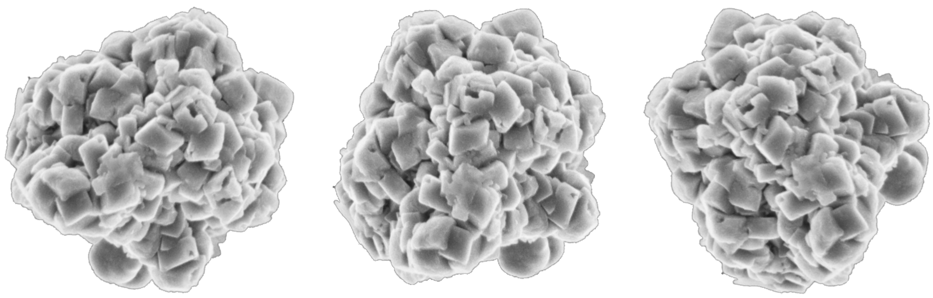
Smart Titanium Dioxide for Economical and Environmentally Sustainable Optimization of Plastic Pipe Formulations

Andy White

15th June 2020



Contents

Introduction

A brief description of the work undertaken

Evaluation

Important formulation properties and tests that were carried out

Results

Charts and tables showing the results obtained with FP-Opacity Pigments™

Conclusion

Summary and conclusion of the evaluation

Appendices

What is FP-Opacity Pigment™?

How does it work?

Why Use FP-Opacity Pigment™

Introduction

This paper will detail the use of our novel primary FP-Opacity Pigments™ as partial replacements for titanium dioxide in rigid PVC formulations. It will show how use of FP-Opacity Pigments™ provides significant performance and cost reduction opportunities for the plastics formulator. The provision of a “fixed dispersion” next generation TiO_2 ensures the best optical efficiency is maintained and thus maximizes the effective use of all of the titanium dioxide particles employed in the pipe compound. All this while maintaining an economically sustainable advantage with no significant effect on the plastic properties.

In addition to maintaining product quality and performance, this next generation TiO_2 has a significantly lower carbon footprint than conventional TiO_2 and thus offers more sustainable technical solutions for the future.

When replacing 10 - 35 wt% of the TiO_2 in a PVC pipe formulation, the unique particle morphology and functionality enables the manufacturer to better optimise their formulations and to positively enhance the overall performance of PVC Pipe systems

Evaluation

FP-510 Opacity Pigment™ was evaluated in a rigid PVC made to the following formulation

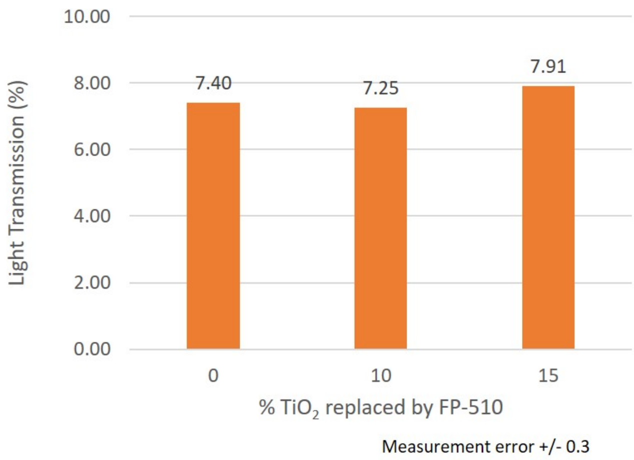
Test recipe (using KRONOS 2220):

- – 100 PVC
- – 3.5 Stabilizer
- – 8 CaCO3
- – 6 Impact modifier
- – 4 TiO_2 (Std) or 3.2 TiO_2 + 0.8 FP-510 (20% FP-510)

Results in PVC

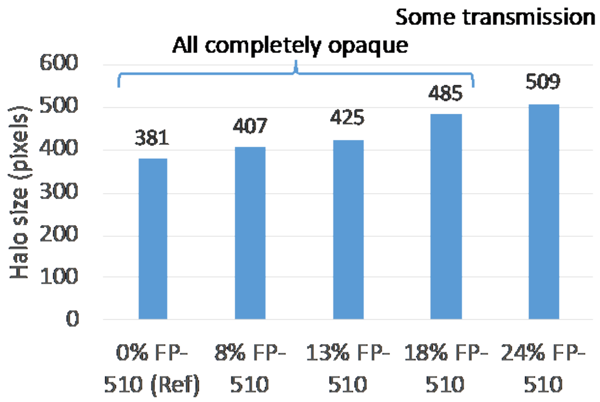
When used at a 20% replacement in the above PVC formulation the following properties were determined.

