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Evaluation of 3M™ Glass Bubbles for Solar Heat Reflection in Waterborne Acrylic Elastomeric Roof Coatings

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Outline

1. Introduction
2. Definitions
3. Characteristics of Elastomeric Roof Coatings
4. Materials
5. Formulation & Sample Preparation
6. Testing & Results
   - Basic Paint
   - PVC Study
   - Glass Bubbles compared to commercial microsphere blend as post addition to commercial paint
   - Energy Calculator
7. Summary

Introduction

1. Increase in construction builds = increased energy demand = **higher cooling costs** in warmer climates
2. Heat reflective roof coatings (typically white/lighter colors) are one option used to combat these costs due to their high solar reflectance and emittance values in the thermal infrared region.
3. Solar radiation spectrum divided into 3 bands:
   - UV: 200–400 nm → 5% of sunlight energy
   - Visible: 400–700 nm → 46% of sunlight energy
   - Near Infrared: 700–2500 nm → 49% of sunlight energy felt as heat

Accounts for **96%** of radiation in sunlight

Definitions

Solar Reflection

Typical “cool roof” coatings have TSRs >80%, primarily in visible and infrared regions. (TSR) is a weighted average of solar reflectance at each solar energy wavelength.

Thermal Emittance

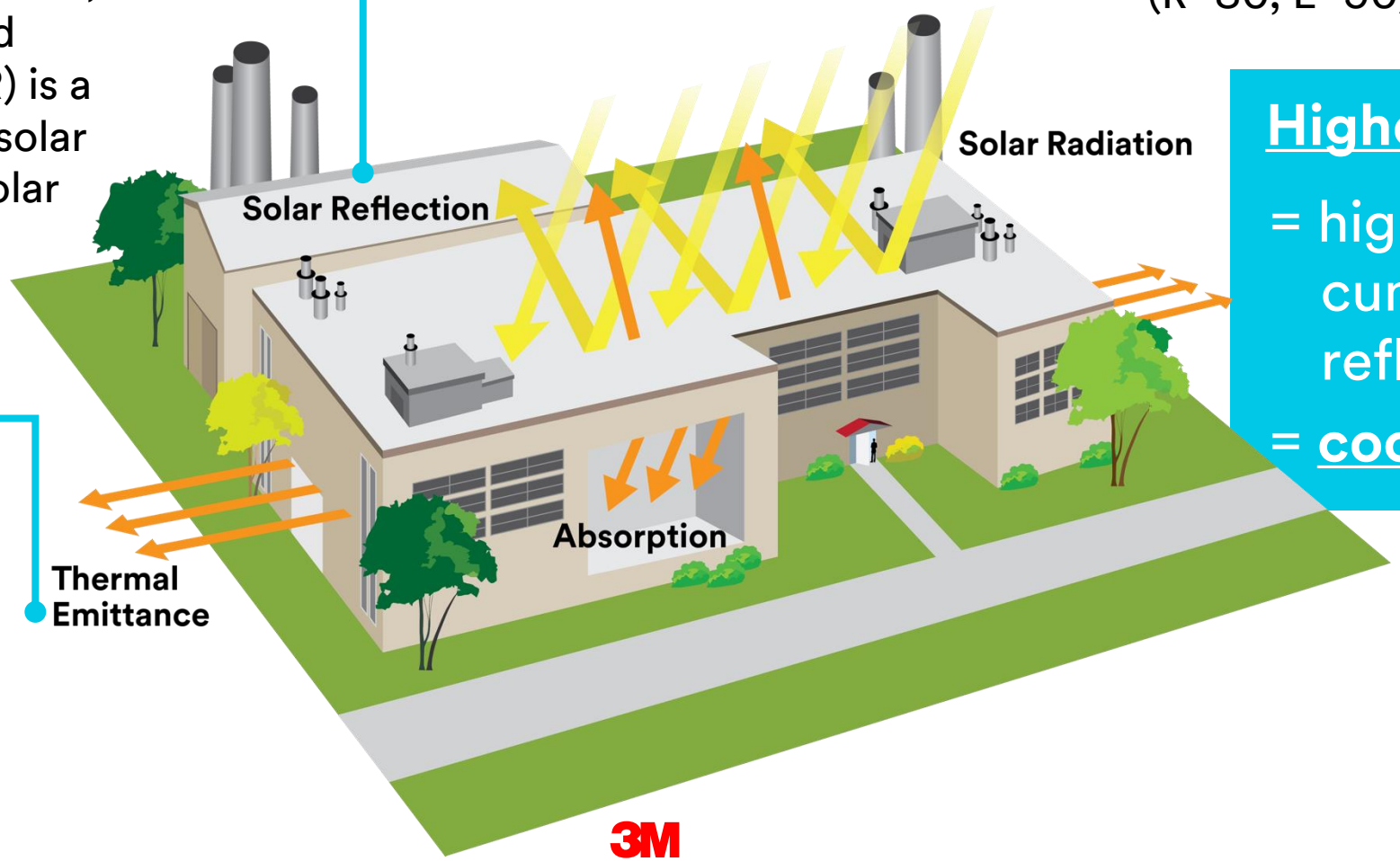
Amount of heat radiated per unit area at a given temperature (ability to give up heat).

Solar Reflectance Index (SRI)

*Calculations allow for SRIs >100.

A combined value of Reflectance and Emittance.*

- Standard black surface = 0 (R=5, E=90)
- Standard white = 100 (R=80, E=90)



Higher SRIs

= higher cumulative solar reflectance

= **cooler surfaces**

Elastomeric Roof Coatings: Typical Characteristics

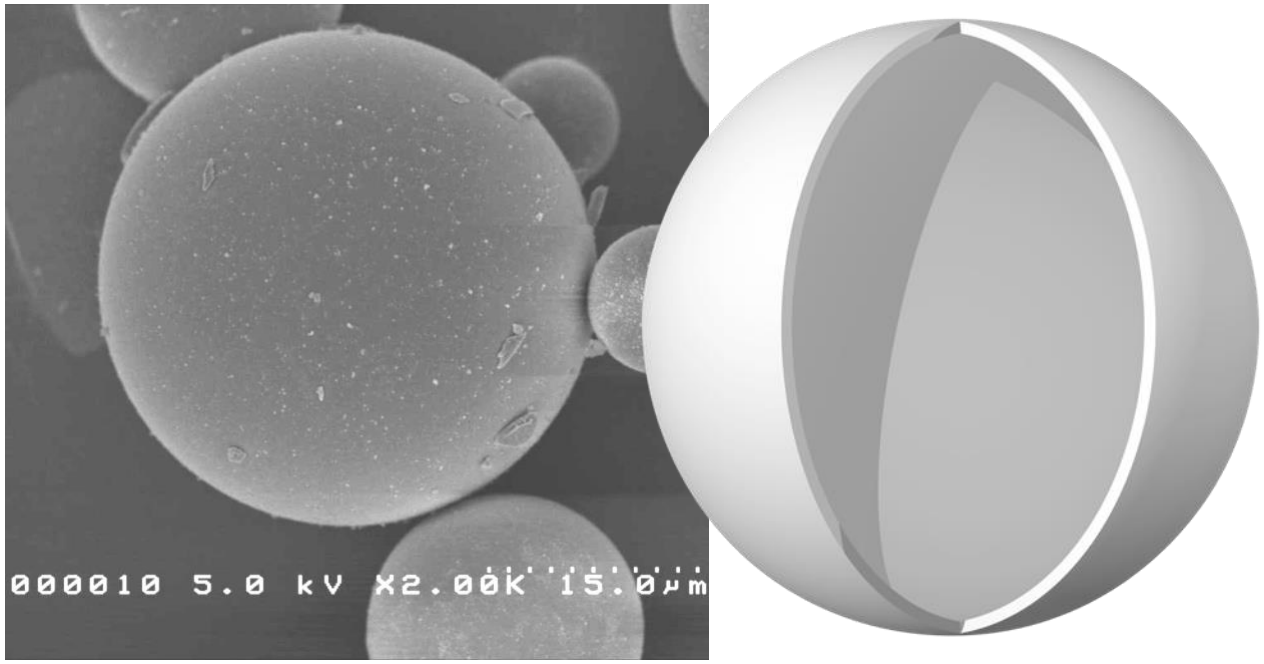
- Adhesion (Dry & Wet) to many construction substrates including polyurethane foams, metal(s), concrete, etc.
- Elasticity
- Low temperature flexibility & excellent elongation
- Water resistance
- Low toxicity and easy clean-up
- **Solar reflectance**
- **UV resistance**
- **DPUR (dirt pick-up resistance)**

These will be evaluated in addition to thermal effects as related to the inside temperature.

