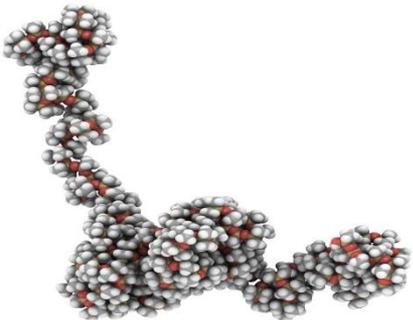
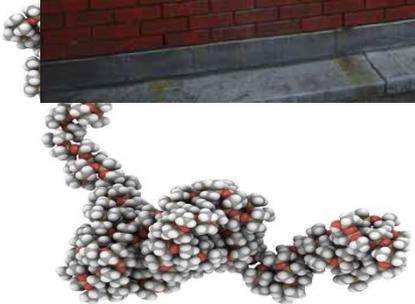


A Unique Class of Fluoroalkyl Silicones with Synergistic Behavior

*Tom Cheung, Bob Ruckle,
Adam Horne, Steve Wilkowski*
Siltech Corporation; Toronto, Canada

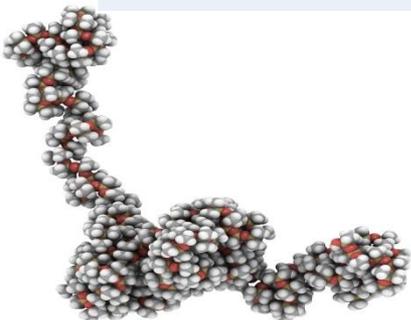


Challenges from Staining, Fouling, Graffiti, Fingerprints, Chemicals....

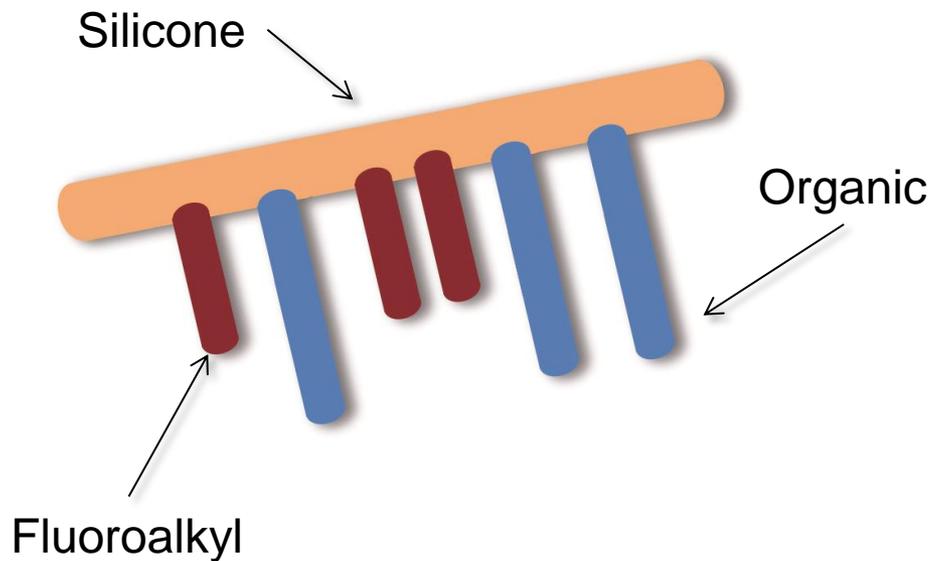


Comparison of Selected Properties of Silicone and Fluoropolymer

Silicone	Fluoropolymer
✓ Low surface energy	✓ Very low surface energy
✓ Very good thermal flexibility	✓ Marginal thermal flexibility
✓ Good chemical resistance	✓ Very good chemical resistance
✓ Marginal oil resistance–swelling	✓ Very good oil resistance
✓ Very good water resistance	✓ Good water resistance
✓ Low abrasion resistance	✓ Low abrasion resistance
✓ High cost (\$10/lb.)	✓ Very high cost (\$80/lb.)
✓ Effective at low use levels	✓ Effective at low use levels

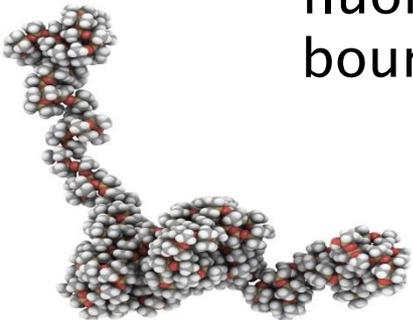


Fluoroalkyl Silicone Variants

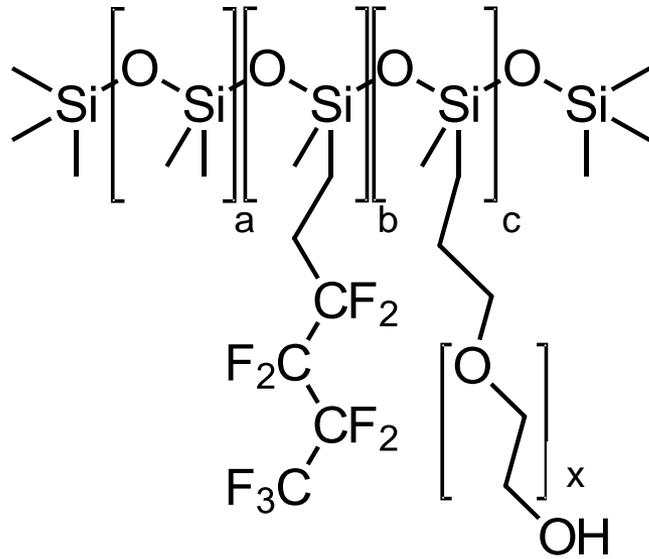


- Silicone provides slip, surface tension reduction, mar resistance, water resistance, flexibility.
- Fluoroalkyl provides these and oleophobicity, stain and chemical resistance.
- Organic provides miscibility.

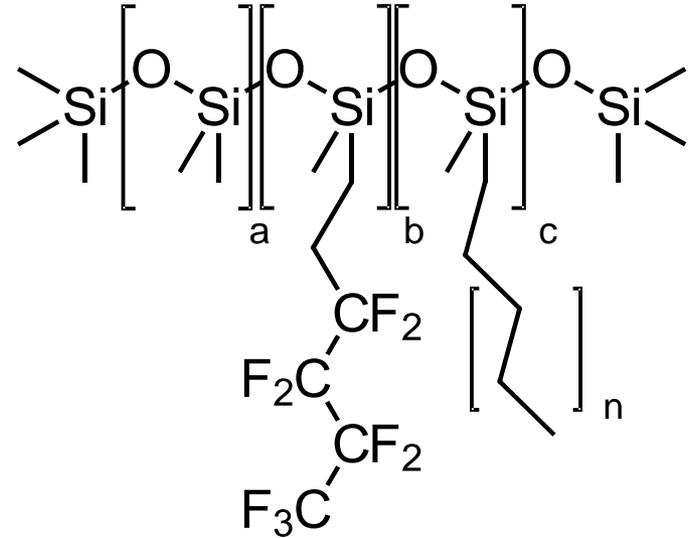
By varying the number, length and type of fluoroalkyl and/or organic substituents covalently bound to the silicone we can control properties.



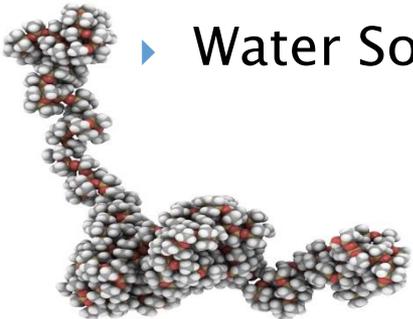
Soluble Non-PFOS Fluorosilicones



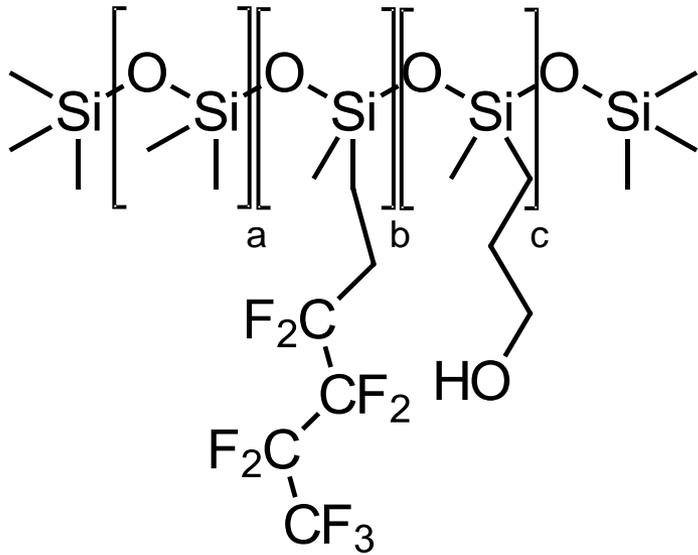
- ▶ Condensation Reactive
- ▶ Solvent Soluble
- ▶ Water Soluble



