UV Technology for Protection of Surfaces

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Ultraviolet (UV) coating technology is widely used for decoration and protection in many different applications in a wide range of industries. The environmental benefits of UV technology are well documented for the reduction of emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs).[1,2] Additional advantages of this environmentally friendly technology include faster cure, increased production speed, improved process efficiency, source reduction, and sustainability. Fast drying under UV lamps eliminates the need for ovens or extensive manufacturing space for drying of coatings, with corresponding savings in energy costs and infrastructure. UV technology can provide a healthier work environment, and can decrease risks and lower insurance costs by eliminating flammable solvents from coating processes. Regulatory costs can be significantly reduced with UV technology which can provide lower applied coating cost and reduced overall cost through improved process efficiency and elimination of pollution.

The capabilities of UV coating technology have now been extended to the high performance protection of a variety of surfaces. The requirements of UV cure do not prevent this technology from providing surfaces with UV protection and resistance to weathering from sunlight. UV technology also provides toughness, solvent resistance, and abrasion resistance for many different substrate materials. For metal surfaces, including steel and high strength aluminum alloys in industrial and aerospace applications, UV coating technology provides this protection along with superior corrosion resistance. When compared to conventional coating technology, high performance solvent-free UV curable coatings provide improved protection with dramatically faster cure and lower material usage, and UV technology provides this protection in addition to improved manufacturing efficiency and environmental benefits.

High performance UV coating technology can provide improved UV absorbance compared to commercial conservation glass that is designed to protect artwork from sunlight. Whereas the conservation glass provides good protection for the UVA band wavelengths, the clear UV coating provides improved protection through UVA, UVB, and UVV bands as shown in Table 1, and can provide this UV protection for a wide variety of surfaces. Very little dosage is measured in the UVC range.

Table 1. UV Dosage Blocked By UV Coating Technology And Commercial Conservation Glass

Protection From Sunlight Measured By The Percent UV Dosage Absorbed And Blocked By A Protective Layer			
UV Band Wavelengths	UVB 280-320 nm	UVA 320-390 nm	UVV 395-445 nm
% Absorbance By Clear UV Topcoat	93%	95%	34%
% Absorbance By Conservation Glass	38%	92%	9%

UV curable protective coatings are suitable for high performance applications that require excellent weatherability. Long-term resistance to weathering from sunlight has been demonstrated for UV coatings through accelerated weathering testing. Table 2 shows results for a clear UV coating that maintained ΔE values less than 1 through approximately 15,000 hours of QUV weatherability testing.

Table 2. Long-Term QUV Weatherability Of High Performance UV Technology

QUV Weatherability Of Clear UV Curable Coating	
Hours QUV Testing	**Δ E**
1008	0.35
2016	0.23
3024	0.25
4032	0.60
5040	0.35
6048	0.47
7056	0.38
8064	0.47
9072	0.36
9912	0.40
11088	0.34
12264	0.38
13104	0.48
14112	0.51
14952	0.61

UV technology is not only applicable in a factory setting, but is also suitable for field use with handheld UV lamps. One such application is the refurbishment of automobile headlamps, where the performance of the field-applied UV coating can be superior to that of the original material. (Figure 1)

After Refurbishing **Before Refurbishing**

Figure 1. Refurbishing Of Automobile Headlamp With High Performance UV Technology

The toughness, solvent resistance, and abrasion resistance of UV coatings are ideal for high performance flooring applications, and the efficiency of UV technology can provide a significant reduction in the time required to apply a high performance coating to a floor and to cure the coating and put that floor back into service (Figure 2).

