Nancy Li, *Cindy Jin*, *William Chen*, *Joyce Zhao* and *Yun Liu*, Dispersions and Resins, BASF, discuss why hybrid technology offers the 'best of both worlds'

High performance and cost-effective polyurethane-acrylic (PUA) hybrids for 1K waterborne wood coatings

Why Polyurethane Acrylic (PUA) hybrids for 1k high end waterborne wood coatings? Acrylic dispersions are known for fast drying, high hardness, good chemical resistance and cost efficiency; and are being extensively used in waterborne wood coatings. However, for some high-end applications, such as tables, flooring and kitchens where there is wear and tear we need excellent scratch and abrasion resistance properties, which acrylic dispersions may not provide. Polyurethane dispersions (PUD) on the other hand, have excellent performance, such as toughness, flexibility and abrasion resistance but are more expensive.

Thus, we consider hybrid technology that brings the 'Best of both worlds' – good performance and cost balance:

- Acrylic dispersions provide good chemical resistance at a lower price
- PUDs provide excellent mechanical properties, such as abrasion resistance, high scratch resistance and block resistance

Key requirements can be segmented under four categories:

- Hardness/scratch resistance/ abrasion resistance
- Chemical resistance
- Appearance/gloss/transparency
- Hand-feeling

While there are already existing PUA hybrids in the market, used as a main binder for high end wood coating topcoats, the existing benchmarks for PUA do not have balanced properties in all four categories and are lacking in one or the other, as shown in **Figure 1**.

BASF has developed a new hybrid EPX-PUA7 by carefully optimising the acrylic phase via core-shell morphology and self-crosslinking technology and polyurethane phase using unique building blocks.

EPX-PUA7 provides the most balanced properties in terms of all the above four categories, as shown in **Figure 2**, including good pencil hardness; dried film clarity, as well as abrasion, scratch and chemical resistance.

There are two commonly used methods for scratch resistance in this article. Scratch method 1, by crock meter, which checks the gloss lost after certain double round rub; and scratch method 2, by needle test, to record the maximum weight without damage when a needle is passed through the film. The two methods represent different film characteristics and, therefore, we use both in this study (see **Figure 3**).

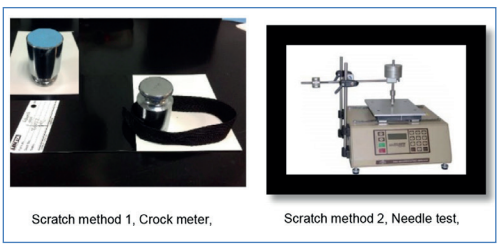


Figure 3. Two scratch resistance test methods

Figure 1. Performance of three popular PUAs in the market

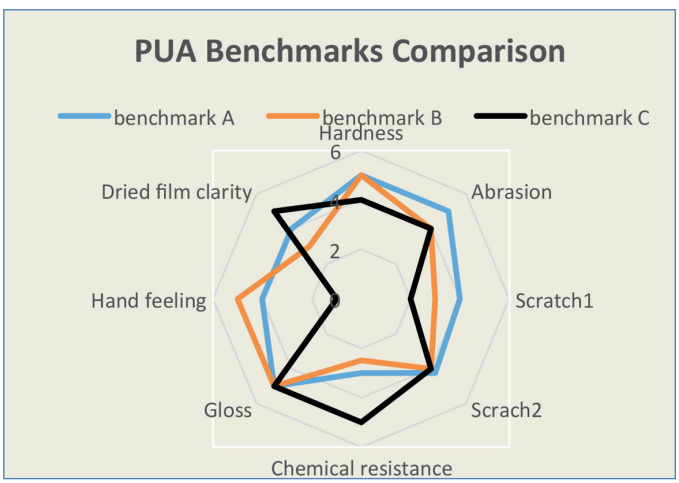
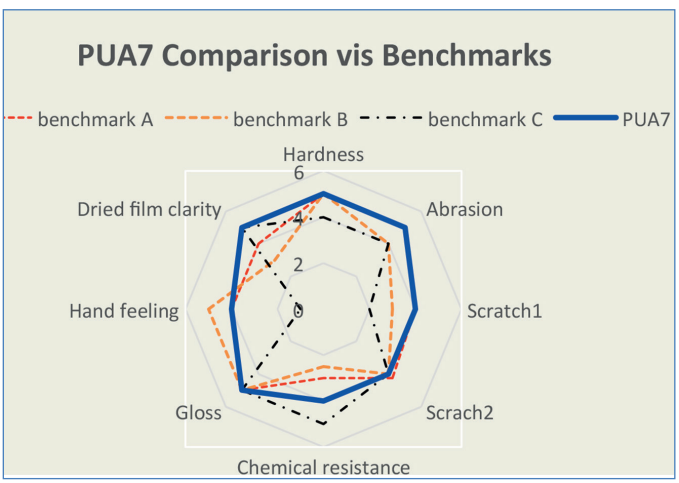