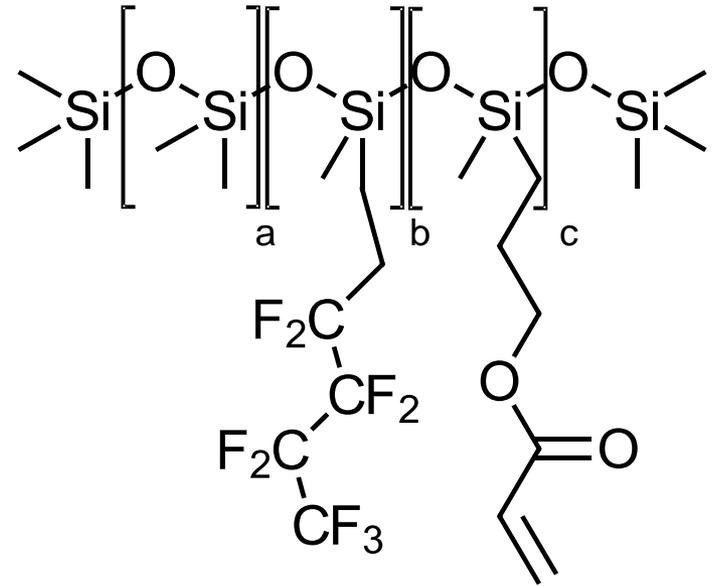
- ▶ Non-Reactive
- ▶ Solvent Soluble



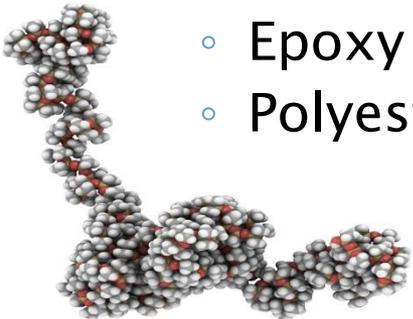
Reactive non-PFOS Fluorosilicones



- ▶ Condensation Reactive
 - Urethane
 - Epoxy
 - Polyester

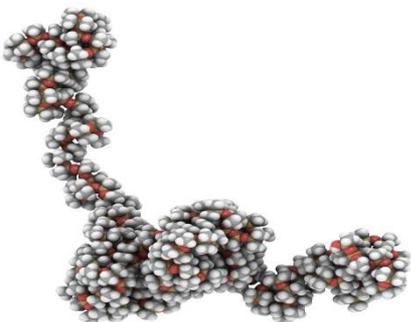
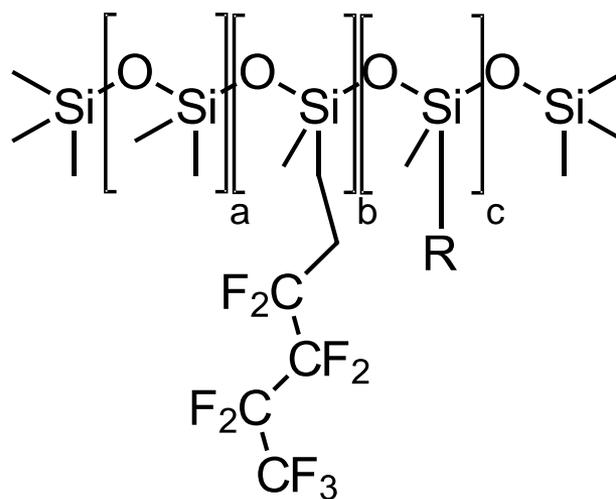


- ▶ UV and Free Radical Reactive
 - Acrylate
 - Vinyl
- ▶ Condensation Reactive



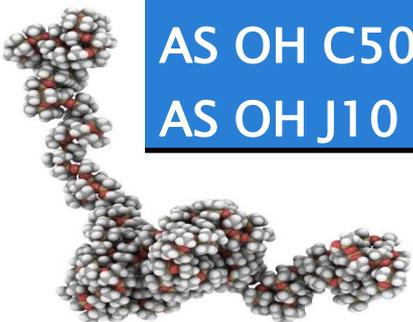
Fluoroalkyl Silicone Variants

	c	b	R
FPE	>0	>0	$(\text{CH}_2)_3(\text{OC}_2\text{H}_4)_d(\text{OC}_3\text{H}_6)_e \text{OH}$
FS	0	>0	None
AFS	>0	>0	$\text{C}_n\text{H}(2_n) \text{R}'$
AS	>0	0	$\text{C}_n\text{H}(2_n) \text{R}'$



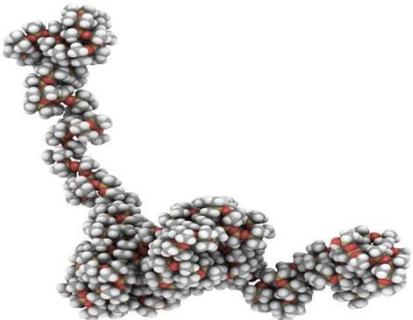
Comparison Silicones Design

Silicone	Wt % Silicone	Wt % CF ₂	Wt % organic	Reactive Site	MW	Type
FPE 2010	L	L	H	OH	3000	fluoroalkyl polyether silicone
FPE 2110	L	L	H	OH	7000	
FS D2	M	H	0%	no	2000	fluoroalkyl silicone
FS J15	H	M	0%	no	14000	
AFS G2-F	H	L	M	OH	3000	alkyl, fluoroalkyl silicone
AFS E3.5-F	M	L	L	OH	2000	
AFS C7-F	H	L	L	OH/ACR	2000	
AFS H418	M	M	M	no	5000	
AS OH C50	VH	0%	L	OH	12000	alkyl silicone
AS OH J10	H	0%	M	OH	8000	



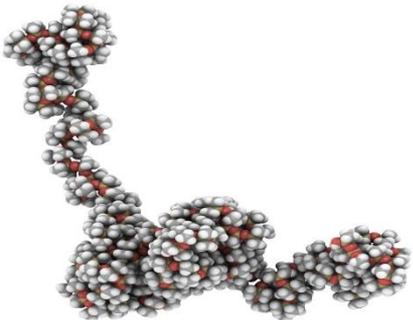
Experimental Design and Methods:

- ▶ Various silicones are evaluated for slip, COF, defects and mar, stain, and fingerprint and chemical resistance.
- ▶ The overall design used four systems:
 - *SB 2k Urethane*
 - *UV cured urethane acrylate*
 - *UV cured epoxy acrylate*
 - *Commercial flat white paint (post addition)*

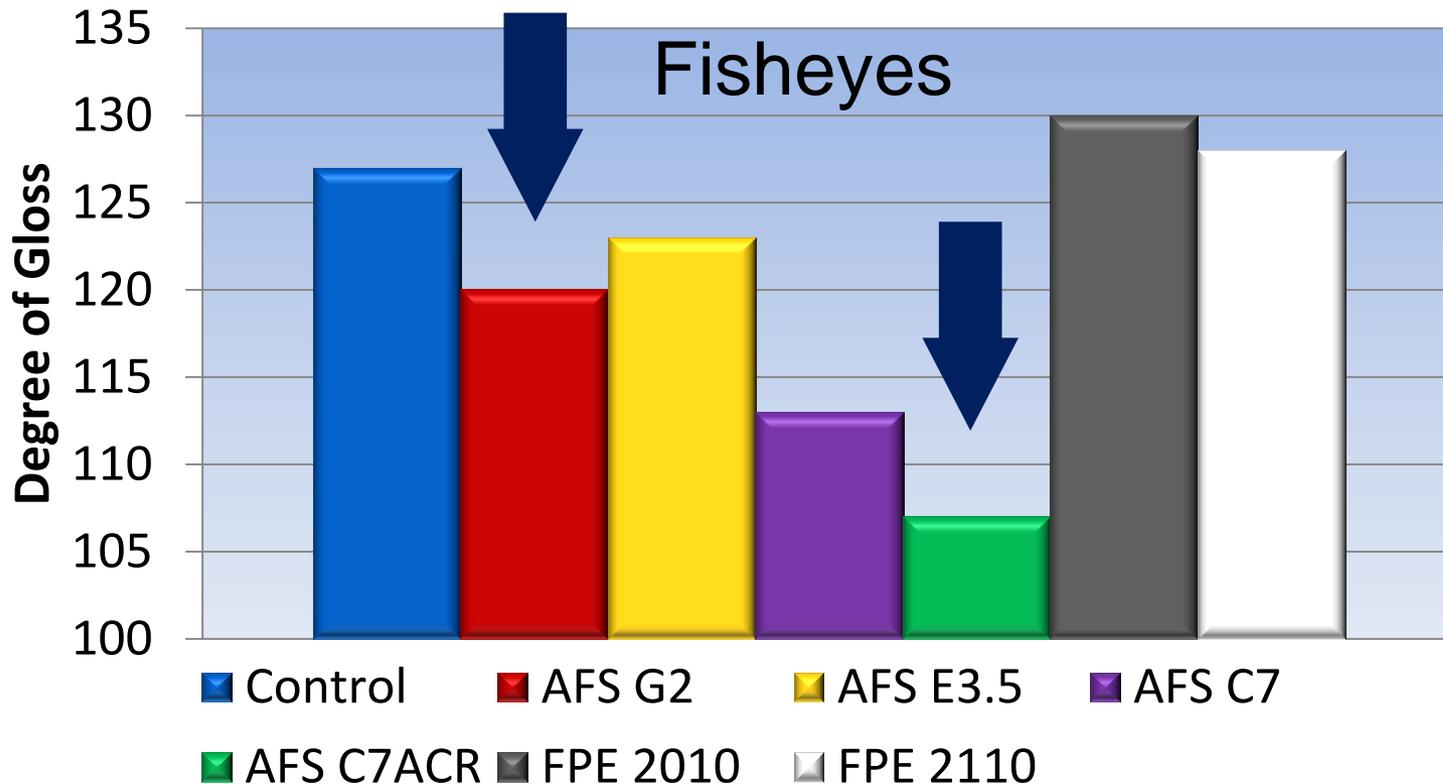


Test Methods Utilized

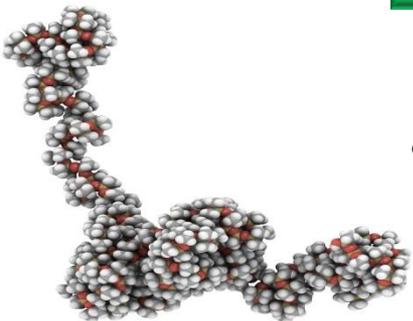
- ▶ CoF (sled method)
- ▶ Gloss (gloss meter)
- ▶ Fingerprint (internal test method)
- ▶ Stain (variations on standard and internal test methods)
- ▶ ASTM D543 (chemical resistance)
- ▶ ASTM D1308 (chemical resistance)
- ▶ ASTM D870 (water absorption)