3M™ Glass Bubbles

Hollow Glass Microspheres

High-strength, low-density additives made from water resistant soda-lime-borosilicate glass.



3M™ Glass Bubbles	
Appearance	White Powder
Crush Strength, psi (90% survival)	250–28,000
True Density g/cc	0.15–0.6
Median Particle Size microns	16–65
Effective Top Particle Size, microns	27–120

Materials

Product	Target Crush Strength, psi (90% survival)	True Density (g/cc)	Particle Size Distribution (microns by volume)		
			10%	50%	90%
Calcium Carbonate ($CaCO_3$)	Hardness: 3–4 mohs	2.72	-	Average = 12 microns	-
Glass Bubble 3 (GB3)	16,000	0.46	12	20	30
Glass Bubble 1 (GB1)	250	0.125	30	65	115
Commercial Microsphere Blend (CMB) (solid particles)	7,000 (>98%)	0.73	-	Average = 100 microns	-
Glass Bubble 2 (GB2)	400	0.22	20	35	65
Commercial W/B Elastomeric Paint	N/A	N/A	N/A	N/A	N/A

Formulations

		$CaCO_3$ (control)	GB3	GB1	CMB	GB2
Material	WPG	Amount (gal)	Amount (gal)	Amount (gal)	Amount (gal)	Amount (gal)
Water	8.34	18.23	18.23	18.23	18.23	18.23
Dispersant	10.00	0.50	0.50	0.50	0.50	0.50
Potassium Tripolyphosphate	21.15	0.07	0.07	0.07	0.07	0.07
Cellulosic Thickener	11.61	0.30	0.30	0.30	0.30	0.30
Defoamer	7.10	0.28	0.28	0.28	0.28	0.28
Microbicide	8.33	0.18	0.18	0.18	0.18	0.18
Wetting Agent	8.97	0.22	0.22	0.22	0.22	0.22
Titanium Dioxide	32.33	2.32	2.32	2.32	2.32	2.32
Zinc Oxide	46.82	0.96	0.96	0.96	0.96	0.96
Calcium Carbonate	22.70	18.72	0	0	0	0
100% Acrylic Elastomeric Binder	8.70	54.60	54.60	54.60	54.60	54.60
Defoamer	7.10	0.21	0.21	0.21	0.21	0.21
Coalescent (e.g. Texanol™)	7.91	0.76	0.76	0.76	0.76	0.76
Mildewcide	8.60	0.28	0.28	0.28	0.28	0.28
Ammonia (28%)	7.69	0.13	0.13	0.13	0.13	0.13
GB3	3.84	0	18.72	0	0	0
GB1	1.04	0	0	18.72	0	0
Commercial Microsphere Blend	6.1	0	0	0	18.72	0
GB2	1.84	0	0	0	0	18.72
Propylene Glycol	8.66	1.62	1.62	1.62	1.62	1.62
Water	8.34	0.61	0.61	0.61	0.61	0.61
TOTALS		**99.99**	**99.99**	**99.99**	**99.99**	**99.99**

Formulations
(continued)

- Adjust viscosity with HASE (Hydrophobically-modified Alkali Swellable Emulsion) or appropriate thickener to 100-125 KUs
- PVC = 42 (details on following slide)
- NV (vol) = 52
- VOC = <50 grams/liter
- Glass bubbles added towards end to minimize breakage
- Commercial paint used as purchased

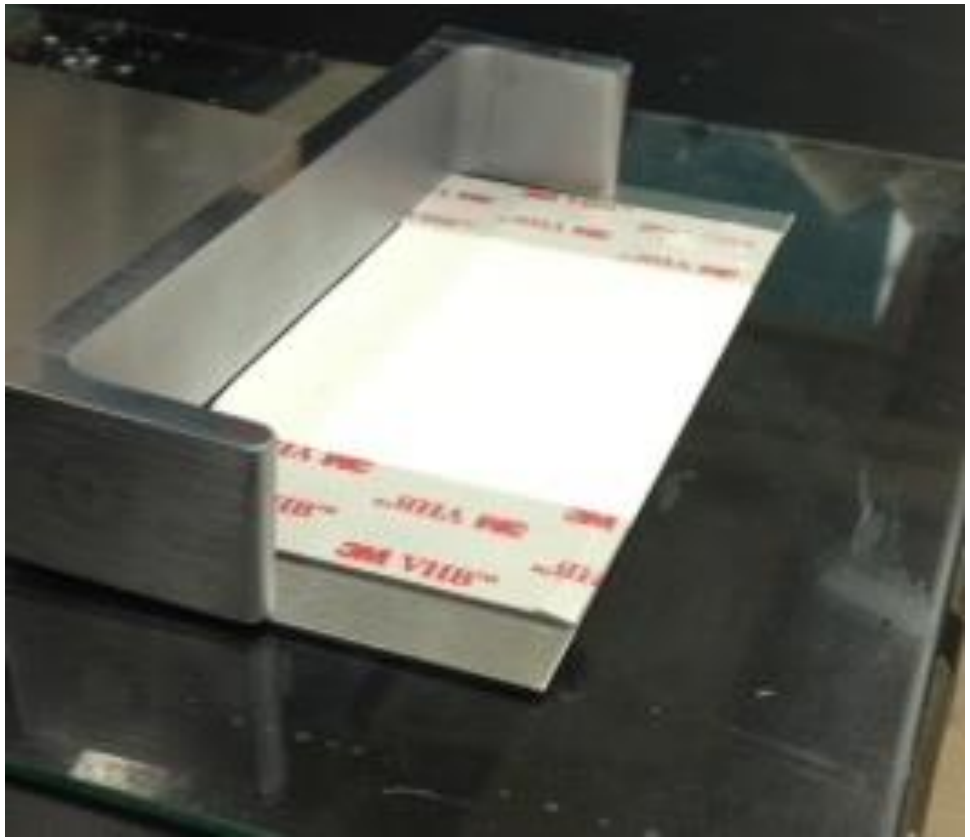
Formulation

42 PVC Paint

Raw Material	V% Wet	V% Dry
TiO_2	2.3	5.3
GB, $CaCO_3$ or CMB	18.7	35.3
Acrylic Binder	54.6	56.7
Other Ingredients	24.4	2.7

