POWDER COATING SUMMIT
SEPTEMBER 8-9, 2022

High dielectric materials as powder charging additives for Powder Coatings

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Introduction

Powder coating application issues

Applying powder coatings can sometimes be difficult:

- Not all the sprayed powder is charged and deposited on the piece
- Reclaimed powder is usually of lower quality
- Coating and thickness are not homogeneous
- Difficult to apply in corners (Faraday cage areas)

Powder coating application issues

Use of **high dielectric constant ceramic materials** as an alternative additive to promote powder charging:

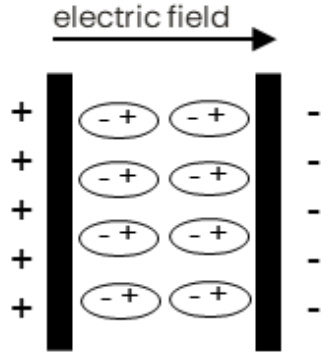
- coating homogeneity
- high first pass transfer efficiency
- high penetration in Faraday cage areas

- productivity in painting process
- reduce cost of application (waste, time and energy savings)
- improve material protection and service life

High dielectric ceramic material

Dielectric material

When placed in an electric field practically no current flows in them, and electric polarization occurs.



Characteristics:

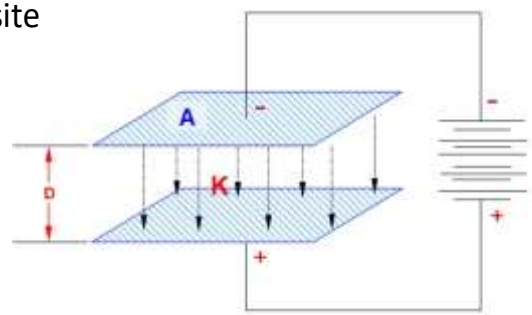
- Dielectric constant (K= relative permittivity)

Expresses the ability of a material to polarize in response to an applied field (store charges)

Material	Dielectric constant, K
Barium Titanate	2,000-7,000
Water	78
PVDF	6
SiO_2	4
Air	1.02

K = Dielectric Constant of the Composite
C = Capacitance (Farads)
D = Thickness
A = Area of Conductor Material

$$K = \frac{C * D}{A}$$



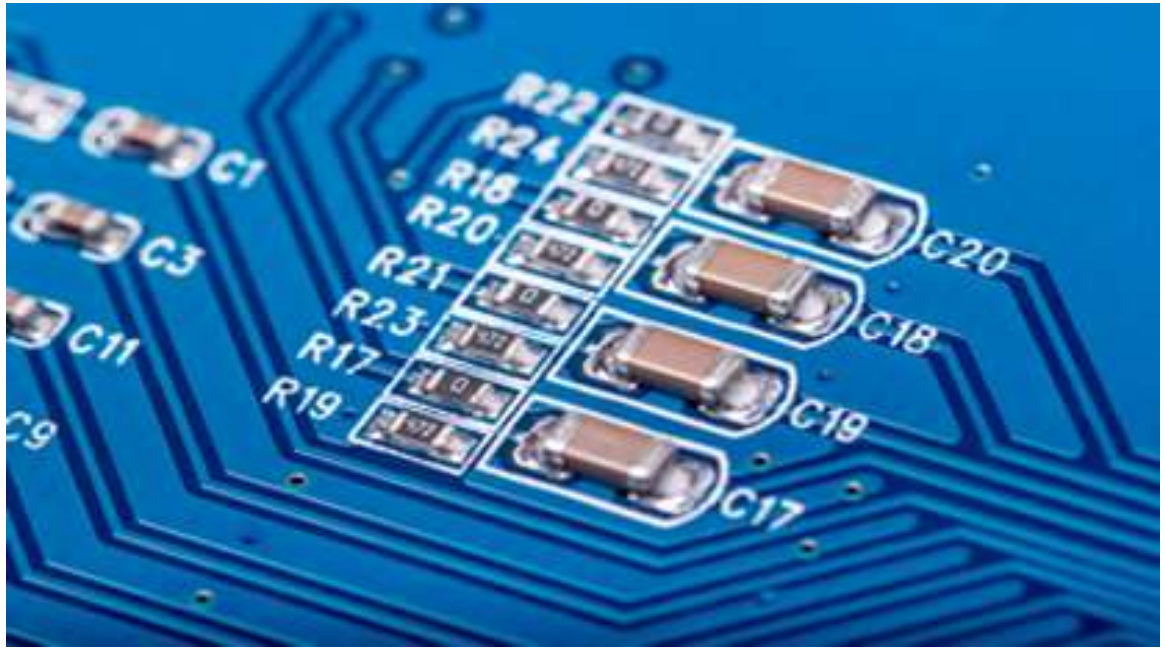
High dielectric ceramic material

Dielectric ceramic materials applications

Commonly used in electronic component manufacturing:

- Capacitors: passive electronic component used to store energy (charge)

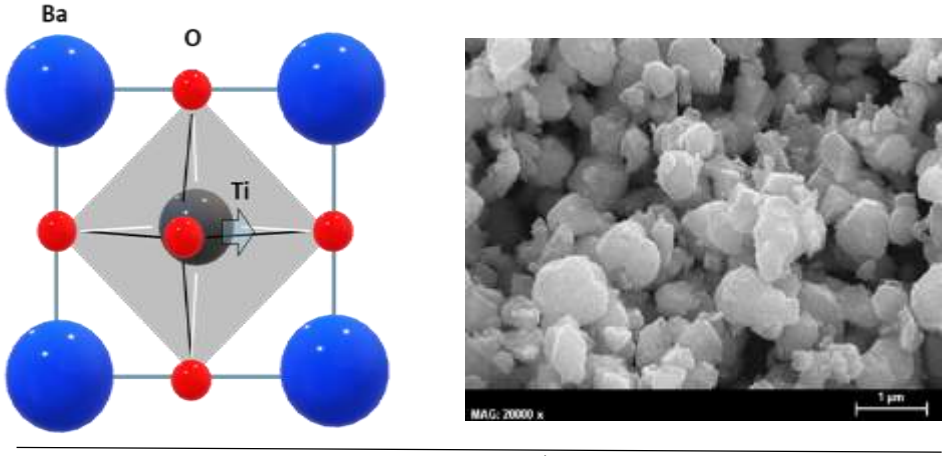
- filled-polymer composites
- microwave components
- implanted medical devices
- aerospace components



