# Energy Curable Coatings for Automotive Interior

- Marcus Hutchins and Jennifer McClung



allnex
The Coating Resins Company

# Content

- Technology/Process Comparison
- Challenges of UV Cure
- Products – 100% Solids and Waterborne UV
- Experimentation
- Results
- Conclusion – 100% Solids UV and Waterborne UV
- Next Generation
- Technology Comparison
- Experimentation
- Results
- Conclusion

# Automotive Interior Technology Comparison

## 1K or 2K Conventional (NCO- OH)

+ Full cure for difficult shape of part
+ Lower shrinkage
+ Outstanding weatherability

- Space and time
- Slow cure
- High energy consumption for drying

## UV Curing

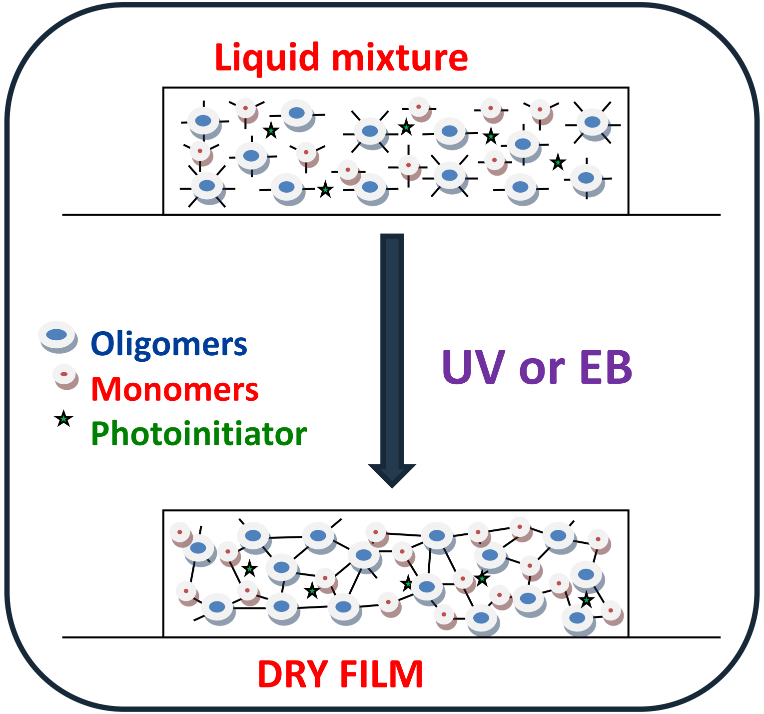
+ Fast cure (high productivity)
+ High scratch & chemical resistance
+ Small footprint & easy line retrofits

- 3D shape => NO UV = NO Cure
- Volumetric shrinkage
- Adhesion is not robust

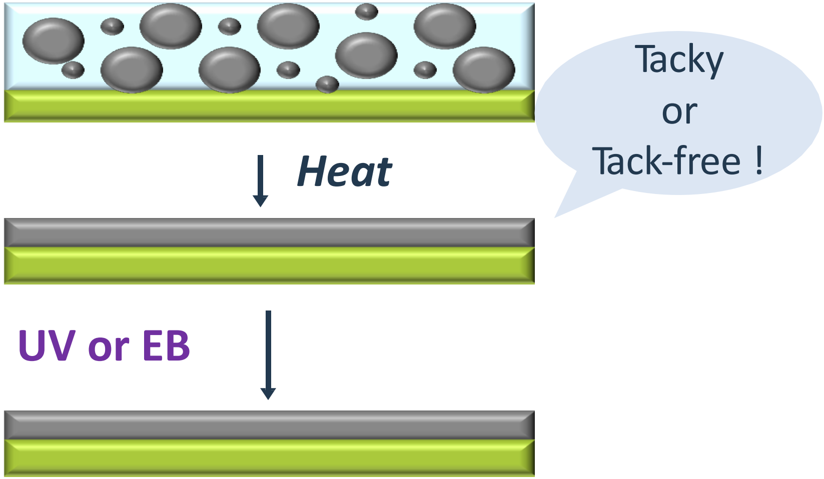
allnex The Coating Resins Company

# Technology Comparison

100% Solids ⟷ Water- or Solvent-borne (1K/2K, UV)