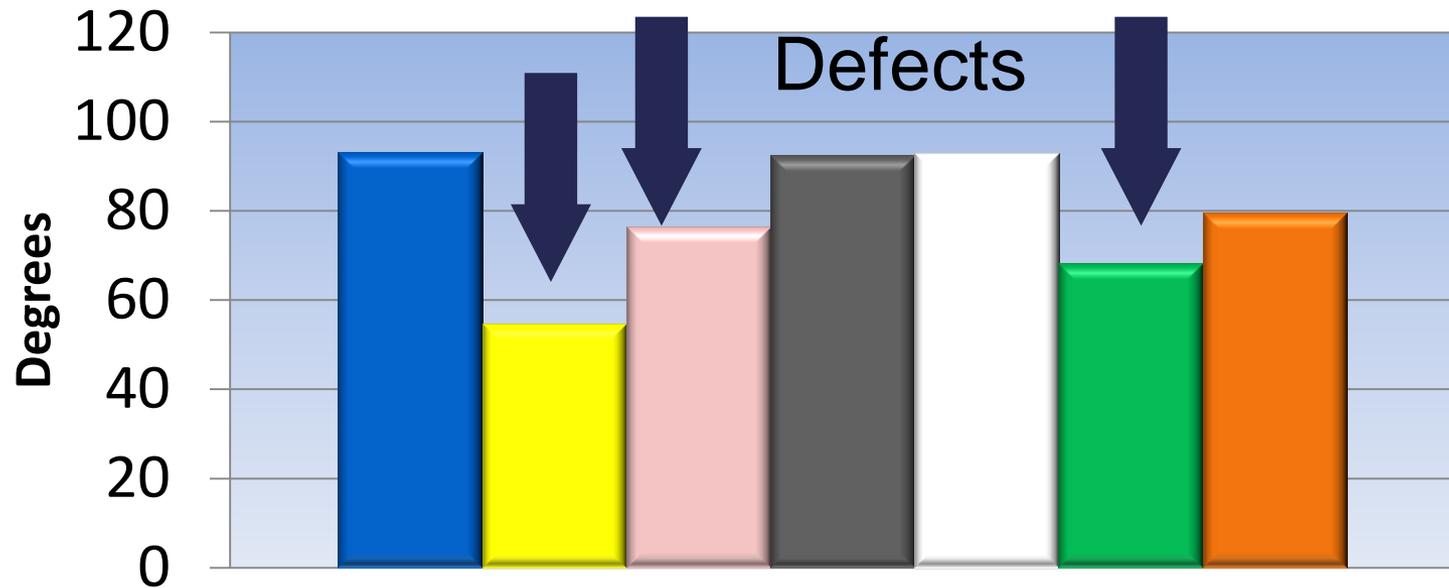
Gloss: SB Urethane



- FPE are most miscible, improve gloss
- AFS type decrease gloss cause defects

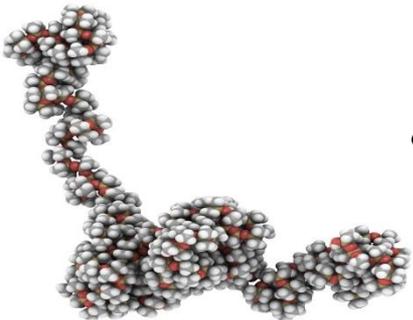


Gloss: Urethane Acrylate

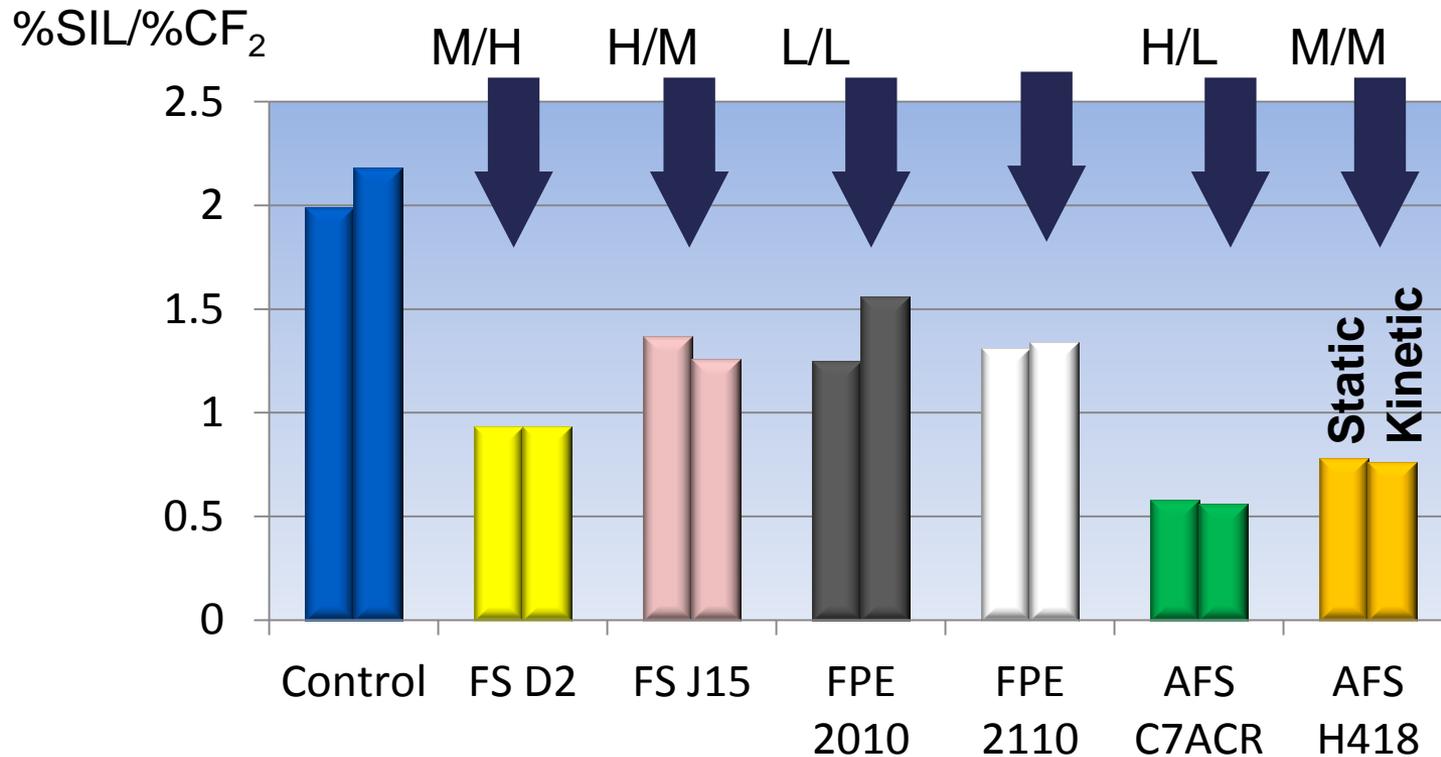


■ Control ■ FS D2 ■ FS J15 ■ FPE 2010
■ FPE 2110 ■ AFS C7ACR ■ AFS H418

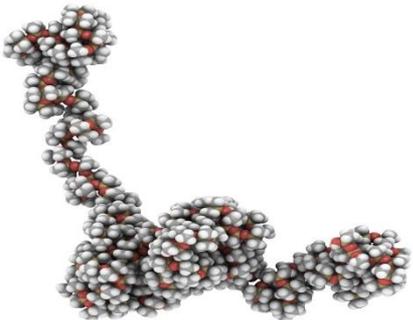
- FPE are most miscible, keep gloss
- AFS, AS and FS types decrease gloss