<u>Light Transmission through a 160µm Film</u>



Light transmission behaves similarly at 10% replacement and then begins to rise slightly as more TiO_2 is replaced.

However, in PVC-u Plaques at 1mm thickness a similar effect can be seen which implies that around 20% of the TiO_2 can be effectively replaced and the same optics maintained.



What about other properties? Introducing particles of a 1µm size, replacing many smaller ones at 300nm might affect the other properties of the system.

Brabender Rheology

	Gelation time (s)	Gelation time (s)	Gelation time (s)	Gelation time (s)
Ref. 4 Phr TiO_2	80	46.9	34.8	62.3
0.8 Phr FP-510/3.2 Phr TiO_2	78	47.3	34.7	68.7

Overall there is no real effect on Rheology. There is no change in gelation time and torque, but a slightly higher gelation rate. This small difference can be an advantage since faster gelation and lower melt viscosity at screw tip, reduces stress built up.

KMDL-25 Extrusion Data

	Torque (Amps)	Melt pressure (Mpa)	Output (kg/hour)	Melt temp (C)
Ref. 4 Phr TiO_2	3.68	18.0	10.9	171
0.8 Phr FP-510/3.2 Phr TiO_2	3.65	17.6	10.9	171

Overall, replacement of 20% of the TiO_2 with FP-Opacity Pigment™ has little effect other than a slightly lower melt pressure.

Optically after seeing the results of the transmission experiments one would expect performance to be reasonable.

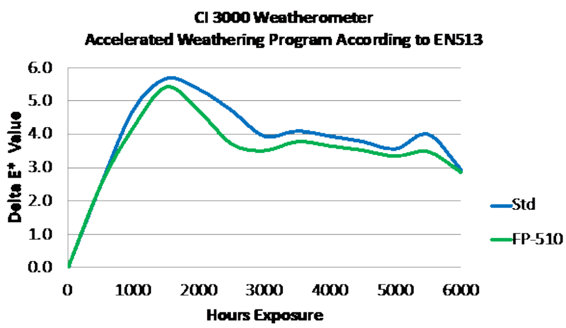
Gloss and Initial Colour

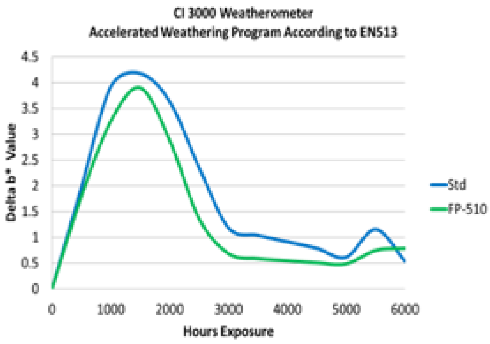
	Gloss @60 degree	L*	a*	b*
Ref. 4 Phr TiO_2	44	94.1	-0.88	2.67
0.8 Phr FP-510/3.2 Phr TiO_2	44	93.9	-0.87	2.57

The Gloss and initial colour are visibly no different from the standard.

It is obvious however to be concerned about the performance of the plastic after weathering. Our study also evaluates the colour changes for both artificial and natural weathering, and looks at the impact resistance changes upon exposure.

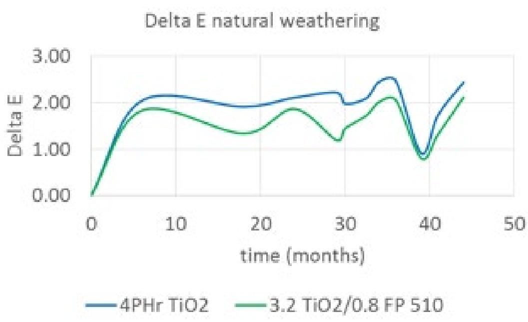
Artificial weathering

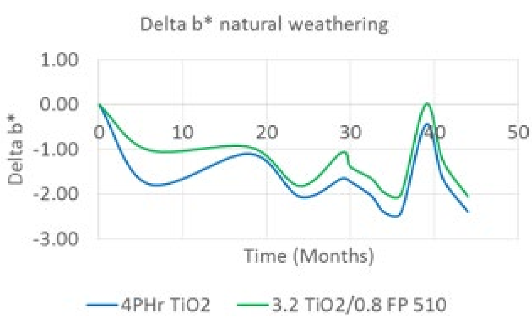




After 6000 hours exposure, the combined colour change for the FP-510 substituted profile is similar to (and perhaps slightly better than) the standard profile. CIE b* value for the same exposure shows a slight photogreying of the plaque, although this has matched the standard by the 6000 hour mark.

