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High-Performance TiO_2-Free Roof Coatings Via Novel Hollow Plastics Microspheres

Evan Montanez

- Headquartered in Houston, Coadtech offers more than 30 years of experience in the specialty chemicals distribution business.

- Coadtech specializes in highly reflective exterior coatings (roof, wall, and pavement) and serves North American CASE manufacturers with climate-resilient and sustainable technologies.

- Coadtech only carries materials with strong sustainability propositions.

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Hollow, Plastic Microspheres (HPMS)

What are they?

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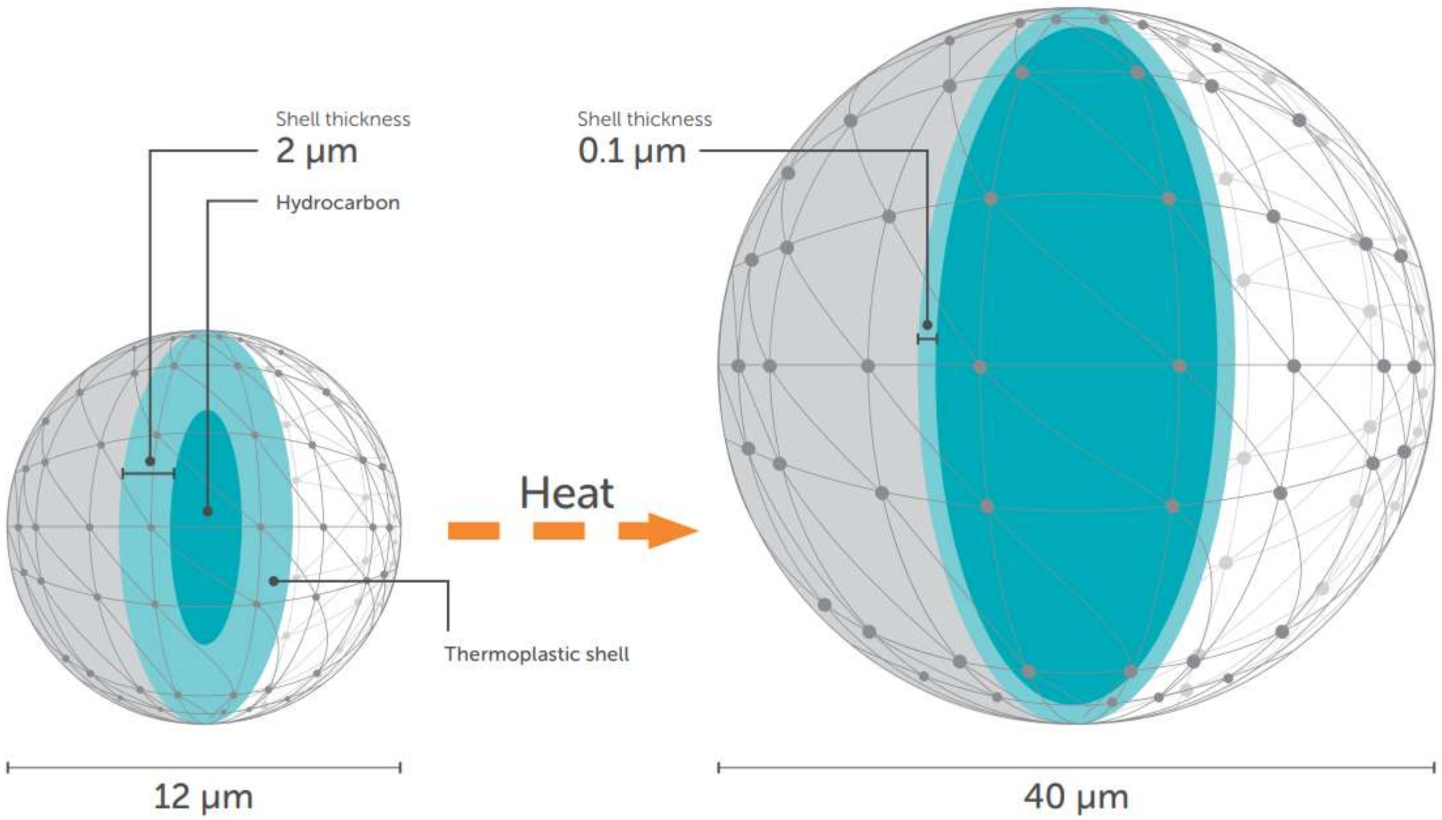
What are hollow plastic microspheres?



- The sphere consists of a polymer shell encapsulating a gas.
- When heated, the internal pressure from the gas increases and the thermoplastic shell softens, resulting in a dramatic increase of the volume of the microspheres.
- This heated step is a highly complex and irreversible reaction.

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Different microspheres for different applications

Hollow, Closed Cell Microspheres		
Mineral		Polymer
Ceramic	Glass	Thermoplastic
High density	Medium density	Low density
Bigger particle size	Medium particle size	Smallest particle size
High resistance	Fragile to shear forces	Moderate resistance with a flexbile shell

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HPMS as a Multifunctional, Climate-Resilient Filler

Ultralightweight and flexible

Full Spectrum Solar Reflective Particle

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Physical Properties of HPMS

How do they differ from traditional fillers and mineral microspheres?

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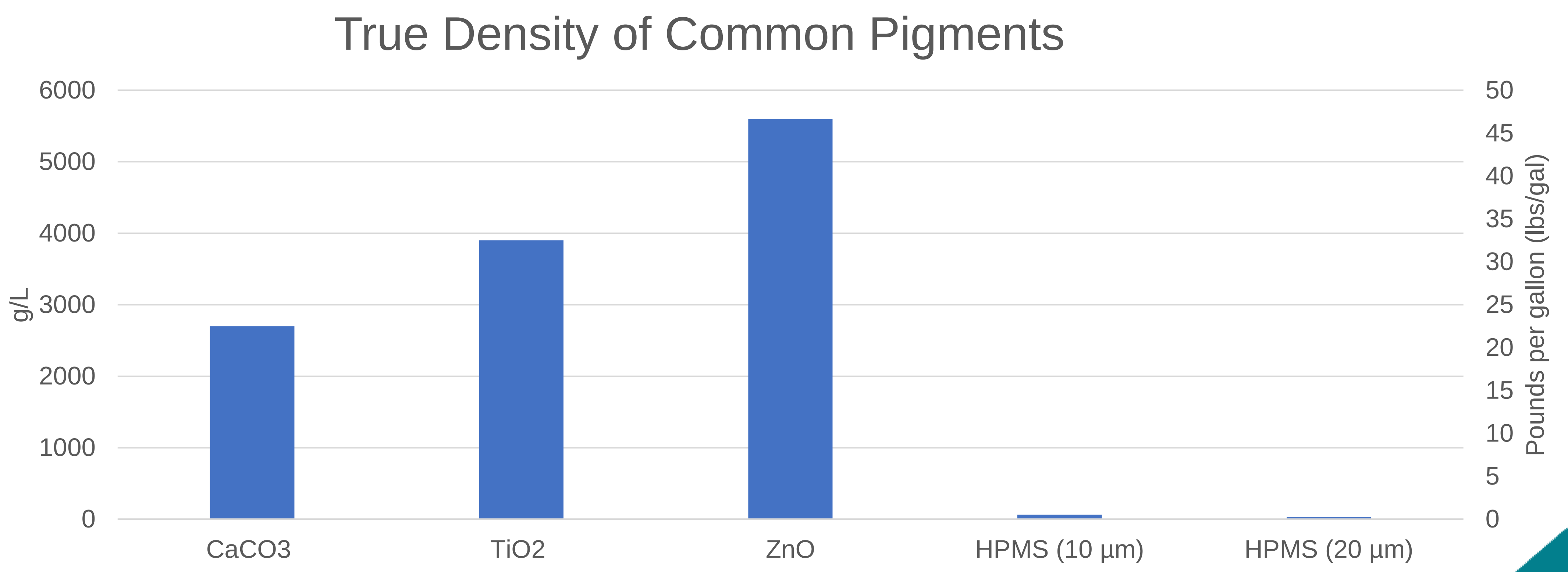
HPMS as an Ultralightweight Filler