Figure 2. Comparison of BASF EPX-PUA7 and three benchmarks



FORMULATION DEVELOPMENT BASED ON BASF NEW PUA

BASF's newly developed PUA, EPX-PUA7 is based on a self-crosslinking acrylic and cycloaliphatic polyurethane hybrid dispersion. It is NMP-free, VOC compliant and offers both enhanced properties and excellent aesthetic properties. The typical physical characteristics are given in **Figure 4**.

Appearance	Translucent emulsion
Solid by weight	37.5%
Viscosity, 25°C (Brookfield)	100mPa.s
pH	8.1
Minimum film-forming temperature	35°C

Figure 4. EPX-PUA7 typical physical characteristics

High end waterborne wood coating formulation development based on EPX-PUA7:

1. Coalescing solvent selection

Di-propylene Glycol n-Butyl Ether (DPnB) is a very efficient coalescent and can obtain a hydrophobic film but it is relatively slow in evaporation. Ethylene Glycol Mono-butyl Ether (BCS) is a fast-evaporating glycol ether with an excellent balance of hydrophilic and hydrophobic characters. Both DPnB and BCS have good compatibility with EPX-PUA7 and can get smooth and transparent film. Meanwhile, a DPnB and BCS combination can give excellent film forming effect and balanced drying speed. The different dosages of coalescent is studied, see **Figure 5**.

Figure 5 shows that, at room drying condition, 10% coalescing solvent on dispersion solid is enough to keep film integral without cracking. At 5°C, 20% coalescing solvent is needed. Therefore, 10 - 20% coalescing solvent on dispersion solid is recommended for different applications.

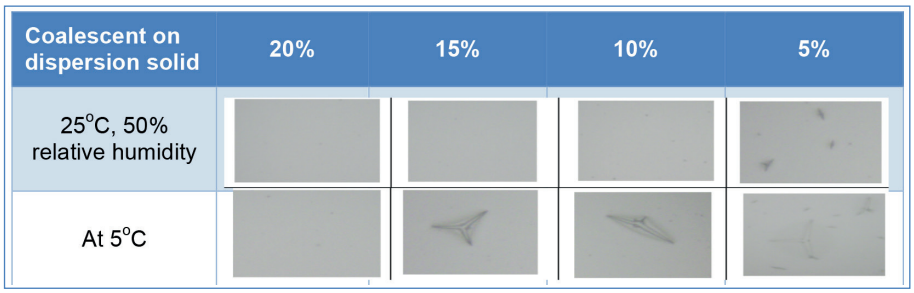


Figure 5. Dried film appearance under 50×microscopy, applied by 100µm bar coater on glass

2. Formulation additives help further improve slipping and scratch resistance

As a high quality topcoat formulation, wax and some silicone additives are commonly used to improve hand feeling, slipping and scratch resistance.

Hand feeling is one of the important parameters for a high-end wood coating to indicate surface slipping effect. The surface slipping effect can be felt by touching the dried film surface. This method may have varying results depending on the individual, therefore we also use Coefficient of Friction (COF) for better assessment. COF method is aligned with ASTM 1894 so that a lower value of COF indicates better slipping effect.

2.1 Wax selection

Three selected polyethylene waxes are added into EPX-PUA7 clear formulation. The effect is shown in **Figure 6**.

From **Figure 6** we see that all three selected waxes can improve some properties from a different perspective but some properties would be sacrificed. All in all, Joncryl WAX 35 shows best overall performance without sacrificing gloss and haze.

Joncryl WAX 35 is a fine particle size polyethylene wax emulsion that improves water resistance and scratch resistance, but has no impact on film gloss and haze.

Therefore, Joncryl WAX 35 is recommended for systems requiring high gloss and transparency.

2.2 Silicone additive

0.5% silicone type slipping agent is added in EPX-PUA7 clear coat formulation separately. The overall performance is shown in **Figure 7**.

All of the silicone type additives can improve the formulations in different ways but all of them impact final film gloss and haze.

Hydropalat SL 3682 is an ultra-high molecular weight silicone dispersion. It can improve abrasion, scratch resistance, hand feeling and COF. Therefore, it can be recommended for formulations that require less gloss and clarity. If it is used in glossy and transparent systems, a low dosage is advised.