Natural weathering

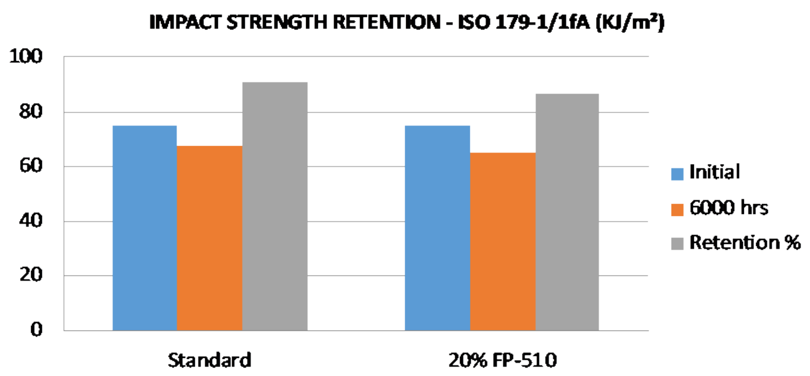




Exposure Site: Puget-Theniers, FR, S-facing, 45˚

After 44 month's exposure, the combined colour change for the FP-510 substituted profile is similar to (and perhaps slightly better than) the standard profile. Under natural exposure conditions, the colour change for this formulation similarly shows a slight photogreying.

Impact Strength Retention



KJ/m^2	Standard	20% FP-510
BS2782/359	12.0 ± 0.3	12.7 ± 0.3
DIN53753	60 ± 1	57 ± 1

Overall the impact strength retention after 6000 hours of artificial weathering is similar.

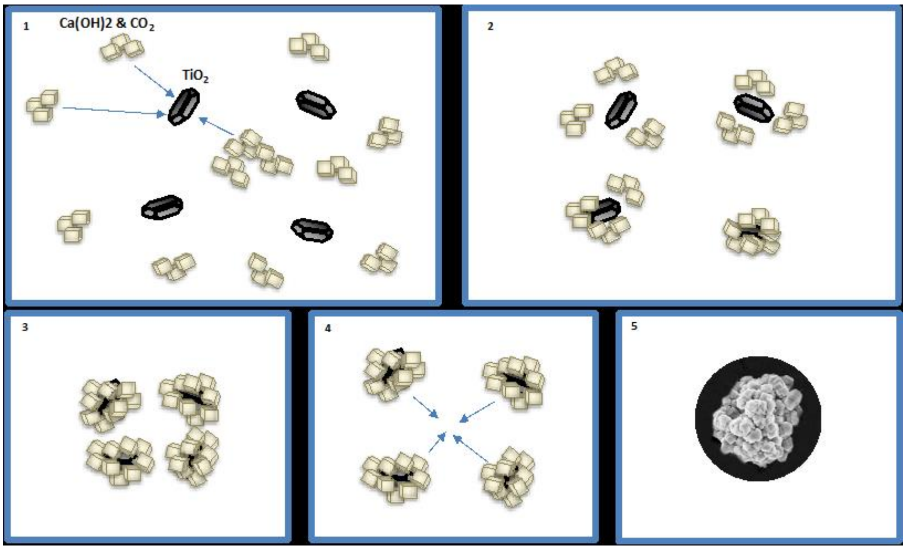
Conclusion

FP-Opacity Pigment™ can be used to replace 10-35% (our example was done at 20% but actual replacement ratios will depend on formulation and application) of the TiO_2 in a given PVC pipe formulation. Cost savings can be considerable considering the high cost of TiO_2, with no other performance properties affected. In addition there is the benefit of sustainability, whether environmental or economic. FP-Opacity Pigments™ provide formulating options which can only be to the advantage of the PVC producer.

Appendices

What is FP-Opacity Pigment™?

