50 Shades of Fuchsia

Controlled Polymer Morphology with Functionality Addresses Consumer Demand for Deeper Tones and Lower VOC

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From flat to eggshell to semi-gloss, architectural paints have made incredible gains in ultra-low VOC paint performance, but achieving a smooth, hard, glossy finish without the help of solvent has been much more elusive across the color spectrum of deep tones. In these polymer-rich paint formulations, ultra-low VOC options typically employ a soft polymer or a hard polymer with a nonvolatile coalescent. Both result in poor block and tack resistance. As titanium dioxide- and extender-rich neutrals and pastels make way for bolder, brighter accent colors, there is growing consumer demand for deep-tone paints that go on smoothly, dry quickly, and maintain a glossy, hard finish without cracking. A controlled polymer morphology has been developed which employs hard, soft, and functional monomers in a single waterborne acrylic binder.* When compared to both low-VOC (< 50 g/L) and ultra-low VOC (< 5 g/L) commercial binders, test results demonstrate that this polymer technology offers improved film formation, hardness, and tack and print resistance when used in ultra-low VOC, deep-base paints.

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Hard Facts about Soft Binders

Neutral tones have dominated the interior color spectrum for many years, with gray scoring back-to-back honors as the top paint color of 2014 and 2015 in surveys by the Paint Quality Institute (PQI). Today, fashion forward trends are calling for more vibrant interiors: purples, reds and other saturated hues are topping the list of recommended colors for accent areas such as doors, railings, window trim, furniture, entryways, and cornices. These deep tones are notably absent of titanium dioxide (TiO_2), the primary white pigment in neutral through mid-tone paints.

Titanium dioxide, and to a lesser extent calcium carbonate, are used to provide hiding through light refraction. They also contribute to film hardness. Deep and accent tone paints, by contrast, do not contain the aforementioned scattering pigments which can reduce the chromaticity of the paint film. These paint formulations derive most of their film hardness properties from the polymeric binder. When used with a volatile coalescent, high T_g polymers are preferred because they promote faster hardness development and overall harder finishes. Thus, challenges emerge in this chromatic ultra-low VOC space due to the combined lack of volatile coalescent and the absence of pigments to promote hardness.

To lower the VOC content of aqueous paints, a nonvolatile coalescent-like plasticizer may be used in place of volatile ones to enhance film formation; however, these plasticizers do not volatilize out of the paint film and the resulting finish remains soft and tacky, with poor block and print resistance. Using a higher T_g binder without plasticizer generally improves hardness, but takes away from film formation and results in poor scrape and crack resistance. A third option is to use a low T_g polymer. While this alternative generally improves scrape and crack resistance, it does so at the expense of hardness and tack.

PROPERTY	TYPICAL VALUES
CHEMISTRY	ACRYLIC
SOLIDS (WT%)	46%
PH	8
MFFT (°C)	0

TABLE 1—Typical Properties of 100% Acrylic Binder Featuring Controlled Polymer Morphology with Functionality Developed for Ultra-Low VOC, Deep Tone Architectural Paint. NOTE: These are typical properties, not to be construed as specifications

The Goldilocks Solution

Research was conducted to achieve an optimal balance between the soft and hard phases during film formation for ultra-low VOC, deep-base paints. The research focused on post film formation crosslinking chemistries used in combination with latex particle morphology optimization. Initial experiments were conducted to establish structure-property relationships between binder compositions and formulation variables. Then, predictive models from the experimental designs were used to develop an optimized binder for ultra-low VOC, deep-tone paints.

As demonstrated in *Figure 1*, the optimized binder is based on controlled morphology that combines hard and soft monomers plus a functional ambient crosslinking monomer (see *Table 1* for typical binder properties). When used in low-pigmented and zero-pigmented test formulations, this controlled polymer morphology with functionality exhibits excellent film formation as well as faster hardness development, harder final films, equal block resistance, and improved print and tack resistance compared to commercial low-VOC and ultra-low VOC offerings.

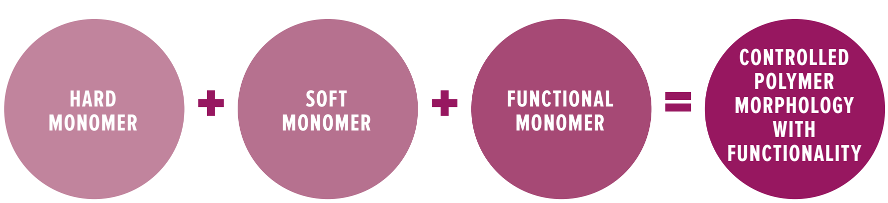

FIGURE 1—Ultra-low VOC technology for deep-base paints optimizes film formation and hardness by precisely engineering hard, soft, and functional monomers in a waterborne acrylic binder.