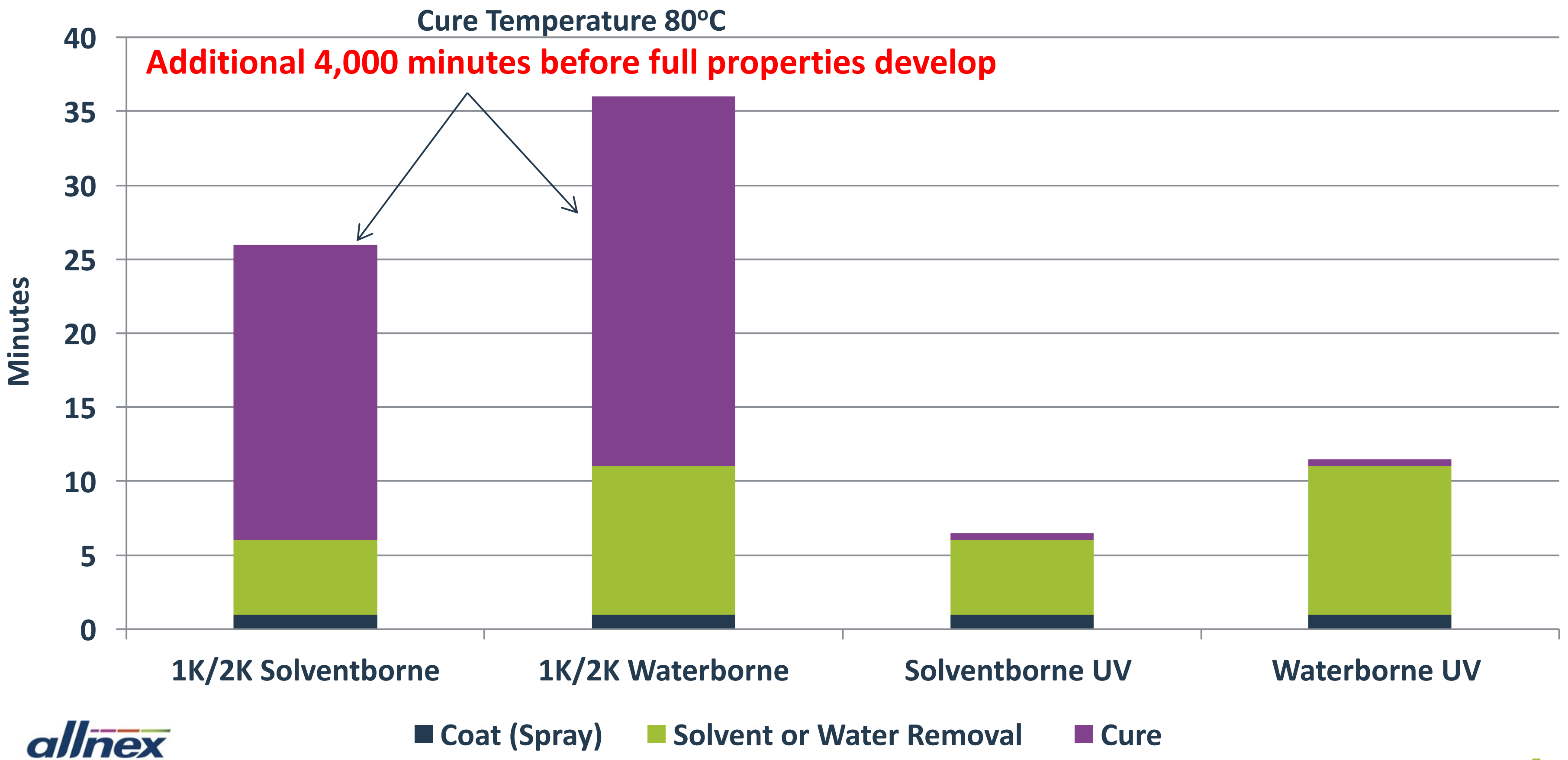

- Water or Solvent evaporation
- Physical drying
- Higher MW – Low Viscosity



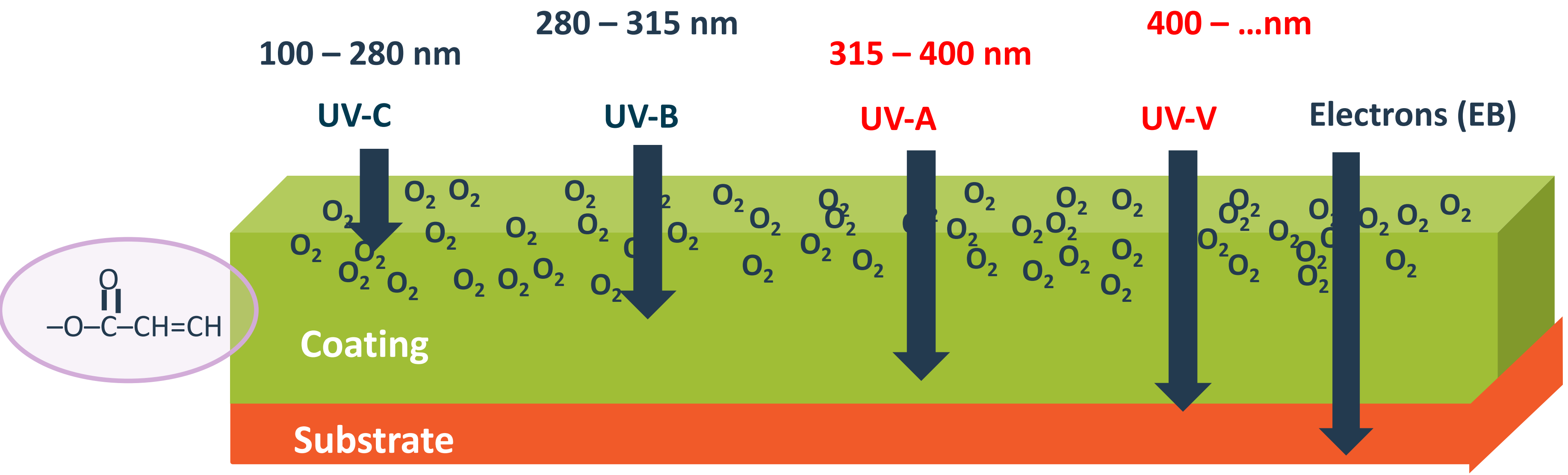

UV/EB: Ready for immediate use after cure

1K/2K: Ok to handle, hours and days before full properties

# Technolgoy Comparison



# Challenges of UV Cure




- Different parts of the UV spectrum can penetrate to different depths of the coating.
- The right photoinitiator choice will initiate the reaction in the entire coating.
- UV LED is typically 385 nm, 395 nm, 405 nm. (365 nm is available at low energy output)

# Products

| | Functionality, Acrylate | Hydroxyl Value (NCO, %) | Viscosity, cP at 25ºC | Non-volatile, % |
|---|---|---|---|---|
| Bio-base Polyester | 2 | - | 450 | 100 |
| Urethane Hexa-acrylate | 6 | - | 85000 | 100 |
| RX 81100 | 4 | - | 1500 | 100 |
| UV Curable PUD | 6 | - | 50 | 40 |
| Hexa-acrylate Emulsion | 6 | - | 500 | 65 |
| 1K Polycarbonate PUD | - | 170 | 200 | 40 |
| 1K Thermal Silicone | - | | 10 | 20 |

