SIGNIFICANTLY INCREASED TRANSFER EFFICIENCY

Enhanced technology for electrostatic spray on nonconductive substrates and complex geometries. By Atman Fozdar, Ronald Lewarchik, Chemical Dynamics LLC, USA, and Vijay Mannari, Eastern Michigan University, USA.

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Rapid drying conductive adhesion promoters provide improved adhesion of powder and liquid coatings to nonconductive substrates such as ABS and polycarbonate and improve transfer efficiency by dissipating static charge.

ight vehicles represent an important market for plastics and polymer composites, one that has grown significantly in the last five decades. Among other reasons, this is due to being inexpensive com- pared to their metal counterparts, to being able to mould complex geometry, to reduced weight, and to increased fuel economy due to the reduced weight. Various plastics and composites are used for au- tomotive interiors, exteriors, electrical systems, powertrains and en- gine components. Their complex geometries and the non-conductive nature of the substrate mean that coatings cannot be applied using electrostatic spraying, which limits the methods for applying coatings by the conventional spraying method. A conventional liquid coating spray method causes significant loss in transfer efficiency (about 40- 60% depending on geometry of the substrate), so there is an obvious market opportunity here.

Powder coatings have been identified as the most suitable and eco-friendly coatings for plastics because, for instance:

ą No hazardous Volatile Organic Compounds (VOCs)
ą Higher first-pass transfer efficiency (up to 90-95 %),
ą Overspray can be reused/reclaimed.
ą Superior film properties (tough, durable, hard, scratch resistant)
ą Lower process time and energy requirements.
ą One-step finishing process.

However, powder coating plastics and composites gives rise to certain challenges, such as:

ą Applying a powder coating using electrostatic spray on non-conductive plastics and composites.
ą Adhering a powder coating on plastics with low surface energy.
ą Selecting the right powder chemistry that cures at low temperature due to low heat-deflection temperature of plastics and composites.

We have developed a method that overcomes these challenges.

Use of CAPs eliminates the need for preheating, plasma treatment and chemical etching of plastic substrates while improving both film appearance and application efficiency.

RESULTS AT A GLANCE

ű A new conductive adhesion promoter (CAP) technology for application in a continuous/conveyorised production line, dries quickly.

ű UV curable as well as low temperature cure (LTC) powder and liquid coatings can now be applied uniformly even in re- cess/ Faraday cage areas on plastic composites.

ű CAPs work more efficiently at lower film thickness on non- porous substrates.

ű CAPs can significantly increase the transfer efficiency of applying a liquid or powder coating to plastic composites with complex geometry.

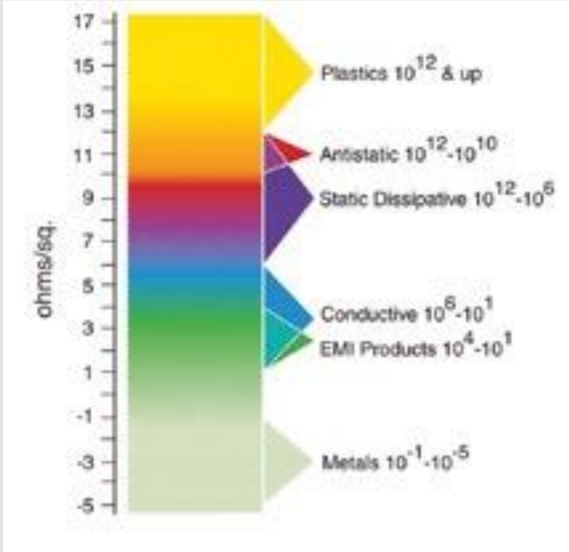
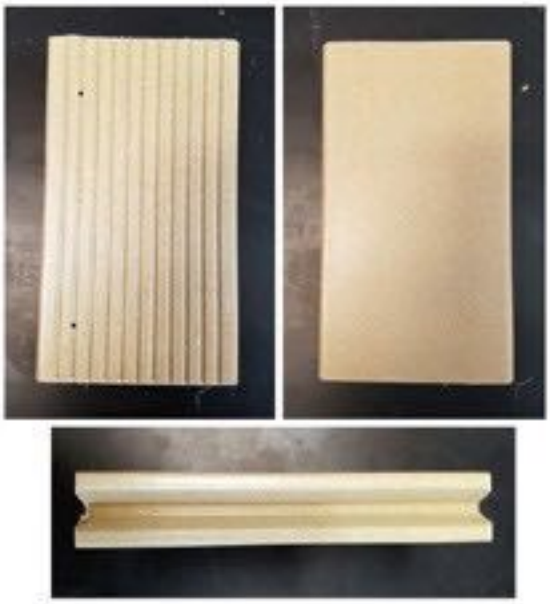