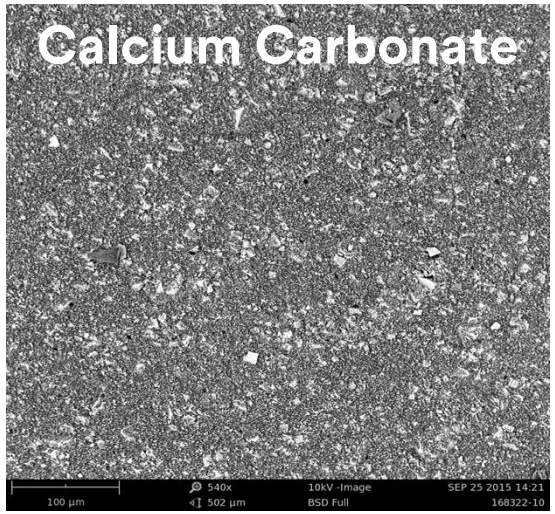
Sample Preparation

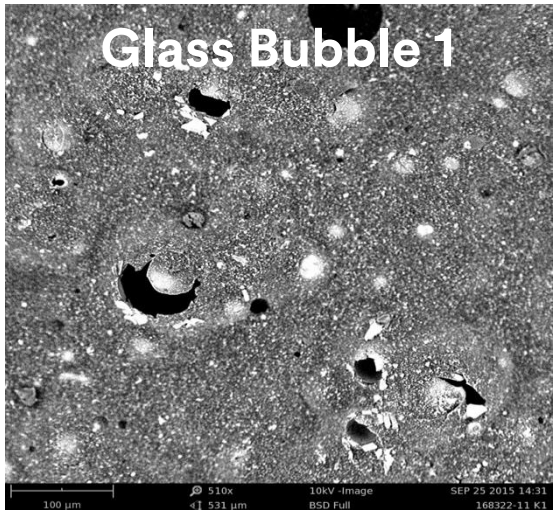
1. **Application:** Used drawdown bars and/or cast film(s) on black/white Leneta charts & 3003 H14 aluminum.
2. **Cure:** Air dry minimum 72 hours before testing. QUV samples aged minimum of 1 week before testing.

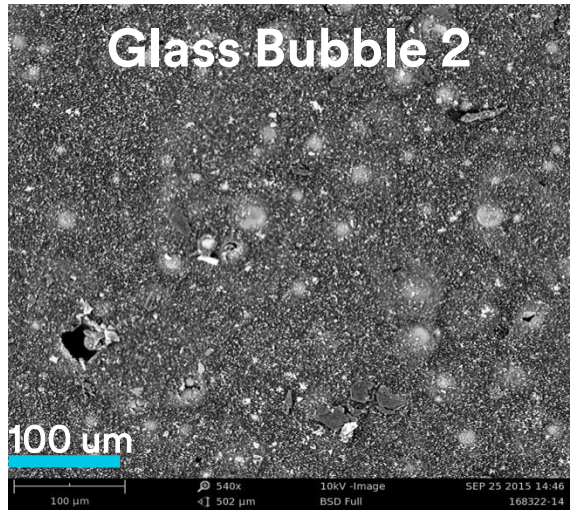


Scanning Electron Microscopy (SEM) of finished paint surface: 500X

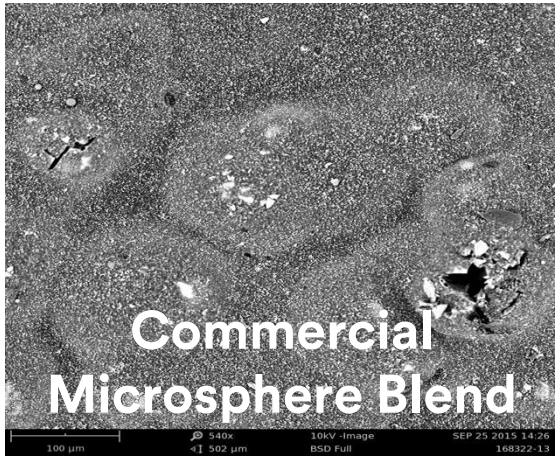
Images display surface topography of dried film

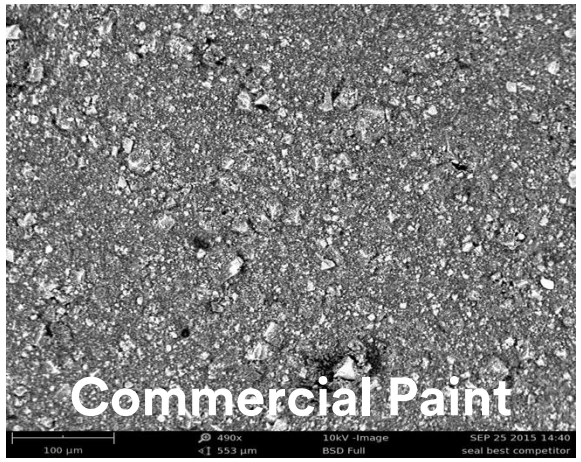






Smallest & strongest bubble





Test Methods

Property	Test Method
Opacity	ASTM D2805
Reflectance	ASTM E1347, ColorFlex® EZ Instrument
Gloss	ASTM D523
Dry Film Thickness	PosiTector® 6000
Solar Reflectance	ASTM E903/G173
Solar Reflectance Index	Computer model based on ASTM E1980
Thermal Emittance	ASTM C1371 (Total Hemispherical at ambient temp 72–78°F)
Infrared Lamp Test	3M Test Method
QUV Weathering	1000 hours, Proprietary Method (Reference G154)
DPUR	Dirt Pick-Up Resistance (24 hours/0–70 micron Arizona test dust)

Basic Paint Results

General Test Results: 15–20 mil films

Filler	Opacity	Reflectance Value Y	60° gloss
GB3	99.5	95.6	5
GB1	99.2	94.9	4.4
GB2	100.0	94.8	4
$CaCO_3$	99.5	92.7	4.5
Commercial Paint	100.3	89.1	3.1
Commercial Microsphere Blend	100.6	87.7	3.5

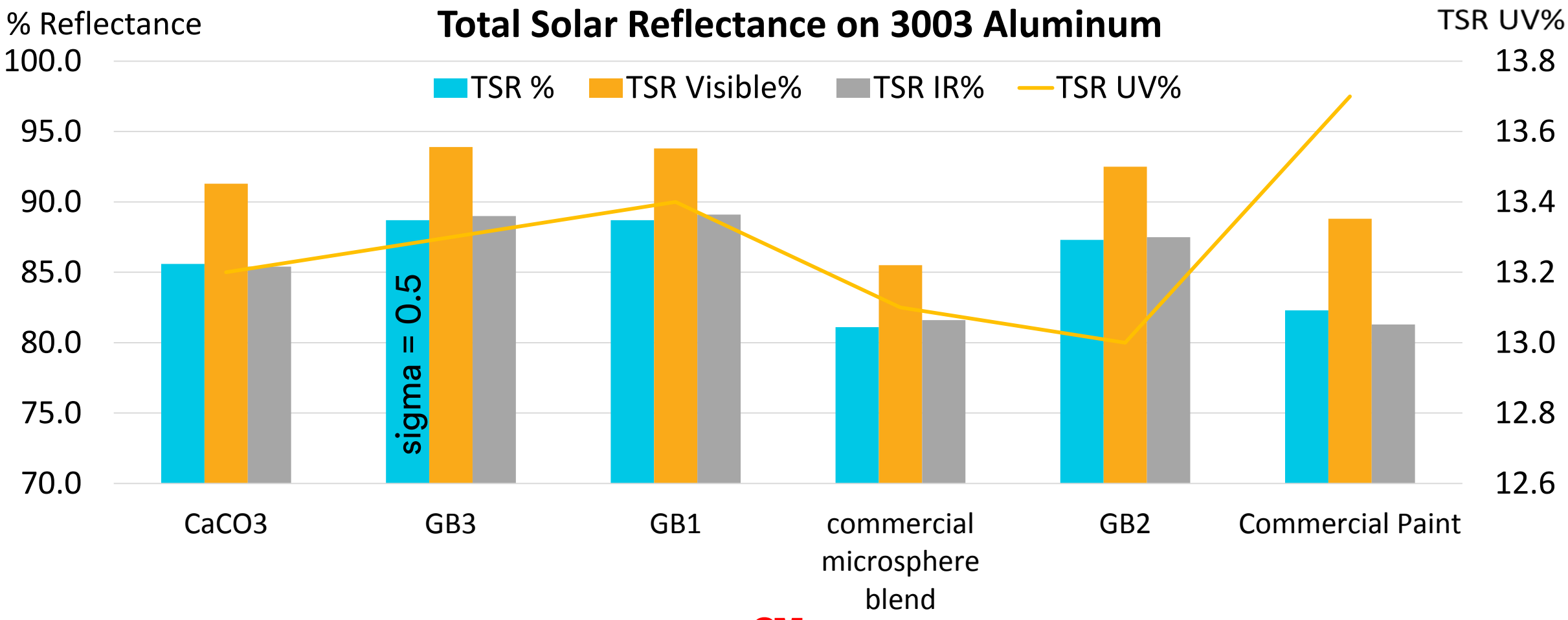
Similar gloss and opacities, but Glass Bubbles yield brighter/whiter appearance.