# Testing

- **Abrasion:** Taber Haze
  - 100 cycles on PC sheet with 500g load, CS10F wheels
- **Scratch:** Steel Wool
  - 0000 and 1kg weight
- **Automotive Chemical Testing**
  - Sun lotion and hand cream are applied on a bandage
    - The sample is put in a ventilated oven for 24 hours at 80°C
    - Lotion and cream removed and sample are left for 4 hours at room temperature before making an assessment
      - *Visual assessment and rating*
        - 0 no attack
        - 1 visual gloss change
        - 2 change in surface appearance
        - 3 delamination, blistering, loss of adhesion

# Formulations for Testing

- 100% resin
- UV cured systems initiated
  - 100% solids: 4% based on total weight of solids,1-hydroxy-cyclohexylphenyl-ketone
  - Waterborne UV: 4% based on total weight of solids of a blend of 1-hydroxy-cyclohexylphenyl-ketone and benzophenone (1:1)
  - Dry film target 12-14 $g/m^2$
- Water and Solvent removal
  - 80$^o$C for 10 minutes for water removal
  - 80$^o$C for 10 minutes for solvent removal
- 1K/2K and Thermal Silicone: Thermal Curing
  - 80$^o$C for 30 minutes
  - Samples keep at room temperature for 72 hours before testing

# Results: UV Curable Resins – 100% Solids

| | % Haze After Abrasion (CS10F,500g, 100 cycles) | Sun Lotion and Hand Cream (80°C, 24hr) | Steel Wool Scratch (0000, 1kg) |
|---|---|---|---|
| **Bio-base Polyester** | 10 | 1 | 100 double rubs |
| **Urethane Hexa-acrylate** | 7 | 0 | 100 double rubs |
| **RX 81100** | 15 | 0 | 3 double rubs |
| **Thermal Silicon** | 6 | 0 | 100 double rubs |
| **1K: PC PUD** | 25 | 3 | 0 |
| **2K: PC PUD + HDI Trimer** | 15 | 0 | 3 |

# Results: UV Curable Resins – Waterborne

| | Percent Haze After Abrasion (CS10F,500g, 100 cycles) | Sun Lotion and Hand Cream (80°C, 24hr) | Steel Wool Scratch (0000, 1kg) |
|---|---|---|---|
| UV Curable PUD | 12 | 1 | 5 double rubs |
| Hexa-functional Urethane Acrylate Emulsion | 6.5 | 0 | 100 double rubs |
| 1K Water-based Polycarbonate PUD | 25 | 3 | 0 rubs |
| 1K PC PUD + HDI Trimer | 15 | 0 | 5 double rubs |
| 1K PC PUD + UV PUD (Dual Cure) | 18 | 1 | 0 rubs |

# Conclusion: 100% Solids and Waterborne UV

- UV/EB system can meet more stringent automotive chemical test
- Waterborne UV can be designed to have equivalent performance to higher functional acrylate system
- Bio-based resin can be designed to delivery not on improve sustainability without sacrificing performance

- Idea for flat substrates
  - Glass transition and cross-linking (higher) important for sun lotion and hand cream resistance
- Adhesion varied based on supplier and type
- 100% solids is not ideal for current coating processing conditions

➢ **Dual Cure technology could possible bridge the between conventional and energy curable chemistries**

# Next Generation: Dual Cure

## Conventional 1K or 2K SB (NCO- OH)

+ Full cure for difficult shape of part
+ Lower shrinkage
+ Outstanding weatherability