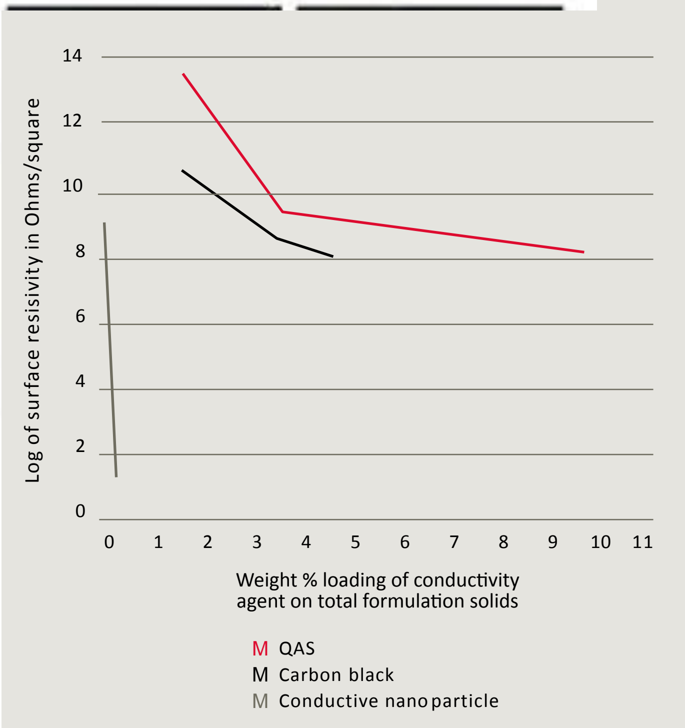
Figure 1: Classification of conductive materials by surface resis- tivity.

Figure 2: (Left) Uncoated polycarbonate/ABS composite; (Right) polycarbonate/ABS coated with UV curable powder coating.

SURFACE RESISTIVITY IS KEY

Figure 1 classifies conductive materials by surface resistivity. For suc- cessful application of powder coatings on plastic substrates, surface resistivity of the substrate has to be less than 10^{8} Ohm/Square (from our previous work published in *European Coatings Journal,* 20171). This places it in the conductive, static dissipative range as per *Figure 1*. (We define a successful application as uniform appearance, film formation and deposition of powder particles on substrate as well as in recess areas where there is no direct line of sight at the time of application.)





We evaluated different types of conductivity agents such as quater- nary ammonium compounds (QAS), carbon black, graphene and also conductive nanoparticles. To determine the most suitable conductiv- ity agent, we formulated a design of experiments and coated various porous and non-porous, non-conductive substrates with different conductivity agents at various loadings. Their surface resistivities are given in *Table 1* & *Figure 5* & *6*. These results show very little or no discrepancy since the variations on all of the substrates are very small.