High dielectric ceramic material

Barium Titanate ($BaTiO_3$)

- Key ingredient of ceramic capacitor components
- White piezoelectric ceramic material with high dielectric constant



Barium Titanate structure and SEM picture

"Barium Titanate A" characteristics

Properties	Value	Analysis Method
Specific gravity (g/cm^3)	6.0	ASTM D-153
Oil Absorption (g/100g)	13	ASTM D-281
Particle size D50 (µm)	1.24	Horiba LA-910, QC135
Loss on ignition (wt-%)	0.02	QC016
pH	10.0	QC010E
Surface Area (m^2/g)	2.15	Micromeritics Tristar, QC145
Refractive index	2.4	RefractiveIndex.INFO
Appearance	White powder	Visual

Experimental

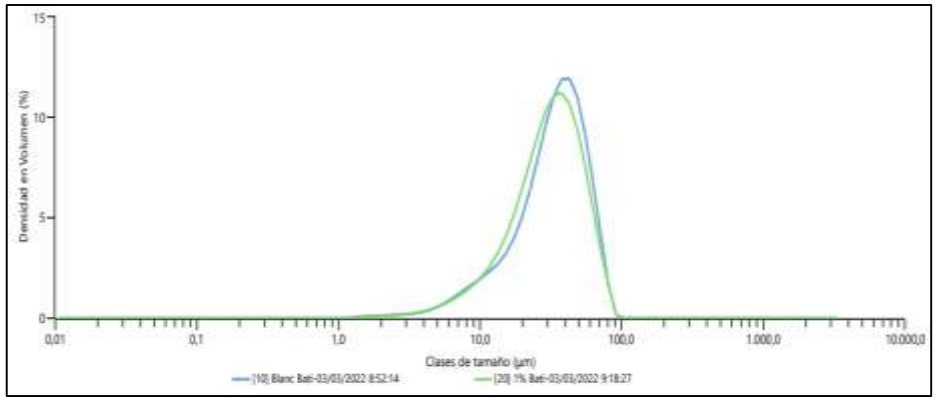
Paint formulation and process

White Polyester-HAA Powder Coating

	Control		
	%	%	%
Polyester resin	61.9	61.9	61.9
Hydroxyalkylamide	2.7	2.7	2.7
Degassing agent	0.2	0.2	0.2
Leveling agent	0.8	0.8	0.8
Flow agent	4.5	4.5	4.5
Barium Sulphate	9.9	9.4	8.9
Titanium Dioxide	20	20	20
BariumTitanate A	**0**	**0.5**	**1.0**
	100	**100**	**100**

Process:

- Manual premix, 5 minutes
- Double extruder: High Speed Twin Screw Extruder
- Extrusion T: 120°C (248ºF) zone 1 / 140°C (284°F) zone 2
- Grinding in a household-grinder
- Sieved <105µm (140 mesh)
- PSD: Dv(50) ≈ 30 µm



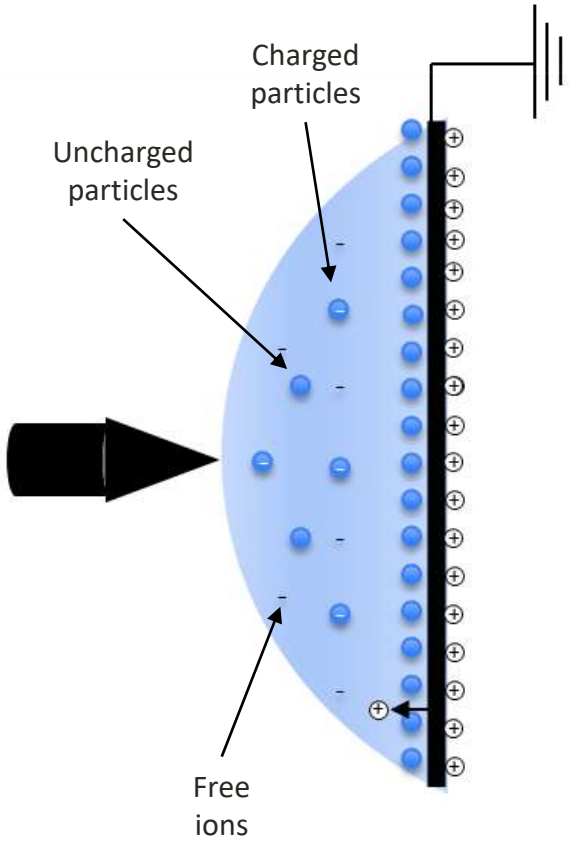
PSD: Malvern Mastersizer 3000

Powder Coating application

Process:

- Corona Electrostatic spraying gun: 70 kV, 40 µA, 1 bar
- Distance of gun to piece: 25cm

-> Barium Titanate polarization and charge retention

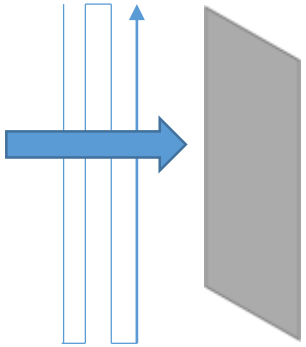


Substrates:

- Flat Shape:
  - Cold rolled steel
  - Galvanized steel
  - Phosphated steel
  - Aluminum
- 3D-Shape (Faraday cage):
  - Aluminum
- Stoving in an air-circulated oven (8 minutes 200°C (392°F))

Application on flat surfaces

Application pattern:



