Novel Energy-Curable Polyurethane Dispersion with High Formulation Versatility

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Introduction

Due to the fact that release of chemicals into the atmosphere is becoming one of the major environmental concerns in the coating industry, Waterborne **UV-PUD's** could be a significant solution to this phenomenon due to their low VOC contents. In addition to being more environmentally friendly, they also bring other valuable properties that can compete well with solvent borne coatings. Some of the benefits of waterborne UVPUD's include, but not limited to:

- Very minimal to zero VOC
- Excellent adhesion due to no to very low shrinkage
- Ability to reclaim overspray
- Ease of gloss and viscosity control
- Hardness & flexibility
- Low viscosity.

Allnex is a leader in the development of energy curable waterborne dispersions which bring quality to the world of coatings. The company proudly introduces UV-PUD 7788, a cost-effective, innovative solution for formulators of water-based UV curable wood coatings looking to differentiate and customize their products.

UV-PUD 7788 is a tin and VOC-free radiation-curable polyurethane dispersion developed for industrial Wood and Furniture applications. It offers a unique combination of versatility, stability and performance/cost ratio.

Market Needs

Market analysis indicated that there was an essential need for a UV-PUD that performed good dispersion stability at elevated temperature and also performs good compatibility with blends of conventional waterborne and other UV-PUD's alike (Figure 1). These two properties will give formulators an option of cost reduction, coating properties modification as well as ease of transport and storage of materials where temperature rises significantly. Rise of temperature is a detrimental factor in the stability of waterborne UV-PUD's. UV-PUD's that currently exist in the market and some are popular in the industry, lack either or of these two characteristics. The company recently developed a UV-PUD which is novel to the coating market and eliminates concerns about stability and compatibility. UV-PUD 7788 offers benefits that its counterparts in the market could not offer.

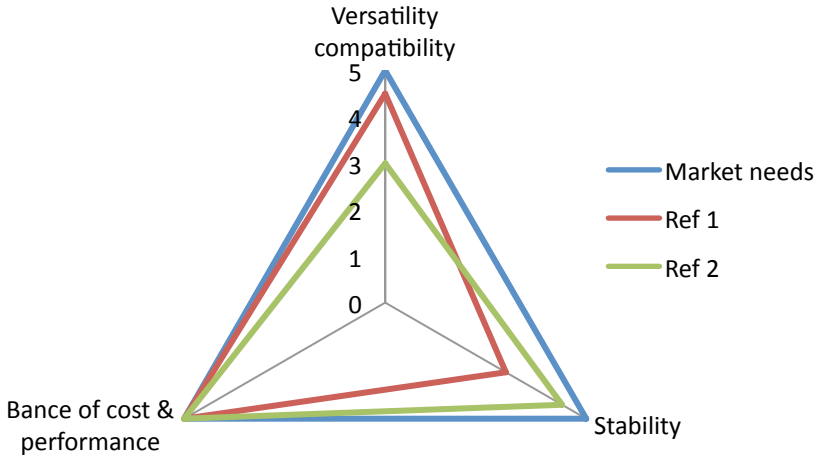


Figure 1: Qualitative analysis of market needs for waterborne UV resin for wood coatings

Compatible and Versatile

Colloidal stability of most UV-PUD's is affected when they are exposed to severe temperature differentiation. Cold or hot temperature could negatively affect the properties of a substance. When a substance goes through temperature differentiation, its particle size may change and affect properties of bulk verses surface molecules.

To overcome the instability of colloidal system, the polymer structure and ingredients involved in producing the polymer should be selected in a way that temperature phenomenon would not affect the polymer's properties. Polymer structure can be achieved by fine tuning of the urethane, acrylate and urea mole weight. UV-PUD 7788, an aliphatic resin, possesses both stability and versatility properties.

Evaluations

To evaluate UV-PUD 7788 properties, the same was formulated to the market standard formulation (Table 1). To determine application results, different test methods and substrates were used. In formulation 1, glass and lenetta charts were used as substrates and a bar coater was utilized to apply coating. Formulations 2 and 3 were developed to evaluate high gloss and matte coatings. Formulation 4 was developed to represent pigmented coating and number 5 was used as primer. Formulations 2-5 were applied on oak, sapelli and beach substrates using spray method. Coating applications were performed as follow:

1. Wood substrates were sanded before coating was applied
2. 100-200 g/m² of coating was applied
3. Coating was oven cured (air circulated) at 50° C for 10 minutes and UV cured at ~1100 Mj/cm²
4. Coated substrates were sanded
5. Second layer of coating (same thickness) was applied and cured as step 3.