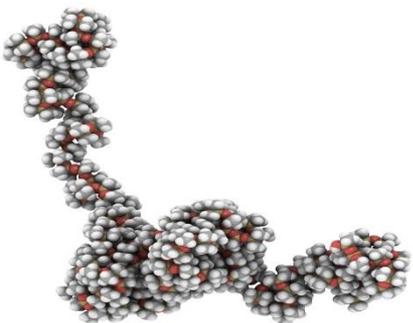
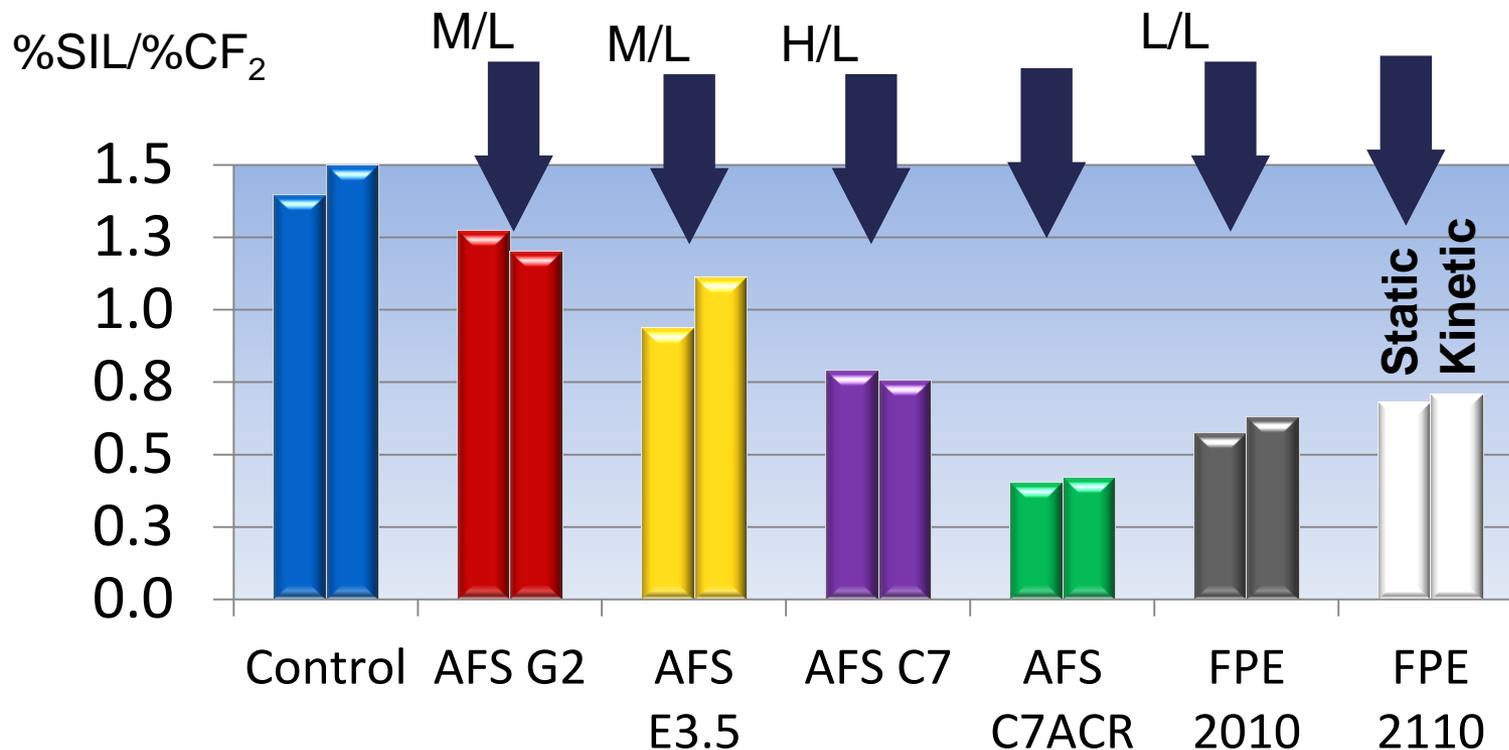
Slip: Urethane Acrylate



- All improve COF
- AFS C7 is best

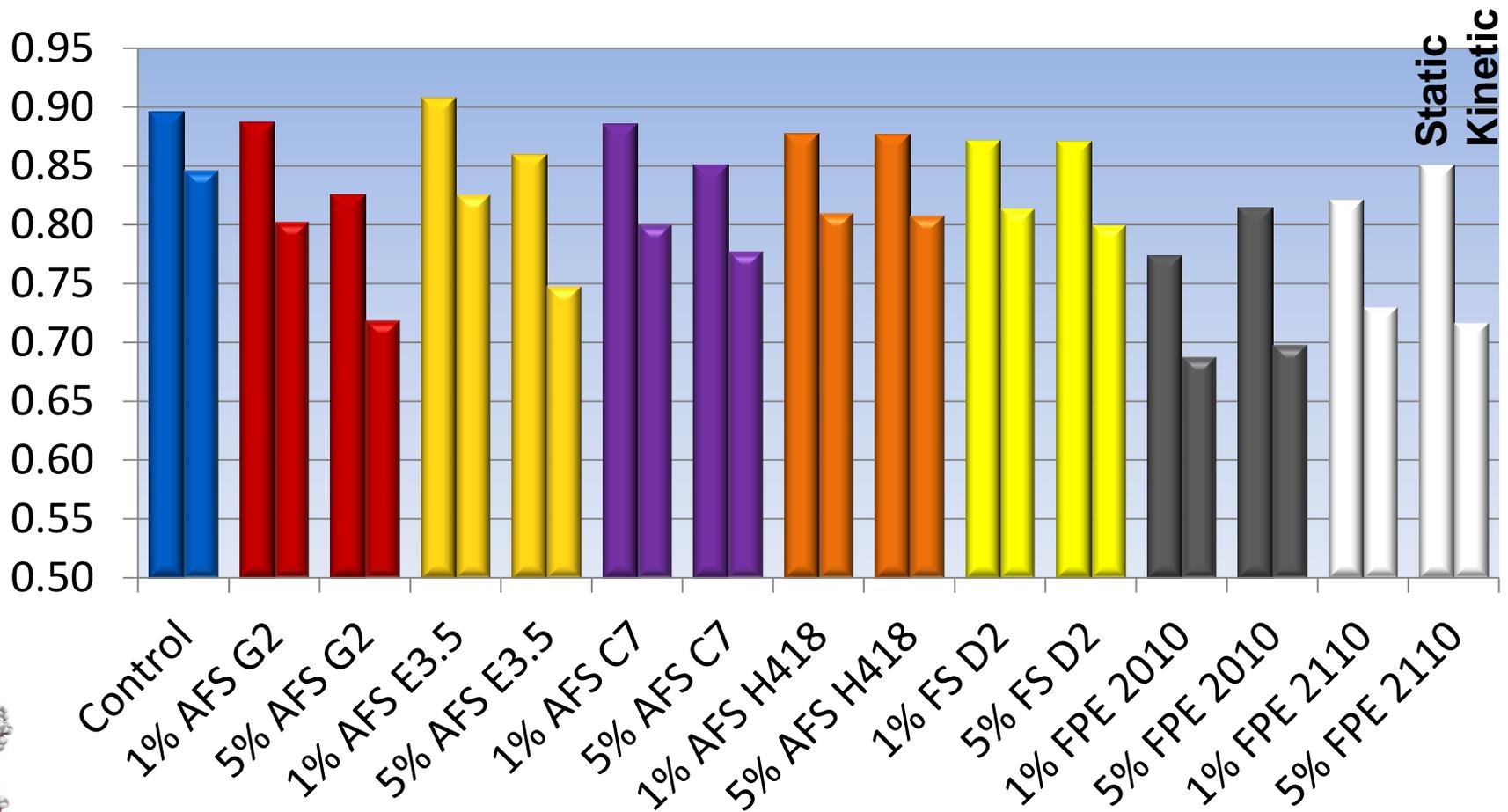


Slip: SB Urethane

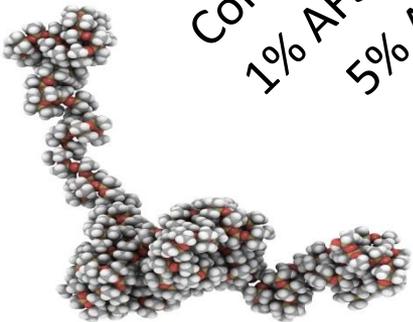


- All improve COF
- AFS C7 structures are best
- ACR better than OH

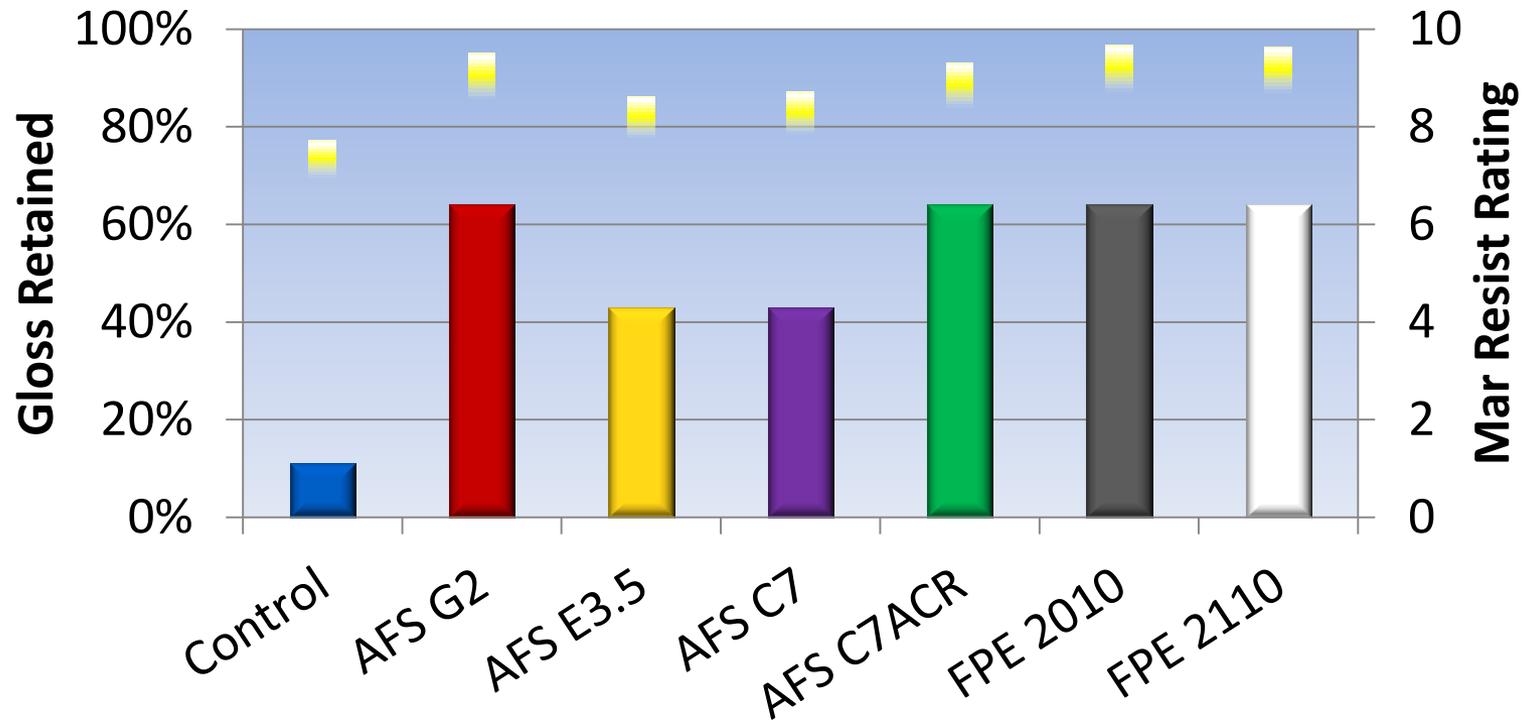
Slip: Post-added to Paint



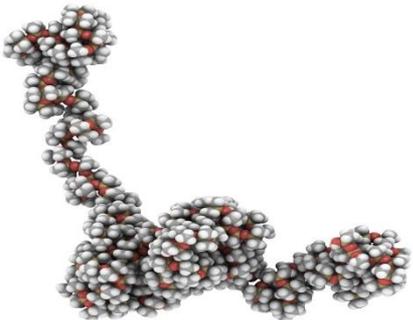
- All improve COF, more at 5%
- FPEs are very good