Solar Reflectance

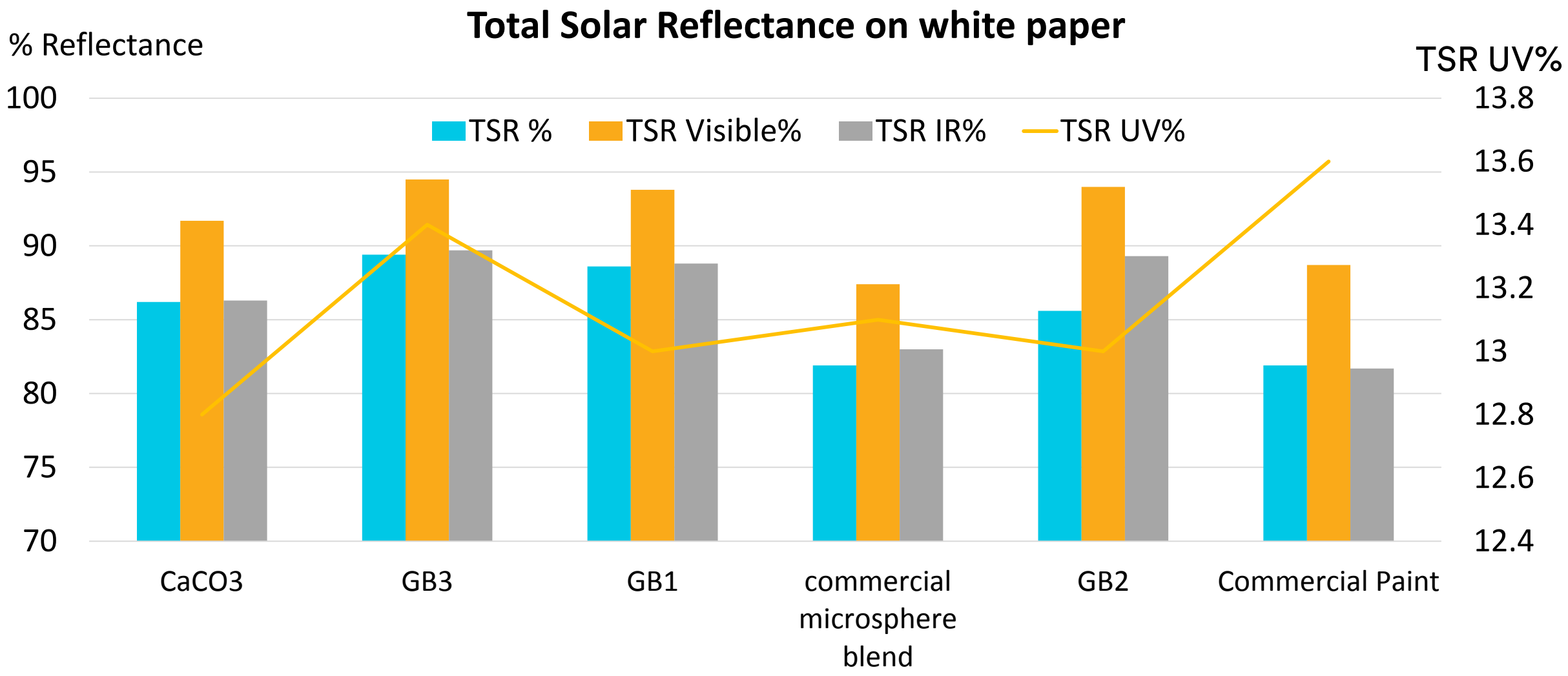
Perkin Elmer Lambda™ 950 Spectrometer – Near IR attachment (scan 250–2500 nm)

Solar Reflectance: Aluminum

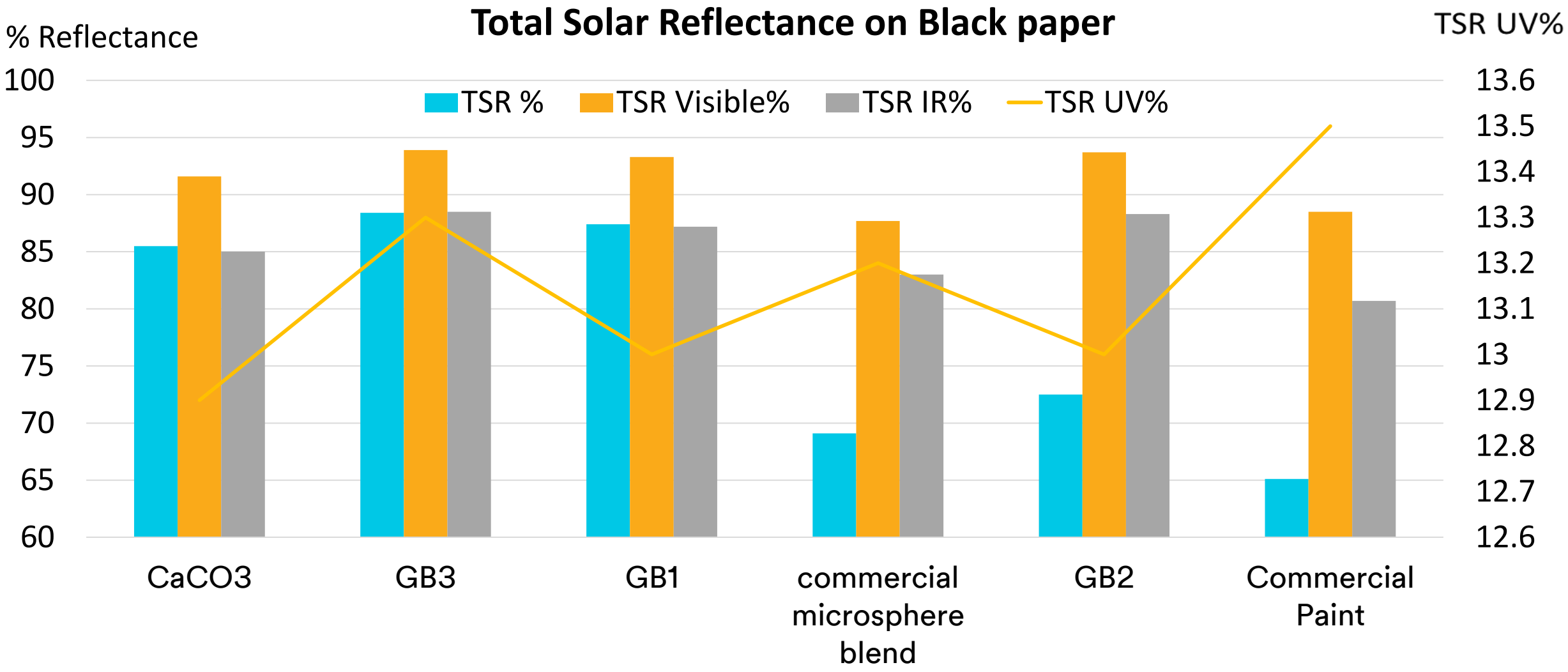
In general, Glass Bubbles offer very good overall Total Solar Reflectance (TSR).