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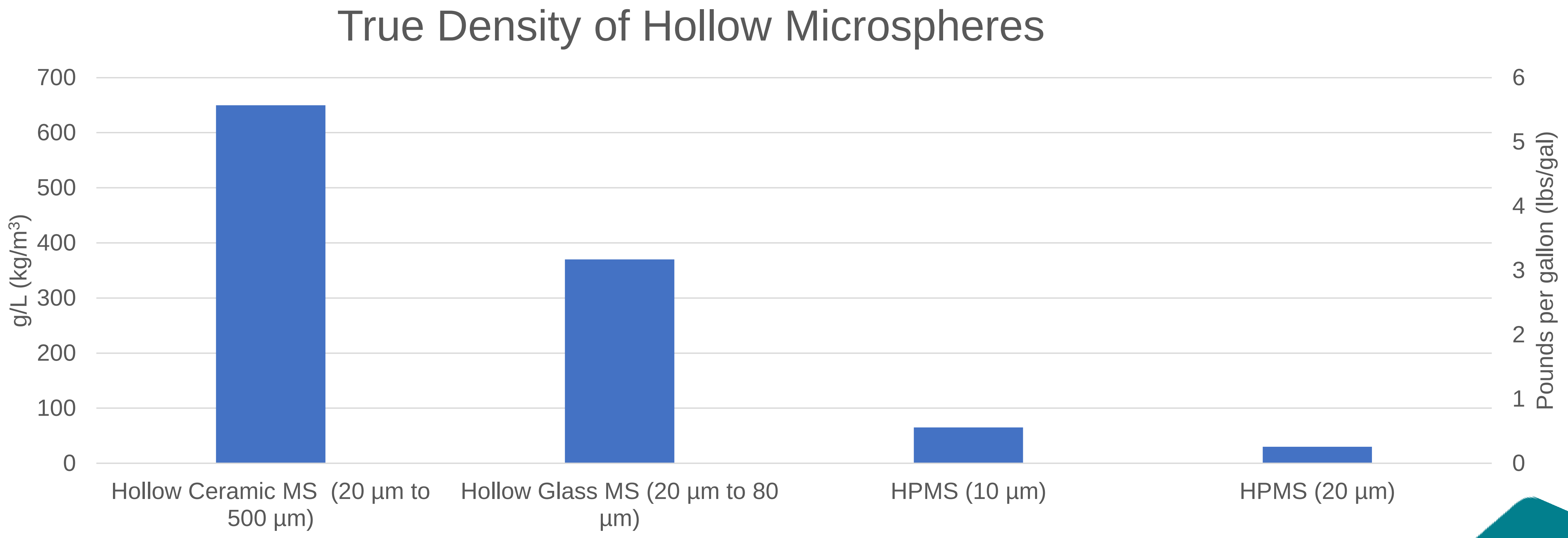
HPMS as an Ultralightweight Filler



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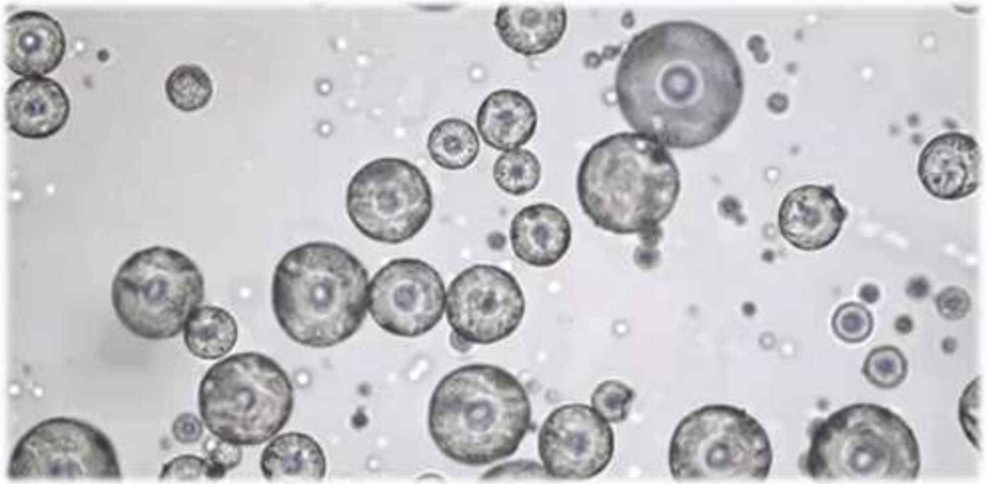
Flexibility from a Filler

- Thermoplastic Shell
  - Glass transition temperatures ranging from 100°C to 200°C
- HPMS are capable of contracting under stress, such as shear forces from dispersion blades and airless sprayers
  - This allows the microspheres to dampen sound and effectively fill cracks.



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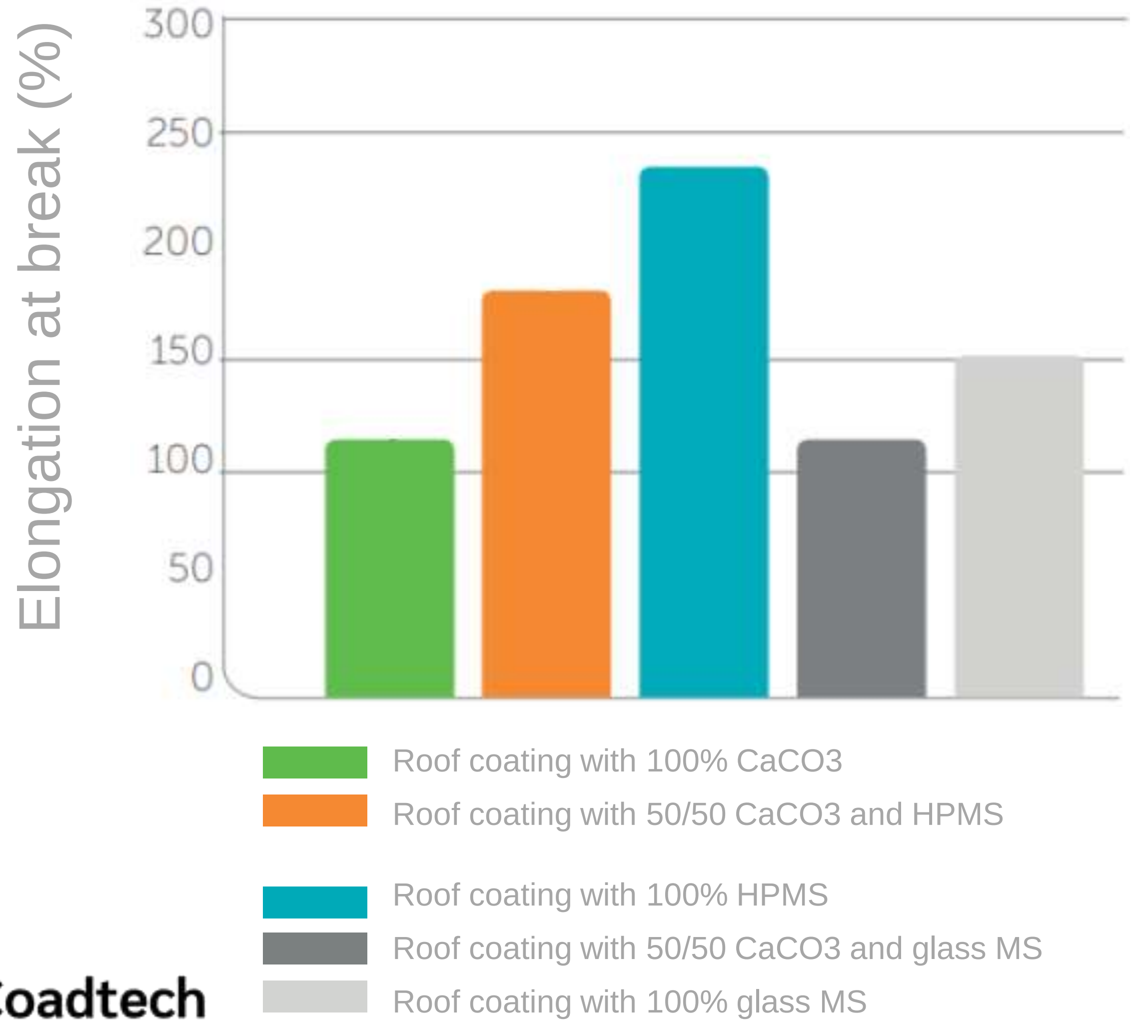
What happens with elongation?



- In a collaboration with PRA World Ltd (UK), it was observed that HPMS can dramatically increase the elongation at break when substituting CaCO3.
- A comparison with glass MS was also done.

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Achieving Solar Reflectivity With HPMS

How can we use Foam Optics to make higher performing solar reflective coatings and more energy efficient structures?

