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Thank you!

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