	Control	1% Barium Titanate A

Cold Rolled Steel (S-46) 6 spray passes (6”)

		Film thickness (up/mid/bottom)	% vs Control	Paint weight on panel (g)	% vs Control
Galvanized Steel Espancolor SG015 6 spray passes (6”)	**Control**	29µ/23µ/25µ		1.3	
	+1% Barium titanate A	33µ/24µ/35µ	+19%	1.5	+16%

		Film thickness (up/mid/bottom)	% vs Control	Paint weight on panel (g)	% vs Control
Cold Rolled Steel S-46 Q-Panel 6 spray passes (6”)	**Control**	29µ/23µ/30µ		1.7	
	+1% Barium titanate A	45µ/50µ/60µ	+109%	2.5	+51%

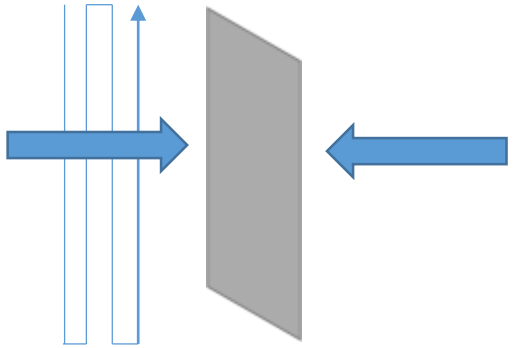
		Film thickness (up/mid/bottom)	% vs Control	Paint weight on panel (g)	% vs Control
Phosphated Steel R-36I Q-Panel 4 spray passes (4”)	**Control**	45µ/49µ/63µ		1.0	
	+1% Barium titanate A	58µ/58µ/59µ	+11%	1.3	+28%

		Film thickness (up/mid/bottom)	% vs Control	Paint weight on panel (g)	% vs Control
Aluminium AA3015 Espancolor 12 spray passes (12”)	**Control**	64/66//72		2.80	
	+1% Barium titanate A	112/102/108	+59%	3.15	+13%

Application on flat CRS panels

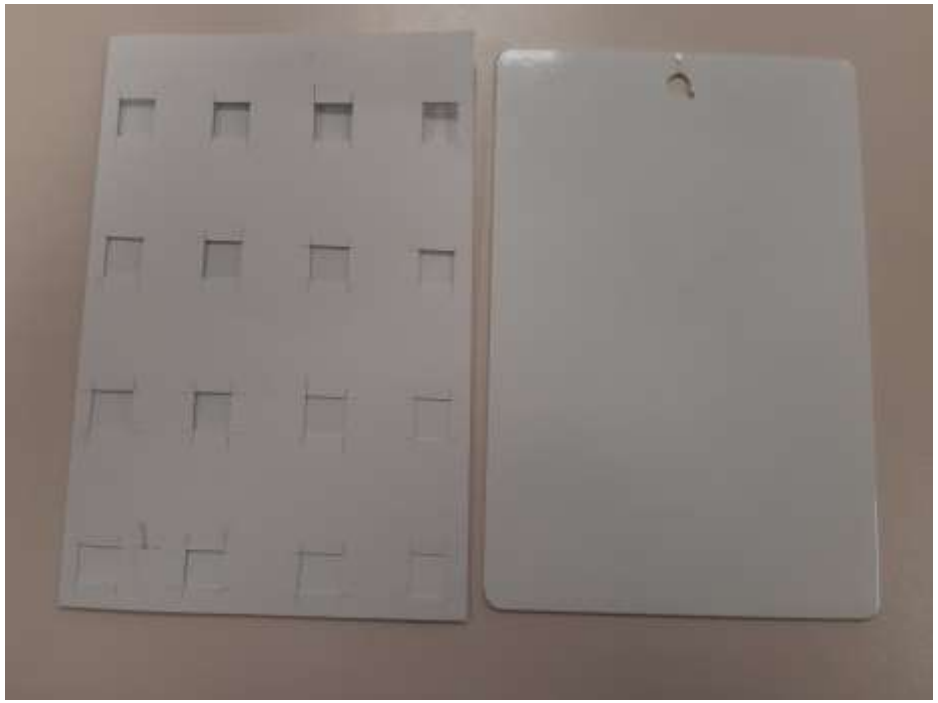
Application pattern:

Cold Rolled Steel (S-46 Q-Panel)
4 spray passes (up/down)
on front and back sides
(2x4”=8”)



DFT measurement pattern:

16 DFT measurements on same parts of each panel



Application on flat CRS panels

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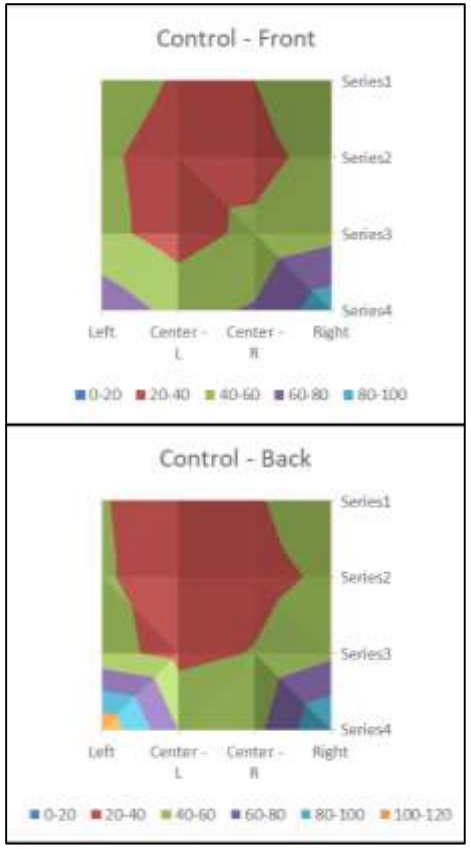
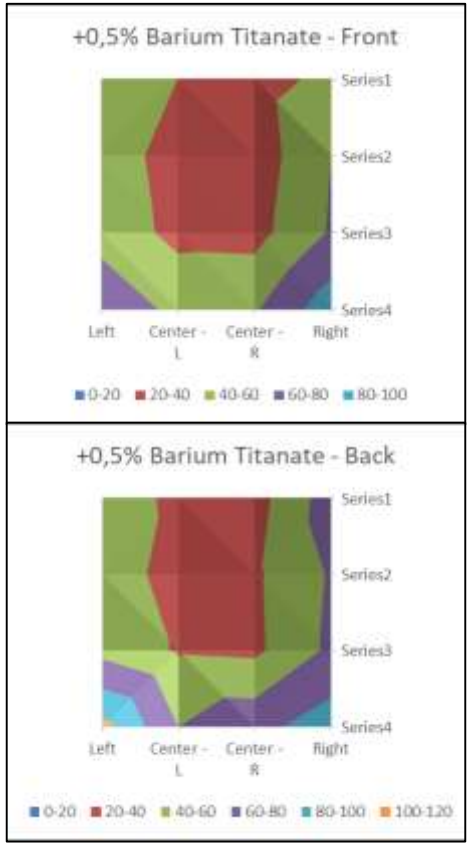
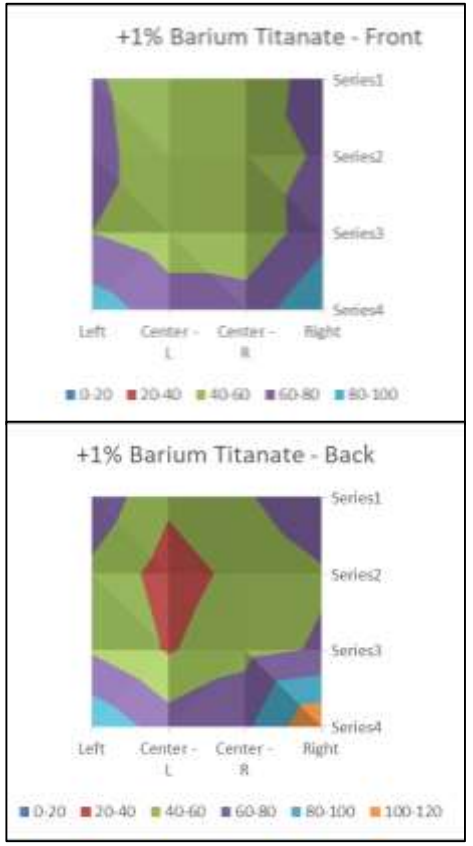
Film thickness (µm)

Side	Zone	Control				0.5% Barium Titanate A				1% Barium Titanate A			
		L	LC	RC	R	L	LC	RC	R	L	LC	RC	R
Front	1	50	38	40	60	52	40	32	45	64	43	41	74
	2	44	30	32	50	52	31	29	60	66	49	45	64
	3	46	31	45	54	54	34	33	62	60	49	44	74
	4	72	54	62	92	72	56	58	92	90	70	70	96
Back	1	42	23	38	52	52	35	32	70	74	44	58	74
	2	44	22	33	44	54	30	37	62	56	31	46	58
	3	46	34	41	56	54	38	36	64	58	38	54	62
	4	116	60	54	100	106	60	74	90	96	70	76	118
Front	Mean	50				50				62			
	Dev Std	16				17				17			
Back	Mean	50				56				63			
	Dev Std	25				22				22			
Total panel	Mean	50				53				63			
	Dev Std.	21				19				19			
						+6% FT increase				+20% FT increase			







Application on flat CRS Panels

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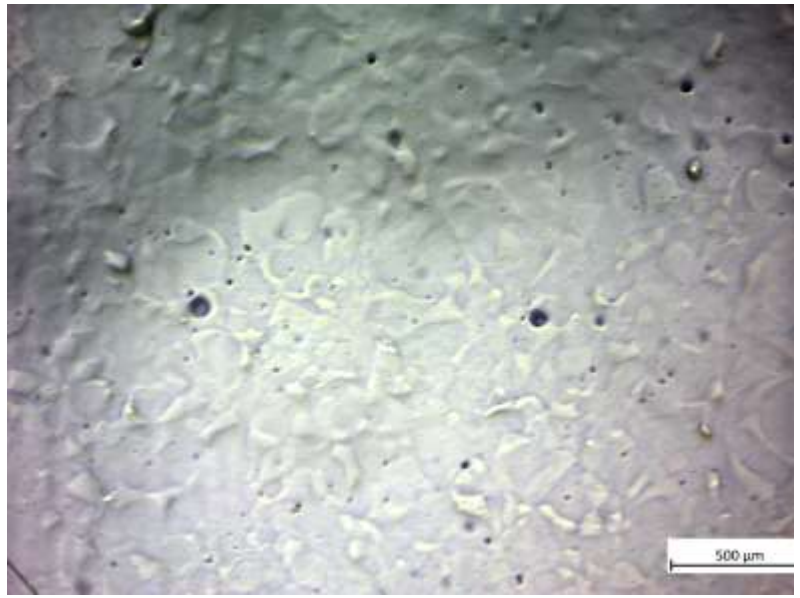
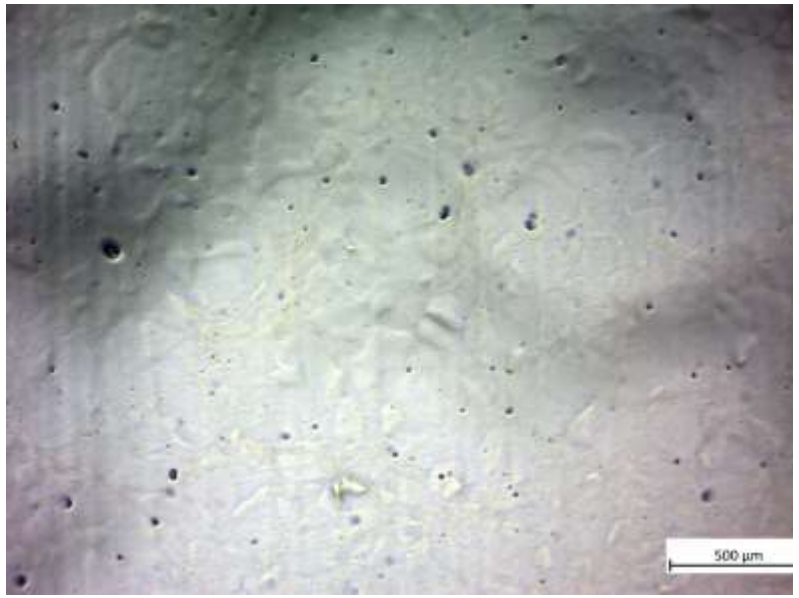
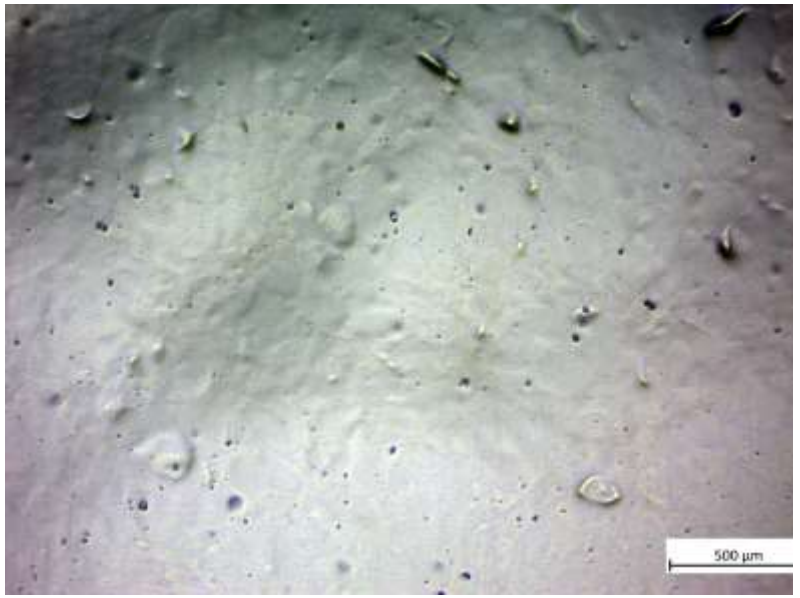
Surface observation (optical microscope, 5x)