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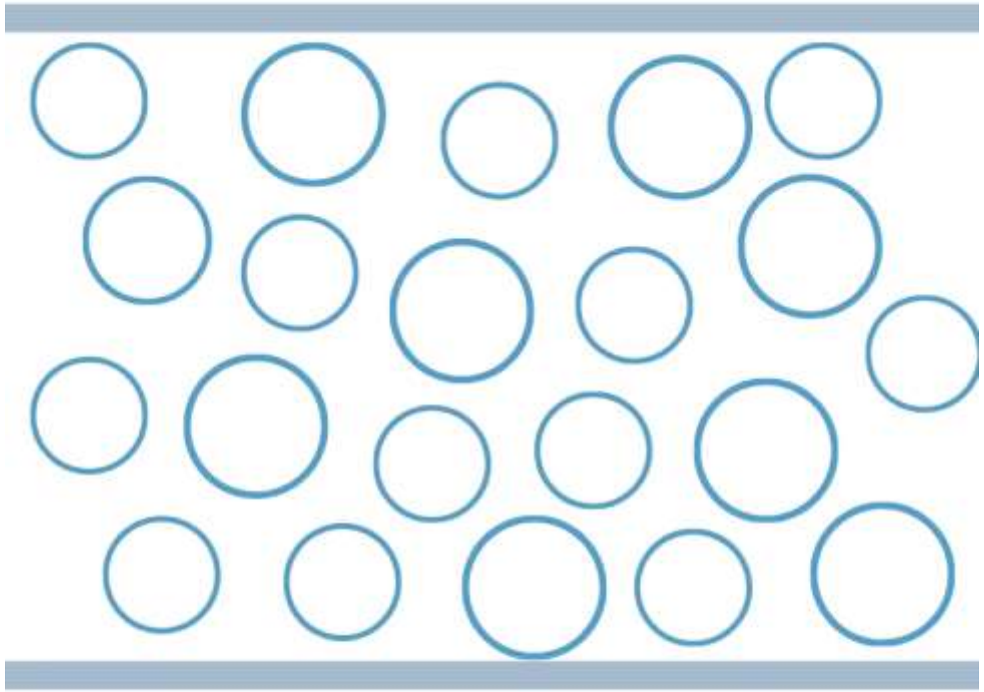
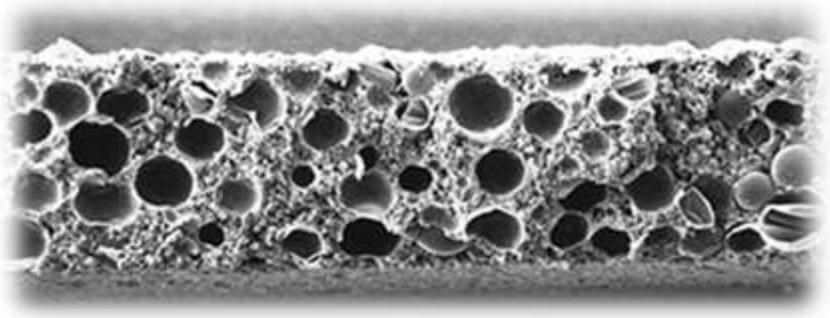
Solar reflectance with HPMS



- Shell is transparent to the medium.
- HPMS behave as microbubbles.
- Light is serially refracted due to the multiple air-resin interfaces.
- This Foam Optic effect can also be seen in polar bear fur and and the foamy head of a beer.



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Solar Reflectance with HPMS

- The amount of radiation reflected is indirectly dependent on the particle size.
  - Light is serially refracted by the air-resin interfaces.
  - Achieving the required density of air-resin interfaces in a commercial coating leads to a smaller size micropshere

- The smaller the microsphere is, the more interfaces you can have in the same volume

- Incident light is the same wavelength of reflected light
  - Allows reflected light to escape Earth’s atmosphere and prevents Greenhouse effects
  - Avoids issues with the “Atmospheric Window”

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Reflectivity Gains Based On *Interface Density*, Not *Composition*

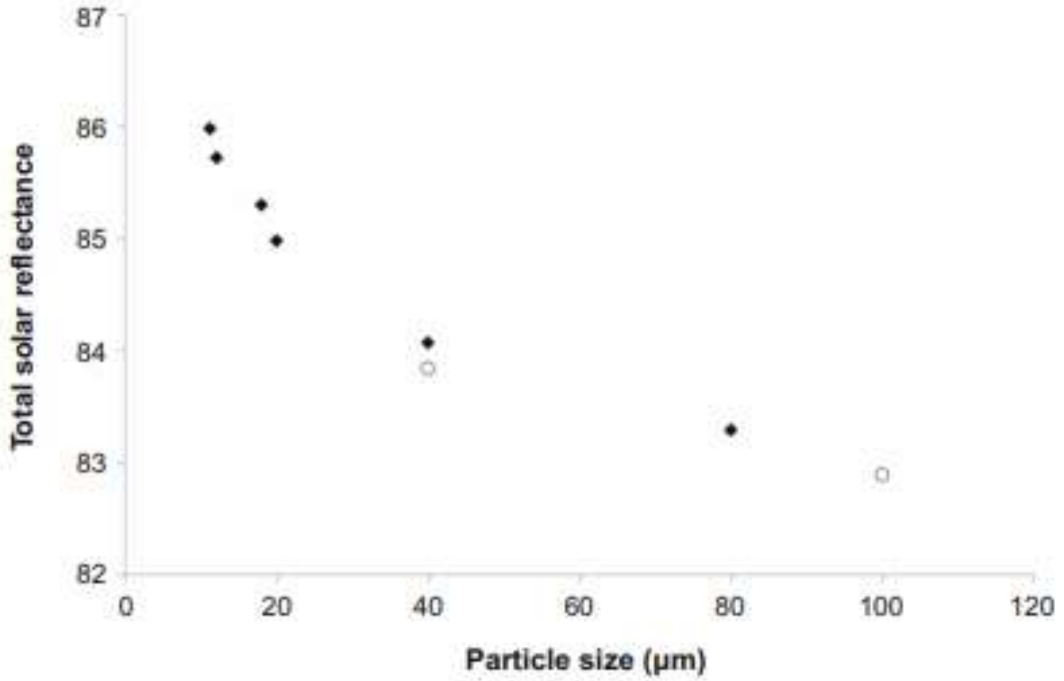
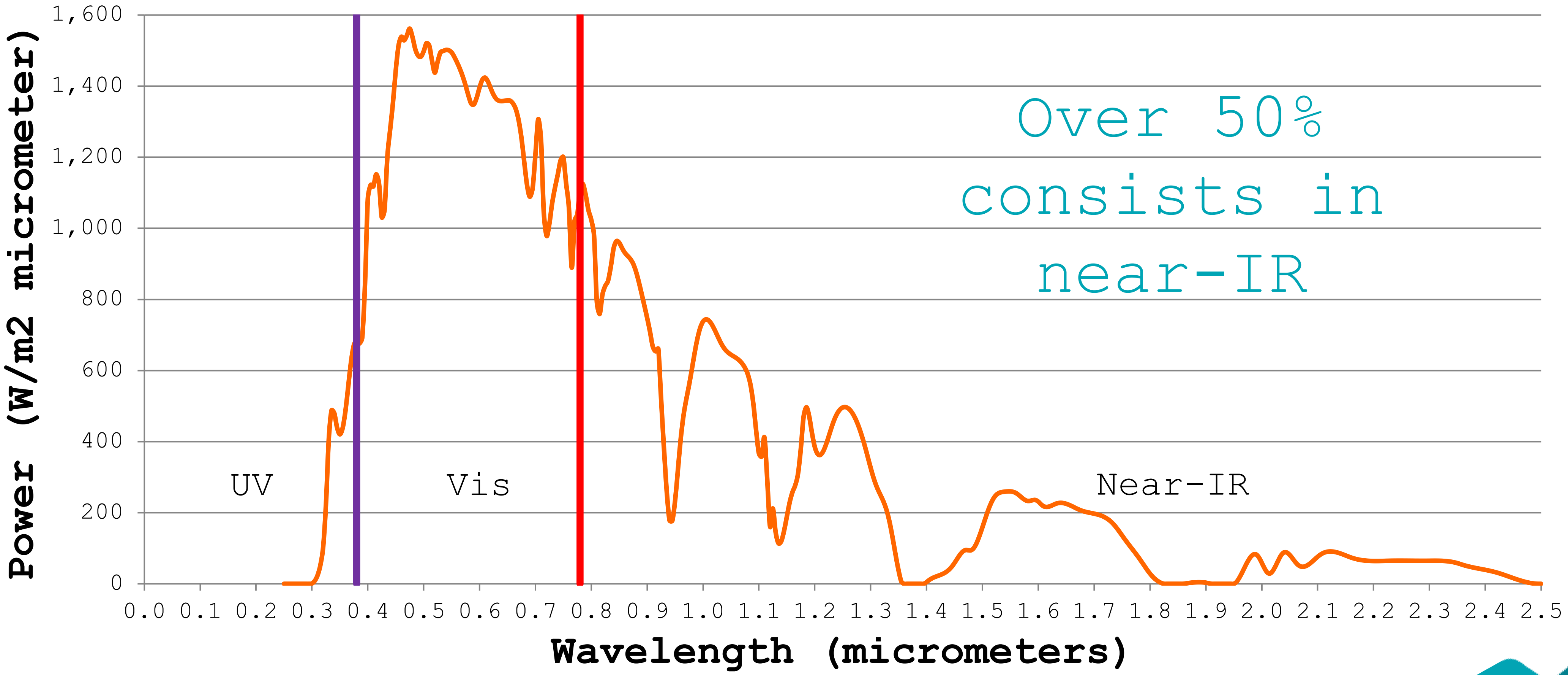