TESTING AND RESULTS

Binder technology based on controlled polymer morphology with functionality was evaluated against three competitive ultra-low VOC (< 5 g/L) binders and a leading low-VOC (< 50 g/L) binder in a deep-base gloss test formulation and a gloss accent base formulation (see *Tables 2 and 3* for starting point test formulation details).

Improved Hardness Profile

Hardness properties as affected by binder selection were evaluated over a seven-day period per ASTM D-4366 method for a deep-base gloss paint (4% PVC/30% VS) tinted with 12 oz/gal of black colorant and applied to aluminum panels via 5-mil drawdown bar. As demonstrated in *Figure 2*, the deep-tone test paint formulated with the optimized binder demonstrated significant improvement in hardness development compared to test paints formulated with competitive binders at equal VOC level (< 5 g/L) and a leading commercial binder at higher VOC level (< 50 g/L).

Reduced Tack

Tack resistance is a key performance benefit derived from harder paint films. This performance property was evaluated using 5 mil drawdowns of deep-base gloss test paint formulations (4% PVC/30% VS) tinted with 12 oz/gal of black colorant applied to aluminum panels and dried for 24 hr. Cotton balls were placed on each panel and subjected to 15 min of pressure from a 1000-g weight. Resistance to tack was measured by the amount of cotton ball fibers remaining after the cotton balls

MATERIAL NAME	POUNDS	GALLONS	LEVEL	
GRIND				
WATER	20.36	2.44		
FOAMSTAR A-34 DEFOAMER	1.02	0.13		
TERGITOL™ 15-S-9 SURFACTANT	4.07	0.52		
TAMOL™ 2011 DISPERSANT	5.09	0.56	5.50%	% DISP
AMP-95 NEUTRALIZER	1.02	0.13		
MINEX 10 EXTENDER	25.46	1.17	3.94%	PVC
WATER	101.82	12.2		
GRIND SUB-TOTAL	**158.84**	**17.15**	**3.94%**	**PVC**
LETDOWN				
BINDER	603.8	68.18		
TEXANOL ESTER ALCOHOL	6.92	0.87	2.55%	% COAL
OPTIFILM ENHANCER 400 PLASTICIZER	2.75	0.34	1.01%	% COAL
WATER	53.56	6.42		
ADD GRIND HERE				
ACRYSOL™ RM-1600 RHEOLOGY MODIFIER	43.78	5.03		
ACRYSOL™ RM-995 RHEOLOGY MODIFIER	17.82	2.01		
TOTALS	**887.47**	**100.0**		

PROPERTY*	VALUE	(WITHOUT ADDITIVES)
TOTAL PVC	3.94	%
VOLUME SOLIDS	29.65	%
WEIGHT SOLIDS	33.48	%

*These are typical properties, not to be construed as specifications.

Post Added 12oz/gal Colortrend 808-9907 Lamp Black

TABLE 2—Starting Point Formulation for Deep-Base (4% PVC/30% VS) Waterborne Acrylic Test Paint

PROPERTY *	VALUE
%VOLUME SOLIDS	31.68
%WEIGHT SOLIDS	34.52
DENSITY	8.757
TOTAL % COALESCENT	2.5
VOC GENERIC WATER EXCL.	50

*These are typical properties, not to be construed as specifications.

MATERIAL NAME	LBS	GALLONS
LETDOWN		
BINDER	671.7	75.9
BYK-024 DEFOAMER	1.0	0.12
WATER	83.5	10.0
DOWANOL™ DPNB PLASTICIZER	7.56	0.99
PROPYLENE GLYCOL	6.0	0.69
KATHON™ LX 1.5% MICROBIOCIDE	1.5	0.18
ADJUST VISCOSITY		
WATER	46.45	5.57
ACRYSOL™ RM-3000 RHEOLOGY MODIFIER	40.0	4.6
ACRYSOL™ RM-995	10.0	1.15
BYK-024	1.0	0.12
BIOBAN™ IPBC 40LE	7.0	0.69
TOTALS	**875.71**	**100.0**

*Clear Formulation | 12 ozs/gal of Pure Options Black Colorant was added for performance testing.