Table 1: Formulations based on UV-PUD 7788

	1 Films	**2** Glossy	**3** Low gloss	**4** Pigmented	**5** Primer
UV-PUD 7788	100	100	100	100	100
Di- water		10	10		
Matting agent			1.5	1.5	1.5
Wax			3.0	3.0	3.0
Leveling agent		1.0	1.0		
Defoamer		0.3	0.3		
Defoamer		0.3	0.3		
Photo-initiator	1.5	2.0	2.0	1.5	1.5
Photo-initiator				0.5	
Thickner (50%)	1.5			2.0	0.5
Pigment paste				15-25	

Results:

Test results prove that UV-PUD 7788 is versatile in terms of compatibility with other resins and stable in term of dispersion stability when it is exposed to an elevated temperature. These two characteristics of UV-PUD 7788 will give formulators the option to adjust their formulations to achieve desired properties.

Versatility

UV-PUD 7788 versatile property makes it possible for this resin to be blended with other radiation curable dispersions and also conventional waterborne resins. Blending UV-PUD 7788 with other resins will give formulator leverage to enhance properties of their formulation in addition to being cost effective. Another advantage of UV-PUD 7788 is that it could be used as either clear coat or pigmented. Its acceptance of pigment will make it possible to be used as pigmented coating (Figure 2). .

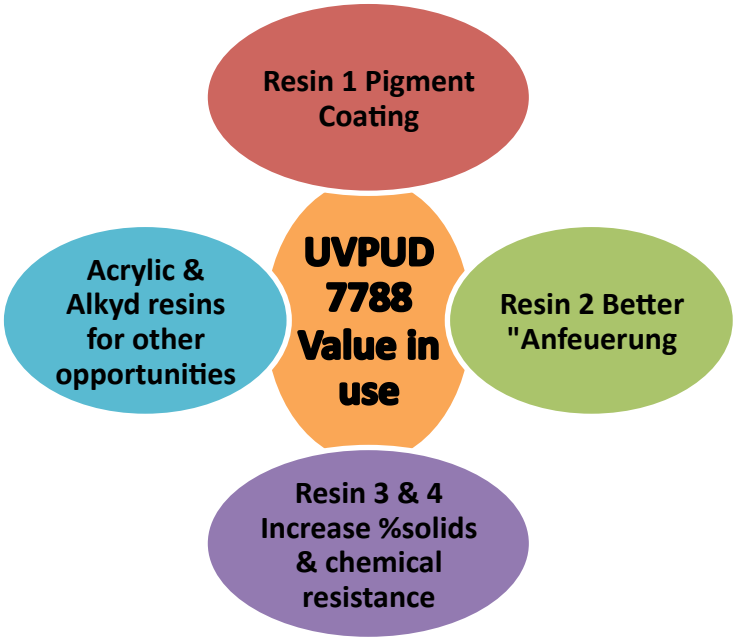


Figure 2: Four versatile blending options of UV-PUD 7788 for distinctive benefits

To enhance wood wetting property of desired coating and also scratch resistant and stain resistant, UV-PUD 7788 can be blended with other resins (Figure 3 & 4). Blending UV-PUD 7788 with resin 3 and resin 4 will lead to an increase in solids content (Figure 5).

Figure 3: Versatile blending - Pigmented coatings

Formulation 4 120µ wet by spray Drying 10 min at 50°C Curing at 1100mJ/cm²	UV-PUD 7788	UV-PUD 7788 Resin 1 (50/50)
Scratch resistance	5 (white only)	5 (all colors)
Stain resistance	2-3	4
Coating aspect	5	5

Rating: 5: very good, 4: good, 3: moderate, 2: weak, 1: bad

The stain resistance test was performed after substrate was coated and cured. Stain was placed on the coated area and covered with watch glass for a given amount of time at room temperature. To do a scratch test, the coating was cured and waited for one hour before using finger nail to scratch off the coating. The test was performed with pigmented coating as well. When TiO2 white pigment was used in coating based on UV-PUD 7788, it passed scratch test. However, when the same was blended with difficult colors it failed. Difficult colors' scratch resistance can be improved by blending UV-PUD 7788 with resin 1. Resin 1 is specially developed for pigmented coating. By blending these two resins, stain resistant will improve as well, while other properties remain the same (Figure 3).