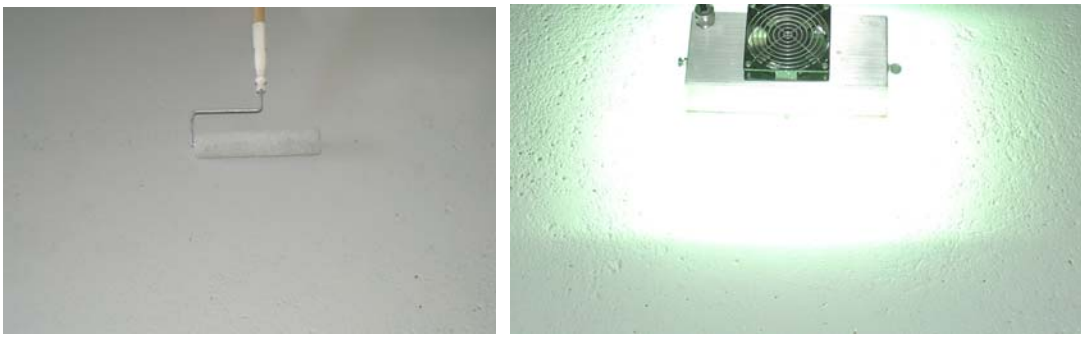


Figure 2. High Performance UV Technology For Fast Cure Flooring Applications

Abrasion resistance for a UV curable floor coating can be significantly improved over that of typical epoxy floor coatings (Table 3), with a dramatic reduction in cure time with the UV system.

Table 3. Abrasion Resistance Of High Performance Coatings For Flooring Applications

Abrasion Resistance Of High Performance Floor Coatings*	
Coating	**Milligrams Weight Loss***
Clear UV Coating	18
Gray UV Coating	27
Commercial Epoxy 1	32
Commercial Epoxy 2	36
Commercial Epoxy 3	50
Commercial Epoxy 4	65
Commercial Epoxy 5	96
Commercial Epoxy 6	100
Commercial Epoxy 7	120
* Taber Abrasion Resistance Rating Was Determined According To ASTM D 4060, Milligrams Of Weight Loss, 1000 Cycles, CS-17 Wheels, 1000 Gram Load	

Solvent resistance properties for high performance UV curable floor coatings are excellent and can be tailored to the requirements of the application. Table 4 shows the results of solvent resistance testing using standard chemicals.

Table 4. Solvent Resistance Of High Performance UV Technology For Flooring Applications

Solvent Resistance Of UV Curable Floor Coating*	
Chemical	**Resistance Rating***
Methyl Ethyl Ketone (MEK)	No Effect
Isopropyl Alcohol	No Effect
Denatured Alcohol	No Effect
Xylene	No Effect
Heptane	No Effect
Water	No Effect
Bleach	No Effect
Alkaline Cleaner	No Effect
35% Hydrogen Peroxide	No Effect
Vinegar	No Effect
Vegetable Oil	No Effect
Red Hot Sauce	No Effect
Ketchup	No Effect
Mustard	Slight Stain, Removes With Bleach
Betadine	Slight Stain, Removes With Bleach

* Solvent Resistance Rating Was Determined From 24 Hour Covered Test According To ASTM D 1308. In Some Cases, Remaining Chemical Residue After Wiping Was Removed With Isopropyl Alcohol

Corrosion is a tremendous problem and cost to society. Over a decade ago, as part of the Transportation Equity Act for the 21st Century, the United States Congress mandated a comprehensive study to provide cost estimates and national strategies to minimize the impact of corrosion. The study was conducted by CC Technologies Laboratories, Inc. of Dublin, Ohio with support from NACE International - The Corrosion Society and the United States Federal Highway Administration (FHWA). This study titled "Corrosion Cost And Preventive Strategies In The United States" is the most comprehensive reference on the economic impact of corrosion, estimated at the time to be a staggering annual cost of $276 billion. According to the study, reported to the Office Of Infrastructure Research and Development, corrosion and metal wastage arising from oxidation as caused by exposure to the elements and reactivity between dissimilar materials costs many segments of the United States economy billions of dollars every year, including aircraft, motor vehicles, bridges, gas and liquid transmission pipelines, water and sewer systems, electrical utilities, ships, railroad cars, petroleum refining, pulp and paper processing, food processing, and home appliances.[3] The United States Government Accounting Office (GAO) now reports that the annual cost of corrosion in the United States has grown to $400 billion.