TABLE 3—Starting Point Formulation for Gloss Accent Base (0% PVC/30% VS) Waterborne Acrylic Test Paint

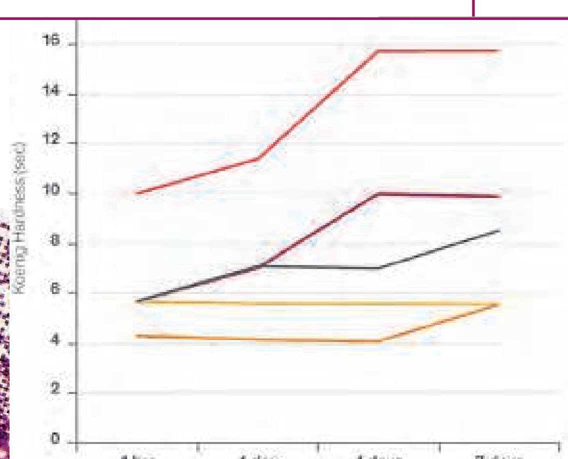

FIGURE 2—Ultra-low VOC, deep-base test paint formulated with binder based on controlled polymer morphology with functionality demonstrates faster hardness development and improved overall hardness versus test paints formulated with competitive binders and a commercial Dow binder.

FIGURE 3—Photographs of coated test panels after removal of cotton balls that were placed on each panel and subject to 15 min of pressure from a 1000 g weight.

were removed from the coated panels. As shown in *Figure 3* and presented in *Table 4*, the binder technology based on controlled morphology with functionality demonstrated excellent tack resistance versus competitive binders at equal VOC (< 5 g/L) and the commercial binder at higher VOC (< 50 g/L).

Improved Print Resistance

Print resistance is influenced by film hardness and is particularly important where deep-base coatings are used on window sills, accent tables, shelves, and other horizontal surfaces. Longer-term pressures from flower pots, cups/saucers, and similar household items can lead to permanent deformations in the paint film. This key property was evaluated by a method based off ASTM D-2064 using 5 mil drawdowns of 4% PVC/30% VS paints tinted with 12 oz/gal of black colorant. Formulations were applied to aluminum panels and dried for 24 hr before lids were placed on films with 1000 g weight for 20 hr. As shown in *Figure 4*, the optimized binder technology for deep-base paints demonstrated excellent resistance against imprinting compared to a test paint formulated with a commercial binder and the high gloss commercial binder.

Superior Scrape Resistance

A paint's scrape resistance is influenced by both its mar resistance and its adhesion to the substrate. This performance property was evaluated using a scrape adhesion test method based on ASTM D-2197. Five mil drawdowns of 4% PVC/30% VS deep-base gloss paints tinted with 12 oz/gal of black colorant were made on aluminum panels and dried for 24 hr before a controlled metal loop stylus was slid across the films with increasing amounts of weight and film damage was observed and rated. As shown in *Figure 5*, the binder technology based on controlled morphology with functionality demonstrated excellent scrape resistance far exceeding the other competitive binders tested.

Overall Performance

In addition to extensive testing in low-pigmented paint formulations, the new binder technology optimized for ultra-low VOC (< 5 g/L), deep-base paints was compared to a commercial low-VOC (< 50 g/L) gloss binder in a zero-PVC gloss accent base. As demonstrated in *Table 5*, the ultra-low VOC binder technology performed as well or better than the higher VOC commercial offering in gloss and hardness, as well as tack, print, and block resistance.

SUMMARY

A 100% acrylic binder has been developed that offers early hardness development in ultra-low VOC, deep-base architectural paints. The binder technology is based on controlled morphology that combines hard and soft polymers with ambient crosslinking functionality. Test results demonstrate that this binder technology offers world-class scrape adhesion and hardness, better or comparable print resistance to all other binders tested, and better block and tack resistance versus both low- and ultra-low-VOC alternatives. It can be used to formulate ultra-low VOC, binder-rich, highly colored architectural paints that still have excellent hardness, and excellent tack, block, print, and scrape resistance. ❊

VOC	BINDER	TACK 24 HR (15 MIN)
<5 G/L	OPTIMIZED FOR DEEP BASE	4
<5 G/L	COMPETITIVE A	2
<5 G/L	COMPETITIVE B	2
<5 G/L	COMPETITIVE C	3
<50 G/L	COMMERCIAL GLOSS	3

LEGEND (COTTON-BALL REMAINING)
1=MOST
2=MUCH
3=SOME
4=SLIGHT
5=NONE

TABLE 4—Tack Ratings after 24 hr

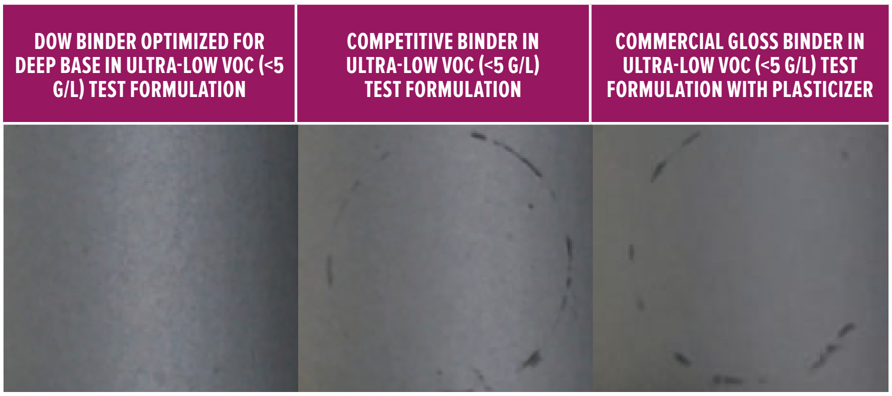

FIGURE 4—Print resistance was tested by placing lids on coated panels that were dried for 24 hr and then subject to pressure applied by 1000 g weights for 20 hr.