See **Table 1** and **2** for final EPX-PUA7 clear topcoat formulation and key performance

CONCLUSION

With this anionic cycloaliphatic self-cross linking polyurethane hybrid dispersion EPX-PUA7, we can obtain not only excellent toughness but also very good chemical resistance. Joncryl WAX 35 wax emulsion can further improve scratch resistance and chemical resistance of the formulation without influencing dry film gloss and clarity. Hydropalat SL 3682, used as a silicone slipping agent, can improve scratch

Figure 6. Different wax effect on PUA7 clear formulation

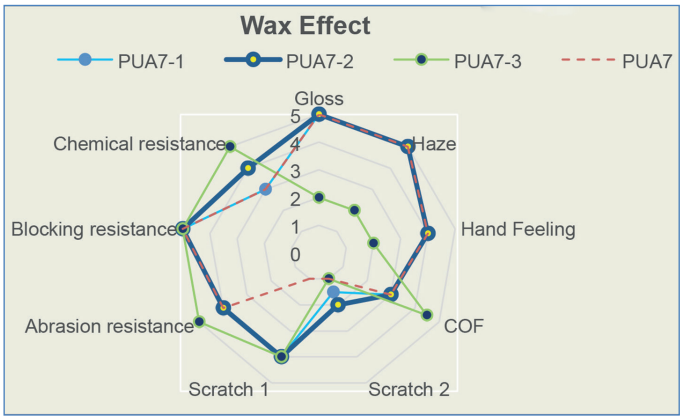
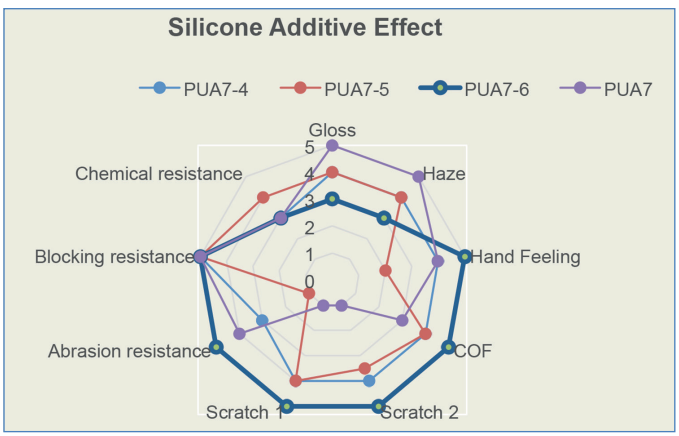


Figure 7. Effect of different silicone type slipping agents on PUA7 clear coat



Raw material	Function	% by weight
EPX-PUA7	Polyurethane acrylic dispersion	84.3
Foamstar SI 2280	Defoamer	0.3
DPnB	Coalescent	6
BCS	Coalescent	0.5
Di-water	Water	4.5
Joncryl wax 35	Polyethethylene wax dispersion	2
Hydropalat WE 3650	Wetting agent	0.3
Rheovis PU 1291 (50% in water)	Thickener	1.0
Di-water	Water	1.1
Total		**100**

Table 1. EPX- PUA 7 clear coat formulation

Test items	Standard	Results
Pencil hardness	ISO15184-2012	HB
Dry film clarity	ASTM D 1033	0.79/ 93.1
Gloss, 20° 60° 85°	ASTM D 523	81.3 93.3 99.6
Water resistance	GB/T 4983.1-2005	5
Alcohol resistance	GB/T 4983.1-2005	4
Scratch resistance 1	NA, see **Figure 2**, gloss lost after 10 times double rub	26%
Scratch resistance 2	ASTM 2496	80g
Kinetic COF	ASTM D1894	0.74
Abrasion resistance, Taber5135	ASTM D 3884	10mg

Table 2. Key performance of EPX-PUA7 clear coat

resistance, reduce coefficient of friction and enhance the slipping effect.

High performance and cost effective waterborne wood coatings are no longer difficult. This new PUA can also be extensively used for high-end segments in furniture and parquet flooring coating formulations, as well as plastic, metal and concrete coatings as both interior and exterior industrial applications. ■

Acknowledgements
The authors would like to thank Dr Vijay Immanuel Raman and Dr Qiuling Feng's for their consistent support on the work; Ami Ganatra and Kin-Sum Kong's professional inputs.

Contact Author: Ms Nancy Li, Technical Manager, Coating Formulation Team, Dispersions and Resins (ED) R&D Center, Asia Pacific, BASF
Tel: +86 21 2039 1667;
Email: nancy.li@basf.com