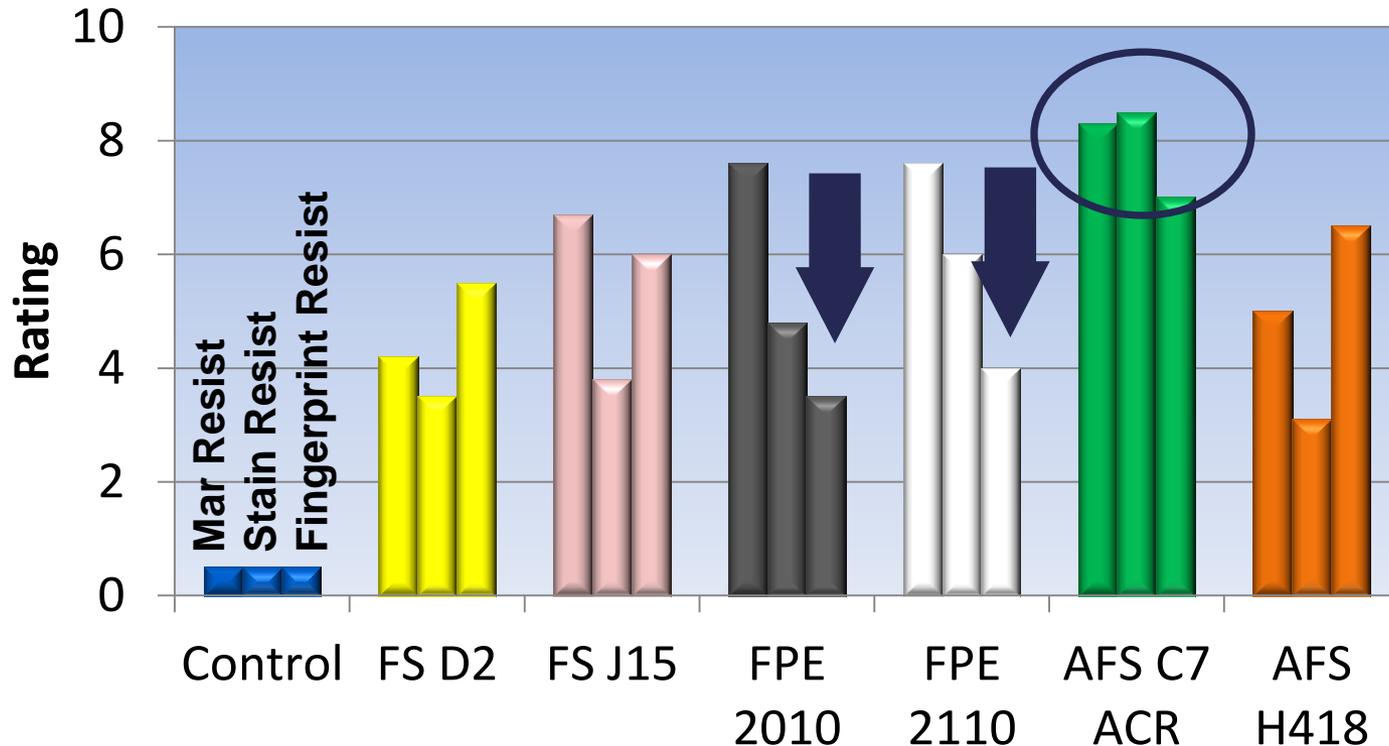
Mar Resist: SB Urethane



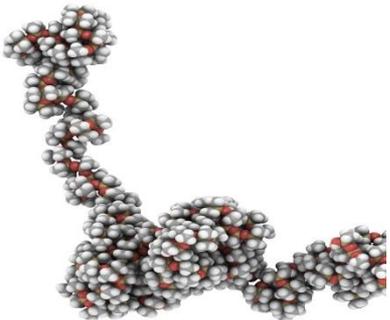
- All improve mar resistance
- FPE are better than expected



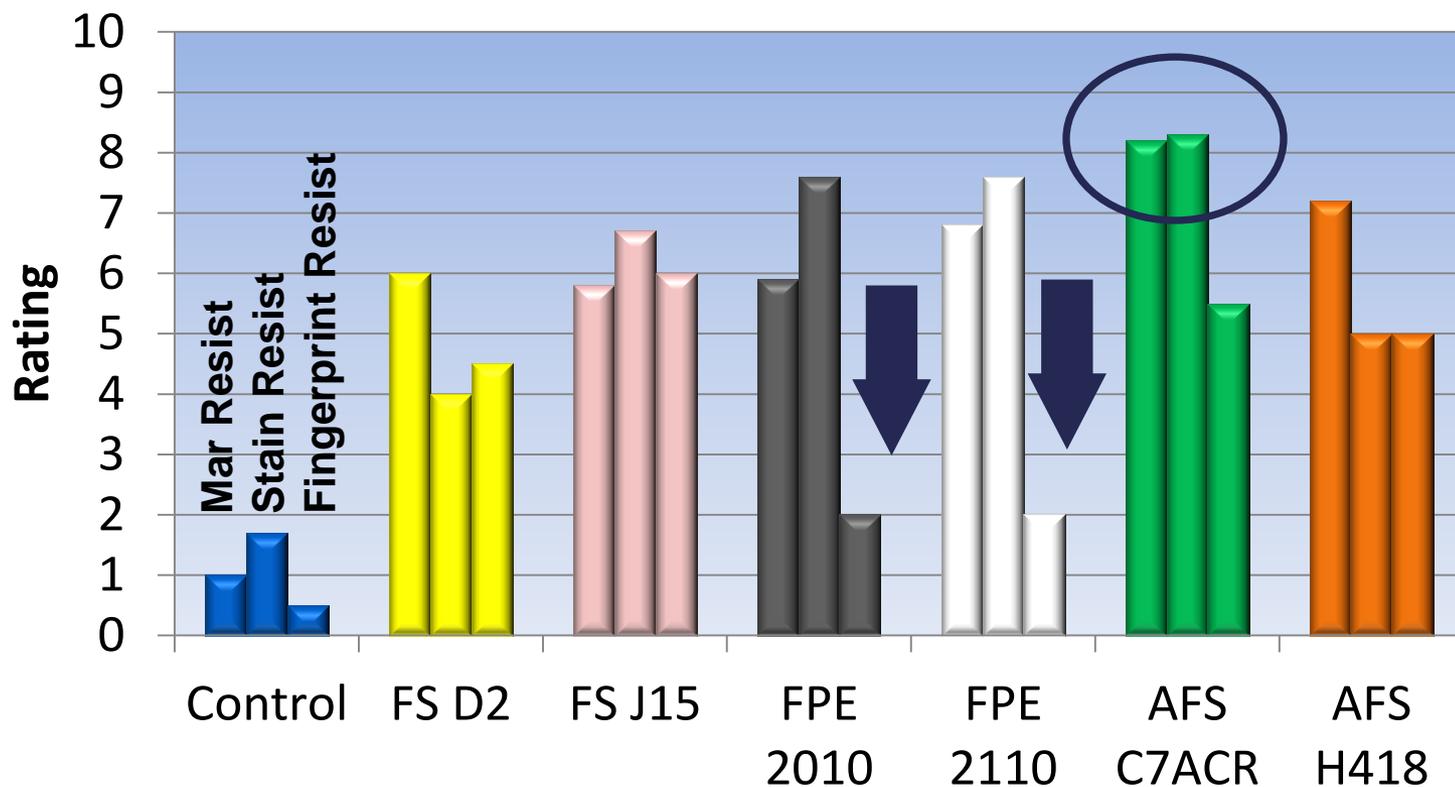
UV Epoxy Acrylate: Mar, Stain, Print



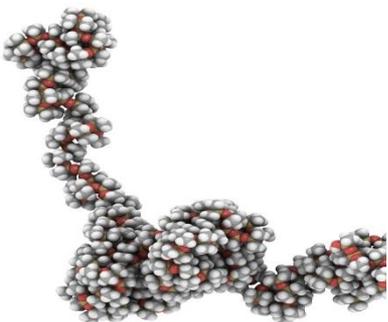
- All are improved over control
- The high %CF₂ FS D2 is not best
 - FPEs are weak on fingerprint
 - AFS C7 ACR strong on all