Our products use commercially available TiO_2 pigments and a proprietary process that locks in an improved state of TiO_2 dispersion in a shell of high quality precipitated calcium carbonate.



These white pigment composites have an average particle size of 1 micron with a particle of FP-Opacity Pigment™ containing between 3 and 6 TiO_2 particles, each statistically space from each other by the optimum distance for scattering of 280nm.

The nature of the “special structure” of the calcium carbonate shell produced means that this product will maximise the light scattering and hence the whiteness and opacity by several mechanisms.

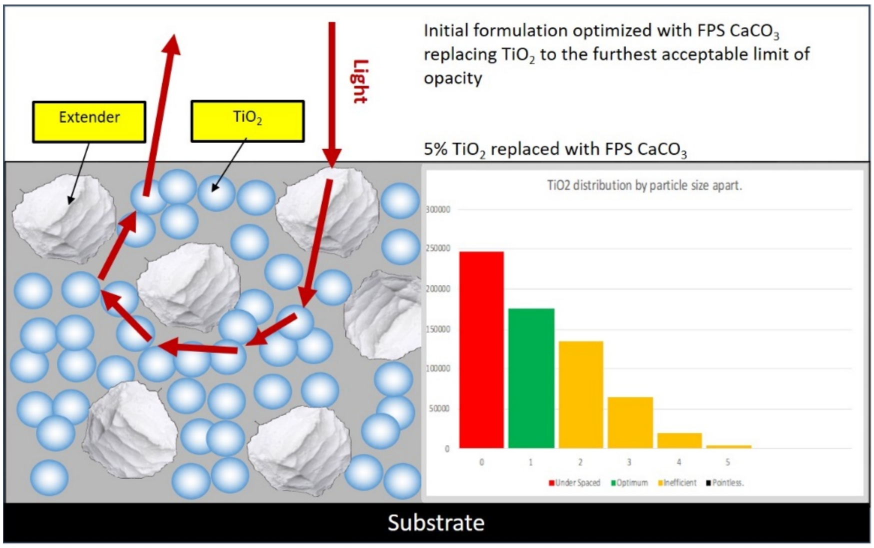
- Optimally spacing TiO_2 inside the FP-Opacity Pigment™ particle.
- Spacing loose TiO_2 around the particle.
- Air voids inside and at the surface of the particle.
- Diffraction from the rough surface of the particle.

As a white pigment, out FP-Opacity Pigments™ have an inherent light scattering functionality and a refractive index between 1.8 and 1.9, unlike extenders and fillers.

The FP-Opacity Pigments™ are used as simple, weight for weight, partial replacements for your existing TiO_2. Depending on the application and formulation type, FP-Opacity Pigments™ can normally replace between 5% and 30% of the TiO_2 without reducing your product quality or performance.