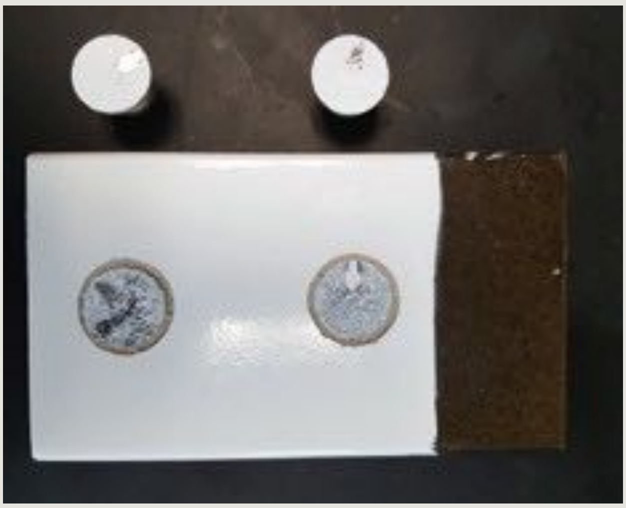
since they are humidity-, process- and temperature dependent. Their migratory nature does not ensure sufficient flexibility or adhe- sion of top coat to substrate. For conductive carbon black, significantly high loading is required to get low enough surface resistivity so that the powder coating forms a uniform film, and they deteriorate me- chanical properties of the film.

Table 1 also shows that if we load the conductive agent beyond a cer-

Figure 3: (Left) Uncoated wood-plastic composite (WPC); (Right) wood-plastic composite coated with UV curable powder coating.

Figure 4: Cohesive failure of powder coating on wood-plastic composite after Positest pull-off adhesion test.

Figure 5: Log of surface resistivity (Ohm/Square) Vs. % loading of conductivity agent on total formulation solids.



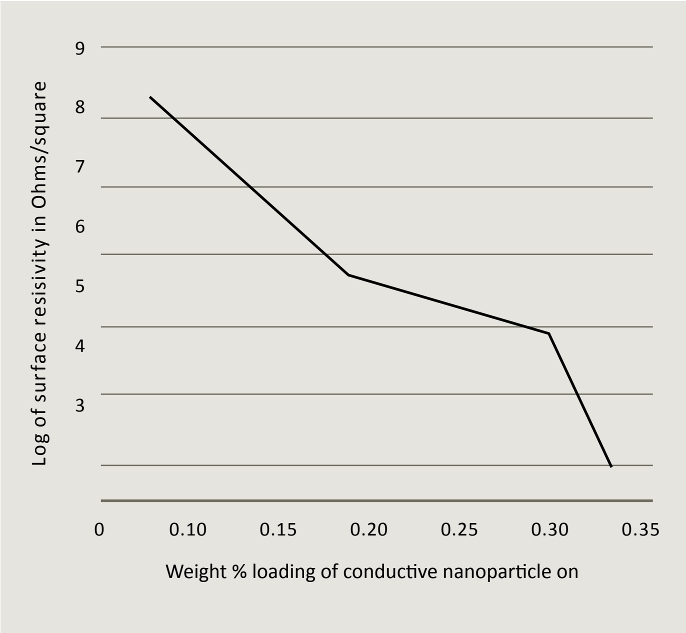


Figure 6: Log of surface resistivity (Ohm/Square) vs. % loading of conductive nanoparticle on total formulation solids.

produces more polar sites for bonding without altering the dispersive contribution significantly. The coating is best applied soon after treatment because the oxidation produces short-lived free radical species and is partially reversible. A major difficulty with 'radiative' techniques is achieving uniform surface coverage without over-treating, which introduces chain-scission and can lead to cohesive failure within the surface of the substrate.

The amount of halogen in the modified polymeric adhesion promotor determines the compatibility with various paint systems. Once the polymeric adhesion promoter is dispersed with conductive nanoparticles, it associates with plastics and composite substrates via dispersion interaction and adheres to it. Halogenated material and grafted functional groups add polarity to CAP which promotes interfacial adhesion to the substrate and the powder/liquid top coat.