Control	0.5% Barium Titanate A	1.0% Barium Titanate A



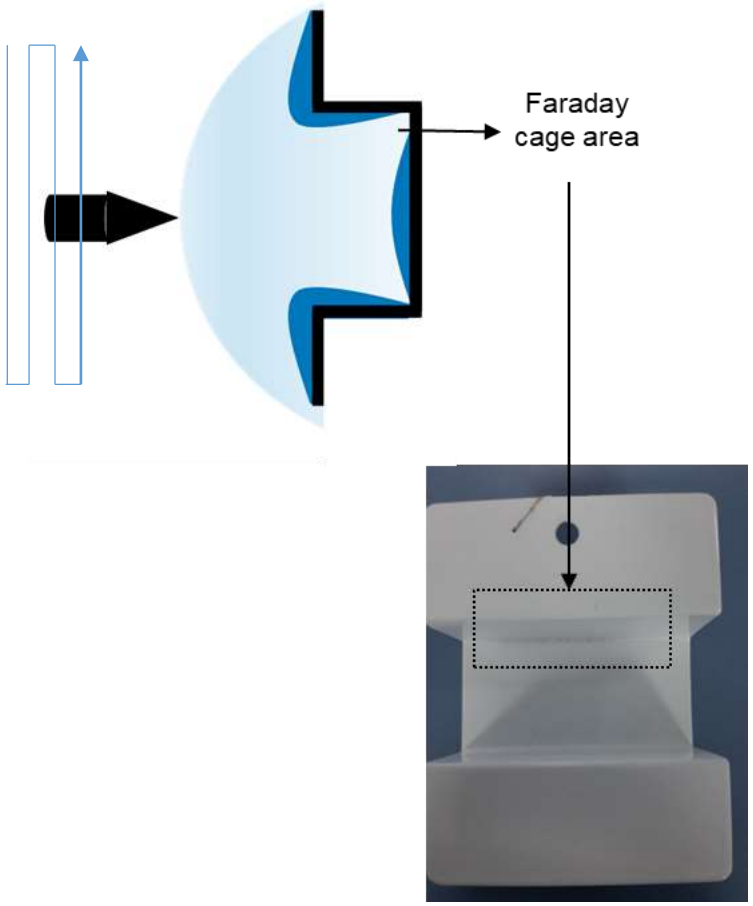


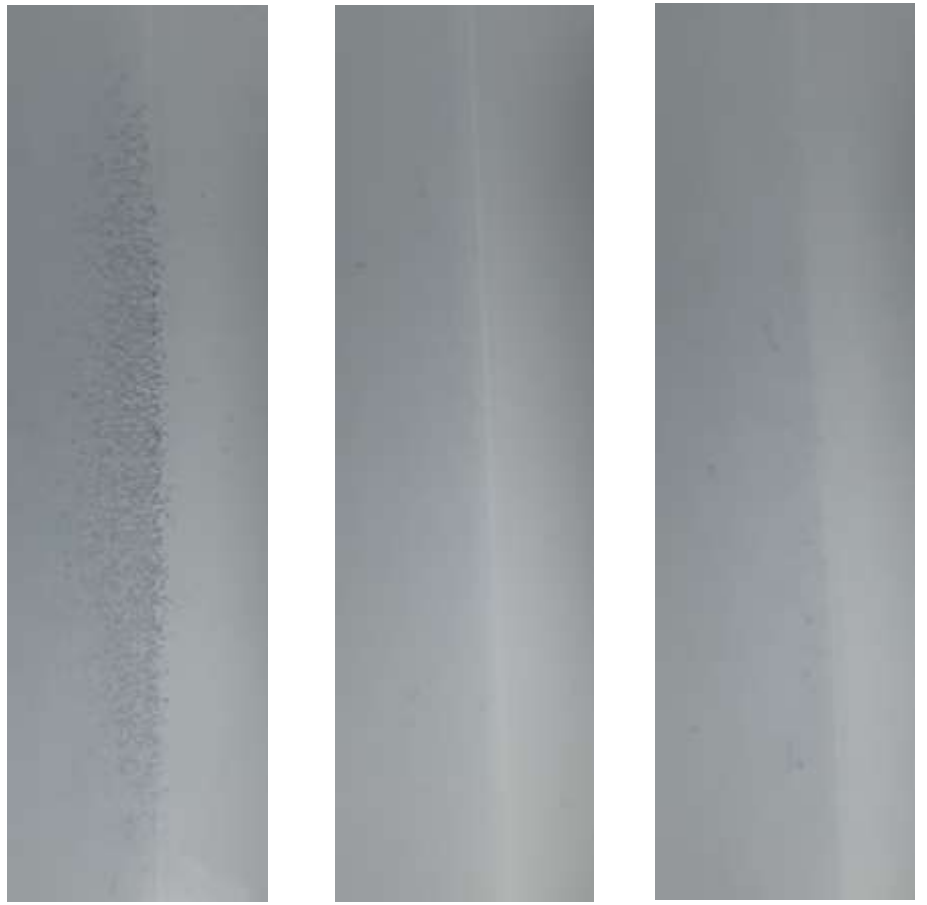


Application on Aluminum 3D panels

Application pattern:

AA3015 Espancolor
18 spray passes (up/down)
(18”)





Application on Aluminum 3D panels

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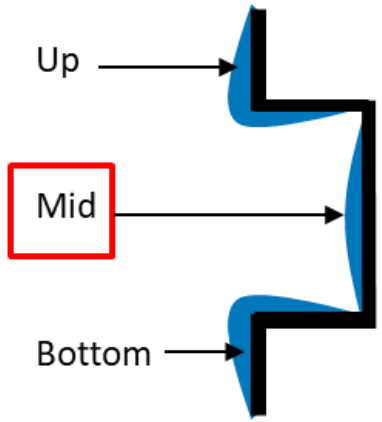
FT measurements:

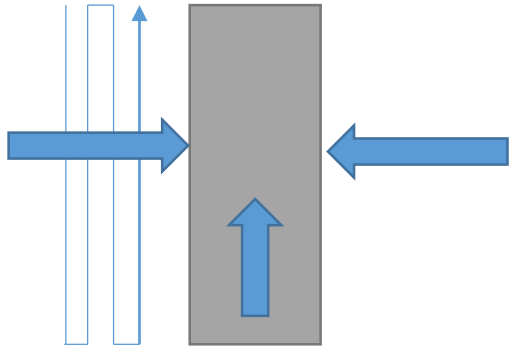


	Film thickness					
	Mean (µm)			% vs Control		
Product	**Up**	**Mid**	**Bottom**	**Up**	**Mid**	**Bottom**
Control	93	52	139			
0.5% Barium Titanate A	139	95	148	+50%	**+82%**	+7%
1% Barium Titanate A	147	106	269	+59%	**+103%**	+94%

Application on Aluminum 3D panels

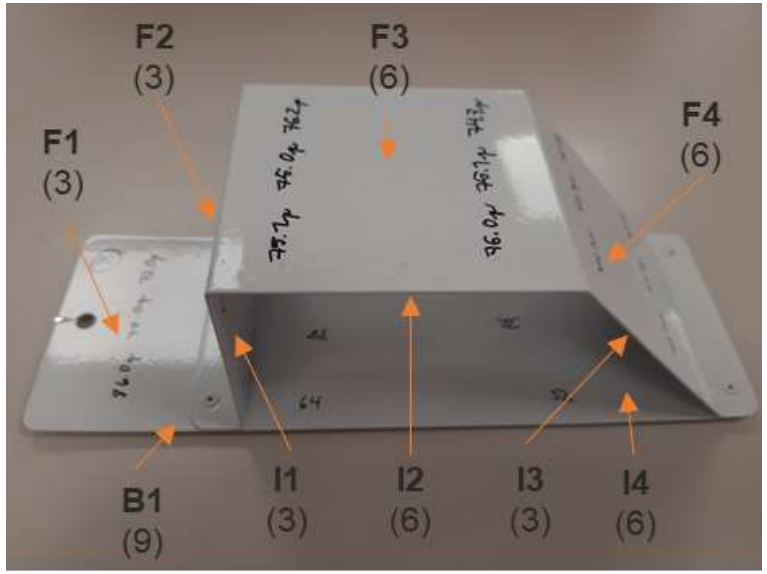
Application pattern:

4 spray passes (up/down) in 3 directions (left, center and right) (3x4”=12”)



DFT measurement pattern:

9 regions (4 front, 4 inside and 1 back)
3-9 DFT measure by region (left, center and right)