Epoxy and polyurethane paints are the commercial materials that are typically used for high performance corrosion-resistant applications, with epoxy paints used as primers and in applications where maintaining color and appearance are not as critical, and polyurethane paints generally used as topcoats and in applications where color and appearance must be maintained. These paints can only be used in a relatively narrow temperature range and present many disadvantages, including corrosive or toxic components in two part systems which must be mixed and have a limited pot life with viscosity continually increasing until full cure. There is commonly an extended period of time of before full cure is achieved, especially at low temperatures. Pollution is a significant disadvantage of commercial high performance paints for corrosion resistance, since these materials typically contain solvents, VOCs, HAPs, and in many cases, chemicals on the Toxics Release Inventory (TRI). Urethane paints contain isocyanates, a significant health hazard, and many paints for corrosion resistant applications contain chromium compounds which also represent a significant health hazard. Not only are polluting compounds and health hazards problematic for the use of these commercial paints, but performance of these systems is sometimes lacking with regard to corrosion resistance.

When epoxies are used as the complete paint system for corrosion resistance, performance disadvantages can include brittleness and poor weatherability, with yellowing and changes in gloss with exposure to sunlight. When polyurethanes are used as the complete paint system for corrosion resistance, performance disadvantages can include poor adhesion to metal surfaces. To avoid performance disadvantages of the two individual systems, these materials are often used in high performance applications as multi-layer systems, with epoxies as the primers containing corrosion inhibitors and providing adhesion to metal substrates, and urethanes as topcoats to provide appearance properties of color and gloss that are more stable to sunlight and weather.

By formulation with urethane acrylates and chromium-free corrosion inhibitors, high performance corrosion protection has been demonstrated with solvent-free UV coating technology. For example, accelerated corrosion testing on steel has shown that superior corrosion resistance can be obtained with high performance UV coatings as compared to conventional epoxy and urethane corrosion resistant paints having much higher thicknesses. UV cure is complete within seconds, and improved performance is obtained using 100% solids UV technology with significantly lower material usage and coating weight than conventional coatings (Table 5).

Table 5. Superior Performance Of UV Technology For Corrosion Protection Of Steel

Corrosion Resistance Rankings For High Performance Coating Systems*				
Coating Layer Description	Layer Wet Mils	Total Wet Mils	Total Dry Mils	Corrosion Resistance Ranking*
UV Topcoat UV Primer	2 2	4	4	1 = Best
Epoxy	22	22	16	2
UV Coating	2	2	2	3
Urethane Epoxy	5 10	15	10	4
Epoxy	14	14	10	5
Urethane	10	10	6	6
Urethane	3	3	2	7 = Worst

* Corrosion Resistance Ranking Based On ASTM D 1654 Ratings Of Scribed Steel Panels After 672 Hours ASTM B 117 Salt Fog Testing

The corrosion resistance properties of conventional systems can also be improved by adding a UV coating layer as a topcoat (Table 6).

Table 6. Coating Systems That Include A Zinc Epoxy Primer For Corrosion Protection Of Steel

Corrosion Resistance Rankings With Zinc Epoxy Primer*				
Coating Layer Description	Layer Wet Mils	Total Wet Mils	Total Dry Mils	Corrosion Resistance Ranking*
UV Topcoat Zinc Epoxy Primer	2 3	5	4	1 = Best
Urethane Zinc Epoxy Primer	7 6	13	8	2
Epoxy Zinc Epoxy Primer	16 6	22	15	3
Zinc Epoxy Primer	6	6	4	4 = Worst
* Corrosion Resistance Ranking Based On ASTM D 1654 Ratings Of Scribed Steel Panels After 672 Hours ASTM B 117 Salt Fog Testing				