- Space and time
- Slow cure
- High energy consumption for drying

## UV Curing

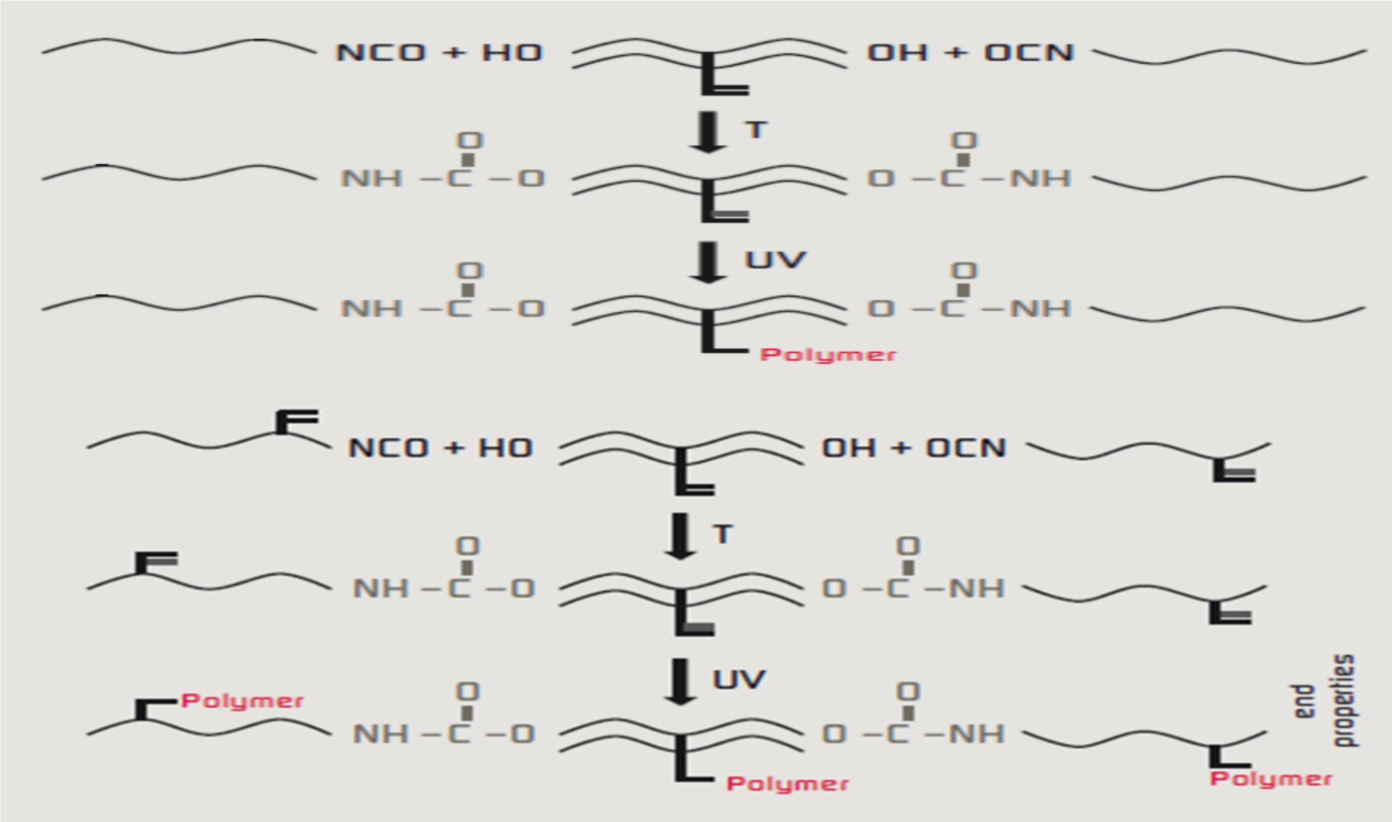
+ Fast cure (high productivity)
+ High scratch & chemical resistance
+ Limited space needed

- 3D shape => NO UV = NO Cure
- More shrinkage
  (adhesion sometimes challenging)

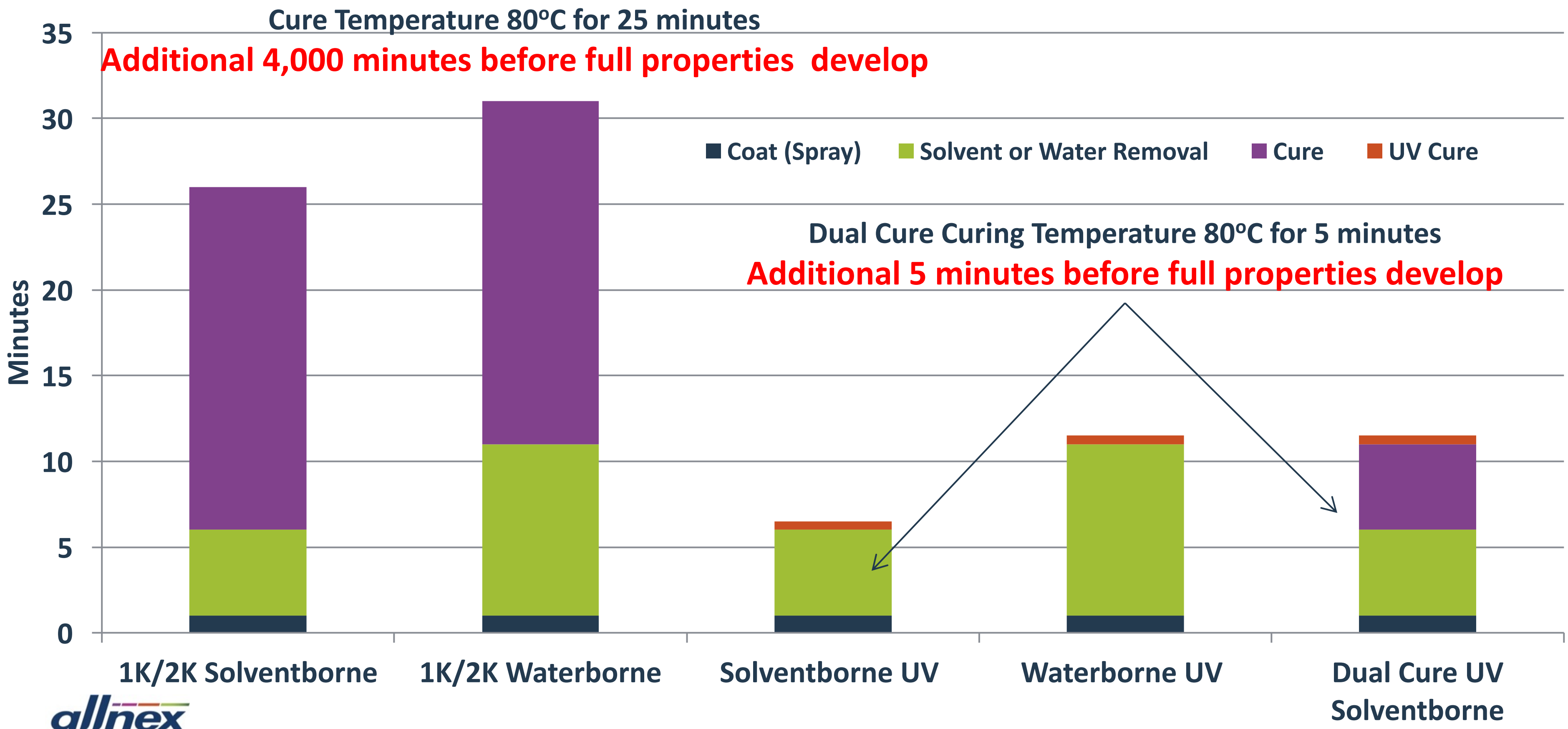
+ Fast cure (high productivity)
+ Low shrinkage – good adhesion
+ Good scratch & chemical resistance
+ 3D shape: NO UV = Cure (NCO-OH)
+ Less space occupation