Fig. 4: Effect of particle size on the total solar reflection (R_{sol}) in coatings (dry thickness 0.6 mm ± 0.05 mm) containing 1.6 vol% TiO_2 and 30 vol% of hollow fillers having different average particle size. Paints containing smaller microspheres have higher reflectance values as these contain more reflecting units. (♦) Hollow thermoplastic microspheres, (○) Hollow glass microspheres

Source: Reflective properties of hollow microspheres in cool roof
Coatings (June, 8th, 2017) Sandin et al., Journal of Coatings Technology and Research (JCTR).

Sunlight Composition



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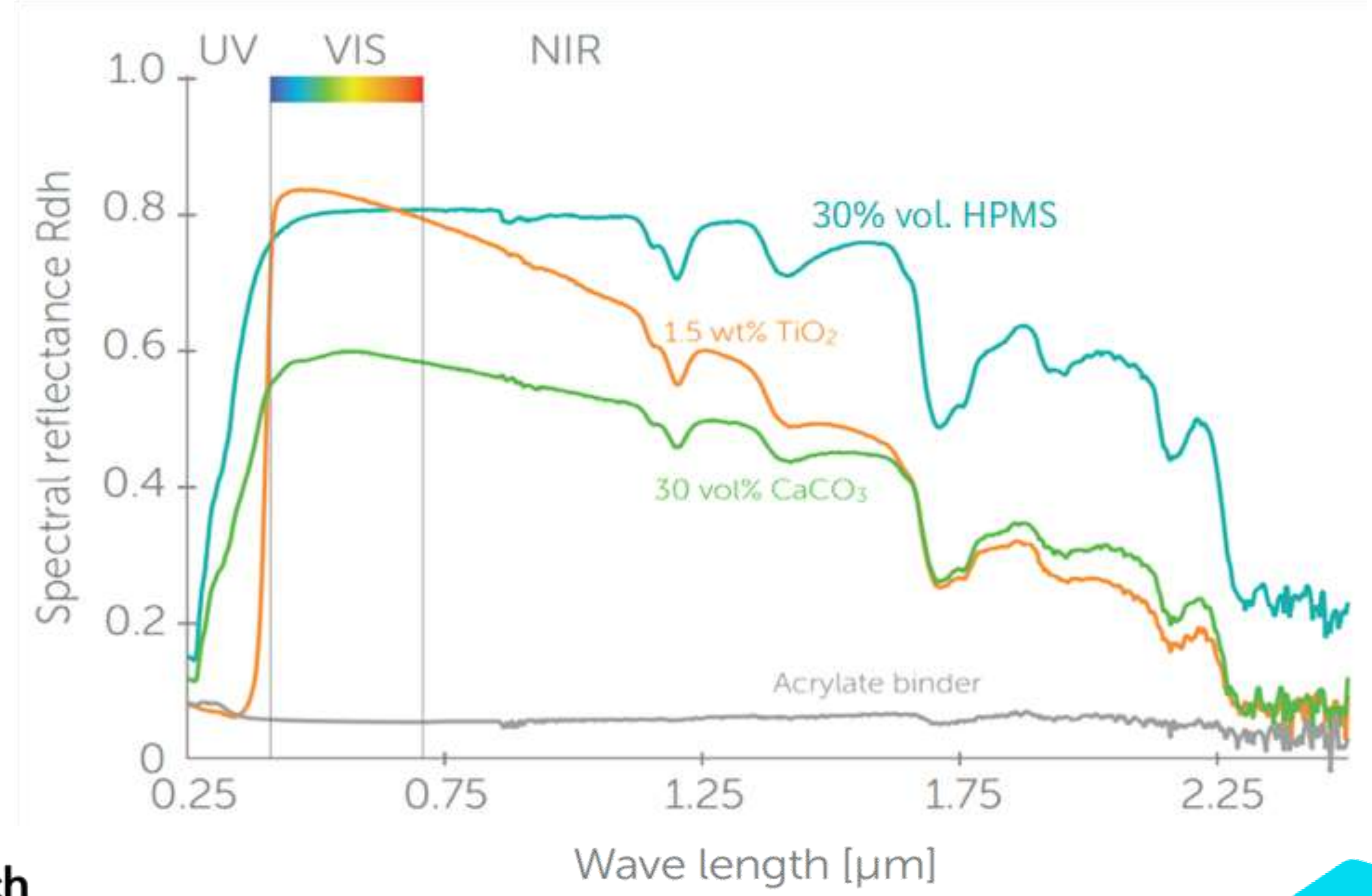
Reflectance Comparison



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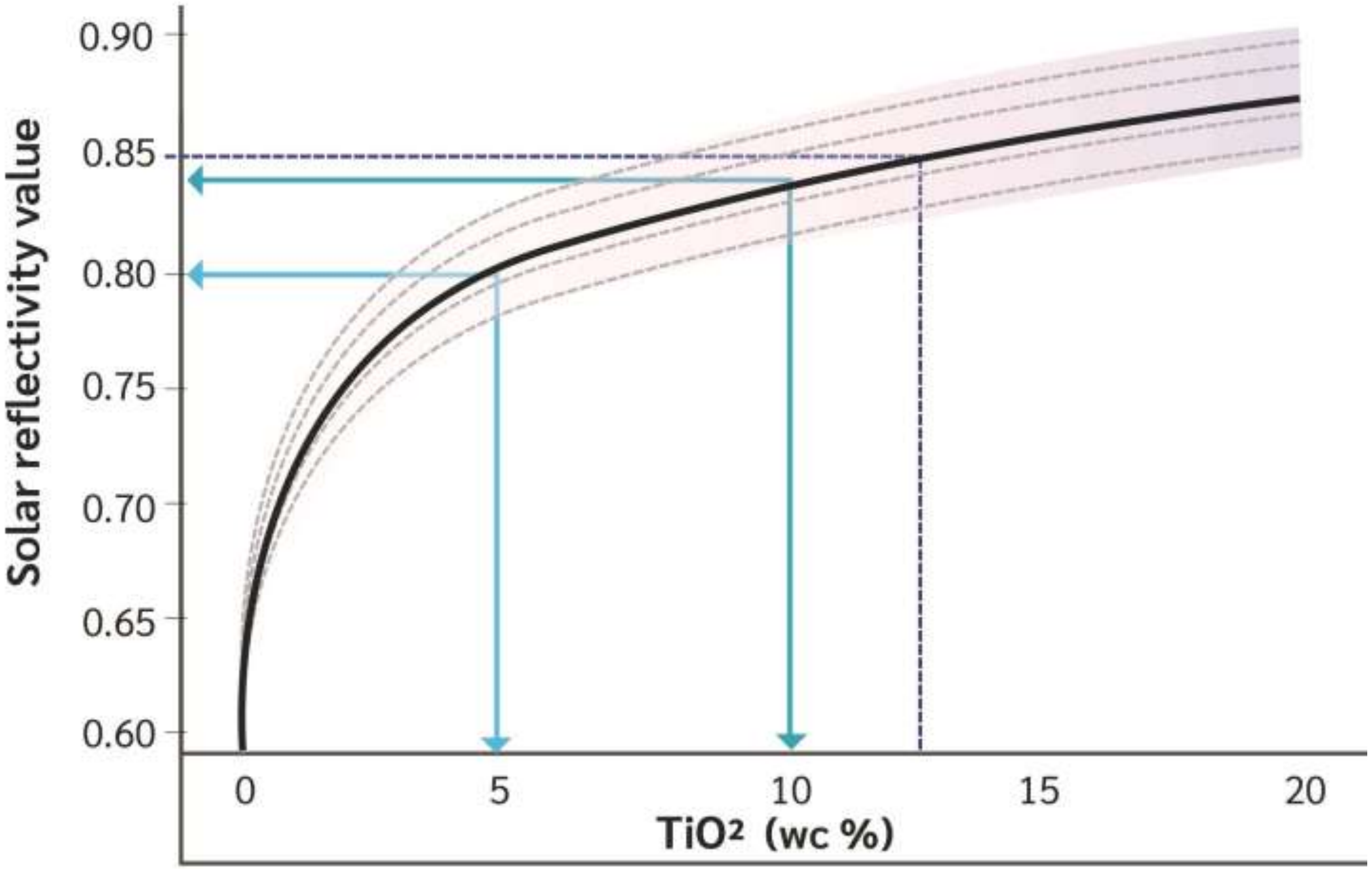
TiO_2 needed to improve SR from 80% to 84%