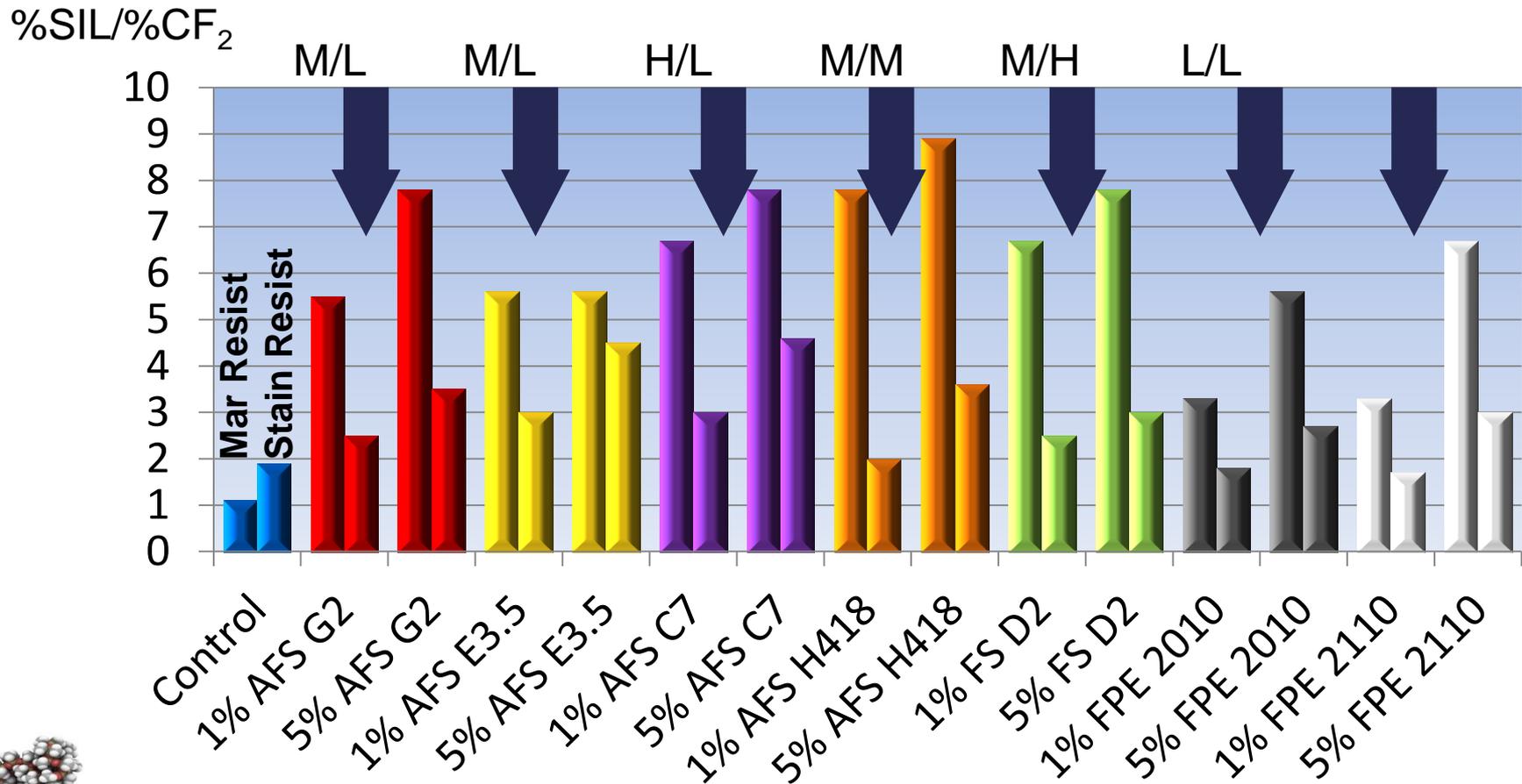
UV Ureth Acryl: Mar, Stain, Print



- All are improved over control
- The high %CF₂ FS D2 is not best
 - FPEs are weak on fingerprint
 - AFS C7 ACR strong on all



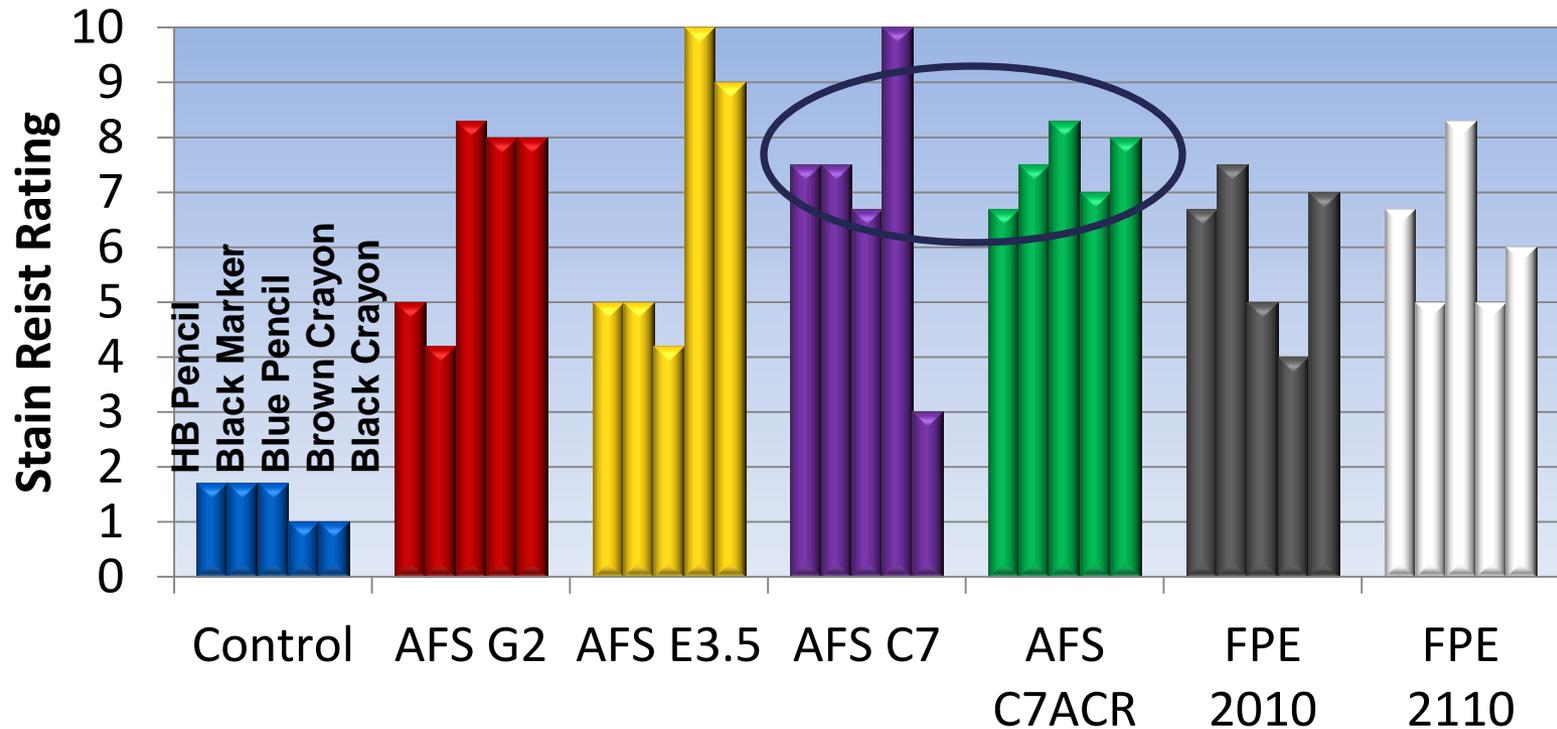
Mar and Stain: Post-added to Paint



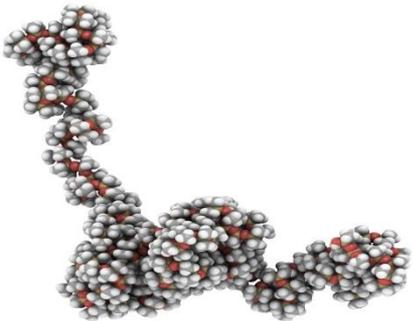
- All improve mar resistance/ more at 5%
 - Both %CF₂ and %Sil help
- Lesser improvement in stain/ 5% better