With improvements in the technology of portable hand-held UV lamps, field application and cure of high performance corrosion resistant UV coatings is now possible for even the largest of structures, with a UV lamp passed over the surface slowly in the same manner as a surface is painted with a spray gun or roller. Just as any surface can be painted with only a few individuals spray-painting or rolling, a UV coating can be applied and cured on that same surface by only a few individuals applying paint and following with a UV lamp. An efficient process can be performed with one person applying paint and another following with a UV lamp, each with proper protective shielding as shown by the painters in Figure 3. Cure is achieved with a motion that can be described as "painting" the surface with the hand-held UV light, passing the light over the surface slowly in the same manner as a surface is painted with a roller or spray gun, with the movement of the lamp taking approximately the same amount of time as applying paint to the surface. For large surfaces, multiple painters and multiple lights can be used. When compared to drying of conventional paints, UV cure is relatively independent of temperature and humidity conditions. Good cure performance has been demonstrated under typical ambient summertime conditions and at temperatures as low as 34ºF.[4]

Figure 3. Field Application And Cure Of High Performance UV Coating Technology

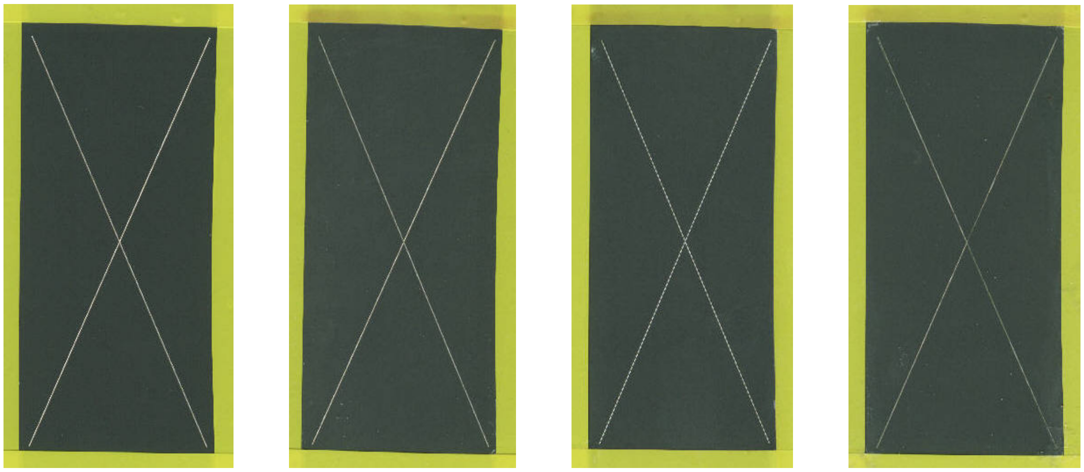
With complete final properties obtained in a matter of seconds under a UV lamp, this fast cure presents a tremendous advantage in expanding the conditions in which it is possible to conduct painting operations for field-applied coatings. Cure within seconds provides many advantages, including time savings and improved efficiency and higher quality coatings due to the elimination of long cure periods when temperature, humidity, or other factors could cause damage to uncured coatings. In addition to complete cure at low temperatures that is currently impossible with conventional paints, it is also possible to apply and cure UV coatings even when rain is expected shortly. This is especially advantageous at hot summertime locations where conditions are often ideal in the morning and rainy in the afternoon. With UV technology, after UV cure the coating has full properties and will be unaffected by rain, unlike conventional materials.