Figure 4: Versatile blending – Better Anfeuerung

Formulation 5 2x 100µ wet (bar coater) Drying 10 min at 50°C Curing at 1100mJ/cm²	**UV-PUD 7788**	**UV-PUD 7788 / Resin 2 (50/50)**
Adhesion	5	5
Anfeuerung (Sapelli)	3	4
Resolubility	3	4
Tack before cure	4	2

Rating: 5: very good, 4: good, 3: moderate, 2: weak, 1: bad

For solubility test, coating was only oven cured and a few drops of water were placed on the coating. With the tip of the finger, it was rubbed to determine how soluble the coating is. This test determines whether end user will be able to reclaim and reuse the coating. Coatings' tack was determined by pressing the finger against the coating which was oven cured. If better wood wetting (Anfeuerung) property is desired, UV-PUD 7788 can be blended with resin 2 (Figure 4). This will increase coating tack, which help resolubility, and as a result, reusability of reclaimed coating. Resin 2 is the best to be used as primer.

Figure 5: Versatile blending – blend with polyurethane acrylic emulsions

Formulation 1 2x 100µ wet (bar coater) Drying 10 min at 50°C Curing at 1100mJ/cm²	**UV-PUD 7788**	**UV-PUD 7788 Resin 3 (80/20)**	**UV-PUD 7788 Resin 4 (80/20)**
Solid content (%)	40	45	45
Stability at 60°C (days)	>10	>10	>10
Stain resistance	3	3.5	2.5
Anfeureung (Sapelli)	3	3	4-5
Tack before cure	4	1	1

Rating: 5: very good, 4: good, 3: moderate, 2: weak, 1: bad

Resin 3 and resin 4 that are high in solids content emulsions can be used to increase solids content of UV-PUD 7788 without affecting other properties. By blending UV-PUD 7788 with either resin 3 or resin 4, colloidal stability is unchanged when the blend is exposed to elevated temperature. It is necessary to adjust the pH of both resins prior to blending with UV-PUD 7788. Stain resistance of coating will be improved by blend of UV-PUD 7788 and resin 3, while blend of UV-PUD 7788 and resin 4 will improve wood wetting (Anfeurung) (Figure 5). Resin 3 and Resin 4 are used for hard coat.

UV-PUD 7788 can be blended with conventional waterborne acrylic resins either for cost reduction or property enhancement. UV-PUD 7788 can also be blended with alkyd emulsions. These two blends will not have a negative effect on other properties of coating. The addition of Conventional resin of an acrylic latex with MFFT ~2°C or a long oil alkyd emulsion with MFFT <0°C represent valuable examples of stable formulations to make hybrid films with good adhesion. When UV-PUD 7788 is blended with alkyd resin, the stain resistance and block resistance of the coating as well as Anfeurung will improve. Block resistance test is determined by the force required to separate coated substrates pressed face-to-face for 2 hours with a pressure of 35g/cm^2 at 45°C. An acrylic and alkyd that are used in this testing are used for outdoor applications (Figure 6).

Figure 6: Versatile blends – compatibility with waterborne acrylic and alkyd polymers

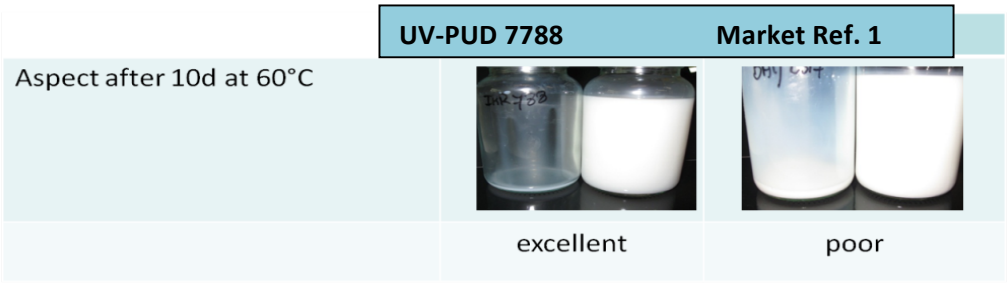
Formulation 1 2x 100µ wet (bar coater) Drying 10 min at 50°C Curing at 1100mJ/cm²	**UV-PUD 7788**	**UV-PUD 7788 Acrylic resin (70/30)**	**UV-PUD 7788 Alkyd resin (70/30)**
Stability at 60°C (days)	>10	>5	>5
Clarity of the film	5	5	5
Anfeuerung	3	3	5
Tack before cure	4	4	4
Stain resistance	3	3	3
Blocking resistance 45°C	4-5	4-5	3