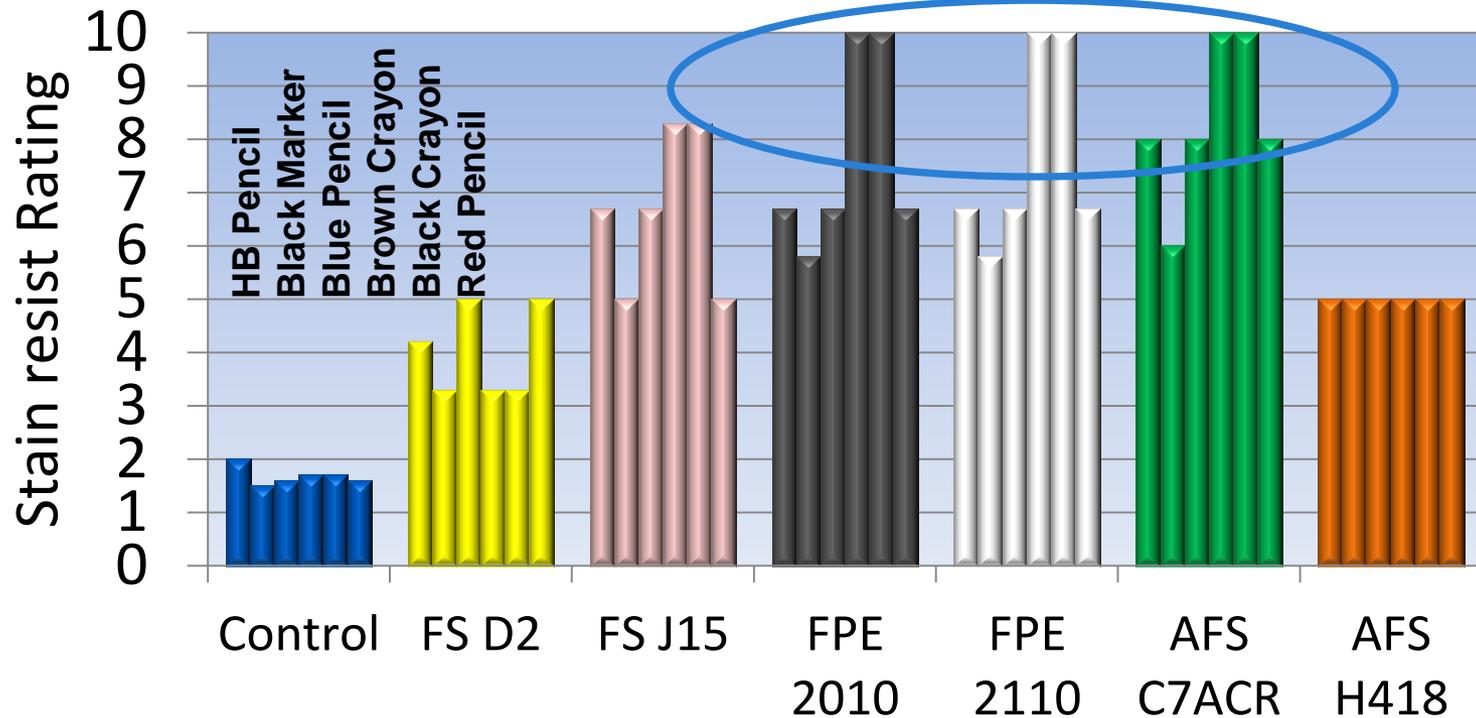
Stain Resist: SB Urethane



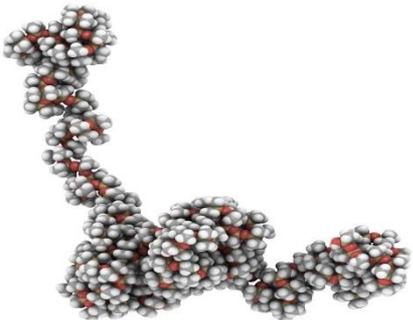
- AFS C7 structures again perform well



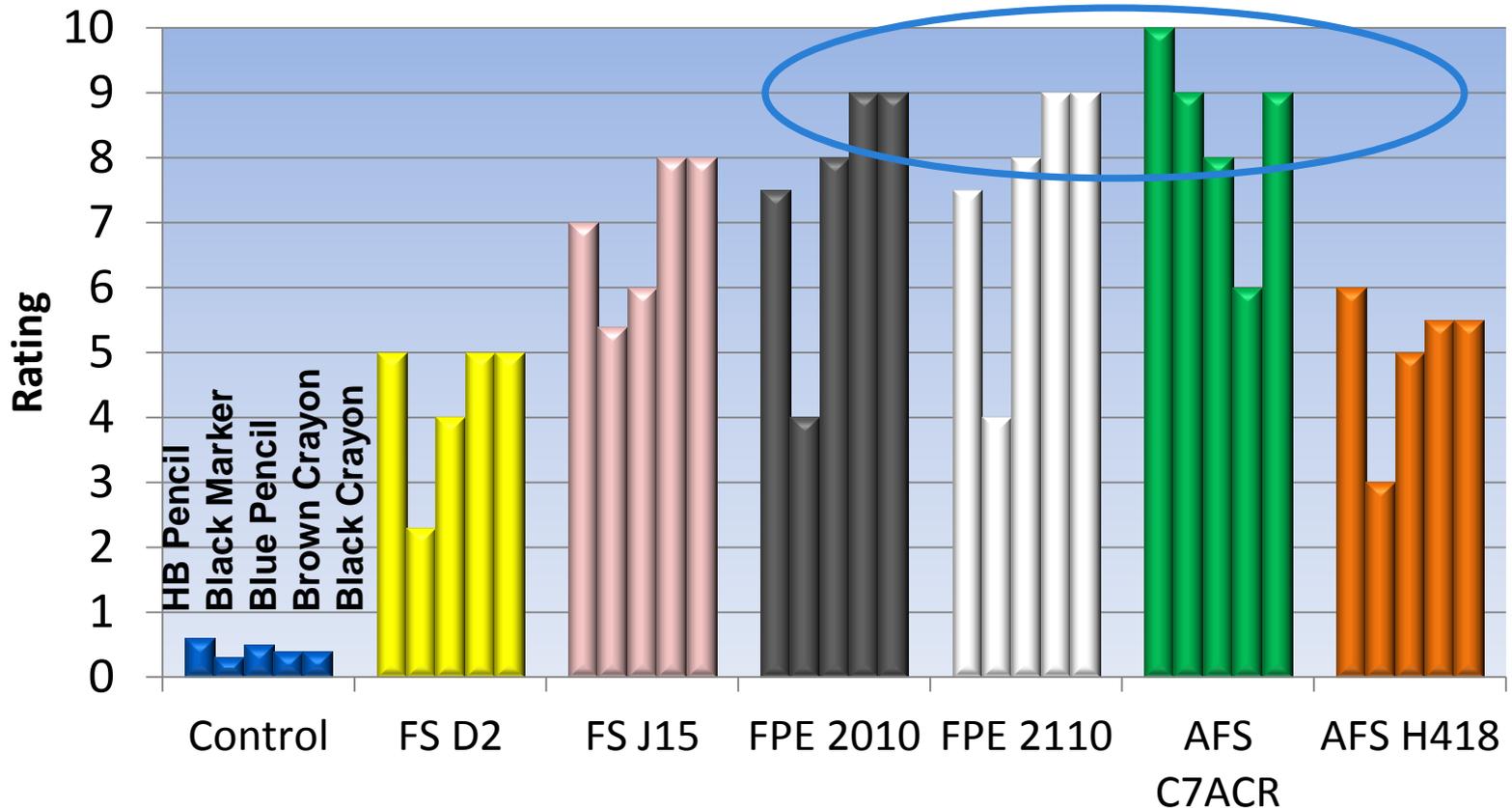
Stain Resist: Urethane Acrylate



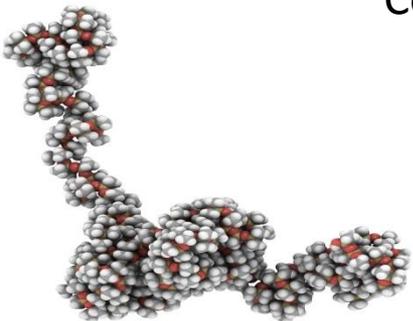
- AFS C7 ACR and FPEs are effective



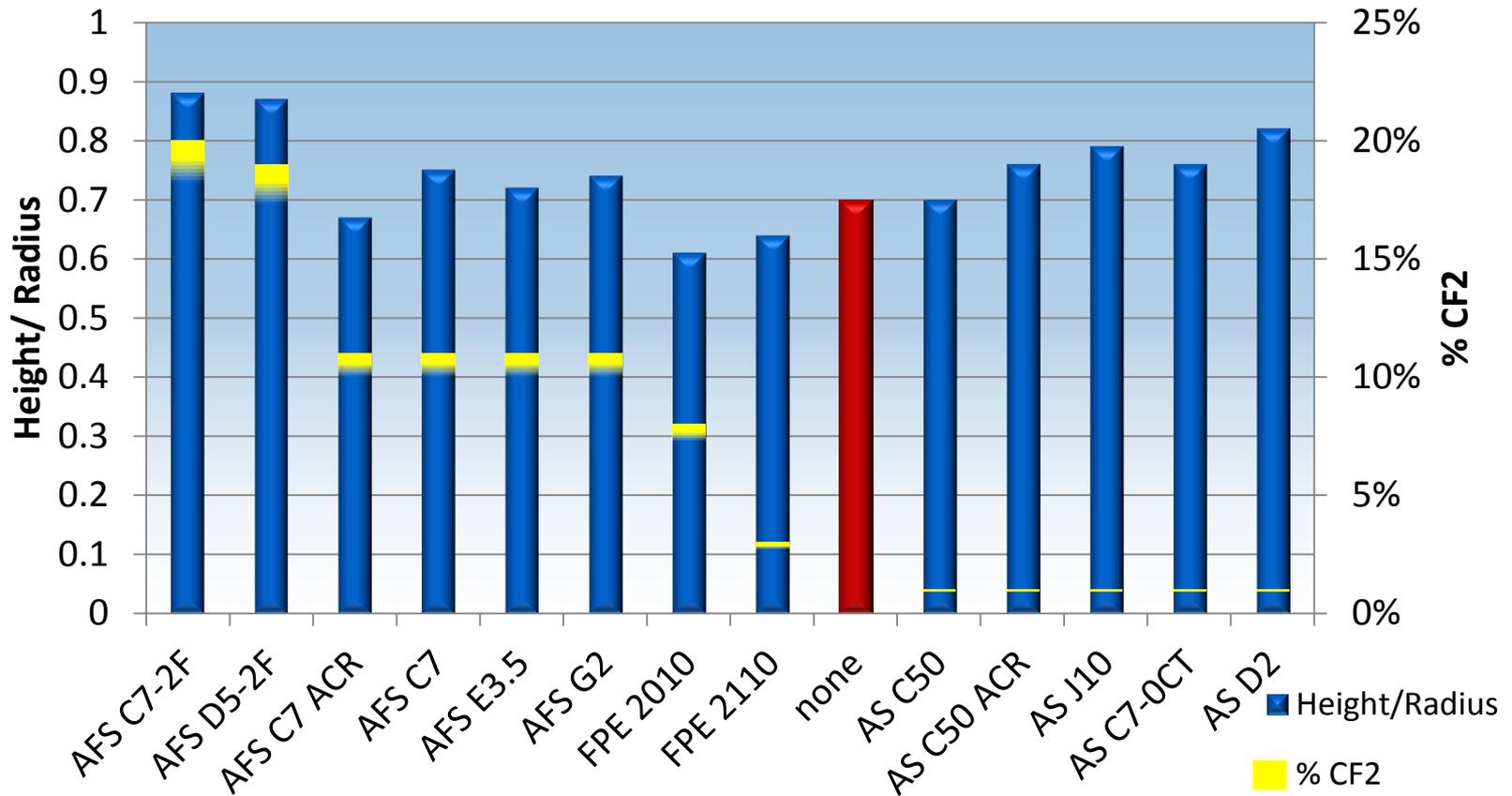
Stain: UV Epoxy Acrylate



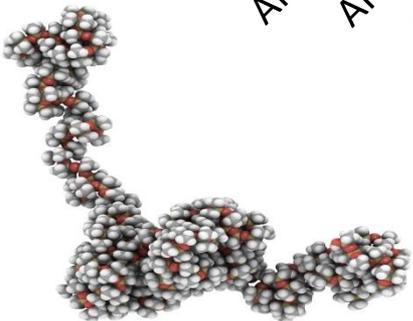
- Highest %CF₂ is least effective
- AFS C7 ACR and FPEs are effective