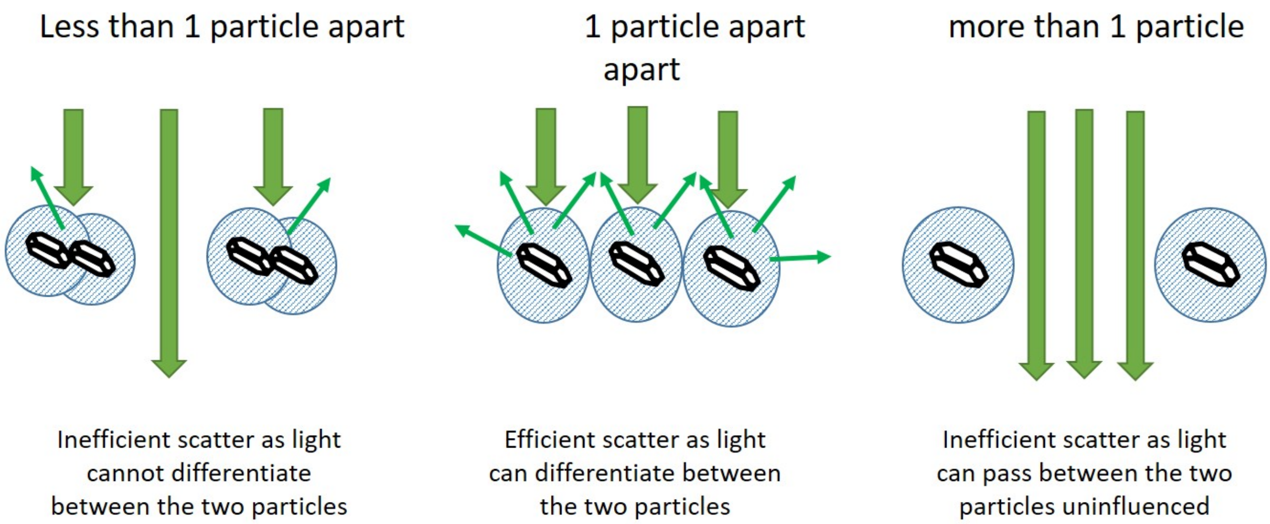
How FP-Opacity Pigments™ Work

In a coating there will usually be a continuous binder phase with TiO_2, extenders and other raw materials dispersed efficiently, yet randomly in that phase. The extenders have a similar refractive index to the binder and, as the TiO_2 cannot occupy the same volume as the extender, the presence of the extenders will create "windows" within the coating through which light can pass without significant scatter. Extenders are also typically much larger than TiO_2 and so TiO_2 is prevented from accessing a significant volume within the coating – this can be considered as TiO_2 crowding, the TiO_2 being forced into the spaces between the extenders and binder which coupled with the random nature of its dispersion leads to only about 30% of the TiO_2 particles having the optimum 280nm spacing.

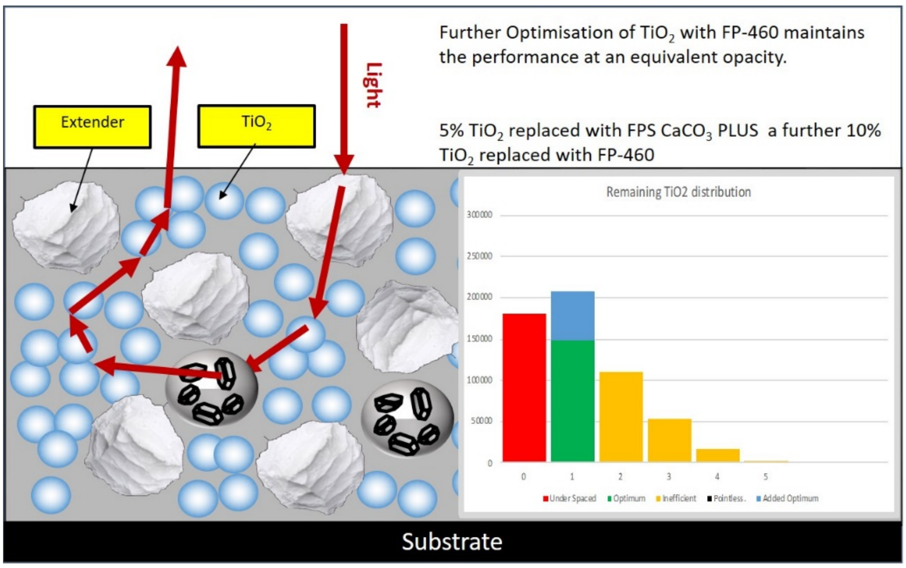


It is well documented that TiO_2 is inefficient if particles are too close together, or in lower concentrations, too far apart.

Inter-particle distance



By replacing a portion of the TiO_2 with FP-Opacity Pigment™ we increase the average distance between TiO_2 particles by a “dilution effect” (fewer particles occupying the same volume) while at the same time we introduce optimally spaced TiO_2 particles within the FP-Opacity Pigment™ structure. This effect can be clearly seen in the statistical model.



By utilising these performance changes, FP-Opacity Pigments™ can be used in coatings, plastics, inks and paper and board to replace between 5% and 30% of the TiO_2 without significantly reducing the opacity and mechanical properties.

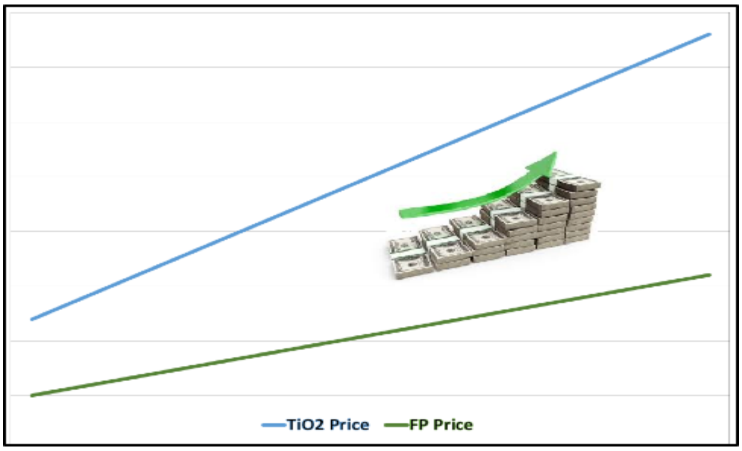
Why Use FP-Opacity Pigments™?