Solar Reflectance: White Paper

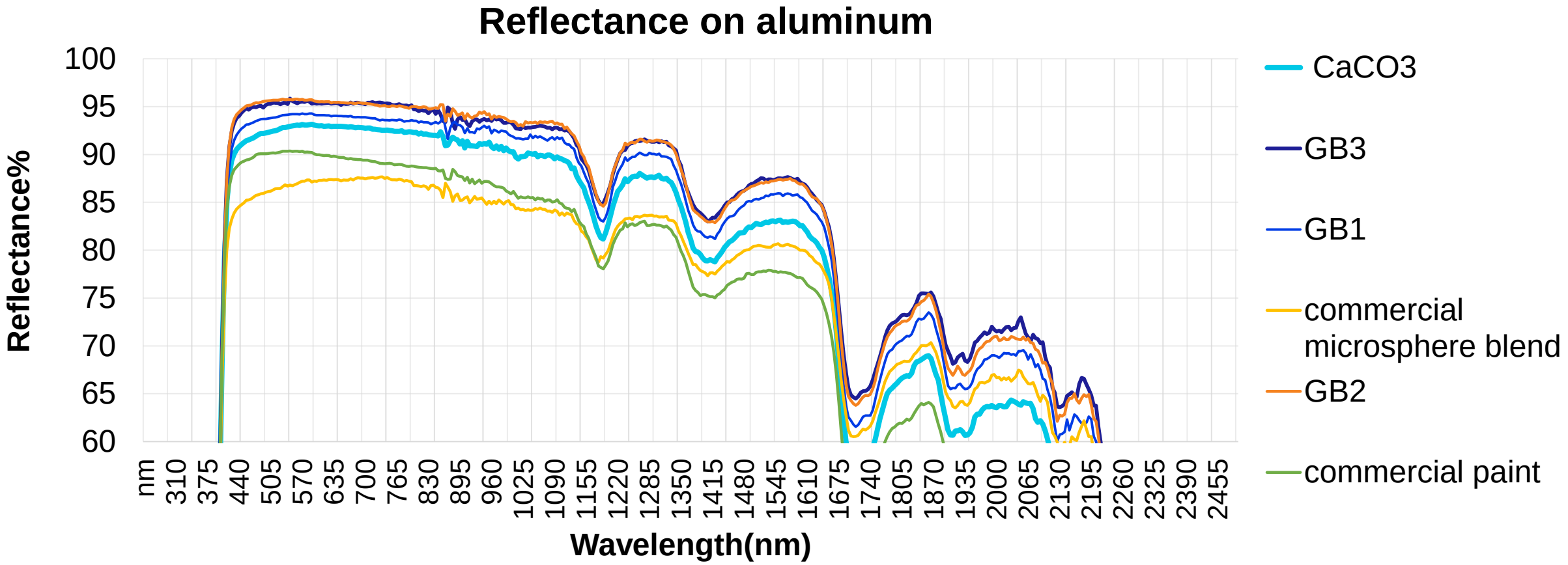


Solar Reflectance: Black Paper



Total Solar Reflectance

Trend is similar on all substrates: Glass Bubbles offer excellent overall TSR.
GB3 (smallest tested) exhibited best solar reflectance at all wavelengths.



Thermal Emittance

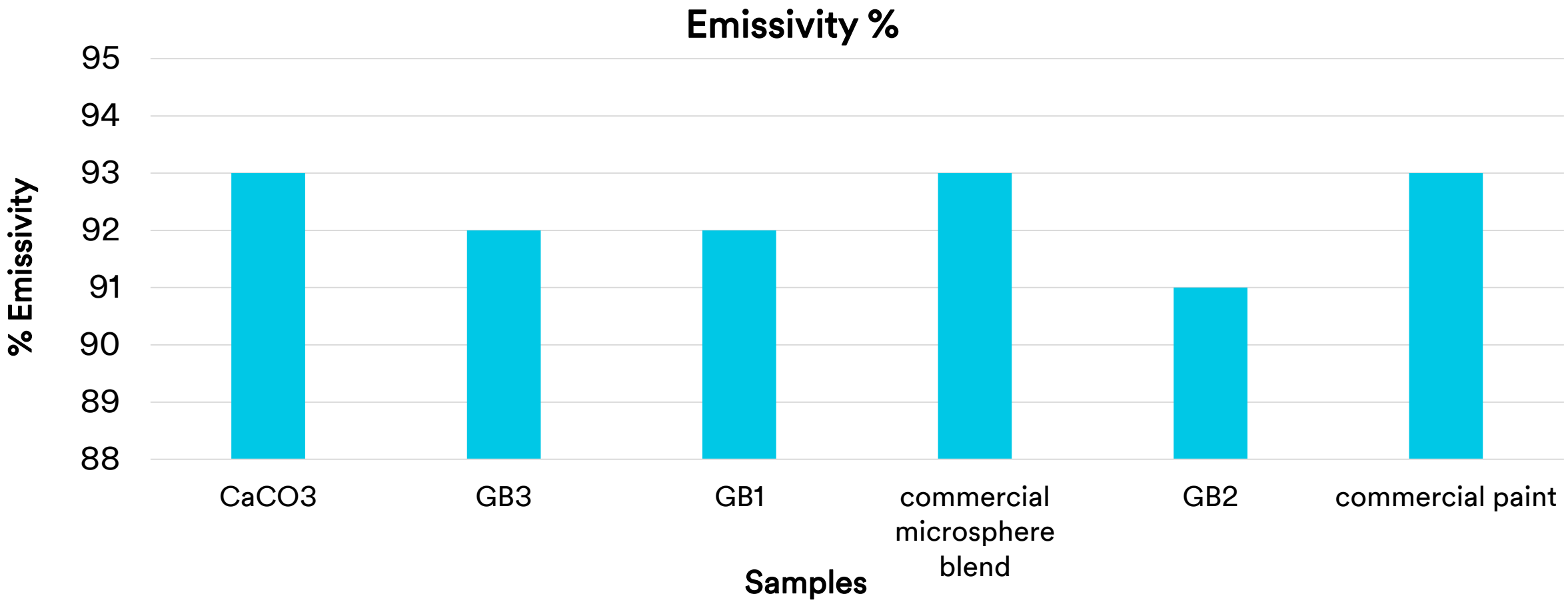
Portable unit, total hemispherical emittance

Black chip calibrated: 0.88

Stainless steel chip calibrated: 0.05

Emissivity Results

No appreciable differences in emissivity: all samples >90% on aluminum



Solar Reflectance Index (SRI)

Combined calculated value using solar reflectance and emittance (can be >100).

Higher value indicates higher overall reflectance.

Sample	Thermal Emittance	Total Solar Reflectance	Solar Reflectance Index (SRI)*	Calculated Roof Surface Temp. (°C)
$CaCO_3$	0.93	0.856	108	41.4
GB3	0.92	0.887	113	39.8
GB1	0.92	0.887	113	39.8
Commercial Microsphere Blend	0.93	0.811	102	43.8
GB2	0.91	0.873	111	40.6
Commercial Paint	0.93	0.823	104	43.2

