UV LED Curing
The Booster Resin Approach

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Agenda

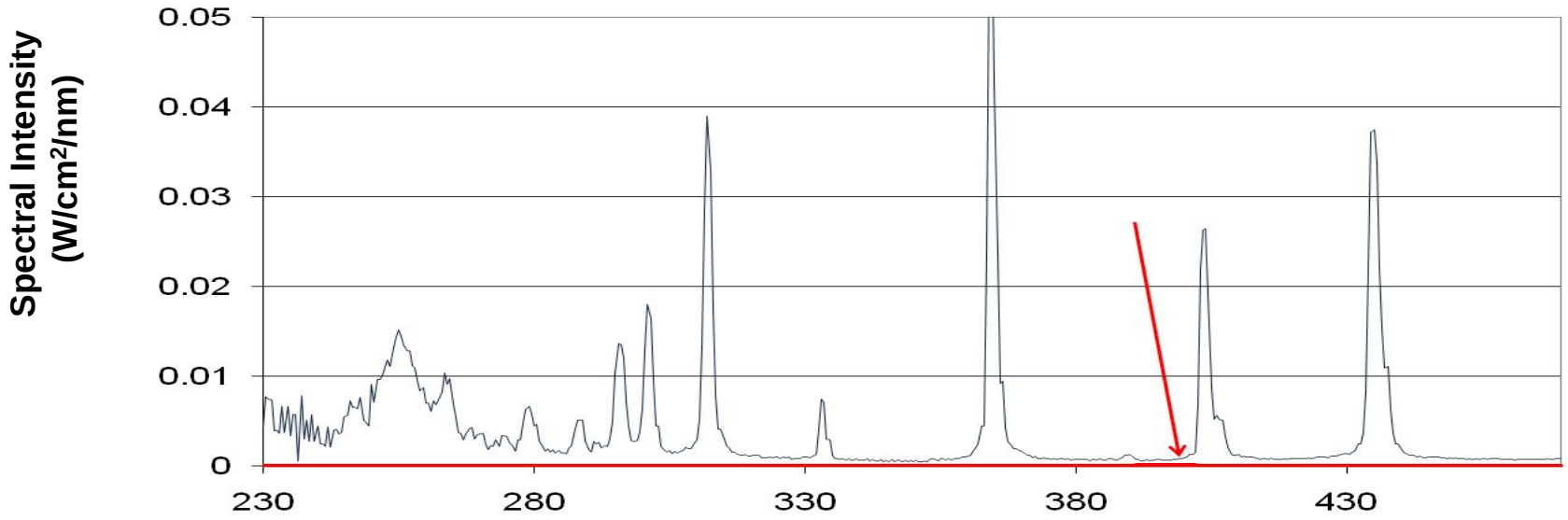
- Introduction
- The Booster Resin Approach
- Application Program
  - Clear Coatings
    - Reactivity
      - LED Line settings (Distance LED to substrate, LED orientation)
      - Coating Thickness
      - Formulation Viscosity & Dilution
      - Dosage of Booster Resin
    - Gloss, Yellowing
    - Stain resistance
  - Pigmented Coatings
- Conclusions

Value Proposition LED

- ✓ Allows coating of heat sensitive surfaces
- ✓ Instant on, instant off
- ✓ Ability to coat small surfaces
- ✓ No ozone generation
- ✓ Others…

Could enable new applications which up to now were not feasible with standard high powered lamps

Comparison spectral intensity of a 80W/cm Mercury lamp with a 1W/cm² LED 395nm



Energy output of LED is much lower !

The first trials

Urethane Acrylate, 3f	85	85	85	75	85
DPGDA	10	10	10	10	10
Amine modified PEA, 4f			5	10	
Amine synergist, 2f					5
Phosphine oxide PI	5	5	5	5	5
Inert atmosphere	Yes	No	No	No	No
Reactivity Finger Nail Resistance (m/min)	> 80	4x5 NOK	4x5 NOK	4x5 NOK	4x 5 NOK

Application : 30µ by Barcoater on Leneta paper
*Curing : LED 8W/cm² 395 nm, 1cm distance from substrate to LED (**perpendicular** orientation)*

Surface curing is an issue !

The Booster Resin Approach

- Transform a UV curable formulation into a UV LED curable by replacing part of the oligomer by a « booster » resin to assist in cure
- This led to the development of the new Booster Resin
- The approach is also valid for other low energy curing UV technologies (e.g. UV-A curing)

The Booster Resin Approach

Example

Urethane acrylate, 3f	85	65
DPGDA	10	10
Booster Resin		20
Phosphine oxide PI	5	5
Reactivity Finger Nail Resistance (m/min)	4x 5 NOK	1x 5

Application : 30µ by Barcoater on Leneta paper
*Curing : LED 8W/cm² 395 nm, 1cm distance from substrate to LED (**perpendicular** orientation)*