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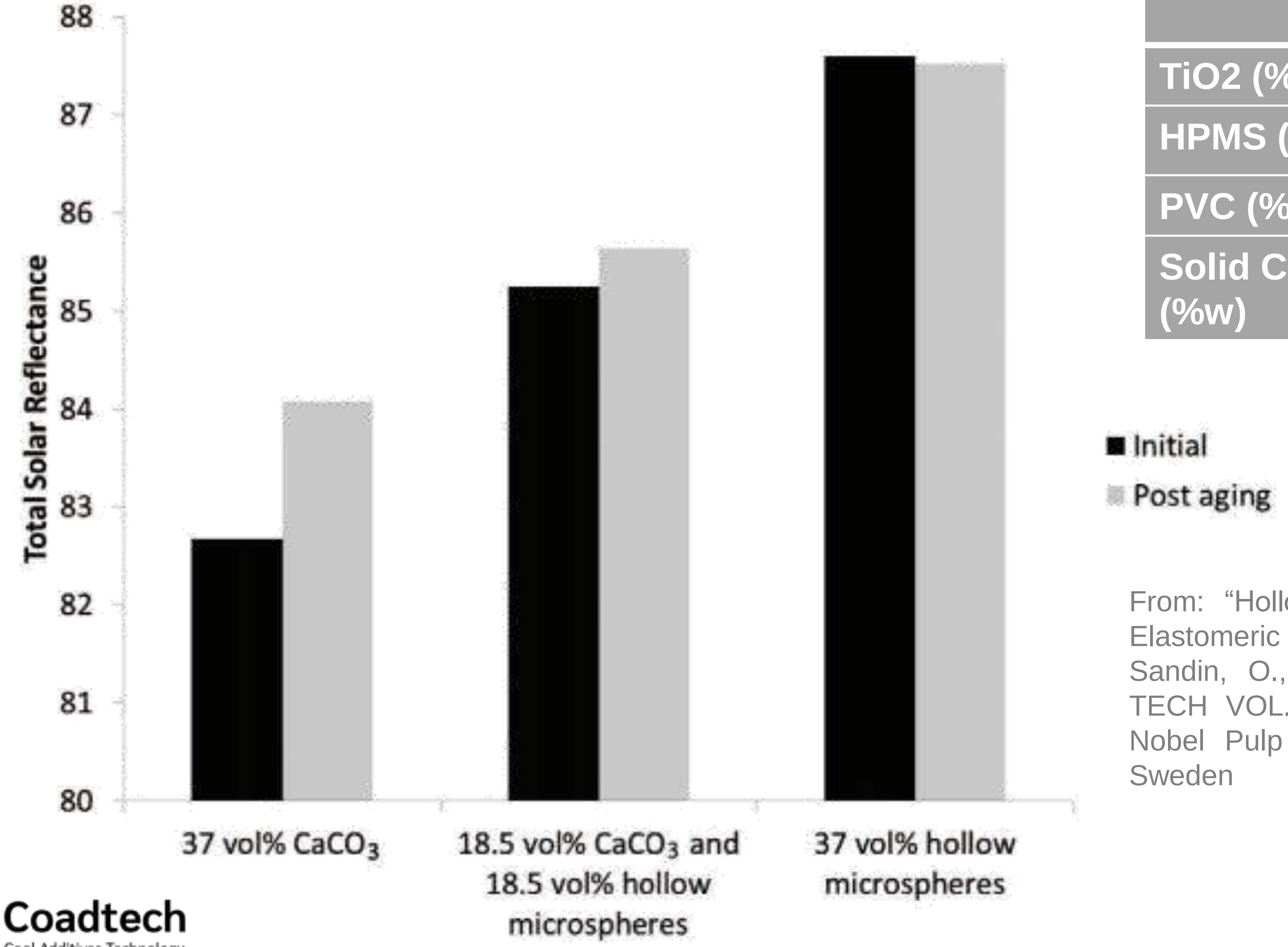
Source: Dupont " Cool Roofing, importance and general considerations highly reflective coatings" 2012.



	37% vol CaCO3
TiO2 (%w)	7.3
HPMS (%w)	0.0
PVC (%)	43.1
Solid Content (%w)	63.8

From: "Hollow Thermoplastic Microspheres in Elastomeric Cool Roof Coatings", Nordin, J., Sandin, O., and Greenwood, P. (COATINGS TECH VOL. 16 / NO. 1 / JANUARY 2019), Akzo Nobel Pulp and Performance Chemicals AB, Sweden

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TiO_2-Free Concept Roof Coating

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TiO_2-Free Concept Roof Coating

Project Aim:

Develop a high performance TiO_2-Free acrylic roof coating

Experimental Criteria of High Performance Roof Coating:

- Sufficient Opacity (>97%)
- High Solar Reflectivity (>.80 TSR)
- High SRI (>104)

Group 1

	Properties	STD	A	B	C	D	E
Characterization	Volume Solids	42.6%	43.1%	43.1%	43.1%	43.1%	43.1%
	Weight Solids	58.0%	43.1%	39.4%	35.7%	41.7%	38.5%
	% Powder Weight	39.4%	17.1%	12.0%	6.4%	17.6%	13.2%
	CPVC	0.577	0.647	0.652	0.657	0.644	0.647
	PVC	0.448	**0.443**	**0.443**	**0.443**	0.494	0.497
	Q	0.778	0.685	0.679	0.675	**0.768**	**0.768**
Weight	CaCO3	**35.4%**	**16.8%**	**11.4%**	**5.7%**	**17.1%**	**12.5%**
	TiO2	**4.0%**	0.0%	0.0%	0.0%	0.0%	0.0%
	MS 20 micron	0.0%	**2.6%**	**2.8%**	**2.9%**	**2.7%**	**2.8%**
	MS 10 micron	0.0%	0.0%	**0.6%**	**1.3%**	**0.6%**	**1.2%**
Dry Volume Solids	CaCO3	**41.8%**	**14.4%**	**9.2%**	**4.3%**	**14.3%**	**9.9%**
	TiO2	**3.0%**	0.0%	0.0%	0.0%	0.0%	0.0%
	MS 20 micron	0.0%	**29.9%**	**30.1%**	**30.1%**	**30.0%**	**29.9%**
	MS 10 micron	0.0%	0.0%	**5.0%**	**10.0%**	**5.1%**	**9.9%**

- 0 % TiO2

  A,B,C: PVC constant

  D+E: Q constant

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Group 1

STD	A	B	C	D	E
Op 100%	Op 79.5%	Op 78.1%	Op 81.6%	Op 82.6%	Op 82.8%

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Group 2

	Properties	STD	F	G	H	I
Characterization	% Volume Solids	42.6%	43.4%	43.3%	43.2%	42.8%
	% Weight Solids	58.0%	38.9%	39.0%	39.1%	41.7%
	% Powder Weight	39.4%	13.7%	13.9%	14.1%	18.1%
	CPVC	0.577	0.646	0.646	0.645	0.642
	PVC	0.448	0.503	0.502	0.502	0.500
	Q	0.778	0.778	0.778	0.778	0.778
Weight	CaCO3	35.4%	12.0%	11.2%	10.5%	15.7%
	TiO2	4.0%	1.0%	2.0%	3.0%	1.9%
	MS 20 micron	0.0%	2.8%	2.8%	2.8%	2.7%
	MS 10 micron	0.0%	1.2%	1.2%	1.2%	**0.6%**
Dry Volume Solids	CaCO3	41.8%	9.5%	8.9%	8.3%	13.3%
	TiO2	**3.0%**	**0.5%**	**1.0%**	**1.5%**	**1.0%**
	MS 20 micron	0.0%	30.3%	30.3%	30.3%	30.5%
	MS 10 micron	0.0%	10.0%	10.0%	10.0%	**5.1%**