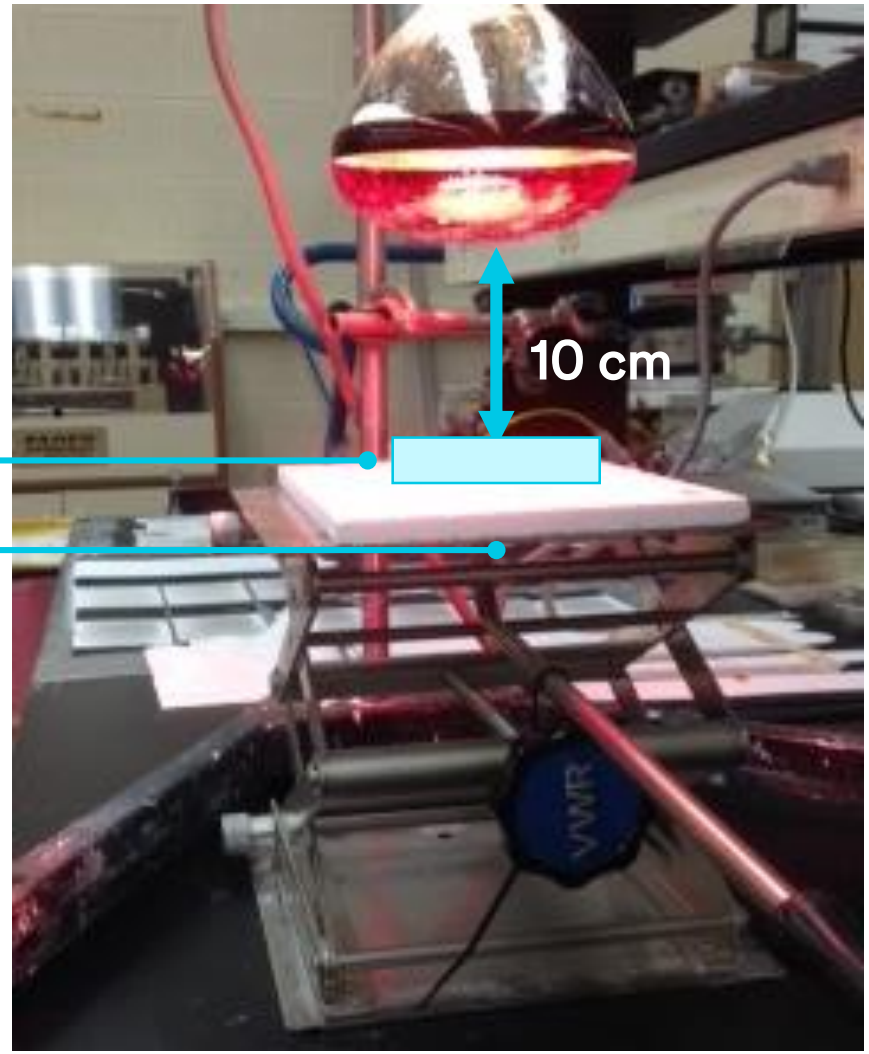
*Tool coded by Ronnen Levinson, Heat Island Group, Lawrence Berkeley National Laboratory (http://HeatIsland.LBL.gov)

For assistance, contact Hashem Akbari@H_Akbari@LBL.gov, or Ronnen Levinson at RMLLevinson@LBL.gov

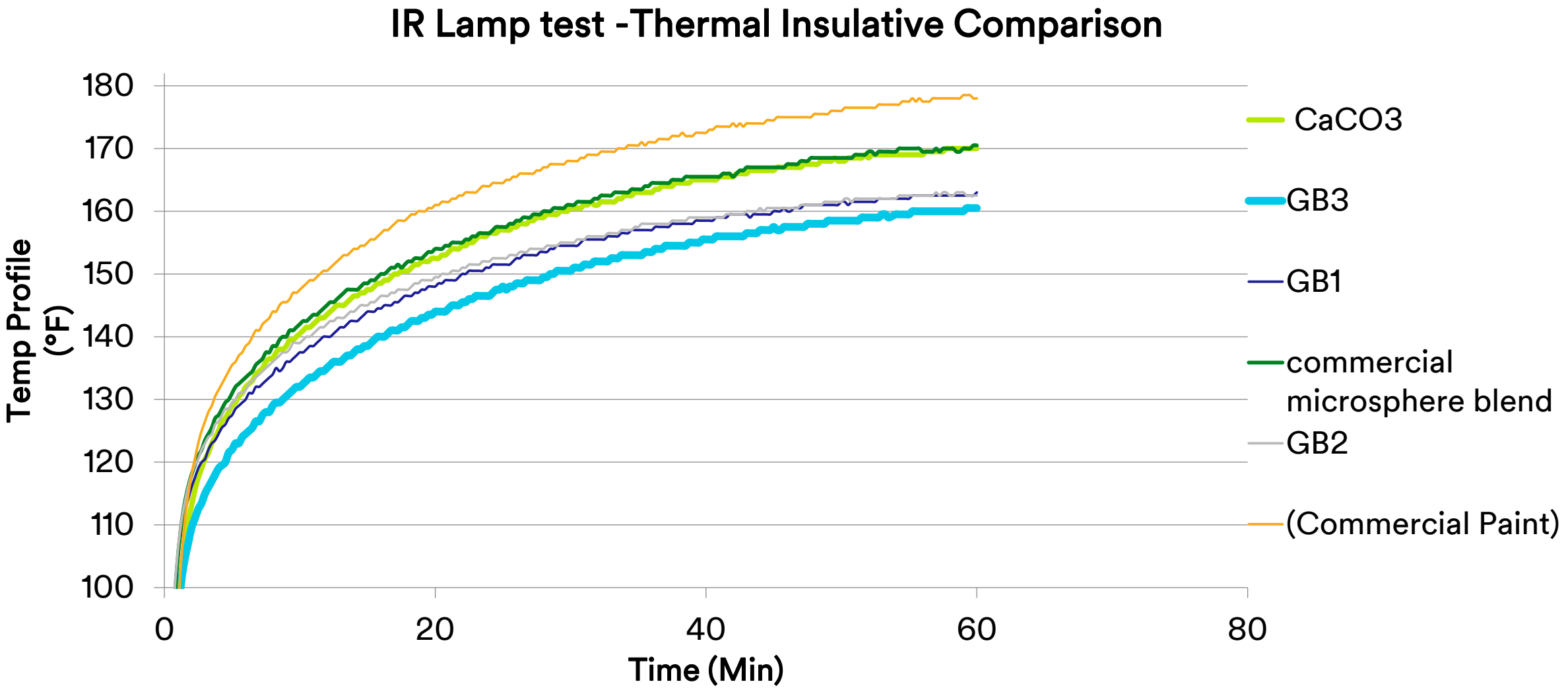
Infrared Lamp Test

Demonstrate effect of filler in coating on inside temperature of buildings

- IR lamp: Incandescent heat Lamp Light Bulb/ 250W/R40 reflector/120V
- Red triangle bulbs-T20931 250R40/red
- **Sample Size:** Approx. 6 x 5 cm. (aluminum chip)
- **Thermocouple:** Omega Engineering Type K with MicroDAQ EL-USB-TC logger
- Chip placed on ceramic plate- thermocouple attached to back side of aluminum through hole
- Distance to target: Approx. 10 cm.