Application on Aluminum 3D panels

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Film thickness (µm)

Zone		Control			Control			1% Barium Titanate A			1% Barium Titanate A		
		Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
F1	Mid	62	43	52	58	60	70	60	47	52	72	60	70
F2	Up	90	49	44	56	70	72	64	44	45	78	60	78
	Down	76	50	52	82	68	84	82	62	64	78	74	72
F3	Up	66	49	66	74	56	86	78	56	56	70	62	76
	Down	70	52	48	64	60	80	72	56	62	82	66	66
F4	Up	54	49	54	47	45	58	56	58	60	68	58	62
	Down	33	33	40	33	39	58	62	50	54	66	50	54
B1	Up	42	43	54	47	48	64	42	50	66	48	50	58
	Mid	54	45	54	35	31	42	46	37	48	44	42	56
	Down	45	35	40	31	24	29	43	32	38	38	42	52
I1	Up	25	14	24	26	11	26	23	14	27	23	13	31
	Down	25	11	23	24	8	26	25	13	29	26	10	27
I2	Up	27	12	50	31	19	52	32	16	45	27	10	50
	Mid	34	20	48	34	19	56	43	20	27	28	23	49
	Down	38	23	54	33	25	44	43	27	37	29	27	44
I3	Up	43	35	64	34	15	38	47	25	42	42	37	50
I4	Up	44	22	45	39	24	58	49	30	38	64	38	45
	Down	48	15	46	31	25	50	35	27	40	52	32	43