allnex
The Coating Resins Company

# Next Generation: Dual Cure



# Processing Comparison



# Products

| | Functionality, Acrylate (NCO) | Hydroxyl Value (NCO, %) | Viscosity, cP at 23ºC | Non-volatile, % |
|---|---|---|---|---|
| OH Functional Acrylic | - | 100 | 3000 | 55 |
| NCO Acrylate | 1.5 (1.5) | - | 20000 | 90 |
| Urethane acrylate | 6 | - | 8500 (25ºC) | 100 |

# Testing

- **Abrasion:** Taber Haze
  - 100-300-500 cycles on PC sheet with 500g load, CS10F wheels
- **Curl upon cure**
  - Coating was applied to PET film (12.5 microns) at 12 microns
  - 4”x4” sample was taken and the height of curl was measured at each corner and four corners were averaged
- **Adhesion:** cross hatch
  - 0= no adhesion, 5= full adhesion
- **Erichsen** (pen 318 with tip of 0.75 mm) pass/fail

# Testing

- **Double bond and NCO conversion**
  - Measured using FTIR spectrophotometer
    - ~810 $cm^{-1}$ absorbance for double bond conversion
    - ~2270 $cm^{-1}$ absorbance for isocyanate conversion
- **Accelerated Outdoor durability (ASTM G154-UVA)**
  - 8 hours at 60$^{o}$C at an irradiance of 0.89 $W/cm^2$
  - 4 hours dark at 50$^{o}$C
- **Humidity resistance: VW TL 226 Aging stability**
  - hydrolysis (72 h, 90 °C, 95 % humidity)
  - Cross hatch adhesion after humidity test

# Testing

- **Automotive Chemical Testing**
  - Sun lotion and hand cream are applied on a bandage
    - The sample is put in a ventilated oven for 24 hours at 80°C
    - Lotion and cream removed and sample are left for 4 hours at room temperature and retested
      - *Cross cut adhesion*
      - *Gloss measured*
      - *Erichsen pen hardness*

# Starting Point Formulation

| | wt % | wt % |
|---|---|---|
| Component I | IV.1 | IV.2 |
| OH Functional Acrylic | 38.9 | 31.9 |
| Alphatic urethane acrylate | | 7.8 |
| Butyl acetate | 15.0 | 15.0 |
| Flow and Leveling additive | 0.5 | 0.5 |
| Photoinitiator * | 4.2 | 4.2 |
| Catalyst** | 0.02 | 0.02 |

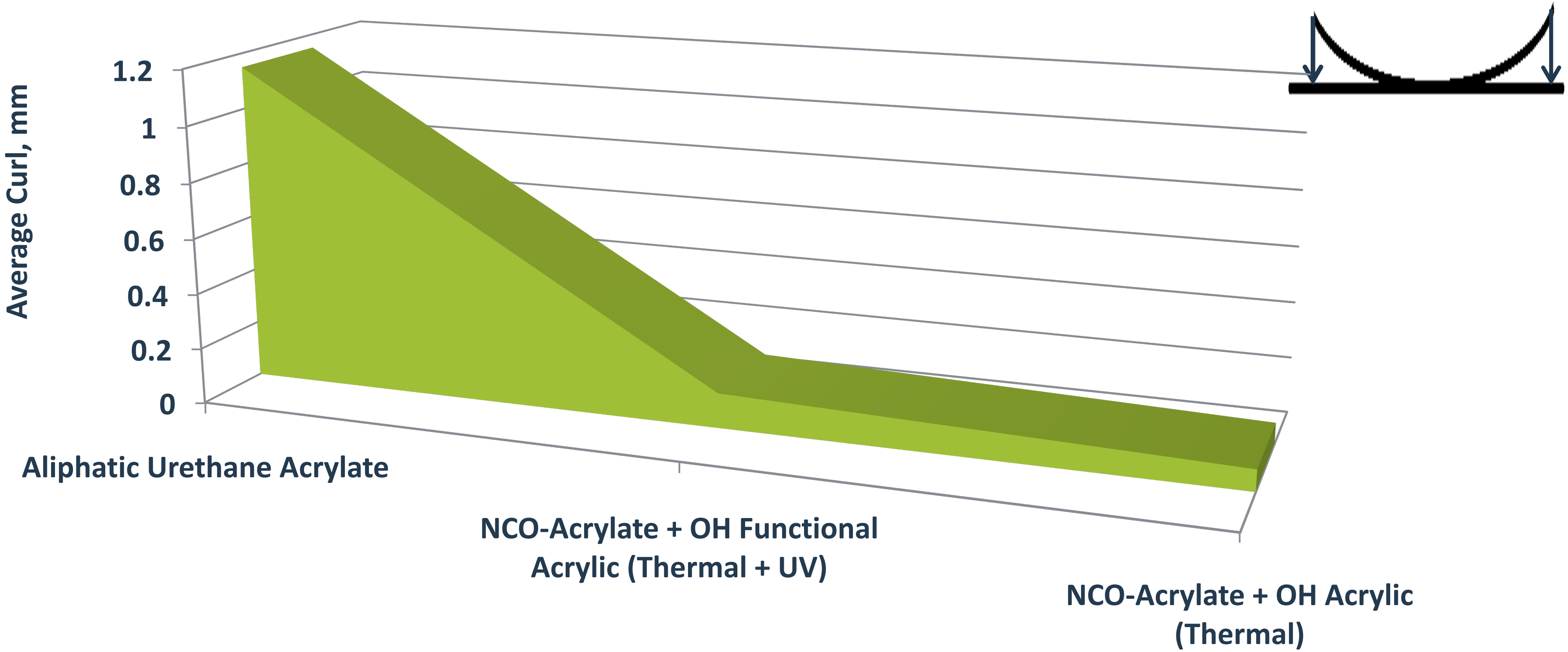
| Component II | wt % |
|---|---|
| NCO Functional Acrylate | 56.2 |