Rating: 5: very good, 4: good, 3: moderate, 2: weak, 1: bad

Dispersion Stability

Most commercial UV-PUD's are not stable when exposed to an elevated temperature (60° C) for 10 days. They show some sort of sedimentation in this environment. Colloidal resin stability determines whether they are stable at elevated temperature or not. When UV-PUD 7788 was tested at elevated temperature, it did not show any sedimentation. After aging the same for 10 days at elevated temperature, it was emptied into another glass container to better determine if there is any sedimentation (Figure 7).

Figure 7: Elevated Temperature Stability of UV-PUD 7788



UV-PUD 7788	initial	10d 60°C
pH	7.6	7.1
Mean particle size (nm)	<100	<100
Viscosity of formulation after thickening (mPa.s)	610	600

Other Properties

Table 2 below shows the results of matte and clear coat evaluations of UV-PUD 7788. Both coatings were tack-free after water. Formulation number 2 showed gloss level above 90 GU and the matte coating (Formulation number 3) exhibited gloss of 20-25 GU. Due to good balance of elasticity, toughness and hardness, UV-PUD 7788 possesses great coin resistance after UV cure. UV-PUD 7788 can be easily adjusted for gloss level by varying the amount of matting agents. The final formulation has an excellent stability due to its versatility.

Table 2: Performance of a clear coat based on UV-PUD 7788

	Formulation 2 (glossy)	Formulation 3 (Low gloss)
Adhesion (beech, oak and sapelli)	5	5
Scratch resistance (beech)	5	5
Anfeuerung (sapelli)	3	3
Gloss level (60°) ; GU	92-93	20-25

Rating: 5: very good, 4: good, 3: moderate, 2: weak, 1: bad

Crosshatch testing was done to evaluate adhesion (DIN EN ISO 2409). Wood wetting property (Anfeurung) was visually compared to that of control. The coating flexibility, hardness and toughness were evaluated using coin test method. Gloss meter was used to measure gloss at a 60° angle and recorded in GU (gloss unit).

Water Release Property

Water release is a very important aspect of a waterborne resin. If water is not fully evaporated from coating, it will result in whitening and delamination. To improve water release, co-solvent is added to keep the film open longer for water to evaporate. UV-PUD 7788, however, offers good water release, so it is not necessary to add co-solvent to improve this aspect. This property of UV-PUD was compared to that of market reference by applying 200µ of wet film and drying for 10 minutes at 50° C. The test was done with pure UV-PUD and also with the blend of acrylic latex (Figure 8).

Figure 8: Fast-dry performance of UV-PUD 7788

Formula 1	UV-PUD 7788 / Acrylic latex* (50/50)	Market Ref. 1 / Acrylic latex* (50/50)
Mud cracking on 200µ film after forced drying 10 minutes at 50°C	no	yes

*: Market reference with MFFT ~ 30°C

Formula 1	UV-PUD 7788	Market Ref. 1
Whitening of 200µ film after forced drying 6 minutes at 40°C and visual inspection after 48 hours	4	3

Rating: 5: very good, 4: good, 3: moderate, 2: weak, 1: bad

Conclusion

UV-PUD 7788, a novel resin, offers valuable properties such as robustness and performance that its counterparts in the market lack as such. UV-PUD 7788 gives formulators the option of formulating their coating as desired by their customers. Storage and transportation of coating based UV-PUD 7788 in geographical areas with hot temperatures will eliminate the concern of stability issue. The overall cost saving and ease of formulation with fast drying property are other values that this resin bring to the market.