Water Repellency: SB Urethane



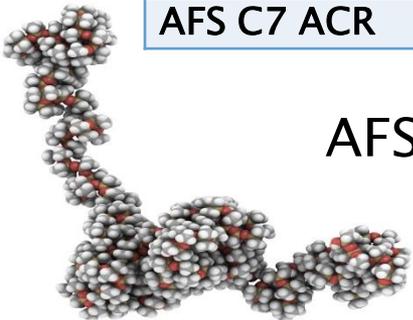
- Highest %CF₂ is most effective
- AS type alone are very effective



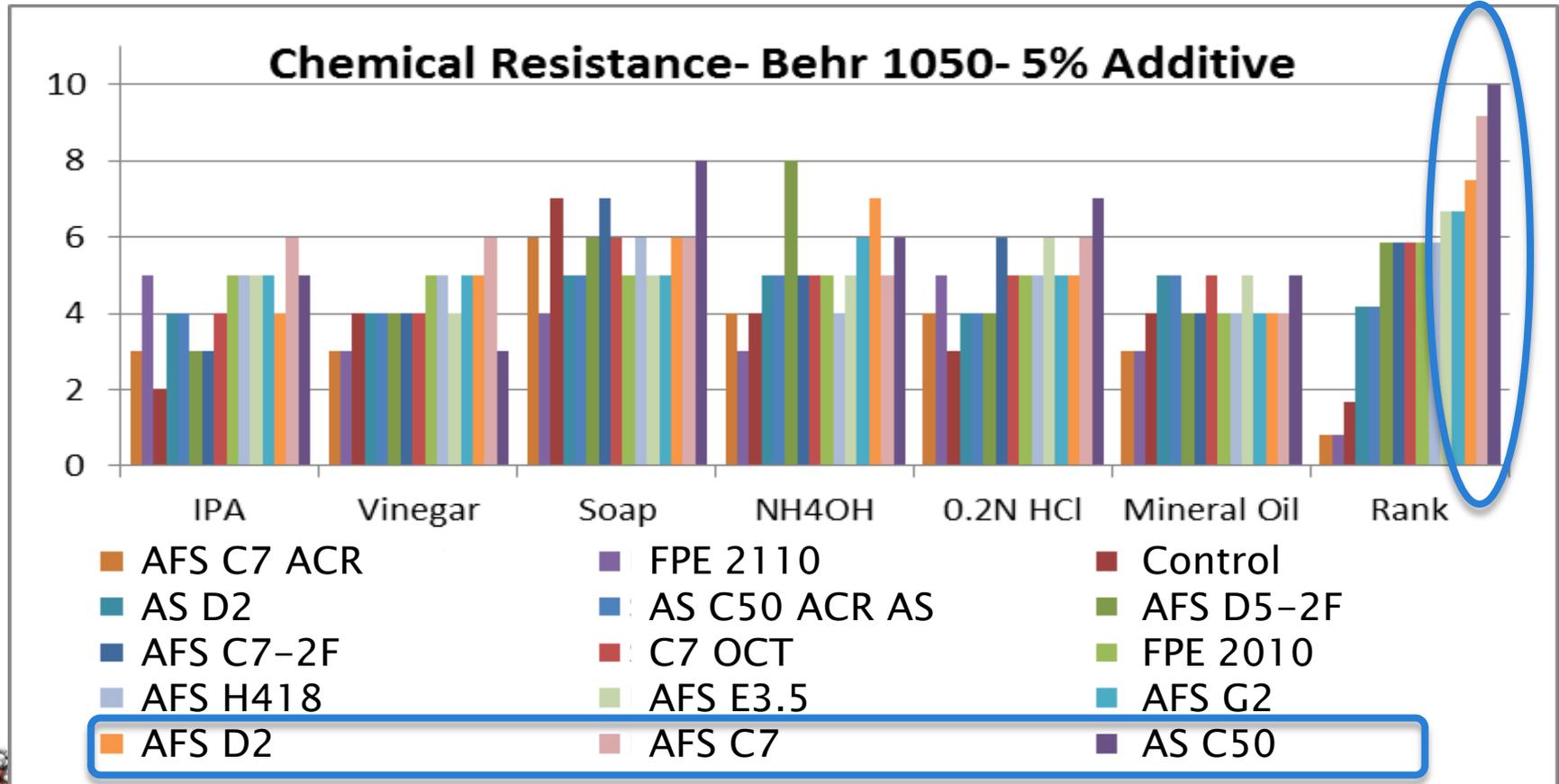
Chemical Resistance: SB Urethane

Additive (1%)	IPA	Vinegar	Soap	NH ₄ OH	HCl	Average	Normalized Rating
AFS E3.5	5	2	3	2	2	2.8	1.0
FPE 2110	6	1	4	3	2	3.2	2.0
AFS C7	6	4	5	2	3	4	4.0
AS C7-OCT	6	2	4	6	4	4.4	5.3
FPE 2010	7	3	5	1	6	4.4	5.3
AFS G2	8	2	4	5	5	4.8	6.7
AS C50	8	3	4	5	5	5	7.3
AS C50 ACR	7	7	6	3	2	5	7.3
C7-2F	6	5	5	5	4	5	7.3
Control	8	4	5	5	4	5.2	8.0
AS D2	8	2	7	6	5	5.6	9.3
AS J10	7	6	6	6	3	5.6	9.3
AFS C7 ACR	8	7	6	5	3	5.8	10.0

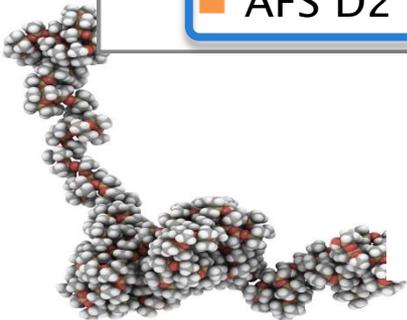
AFS C7 ACR and two AS types gave an improvement here



Summary Chemical: Post add

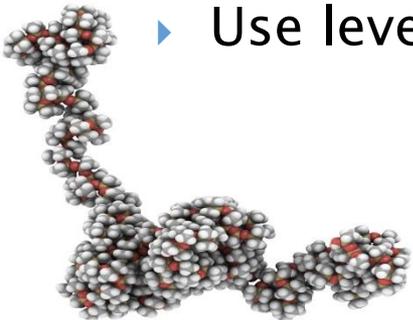


- AS C50 is best.
- AFS C7 and FS D2 are next best
- AFS C7 ACR is worst.



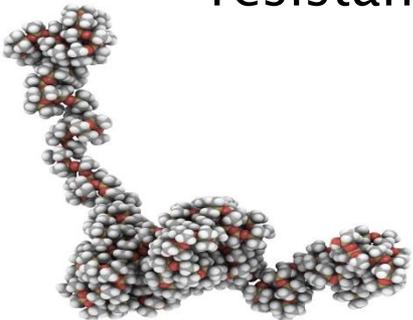
Results

- ▶ All AFS additives improve COF, mar and stain resistance and to a lesser degree fingerprint.
- ▶ The FPE type are the most compatible. Surprisingly, they are also among the best for slip and mar resistance, but not for fingerprint resistance.
- ▶ The very incompatible FA types are not as effective as expected for slip and mar. Formulation should help.
- ▶ Increasing % CF_2 is often not the best in performance.
- ▶ Low CF_2 content AFS structures are usually the best
- ▶ Post-added AFS have little effect on slip and gloss but do affect mar and stain resistance.
- ▶ Use levels needed were up to 5% and more is usually better.



Results

- ▶ Higher use level is better for mar and stain.
- ▶ Best stain results are for waxy stains.
- ▶ Water repellency can be improved with high CF_2 or high silicone content additives.
- ▶ For chemical and water resistance performance varied more depending on the coating system and use level.
- ▶ AFS H418 – which has a balance of % Sil, % CF_2 , & % CH_2 – gives a very good balance of properties.
- ▶ AFS C7–F is often the best for slip, mar and stain resistance.
- ▶ FS J15, AFS H418 and AFS C7 give the best finger print resistance



Thank You



Recommendations

- ▶ Fluorosil 2010 and Fluorosil 2110. These are very good for all but fingerprint resistance
- ▶ Fluorosil ACR C7-F or Fluorosil OH C7-F are best overall including fingerprint resistance. They are not always compatible.
- ▶ Use levels are up to 5% and more is better in most cases.