Infrared Lamp Test Results



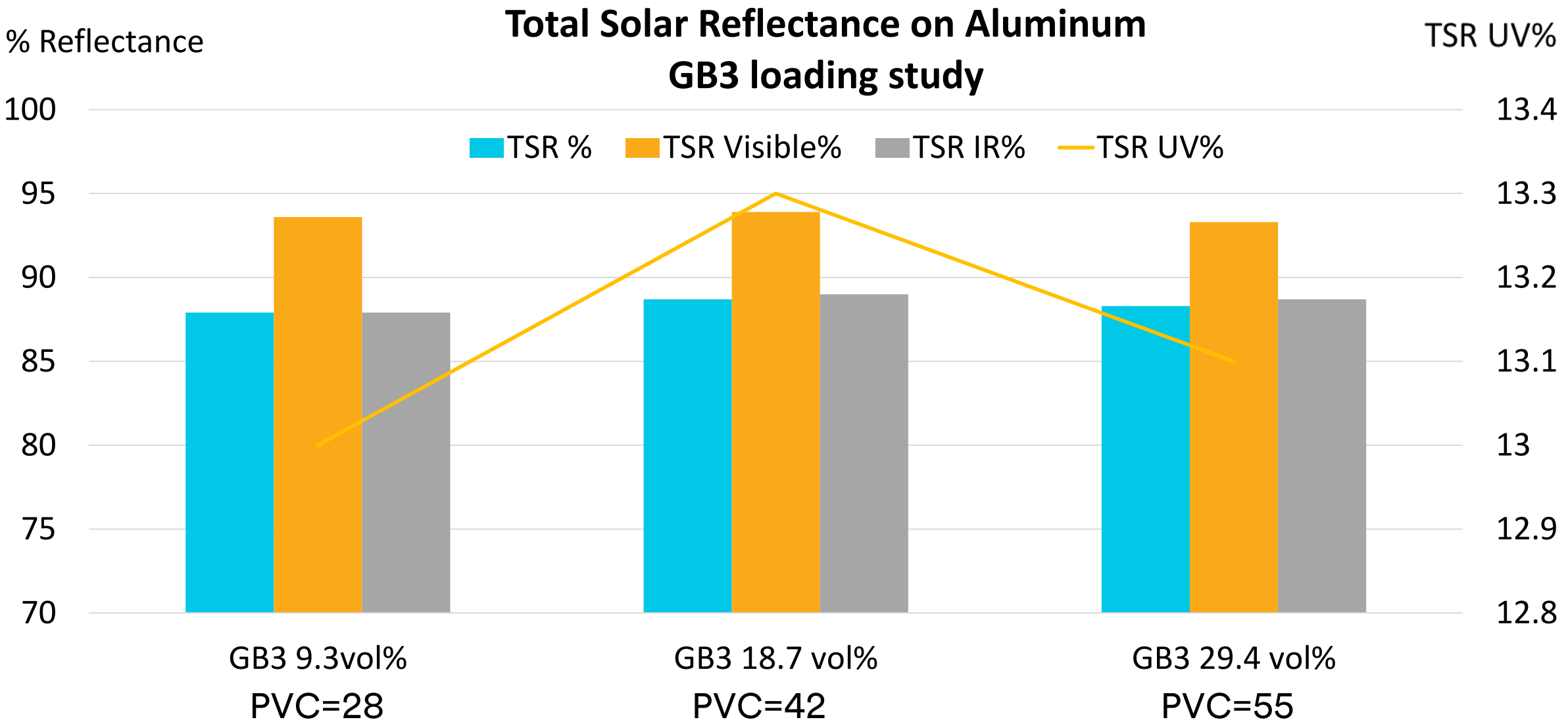
Infrared Lamp Test Results

GBs could yield cooler inside temp as simulation shows on back side of aluminum panel.

Sample	Overall Avg. Temperature (°F)	Avg. After 40 min.	Δ (°F) from $CaCO_3$
$CaCO_3$	154.4	167.9	Reference
GB3	145.6	158.3	↓ 9.6
GB1	149.6	161	↓ 6.9
Commercial Microsphere Blend	155.6	168.3	↑ 0.4
GB2	150.5	161.3	↓ 6.6
Commercial Paint	161.9	175.9	↑ 8.0

PVC Study with Glass Bubble 3

Solar Reflectance: Aluminum



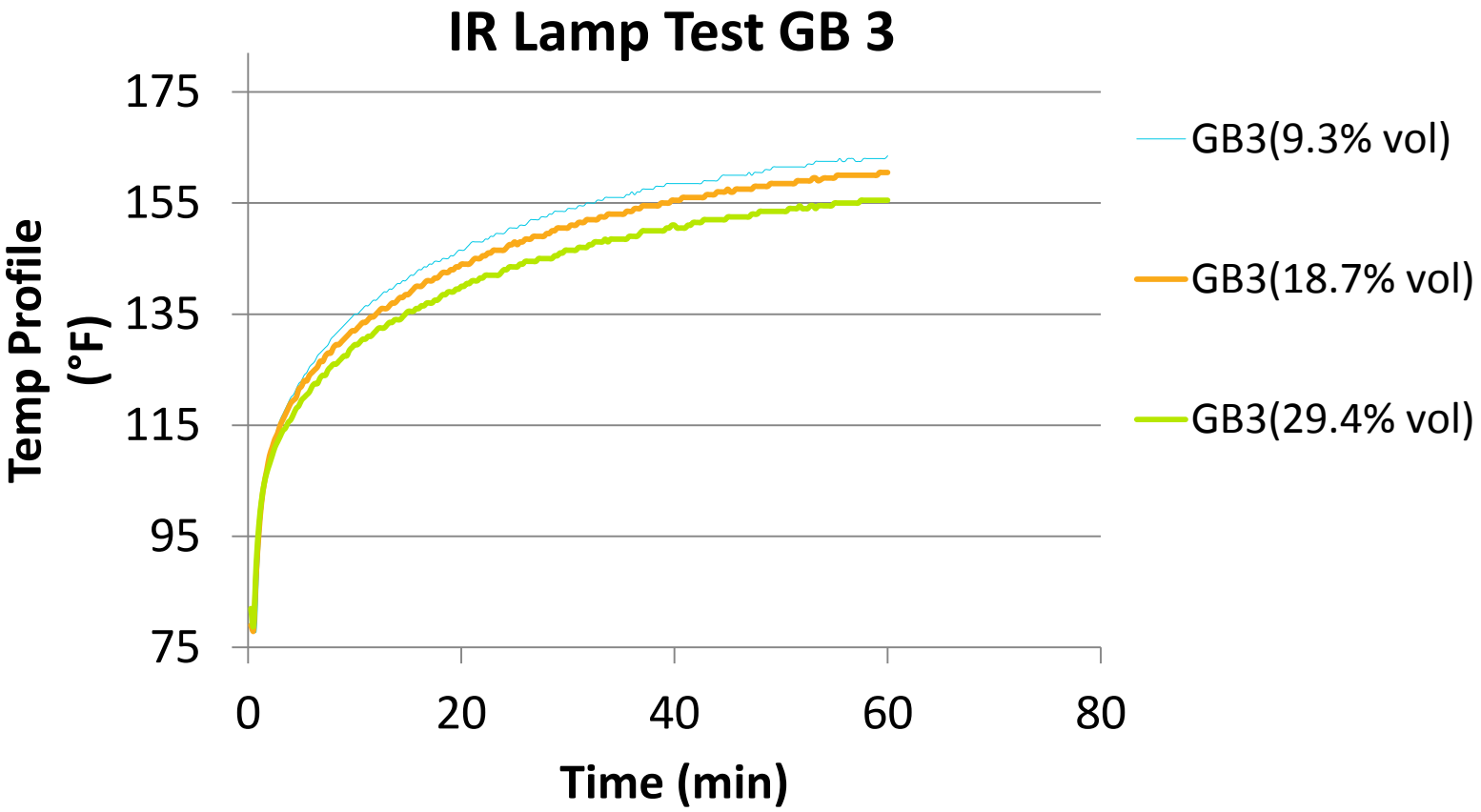
SRI: Solar Reflectance Index

No significant differences in calculated SRI even at lower loading of GB3.

Sample	V% wet	V% Dry	Paint PVC	Thermal Emittance	Total Solar Reflectance	Solar Reflectance Index (SRI)
GB3	9.3	20	28	0.93	0.879	112
GB3	18.7	35	42	0.93	0.887	113
GB3	29.4	50	55	0.92	0.883	112

Infrared Lamp Test Results

Higher GB3 loading levels yield lower temperatures at equilibrium.



Sample	Overall Avg. Temp (°F)	Avg. After 40 Min.	Δ (°F) From $CaCO_3$
$CaCO_3$ 18.7%	154.4	167.9	Reference
GB3 9.3%	148.2	161	6.9
GB3 18.7%	145.6	158.3	9.6
GB3 29.4%	141.7	153.5	14.4

Accelerated Weathering: 1000 Hours QUV

3 mil dry film thickness

Glass bubbles exhibited good gloss retention, and comparable color retention and DPUR.