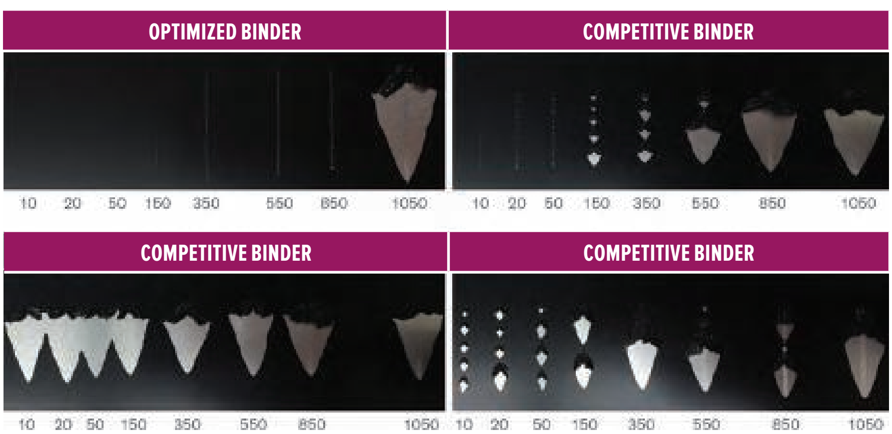

FIGURE 5—Scrape resistance of deep-base gloss test paints formulated with optimized binder vs three competitive binders.

TABLE 5—Performance of Ultra-Low VOC Binder Technology Optimized for Deep-base Paints in 0% PVC/30% VS Accent Base (Tinted with 12 oz/gal of Black Colorant) Relative to Commercial Gloss Binder in a Low-VOC (< 50 g/L) Formulation

	BINDER OPTIMIZED FOR DEEP BASE
TYPICAL FORMULATION VOC	NEAR 0
COALESCING AGENT DEMAND	+
GLOSS	=
TACK -1 DAY (ZAPON)	++
TACK -7 DAY (ZAPON)	=
BLOCK – 1 DAY (RT&HOT)	+
BLOCK – 7 DAY (RT&HOT)	+
PRINT RESISTANCE - 1 DAY	++
PRINT RESISTANCE - 7 DAY	++
HARDNESS - 1 DAY (PENCIL)	++
HARDNESS - 7 DAY (PENCIL)	++

Final Frontiers in Architectural Paint: Expanding the Color Spectrum

While today's color trends in paint are influenced by everything from global events to Game of Thrones, color choices in the past were limited by technology and availability. Before the Revolutionary War, U.S. homes were built of higher quality woods like eastern white pine, white cedar, and white oak and typically not painted. Even into the 19th Century, color choices for paint were restricted to red, black, and hues derived from colored clays due to a lack of supply in pigments that were stable and affordable. The real color revolution arrived in 1856 with the development of synthetic organic dyes and pigments, but the greatest growth happened in the 20th Century, which saw many new advancements in paint formulations and technology. With the development of water-based acrylic emulsion technology in the 1950s, homeowners had an easy-to-use paint that they could apply themselves, as well as a variety of colors to choose from.

Today, home and building owners are turning to high gloss for its durability and the fact that it is easy to clean; high gloss is often used on trim, accent areas, doors and frames–places that must withstand a lot of wear and tear, as well as moisture. Design-forward spaces have also used high gloss on cabinets and accent pieces to add luster and appeal. More recently, high-gloss paints have been finding their way onto even larger surfaces, used in hallways, in living rooms, bedrooms, and even on ceilings in some of the most fashionable restaurants and residences. Those in the know report the finish's ability to add "glamor" and "drama" to a room as key selling points. Wherever it is placed in homes and buildings, high-gloss paint is sure to be part of the color trends for 2016 and 2017 as announced by a leading producer of color and additive solutions for polymeric products.* Their forecast for the coming year includes an array of bold and dark colors that are in keeping with the dramatic look offered by high-gloss paint.

* www.textileworld.com/Articles/2015/September/Americhem_Unveils_Its_20162017_Color_Trends.

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