Figure 7: (Left) Uncoated curved porcelain tile; (Right) curved porcelain tile coated with low temperature cure powder coating with texture finish.

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Table 1: Surface resistivity of coated substrate using different types of conductivity agent at various loadings.

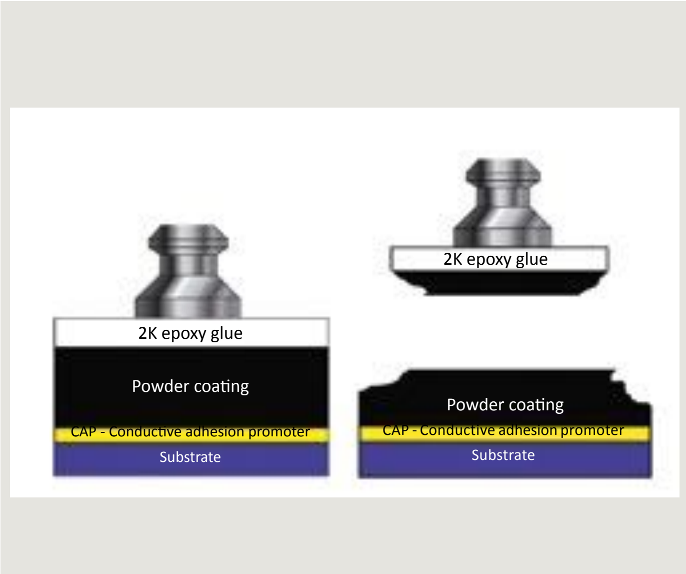
Substrate	Type of conductivity		Surface resistivity (Ohm/Sq)
MDF	QAS	2	3.0×10^{13}
		4	1.5×10^{13}
			8.0×10^{9}
		8	3.0×10^{8}
		10	1.4×10^{8}
	Graphene	2	3.7×10^{7}
	Carbon black	2	6.1×10^{12}
		5	7.2×10^{9}
Polycarbonate	QAS	2	1.2×10^{13}
		4	4.6×10^{9}
		6	1.9×10^{9}
		8	1.1×10^{9}
		10	4.5×10^{8}
	Carbon black	2	5.1×10^{10}
		5	3.6×10^{8}
	Conductive	0.1	3.2×10^{9}
		0.2	5.7×10^{6}
		0.3	3.9×10^{4}
		0.33	2.1×10^{3}
PC/ABS composite	Conductive	0.1	1.9×10^{8}
		0.2	5.1×10^{5}
		0.3	8.9×10^{4}
		0.33	1.1×10^{3}
Wood plastic composite	Conductive	0.2	5.1×10^{5}
		0.33	1.1×10^{3}

ASTM D257

Additional comments: * indicates proprietary material; Surface resistivity (Ohm/Sq) was measured using Monroe Electronics Model 272A as well as EDTM RC2175 for systems which were conductive, as per ASTM D257

Table 2: Heat deflection temperature of different plastics and type of powder coating that can be used.

Sr. No	Polymer type	Heat deflection temperature at 0.46 MPa (oC)	Type of powder coating that can be applied without damaging plastic composite during curing of powder
1	ABS	98	NA
2	ABS + 30 % glass fibre	150	UV, low temp. cure powder
3	Nylon 6	160	UV, low temp. cure powder, standard
4	Nylon 6 + 30 % glass fibre	220	UV, low temp. cure powder, standard
5	Polycarbonate	140	UV, low temp. cure powder
6	PET + 30 % glass fibre	250	UV, low temp. cure powder, standard
7	Polypropylene + 30 % glass fibre	170	UV, low temp. cure powder, standard
8	Polycarbonate/ABS composite (70:30)	150	UV, low temp. cure powder
9	Wood plastic composite	150	UV, low temp. cure powder



temperature cure textured black hybrid (epoxy/polyester) pow- der coating (*Figure 7*) were applied using an electrostatic spray gun on substrates coated with CAP. The UV curable powder was melted first at 120 °C for 3-4 minutes and then cured using a conveyorized UV oven with a medium-pressure H-bulb, and low temperature cure powder was cured at 130 °C for 5 minutes.