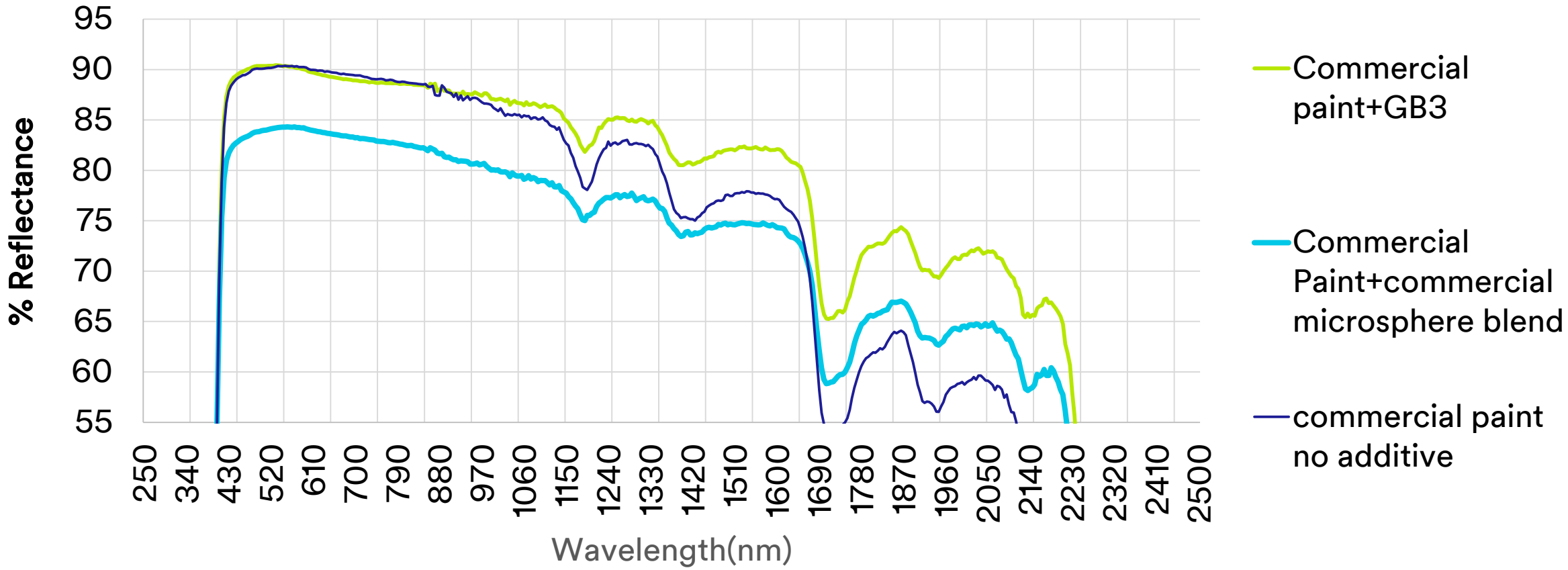
Sample	% 60° Gloss Loss	Total Color Change (DE)	DPUR (% Reflectance Recovery After QUV and 24 Hour Dry Dirt Test)
$CaCO_3$	38	0.4	96.2
GB3	0	0.27	97.0
GB1	0	0.45	94.5
Commercial Microsphere Blend	4	0.42	96.2
GB2	0	0.37	95.2
Commercial Paint	19	1.57	95.5

Glass Bubble 3 vs. Commercial Microsphere Blend

Total Solar Reflectance

GB3 vs. Commercial Microsphere Blend

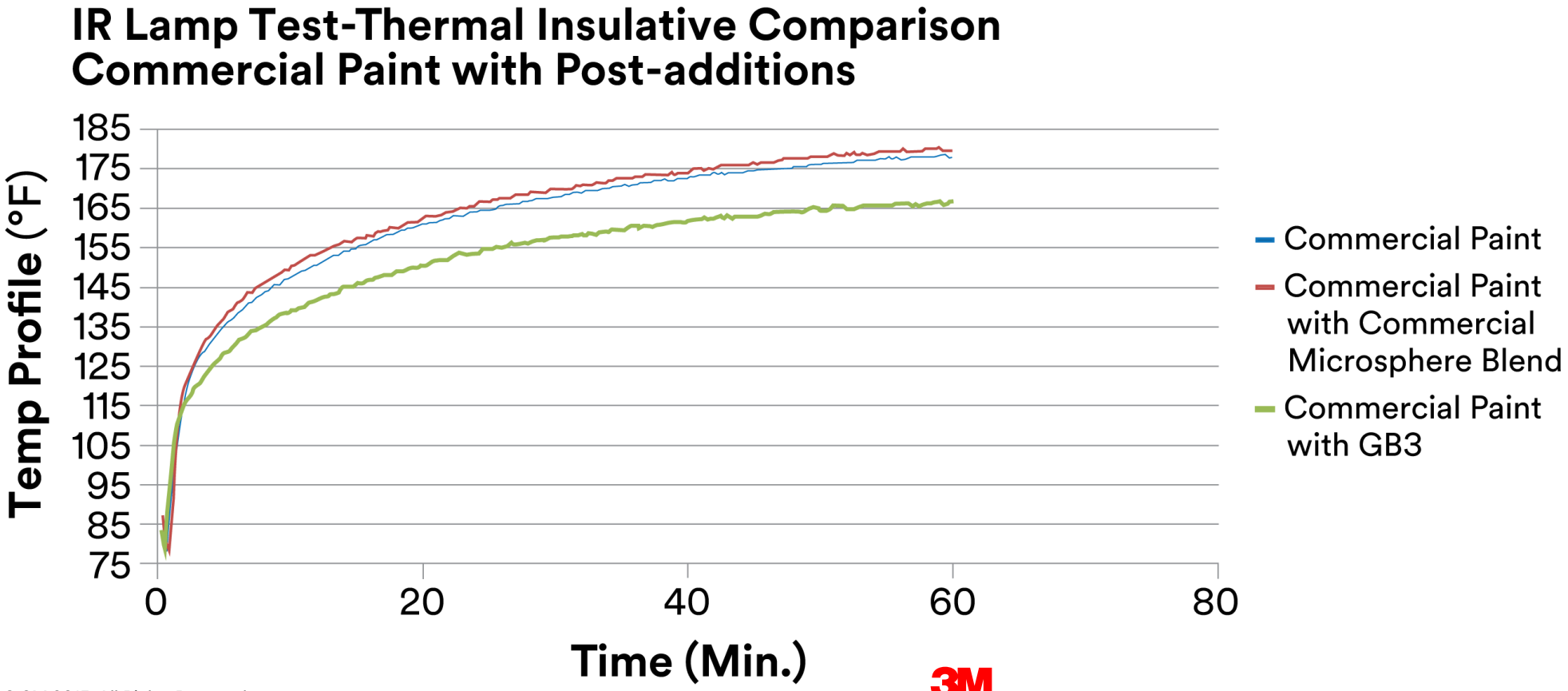
Post Addition of GB3 to commercial paint also increased total solar reflectance.



IR Lamp Test

Comparing GB3 vs Commercial Microsphere Blend

Post addition of glass bubbles could yield cooler inside temp as simulation shows on back side of aluminum panel.



Energy Cost Calculators: $$

One example: http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

Input in = Input out

Acrylic Formulation 42 PVC with 18.7% Volume Loading	TSR	Emittance	Energy Cost ($/kwH)	*Savings Over Black Roof ($/ft²/year)
$CaCO_3$	85.6	93	0.2	0.407
GB3	88.7	92	0.2	0.421
GB1	88.7	92	0.2	0.421
Commercial Microsphere Blend	81.1	93	0.2	0.384
GB2	87.3	91	0.2	0.412
Commercial Paint	82.3	93	0.2	0.391

*R value	Place	Air Conditioner Efficiency	Heat	Heat Cost ($/kwH)	Heat Efficiency
10	Miami, FL	2	Electric	0.2	0.7

Many factors can affect overall savings calculations

Summary

Smaller glass bubbles (GB3) may offer other benefits such as performance in darker colors and TSR after extended outdoor exposure.

Property	Benefits of 3M™ Glass Bubbles
Total Solar Reflectance	✓
Total Emissivity	✓
Insulative Properties/Lower Inside Temperature	✓
Energy Savings	✓
*Weatherability/DPUR	✓

Further optimization work is recommended to quantify other benefits such as benefits in darker colors & TSR after outdoor exposure.

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