- Components I and II are mixed just before application
- Viscosity @ 25°C ~200 mPa.s
- Solid content ~58 %
- Substrate: plastic panel
- Target dry film thickness (DFT): 20 g/m²
- 30' @ 80°C: flash off and thermal step***
- UV curing: 2 x 10 m/min. with 120 W/cm Hg lamp (~2000 mJ/cm²)
- **Testing after 1 week storage at room temperature**

*1-hydroxy-cyclohexylphenyl-ketone
**Dibutyltindilaurate (DBTL)

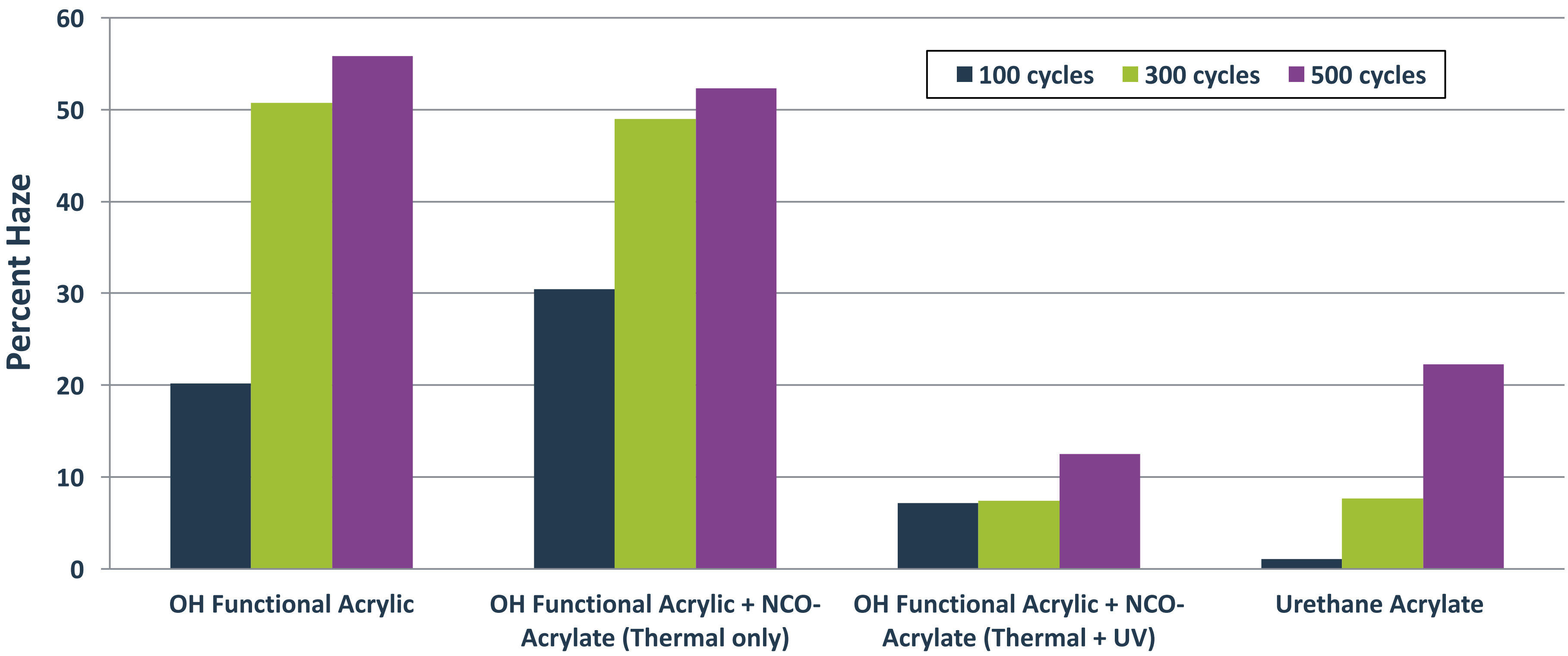
***to be adjusted by the amount of catalyst to the requirements of the line/machine