- “Trace” TiO2 Coatings
  - Heavy TiO2 Reduction
  - Q constant

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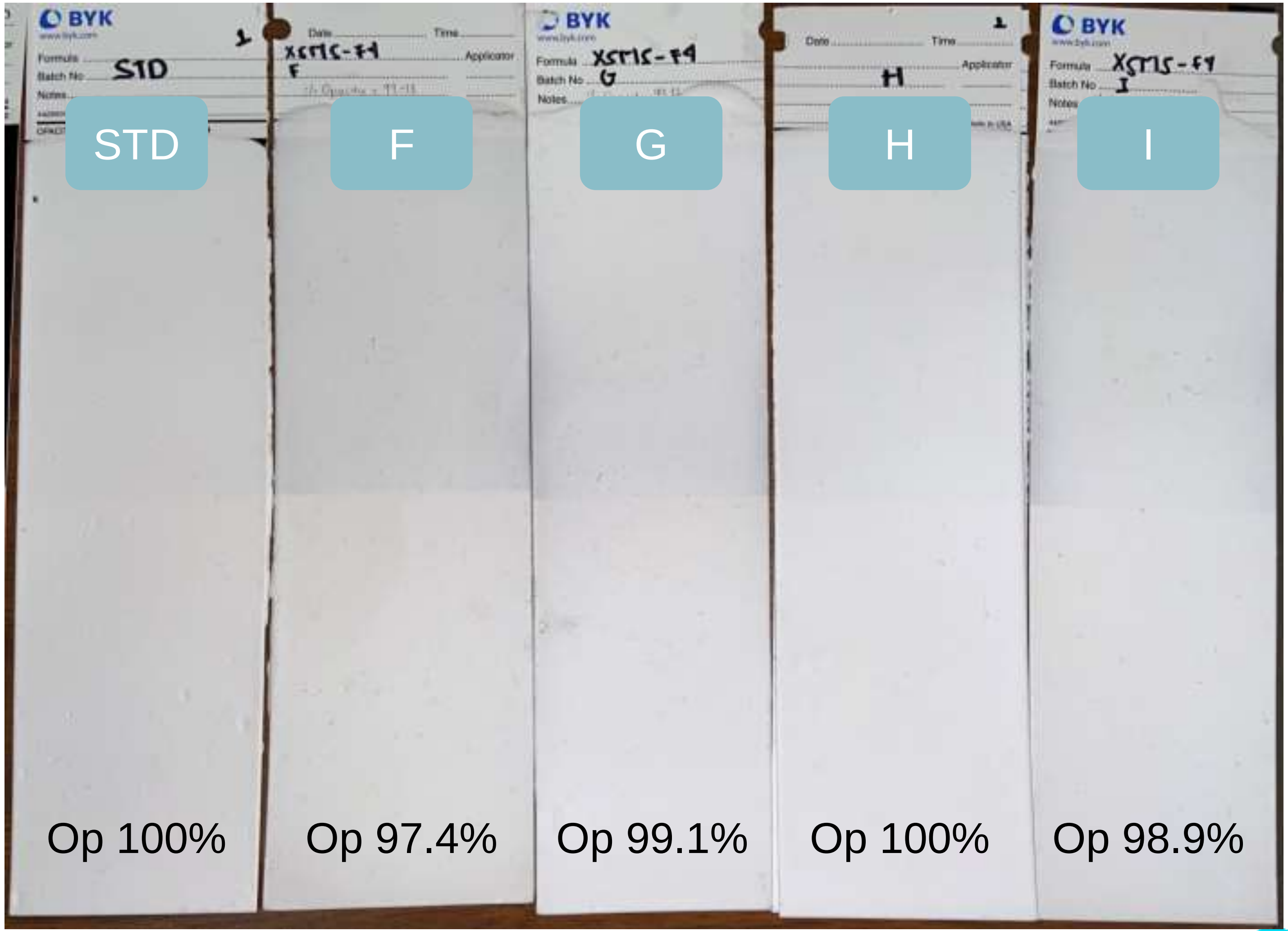
Group 2



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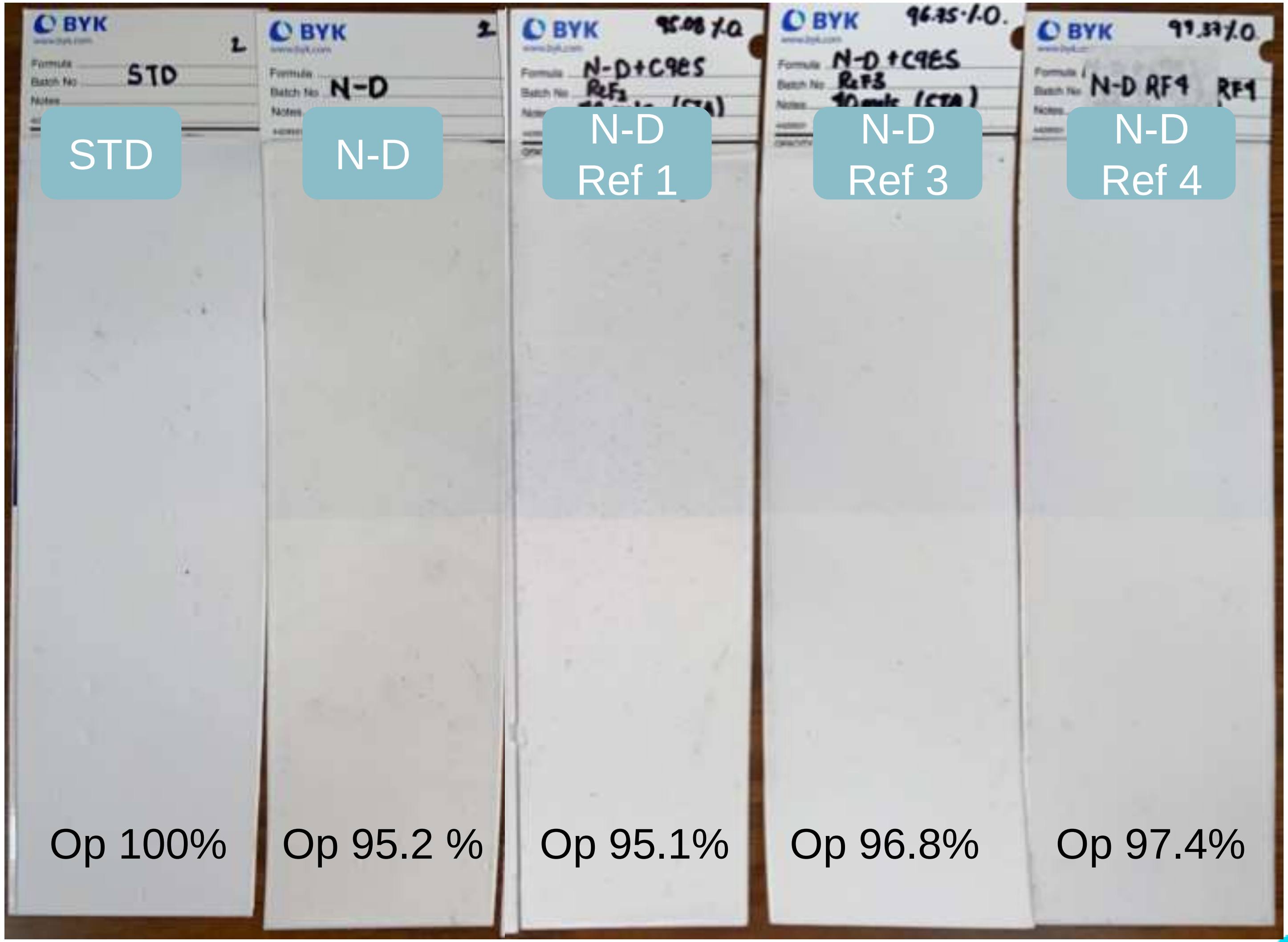
Group 4

	Properties	STD	N-A	N-B	N-D	N-D RF1	N-D RF3	N-D RF4
Characterization	Volume Solids	42.62%	42.91%	43.04%	42.85%	43.00%	**45.00%**	**46.04%**
	Weight Solids	58.04%	31.25%	31.10%	33.09%	33.23%	35.79%	38.30%
	CPVC	0.577	0.605	0.605	0.583	0.579	0.567	0.553
	PVC	0.449	0.471	0.470	0.450	0.450	0.458	0.451
	Q	0.778	0.779	0.777	0.772	0.778	**0.808**	**0.815**
Weight	$CaCO_3$	35.4%	0.7%	0.7%	0.0%	0.0%	0.0%	0.0%
	Opaque Polymer	0.0%	**5.9%**	**6.9%**	**7.2%**	**7.2%**	**8.0%**	**7.9%**
	ZnO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TiO_2	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	MS 20 micron	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	MS 10 micron	0.0%	5.9%	5.9%	5.2%	5.2%	5.3%	5.1%
	Kaolin Clay 1	0.0%	2.1%	2.1%	5.1%	0.0%	0.0%	0.0%
	Kaolin Clay 2	0.0%	0.0%	0.0%	0.0%	**5.1%**	**7.2%**	**9.3%**
Dry Volume Solids	$CaCO_3$	41.8%	0.5%	0.5%	0.0%	0.0%	0.0%	0.0%
	Opaque Polymer	0.0%	**6.0%**	**7.0%**	**7.6%**	**7.6%**	**8.2%**	**8.0%**
	ZnO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TiO_2	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	MS 20 micron	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	MS 10 micron	0.0%	45.1%	44.9%	41.0%	41.0%	40.4%	38.2%
	Kaolin Clay 1	0.0%	1.5%	1.5%	4.0%	0.0%	0.0%	0.0%
	Kaolin Clay 2	0.0%	0.0%	0.0%	0.0%	**4.0%**	**5.4%**	**6.9%**