	Mean DFT			Mean Dev Std.		
	Control	1% BT A		Control	1% BT A	
Zone	Mean	Mean	%	Mean	Mean	%
F1	58	60	3%	8.0	6.5	-18%
F2	66	66	0%	14.3	10.6	-26%
F3	64	67	4%	10.9	8.5	-22%
F4	45	52	16%	9.9	5.6	-43%
B1	42	43	1%	9.7	8.3	-14%
I1	20	20	-1%	7.3	7.5	4%
I2	34	35	1%	14.0	11.9	-15%
I3	38	40	5%	13.6	9.0	-34%
I4	37	40	9%	14.1	9.5	-32%

Effect on color

- **White Polyester-HAA (20% Titanium dioxide PW6)**

	L*	a*	b*	C*	h°	ΔL*	Δa*	Δb*	ΔC*	ΔH*	ΔE*
Control	96.37	-0.84	2.41	2.55	109.2						
+0.5% Barium Titanate A	96.48	-0.78	2.84	2.95	105.3	0.12	0.06	0.43	0.39	-0.19	0.45
+1% Barium Titanate A	96.55	-0.83	2.74	2.87	106.92	0.18	0.01	0.33	0.31	-0.11	0.38
+2% Barium Titanate A	96.61	-0.82	2.82	2.93	106.15	0.24	0.02	0.41	0.38	-0.15	0.47

- **Red Polyester-HAA (15% Red Iron Oxide PR101)**

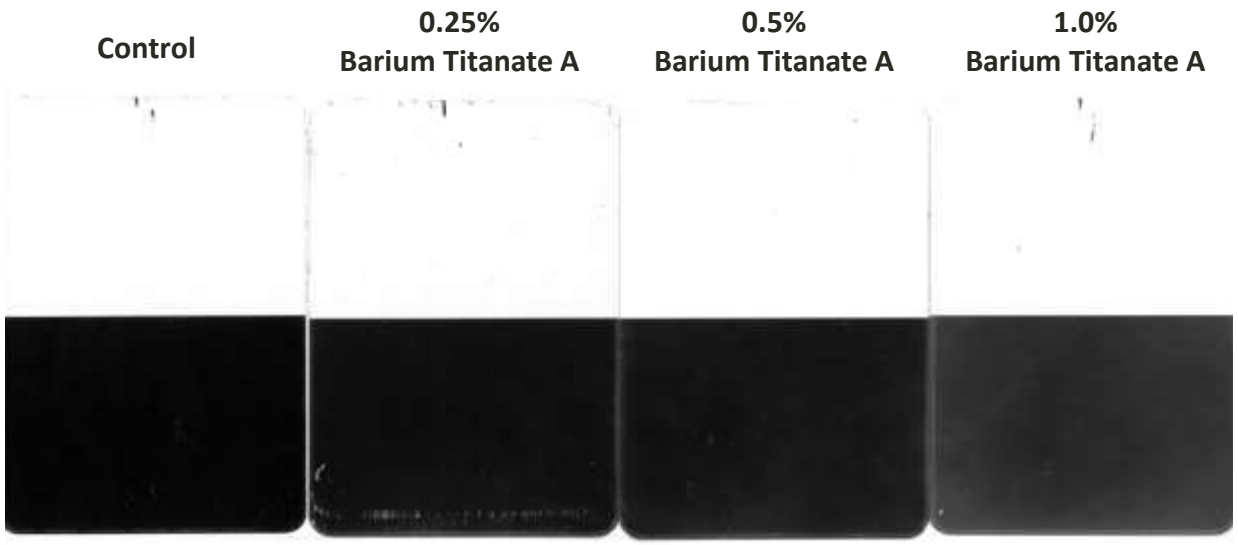
	L*	a*	b*	C*	h°	ΔL*	Δa*	Δb*	ΔC*	ΔH*	ΔE*
Control	37.61	27.17	17.34	32.23	32.54						
+1% Barium Titanate A	37.72	27.25	17.49	32.38	32.70	0.11	0.08	0.15	0.15	0.09	0.21

- **Black paint (15% Chromium Green/Black hematite PG17 - Cool IRR Black)**

	L*	a*	b*	C*	h°	ΔL*	Δa*	Δb*	ΔC*	ΔH*	ΔE*
Control	27.37	0.70	-0.34	0.78	334.55						
+1% Barium Titanate A	27.99	0.70	-0.55	0.89	321.86	0.61	0.00	-0.22	0.11	-0.18	0.65