# Results – Low Curl Upon Cure




allnex
The Coating Resins Company

# Results: Haze after Abrasion

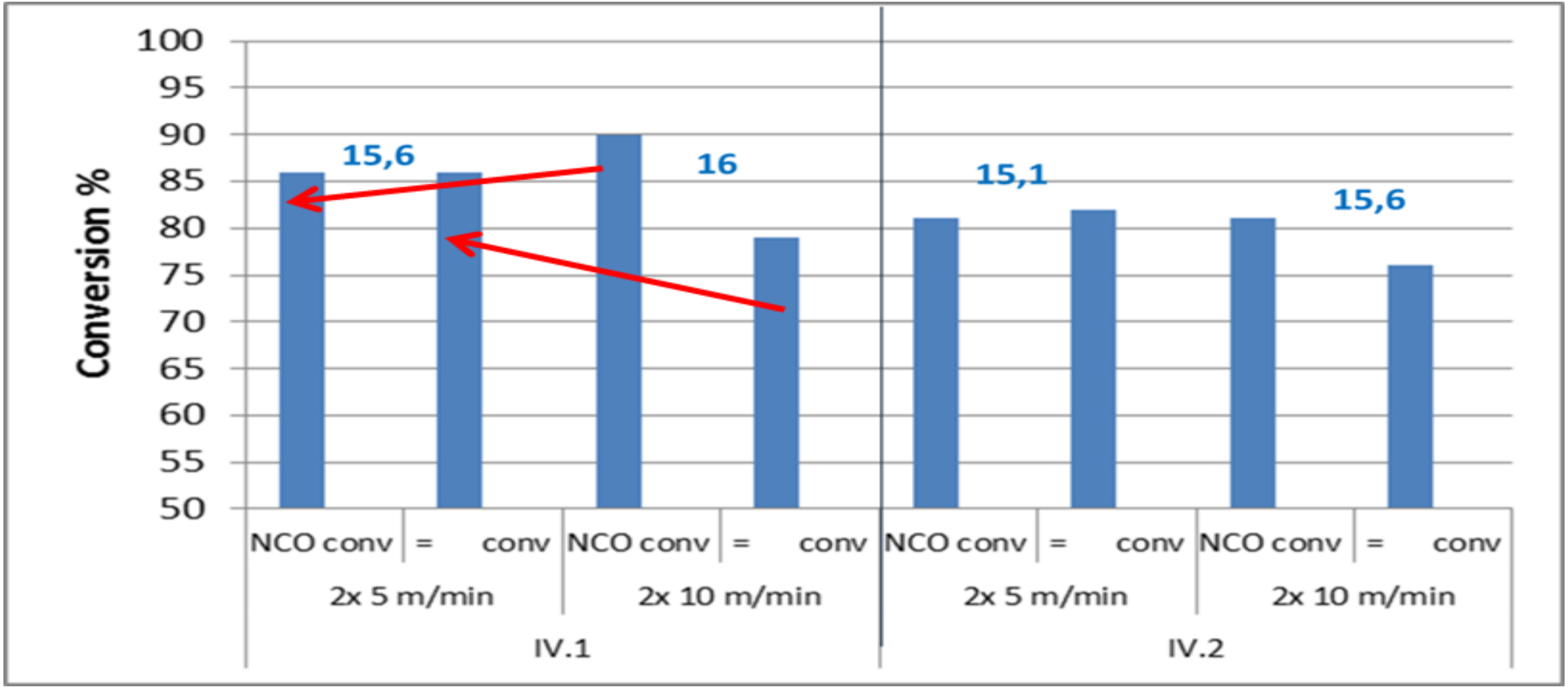



allnex The Coating Resins Company

# Results: Haze after Abrasion – Additional Processing Time

| | | IV.1 | | | | IV.2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2x 5m/m | | 2x 10 m/m | | 2x 5m/m | | 2x 10 m/m | |
| | | after 1 week | + 48hrs 60°C | after 1 week | + 48hrs 60°C | after 1 week | + 48hrs 60°C | after 1 week | + 48hrs 60°C |
| | Uncoated | | | | | | | | |
| % start | 0 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| % after 100 cycles | 24.5 | 6.4 | 6.1 | 6.2 | 6.2 | 6 | 5.9 | 6.5 | 5 |
| % after 200 cycles | 25.8 | 9.1 | 8.8 | 9 | 9 | 8.7 | 8 | 8.8 | 7.4 |
| % after 300 cycles | 28 | 11.8 | 11.5 | 12.5 | 11.5 | 11.3 | 11 | 12.4 | 10.6 |
| % after 500 cycles | 30 | 15.6 | 15.4 | 16 | 14.9 | 14.5 | 15.1 | 15.6 | 13.9 |

# Results: NCO and Double (=) Conversion



# Results: Dual Cure – Stain Resistance

| | IV.1 | | IV.2 | | Urethane Acrylate |
|---|---|---|---|---|---|
| | 2x 5 m/m | 2x 10 m/m | 2x 5 m/m | 2x 10 m/m | 2x 10 m/m |
| mustard | 4 | 3 | 5 | 3 | 5 |
| eosine | 5 | 4 | 5 | 4 | 5 |
| coffee | 5 | 5 | 5 | 5 | 5 |
| isobetadine | 4.5 | 3.5 | 4.5 | 4 | 5 |
| NH10% | 5 | 5 | 5 | 5 | 5 |
| ethanol 50% | 5 | 5 | 5 | 5 | 5 |
| N70 black marker | 5 | 5 | 5 | 5 | 5 |
| Average | 4.8 | 4.4 | 4.9 | 4.4 | 5 |
| NCO conv (1 week) | 86 | 90 | 81 | 82 | Not applicable |
| = conv (1 week) | 86 | 79 | 81 | 76 | 79 (no change) |