Figure 8: Graphical representation of Positest Pull-off adhesion test, ASTM D4541 – cohesive failure within powder coating, no interfacial adhesive failure.

Positest pull-off adhesion tests were carried out to determine interfa- cial adhesion. Multiple adhesion tests with 20 mm dollies were carried out to determine the interface of the coating failure and the force/ area at which failure happens. The dry film thickness of the CAP and the cured powder coating were measured using Positector B100/ B200, an ultrasonic film thickness gauge (*Table 3*, *Figure 4* & *8*).

WHERE ARE WE NOW?

- CAPs ensure sufficient dissipation of negatively charged powder particles applied by electrostatic spray equipment and promote interfacial adhesion.
- CAPs work more efficiently at lower film thickness on non-porous substrates. On porous substrates higher film thickness may be re- quired since some of the material would be absorbed by a porous substrate.
- CAPs enable successful application of powder coating on various plastic composites (uniformity, film formation, ability to coat recess areas, etc.).
- CAPs can significantly increase transfer efficiency of applying liquid or powder coating to plastic composites having complex geometry.

Table 3: ASTM D4541 Positest AT-A pull-off adhesion test.

			ASTM D4541 Positest AT-A pull off adhesion test			
Substrate	Conductive nanoparticle loading (%)	DFT of CAP (µ)	DFT of powder coating (µ)	CAP/substrate interface	CAP/powder coating interface	Type of failure

WPC	0.33%	11	51	No failure	No failure	Cohesive, powder coating
PC/ABS	0.33%	10	45	No failure	No failure	Cohesive, powder coating

“CAP technology enables successful application of powder coatings on non-conductive or non-traditional substrates.“

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3 questions to Atman Fozdar

How do you define “traditional“ and “non-traditional“ substrates? *Current electrostatic application technology only allows metallic substrates (which are inherently conductive and need to be grounded to dissipate static charge) to be successfully powder coated. Conductive Adhesion Pro- moter (CAP) technology enables successful application of powder coatings on non-conductive or non-traditional substrates like glass, ceramic, plastics, composites, wood, WPC etc. by making the surface of the substrate conductive and by improving interfacial adhesion between powder coating and the substrate, which was not possible otherwise with conventional Quaternary Ammonium Salts and other approaches.*

What other plastic coating applications are feasible besides light vehicles applications? *Plastic composites used in automotive is just one of the examples to demonstrate CAP technology. Practically, any plastic substrate or composite (used in appliance, construction, medical or industrial areas) that can withstand 120 °C (melting temperature of powder) can be powder coated. We an- ticipate a huge potential for the wood-plastic composite market as well as recycled plastics for more efficient coating application with higher first-pass transfer efficiency and zero VOC.*

What are the most important challenges that must be overcome before commercialisa- tion of this technology? *We’re working on optimising formulations for porous substrates like MDF. In addition to that, a zero VOC water-borne version of CAP takes about 8-10 minutes to dry/cure. We’re evaluating other polymers to reduce dry/cure time so that it can be used in continuous/convey- orised environment for increased productivity.*

WHERE TO NEXT?

ą A Zero VOC water-borne version of conductive adhesion promoter with reduced dry/cure time of 3-5 minutes.
ą Reduce dry film thickness (DFT) for thinner film applications (3-6 µm).
ą Trials on ceramic tiles and concrete (and other substrates that can withstand 120 °C).
ą Optimise formulation for porous substrates like MDF and particle board.
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REFERENCES

[1] Fozdar A., Mannari V. "Development of Low VOC Static Dissipative Coating for Powder Coating Non-Traditional Substrates." European Coatings Journal, April 2017.