In addition to improved corrosion protection of steel, results have also demonstrated the suitability of UV coating technology for high performance corrosion protection of high strength aluminum alloys for aerospace applications. For instance, environmentally friendly Multifunctional UV (MUV) curable pigmented coatings have been developed to replace both the strontium chromate epoxy primer and isocyanate-containing polyurethane topcoat for aerospace applications.[5] A health and safety assessment of the MUV curable aircraft protective coating alternative to current aerospace coatings is shown in Figure 4.[6]

	Health (HMIS Rating)	Reactivity (HMIS Rating)	Flammability (HMIS Rating)	Carcinogenic (Cal. Prop. 65)	Teratogenic (Cal. Prop. 65)	SARA 313	VOC
MUV	2	2	1	No	No	Yes	None
Epoxy chromate primer	3	1	3	Yes	No	Yes	334 g/l
Polyurethane topcoat	4	1	3	No	Yes	Yes	420 g/l

Figure 4. Health And Safety Ratings Of MUV Technology And Current Aerospace Coatings[6]

MUV coatings have demonstrated good compatibility and excellent corrosion protection for aluminum alloys with a number of different surface treatments. High performance MUV coating technology has satisfied major requirements of aerospace primer specification MIL-PRF-23377 and aerospace topcoat specification MIL-PRF-85285, including low gloss camouflage appearance, good adhesion, hardness, solvent resistance to methyl ethyl ketone (MEK) and Skydrol® hydraulic fluid, and excellent ASTM B-117 corrosion resistance, with the scribe lines of 2024-T3 aluminum alloy panels remaining shiny after 3000 hours of salt fog testing (Figure 5). These high performance properties are obtained with immediate cure using a high intensity UV lamp, and in the complete absence of any solvents, VOCs, HAPs, isocyanates, chromium compounds, or any hazardous materials whatsoever. Similar properties are obtained using low intensity handheld UV lamps.



0 Hrs **1000 Hrs** **2000 Hrs** **3000 Hrs**

Figure 5. Corrosion Protection Of 2024-T3 Aluminum Alloy In ASTM B-117 Salt Fog Testing

For comparison, an unprotected aluminum alloy corrodes very quickly (Figure 6).

Figure 6. 24 Hour Corrosion Of Unprotected 2024-T3 Aluminum Alloy In ASTM B-117 Salt Fog

Conclusion

In addition to providing manufacturing efficiency and environmental benefits, UV coating technology provides excellent protection for surfaces, including UV protection and resistance to weathering from sunlight. UV technology also provides toughness, solvent resistance, and abrasion resistance, along with corrosion protection for metal surfaces, including steel and high strength aluminum aerospace alloys. When compared to conventional technology, high performance solvent-free UV curable coatings provide improved protection with dramatically faster cure and lower material usage. Clean and green UV technology not only improves efficiency in many manufacturing processes, but also addresses important societal issues such as sustainability and the need to improve health aspects of high performance coatings, reducing VOCs, HAPs, and other pollution. UV coating technology provides safer and more efficient alternatives for corrosion resistance in important markets representing major infrastructure of the United States, including vehicles, bridges, storage tanks, and piping.

References

1. RadTech Technical Committee, “UV/EB Technology: A Way to Reduce Greenhouse Gas Emissions,” Radtech Report, pp. 12-13, May/June 2005.

2. Ronald Golden, “Low-Emission Technologies: A Path to Greener Industry,” Radtech Report, pp. 14-18, May/June 2005.

3. “Corrosion Cost and Preventive Strategies in the United States”, Report No. FHWA-RD-01-156, CC Technologies and NACE International, September 30, 2001.

4. Ben Curatolo, “UV Technology For High-Performance Industrial Applications,” RadTech Report, pp. 24-27, Fall 2011.

5. Matthew J. O’Keefe, William G. Fahrenholtz, and Ben S. Curatolo, “Multifunctional UV (MUV) Curable Corrosion Coatings for Aerospace Applications”, Metal Finishing, pp. 28-31, February 2010.

6. Matt O’Keefe, “Corrosion Finishing/Coating Systems For DoD Metallic Substrates Based On Non-Chromate Inhibitors And UV Curable, Zero VOC Materials,” SERDP Project WP-1519 Final Report, August 2010.