The main reason for using FP-Opacity Pigments™ can be given in three words – "Significant Cost Savings". For every kilogram of TiO_2 pigment replaced by FP-Opacity Pigment™ you will make a significant raw material cost saving while maintaining your product performance and quality. Since you are only replacing TiO_2 with FP-Opacity Pigment™ you can also keep the functionality and cost benefit of your current extender package.

Price Δ between TiO_2 and FP € per ton	Annual € savings, per 100 tons of TiO_2 replaced with FP	Annual € savings, per 500 tons of TiO_2 replaced with FP	Annual € savings, per 1000 tons of TiO_2 replaced with FP
€600	€60,000	€300,000	€600,000
€1000	€100,000	€500,000	€1,000,000
€1400	€140,000	€700,000	€1,400,000

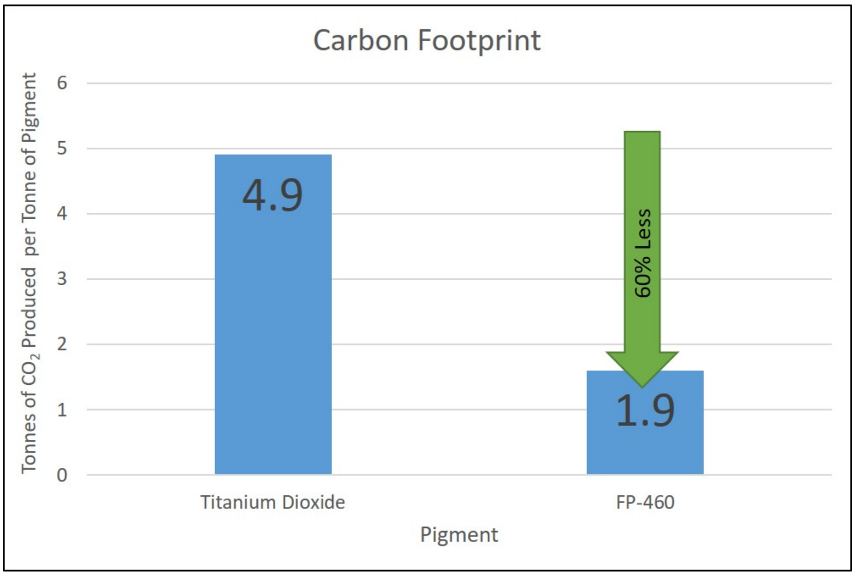
On average, FP-Opacity Pigments™ are 600 to 1000 Euro per tonne lower in price than normal TiO_2 pigment (and this can be even higher in some regions). SO, if your business can avoid using 100 tonnes of TiO_2 pigment by replacing it with FP-Opacity Pigment™ you could save up to €100,000 per year.

In addition, for the same whiteness and opacity produced, FP-Opacity Pigments™ utilise much less TiO_2 and so as TiO_2 prices vary with market conditions, the price of FP-Opacity Pigments™ is more immune to these commodity related price fluctuations.



The graph opposite shows how, as the price of TiO_2 increases, the cost of FP-Opacity Pigments™ rises at a significantly lower rate, helping to minimise the impact of raw material price increases.

Finally, cost savings aren't the only benefit of FP-Opacity Pigments™. For the same opacity product, weight for weight, FP-Opacity Pigments™ have a 60% lower carbon footprint than TiO_2.



The process used by FP-Pigments facilitates a reduction in CO_2 emissions by recycling CO_2 gas throughout our manufacturing route, thus reducing CO_2 losses to atmosphere. We also reduce water usage by having a closed water recirculation system, recycling and reusing process water. All of this as well as our ethical business practices which are regularly audited and qualified by Ecovadis who have awarded FP-Pigments their Silver Medal in both 2018 and 2020.