Effect on clear coats

- **Clear Polyester-HAA applied on opacity panel**

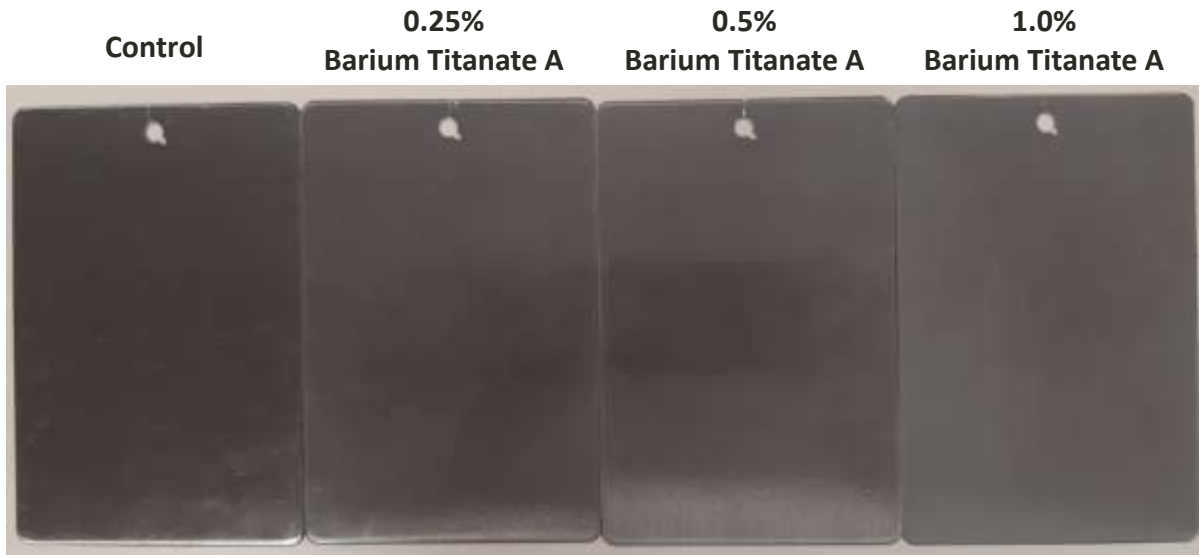


Color measure over black (D65/10º)

Name	L*	a*	b*	C*	h°	Opacity	Gloss 20°
Control	**28.08**	1.23	0.04	1.23	1.93	**7.77**	73.3
0.25% Barium Titanate A	**30.45**	1.38	-0.94	1.67	325.74	**8.77**	78.6
0.5% Barium Titanate A	**31.95**	0.93	-1.47	1.74	302.19	**9.29**	80.0
1.0% Barium Titanate A	**35.09**	0.54	-2.08	2.15	284.51	**11.36**	74.4

Effect on clear coats

- **Clear Polyester-HAA applied in cold rolled steel panel**



Color measure over black (D65/10°)

Name	L*	a*	b*	C*	h°	Gloss 20°
Control	**65.02**	0.34	3.23	3.25	84.01	**96.1**
0.25% Barium Titanate A	**63.16**	0.33	3.29	3.30	84.30	**96.9**
0.5% Barium Titanate A	**63.05**	0.26	2.36	2.38	83.82	**95.1**
1.0% Barium Titanate A	**60.22**	0.21	2.15	2.16	84.47	**81.7**

Transfer efficiency

Name	Paint (g)	%	DFT (µm)	%
Control	0.84		34	
0.25% Barium Titanate A	0.95	**13%**	33	-5%
0.5% Barium Titanate A	0.93	**11%**	32	-6%
1.0% Barium Titanate A	1.11	**32%**	45	**32%**

Effect on weathering

- **Weathering tests in White Polyester-HAA**

Fluorescent UV-Condensation Test (Q-UVA 340)
ASTM D 4587

Irradiance 0.77W/m2, 8 hours 60°C + 4 hours condensation 40°C

							Gloss	
	ΔL*	**Δa***	**Δb***	**ΔC***	**ΔH***	**ΔE***	**20°**	**60°**
Control							69.7	91.9
400 hours	-0.30	-0.03	-0.03	0.01	0.04	**0.30**	36.8	83.2
750 hours	0.20	0.00	0.28	0.16	-0.23	**0.34**	27.9	74.8
+ 1% Barium Titanate A							70.2	91.9
400 hours	-0.16	-0.04	0.04	0.05	-0.01	**0.17**	44.5	88.0
750 hours	-0.21	-0.03	0.08	0.07	-0.05	**0.23**	41.0	85.5

Xenon-arc lamp Test (Q-SUN)
ISO 16474-2

Irradiance 0.51W/m2, Black panel 63°C, Chamber 42°C, Relative Humidity 50%, set time 1h 42min (rain 20 min)

							Gloss	
	ΔL*	**Δa***	**Δb***	**ΔC***	**ΔH***	**ΔE***	**20°**	**60°**
Control							75.2	92.0
400 hours	0.70	0.07	0.07	-0.07	-0.07	**0.71**	57.5	92.8
750 hours	0.39	0.06	0.01	-0.06	-0.01	**0.40**	52.8	92.1
+ 1% Barium Titanate A							73.4	92.7
400 hours	0.05	0.02	-0.17	-0.04	0.17	**0.18**	69.4	93.8
750 hours	0.15	0.03	-0.02	-0.03	0.02	**0.16**	61.1	88.6

Effect with overbaking

- **Overbaking at 230° (446°F) of White Polyester-HAA**

	Curing 8 min in air-circulated oven	**L***	**a***	**b***	**C***	**h°**	**ΔL***	**Δa***	**Δb***	**ΔC***	**ΔH***	**ΔE***
Control	**200°C (392°F)**	95.26	-1.09	1.14	1.58	133.92						
	230°C (446°F) Overbaking	95.00	-1.08	1.70	2.01	122.47	-0.27	0.01	0.56	0.43	-0.36	**0.62**
+ 0.5% Barium Titanate A	**200°C (392°F)**	95.97	-1.06	1.69	1.99	122.07						
	230°C (446°F) Overbaking	95.71	-1.01	2.01	2.25	116.69	-0.26	0.05	0.33	0.26	-0.20	**0.42**
+ 1% Barium Titanate A	**200°C (392°F)**	96.18	-1.00	2.05	2.28	116.12						
	230°C (446°F) Overbaking	95.79	-0.80	2.75	2.87	106.28	-0.39	0.20	0.70	0.59	-0.44	**0.83**

Conclusions and next steps

Conclusions

Barium Titanate A:

- High dielectric constant ceramic material with the ability to carry electrostatic charges
- Small additions on powder coating can help to improve powder chargeability:
  - Helps to increase first pass transfer efficiency
  - Helps to improve coating coverage in Faraday Cage areas
  - No effect on weather resistance or overbaking conditions
  - Slight effect on color/transparency on Clear coats or deep black coatings

Next steps

Characteristics can be optimized according to literature from other applications:

- Other dielectric materials or combinations
- Particle variations
- Particle surface modification

Thanks for your attention
Questions?

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