- 0% TiO_2
- Opaque Polymer
- Kaolin Clay
- HPMS 10 micron only

Group 4



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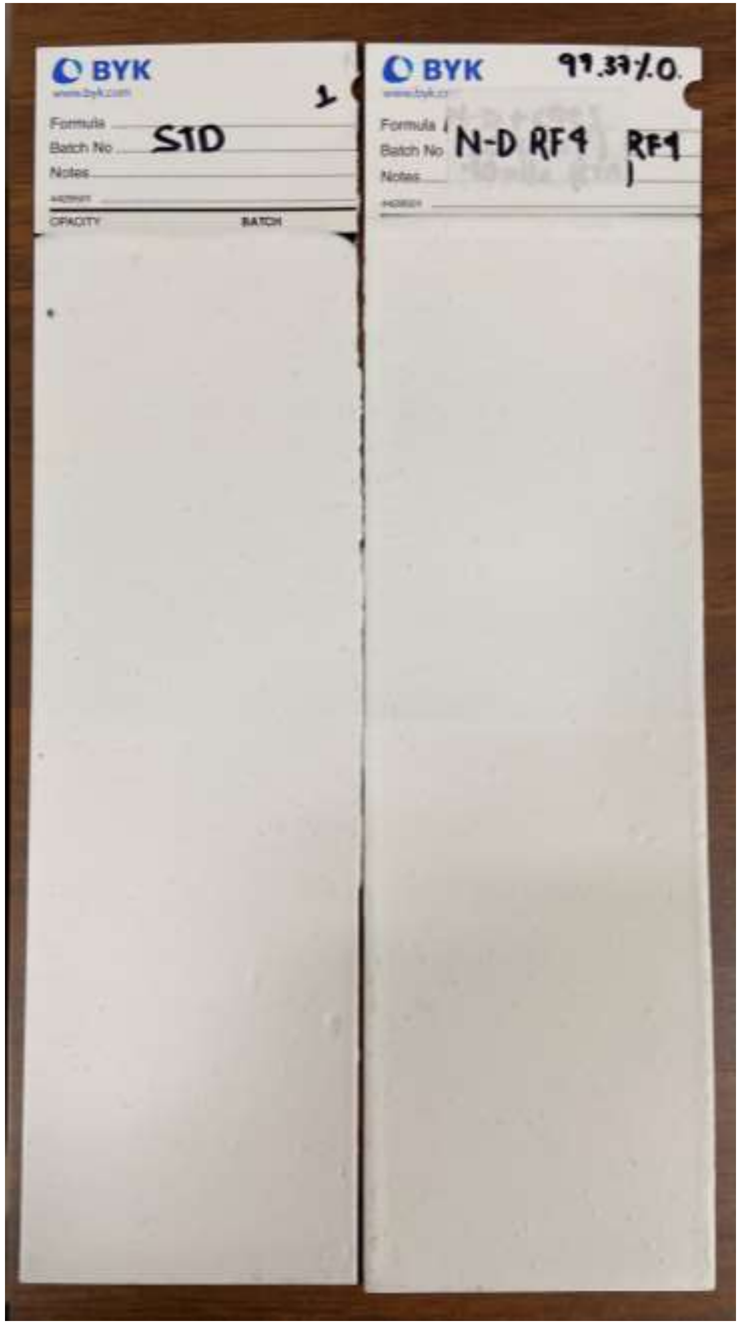
Group 4

Sample	Aluminum Panel
	WI CIE
STD	67.64
N-D	68.72
N-D RF4	69.45



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Contrast Ratio and Solar Reflectivity

Sample	Contrast Ratio			Average	Average
STD 1	0.838	0.837	0.837	0.837±0.017	83.73%
STD 2	0.801	0.807	0.803	0.804±0.016	80.37%
N-D 1	0.865	0.863	0.864	0.864±0.017	86.40%
N-D 2	0.809	0.805	0.812	0.809±0.017	80.87%
N-D RF4 1	0.88	0.878	0.879	0.879±0.018	87.90%
N-D RF4 2	0.838	0.839	0.839	0.839±0.017	83.87%

Sample	Solar Reflectivity Results			Average	TSR
STD	0.818	0.823	0.823	0.821±0.016	0.821
N-D	0.835	0.835	0.835	0.835±0.017	0.835
N-D RF4	0.84	0.841	0.842	0.841±0.017	0.841

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TiO2-Free Formula Properties

	Properties	N-D RF4
Characterization	Volume Solids	46.04%
	Weight Solids	38.30%
	CPVC	0.553
	PVC	0.451
	Q	0.815
Weight	$CaCO_3$	0.0%
	Opaque Polymer	7.9%
	ZnO	0.0%
	TiO_2	0.0%
	MS 20 micron	0.0%
	MS 10 micron	5.1%
	Kaolin Clay 1	0.0%
	Kaolin Clay 2	9.3%
Dry Volume Solids	$CaCO_3$	0.0%
	Opaque Polymer	8.0%
	ZnO	0.0%
	TiO_2	0.0%
	MS 20 micron	0.0%
	MS 10 micron	38.2%
	Kaolin Clay 1	0.0%
	Kaolin Clay 2	6.9%

Rating	N-D RF4
Total Solar Reflectivty	84.1
Emissivity	86.1
Solar Reflectance Index	105.1

Key Findings

- Bimodal distribution of 20 and 10 particles did NOT provide opacity as hoped; Low TiO_2 loadings must use 10 micron particles only
- Group 3 coatings (using ZnO) did not provide aceptable results
- A sufficiently high performing TiO_2-free concept coating is posible with 10 micron particles
- Group 2 coatings (Trace TiO_2 coatings) warrant further investigation

Formulation guidelines

How to incorporate HPMS in your formulation

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Choosing a Grade of Microspheres for Solar Reflectivity

Selecting a grade of HPMS for evaluation in a formulation is a very complex process.

- There are many factors that will impact the performance of HPMS

Smallest is best for maximum reflectivity

- 10 micron particle diameter is smallest commercially avaliable

Key points to consider:

- Colored or White coating?
- Intended gloss of the coating
- Final thickness of the coating

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Formulation guidelines

- **Formulation by volume is key in coatings filled with microspheres.**
  - It is important to keep in mind that HPMS add a lot of volume with very low weight.
- In a roof coating formulation:
  - In order to maintain the mechanical properties and a constant PVC, we recommend to replace $CaCO_3$ with HPMS by volume.
  - **<u>For high solar reflectance, the best start is to have 30% of the dry film volume solids of HPMS.</u>**
- **Incorporate microspheres in the let-down**
  - Modern grades of HPMS are capable of freely dispersing in solvent- and waterborne systems with little to no agitation.
  - Grinding is not necessary, but HPMS will survive the high shear forces if desired.