allnex The Coating Resins Company

# Results: Chemical Resistance

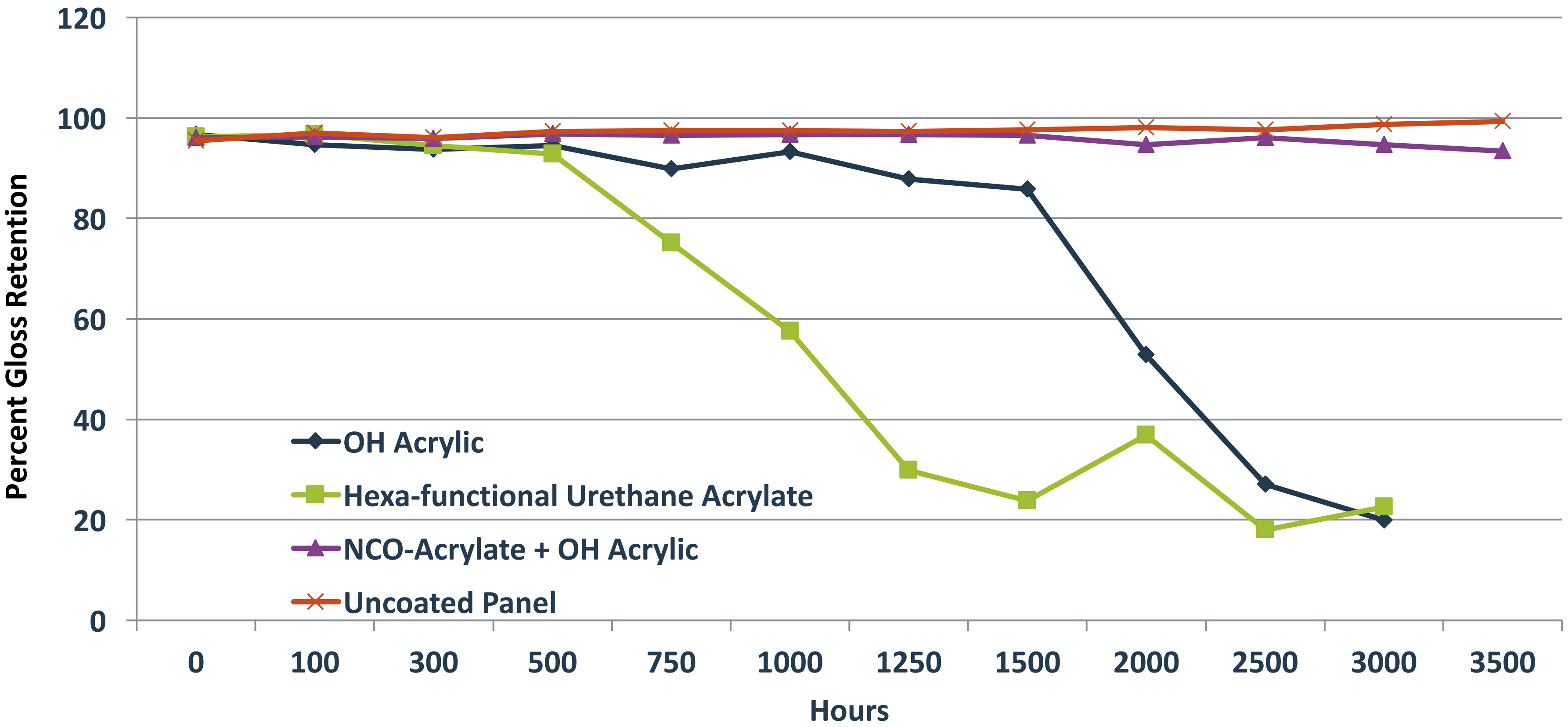
| | | | IV.1 | | IV.2 | | Urethane Acrylate |
|---|---|---|---|---|---|---|---|
| | | | 2x 5 m/m | 2x 10 m/m | 2x 5 m/m | 2x 10 m/m | 2x 10 m/m |
| SUN cream lotion | Initial gloss | 20° | 85.6 | 87.8 | 88.9 | 88.5 | 100 |
| | | 60° | 93.2 | 93 | 93.1 | 92.6 | 100 |
| | Gloss (after test) | 20° | 87.2 | 86.6 | 87.7 | 87.2 | 99.32 |
| | | 60° | 92.1 | 92.8 | 92.8 | 92.5 | 98.83 |
| | Initial Adhesion (crosshatch) | | 5 | 5 | 5 | 5 | 5 |
| | Adhesion (crosshatch) | | 5 | 5 | 5 | 5 | 5 |
| | Erichsen pen 10 N | | pass | pass | pass | pass | pass |

allnex The Coating Resins Company

# Results: Dual Cure – Chemical Resistance

| | | | IV.1 | | IV.2 | | Urethane Acrylate |
|---|---|---|---|---|---|---|---|
| | | | 2x 5 m/m | 2x 10 m/m | 2x 5 m/m | 2x 10 m/m | 2x 10 m/m |
| **Hand cream lotion** | Initial gloss | 20° | 85.6 | 87.8 | 88.9 | 88.5 | 100 |
| | | 60° | 93.2 | 93 | 93.1 | 92.6 | 100 |
| | Gloss (after test) | 20° | 84.1 | 83.9 | 83.8 | 82.9 | 97.62 |
| | | 60° | 91.8 | 91.5 | 91.3 | 91.6 | 94.74 |
| | Initial Adhesion (crosshatch) | | 5 | 5 | 5 | 5 | 5 |
| | Adhesion (crosshatch) | | 5 | 5 | 5 | 5 | 5 |
| | Erichsen pen 10 N | | pass | pass | pass | pass | pass |

# Results: Dual Cure – Weathering




allnex The Coating Resins Company

# Conclusions

- Different combinations of UV curable products enable formulators to creating ideal coating solutions for automotive interior benefiting from intrinsic nature of the UV chemistry
- Dual Cure expands the toolbox; benefiting from the best of both worlds
  - ➡ Ductile behavior for high scratch resistance coatings
  - ➡ Excellent adhesion to ABS, PC, ABS/PC blends
  - ➡ Shorter processing time including faster final property development
  - ➡ Outstanding scratch, abrasion and chemical (sun lotion and hand cream)
  - ➡ Excellent Weatherability
- Drying conditions (e.g. catalyst amount, thermal temperature) can influence performance !
- NCO functional acrylates NOT impacted by NCO restrictions!

allnex
The Coating Resins Company

Marcus Hutchins (marcus.hutchins@allnex.com, 770-280-8391)

**Join us at Booth 301**

# Thank you

**Special Thanks**
**Jennifer McClung**
**Steven Cappelle**
**Paul Gevaert**



allnex
The Coating Resins Company