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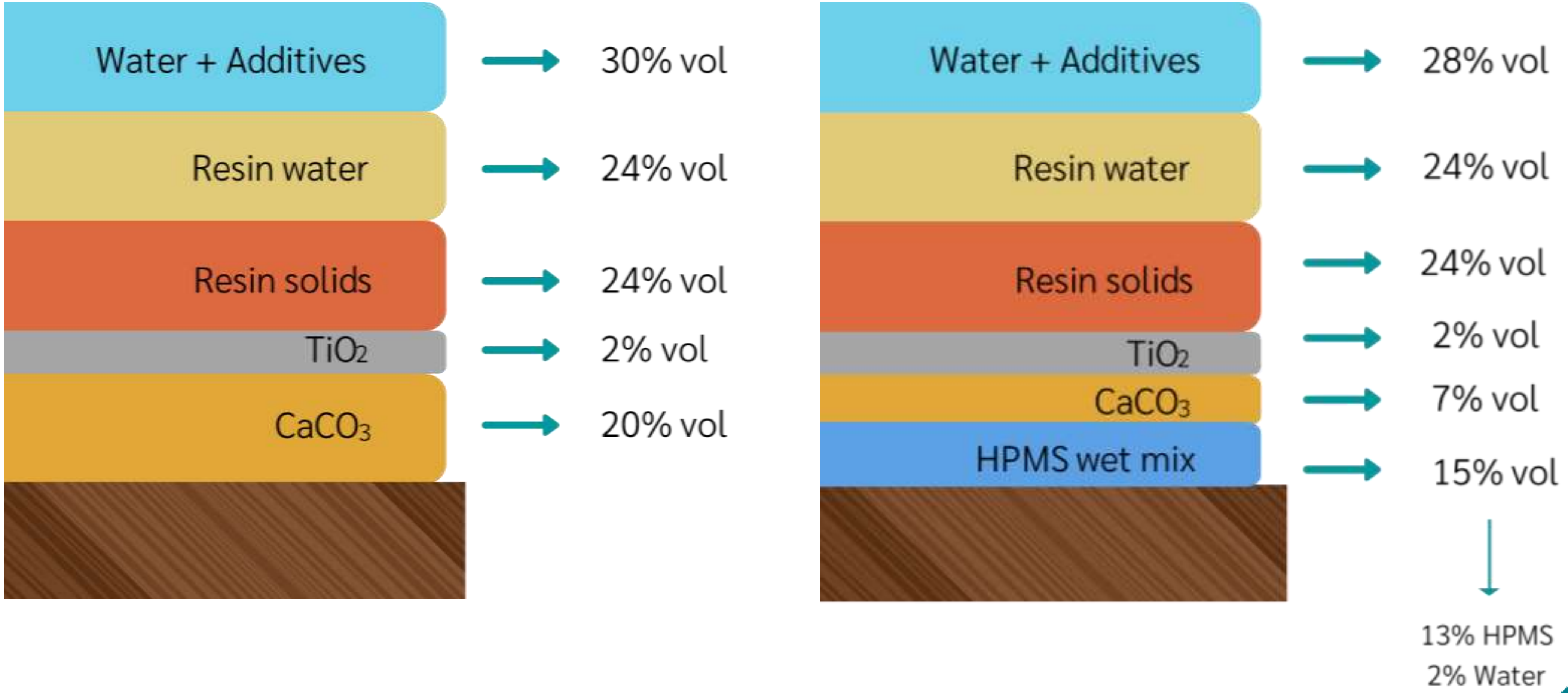
Wet film – Roof coating



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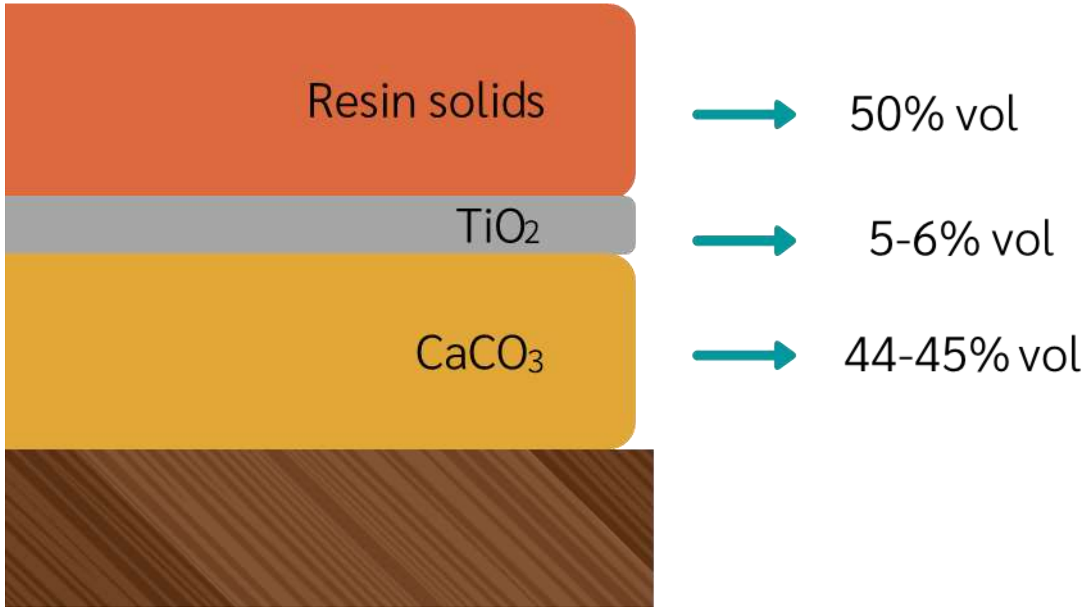
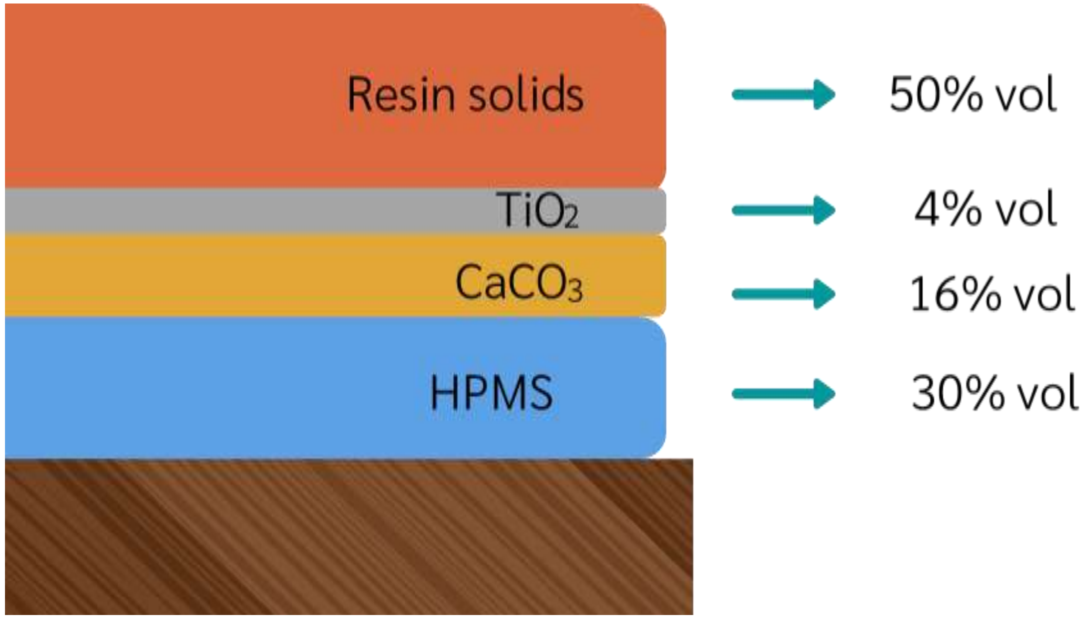
Dry film – Roof coating





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Condensed Starting Formulation Info
(Roof Coating)

NO HPMS Solid Calculations						WITH HPMS Solid Calculations				
	Solid Weight (lbs)	Solid Weight (%)	Solid Volume (gal)	Solid Volume (%)			Solid Weight (lbs)	Solid Weight (%)	Solid Volume (gal)	Solid Volume (%)
Acrylic binder	48.4	33.8%	104.1	64.1%		Acrylic binder	48.4	71.7%	104.1	64.1%
TiO2	8.8	6.2%	3.6	2.2%		TiO2	8.8	13.0%	3.6	2.2%
HPMS	0	0.0%	0	0.0%		HPMS	0.8	1.3%	48.7	30.0%
CaCO3	85.8	60.0%	54.7	33.7%		CaCO3	9.4	14.0%	6	3.7%

Solids Volume (%)	64.7%	Solids Volume (%)	64.7%
Solids Weight (%)	65.0%	Solids Weight (%)	45.2%
CPVC	0.64	CPVC	0.70
PVC	0.36	PVC	0.36
Q (PVC/CPVC)	0.56	Q (PVC/CPVC)	0.51

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	Opaque Polymer	7.9%
	ZnO	0.0%
	TiO_2	0.0%
	MS 20 micron	0.0%
	MS 10 micron	5.1%
	Kaolin Clay 1	0.0%
	Kaolin Clay 2	9.3%
Dry Volume Solids	$CaCO_3$	0.0%
	Opaque Polymer	8.0%
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Future Developments

- Enhanced weathering resistance from insoluble fillers like HPMS.
- Synergistic effect as matting agent and TiO_2 substitution in architectural paints.
- Further exploration into “trace” TiO_2 coatings
  - 100% opacity at 0.5% w/w TiO_2 with 10 micron particles demonstrated in unpublished data

Thank you!

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