The Booster Resin is a co-resin,
used to increase surface cure

Booster Resin– Physical Data

• Appearance	Liquid
• Viscosity, 25°C, cP	210
• Colour	pale, pinkish
• Boiling point	>200°C
• Vapour Pressure	< 1.33 hPa @ 20°C
• Flash Point	> 100°C Cleveland Open Cup
• Stability	>10 days @ 60°C

Booster Resin - Compatibility

Urethane acrylate, 6f	75	55			
Urethane acrylate, 4f			45		
Urethane acrylate, 3f				45	
Urethane acrylate, 2f					45
HDDA			10	10	10
Booster Resin	20	40	40	40	40
Phosphine oxide PI	5	5	5	5	5
Thioxanthone PI	0,1	0,1	0,1	0,1	0,1
Fingernail resistance	1 x 5	1 x 10	1 x 25	1 x 15	1 x 20

Application :10µ on Leneta
Cured with 8W /cm^2 395nm LED at 2cm substrate lamp distance

Good Compatibility with Selected UA

Booster Resin - Compatibility

Epoxy acrylate, 2f	65	45		
Polyester acrylate, 4f			75	55
HDDA	10	10	10	10
Booster Resin	20	40	20	40
Phosphine oxide PI	5	5	5	5
Thioxanthone PI	0,1	0,1	0,1	0,1
Fingernail Resistance	1 x 35	1 x 50	< 1 x 5	1 x 10

Application :10µ on Leneta
Cured with 8W /cm^2 395nm LED at 2cm substrate lamp distance

Good Compatibility with Selected EA and PEA

Booster Resin - Compatibility

Polyester acrylate, 4f	34
Polyester acrylate, 6f	10
Pigment Paste	36
Booster Resin	20
Acidic adhesion promoter	4
Phosphine oxide PI	4
Thioxanthone PI	0.5
Viscosity (mPa.s)	*390*

Application : 20 µm by barcoater on sanded untreated steel
Cured with Panacol 254 UV-H (UVA-lamp) at 15 cm substrate lamp distance

Good Compatibility with Acidic Adhesion Promotors

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      - Dosage IRR 746
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LED Equipment

8W/cm^2 LED 395 nm (2.5cm x 22.0cm)

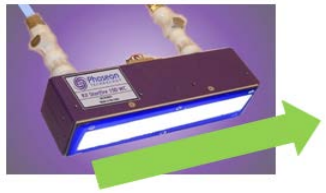
Clear Coating - Starting Point Formulation

Urethane acrylate, 3f	65
DPGDA	10
Booster Resin	20
Phosphine oxide PI	5
Viscosity (mPa.s)	*4000*

Application : Barcoater on Leneta paper, thickness as mentioned
Curing : LED 8W/cm^2 395 nm, geometry LED and distance LED to substrate as mentioned

Urethane Acrylate is 3f with balanced properties

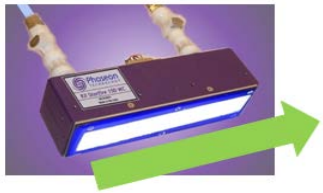
Reactivity – Distance to Substrate & Lamp Orientation

	"perpendicular" 	"in-line" 
Distance LED to substrate (cm)		
0.5	1X 5	1x 15
1	1x 5	1x 15
2	2X 5	1x 15

SPF, 30 µ on Leneta
Reactivity (m/min) - finger nail resistance

Lower Influence of distance to substrate with "in-line" orientation

Reactivity – Coating thickness



	10µ	30µ
Distance LED to substrate (cm)		
0.5	3x 5	1x 15
1	3x 5	1x 15
2	4x 5	1x 15

SPF, on Leneta, thickness as mentioned
LED orientation : “in length”
Reactivity (m/min) - finger nail resistance

Significantly lower reactivity for thin coatings (<20µ)

Reactivity - Viscosity & Dilution

SPF

Urethane acrylate, 3f	49	57	65
DPGDA	26	18	10
Booster Resin	20	20	20
Phosphine oxide PI	5	5	5
Sum	100	100	100
Viscosity (mPa.s)	*1000*	*2000*	*4000*
Reactivity-Finger Nail Resistance (m/min)	1x5	1x10	1x15
Gloss 60°	90	90	90

Application : 30 µ on Leneta
Cured with 8W /cm² 395nm LED at 1cm substrate lamp distance, LED "in-line" with the substrate (22cm)

Cure speeds drops with monomer dilution

Reactivity – Dosage of Booster Resin at iso formulation viscosity

Urethane acrylate, 3f	65	65	65
DPGDA	10	10	10
Booster Resin		20	40
Polyester acrylate, 4f	40	20	0
Phosphine oxide PI	5	5	5
Viscosity, 25°C, mPa.s	2300	2400	2500
Reactivity – Finger Nail Resistance (m/min)	4 x 5 NOK	1 x 5	> 1 x 40

Application : 30 µ on Leneta
Cured with 8W /cm^2 395nm LED at 1cm substrate lamp distance, LED "in-line" with the substrate (22cm)

> 40m/min with 40 parts Booster Resin

Reactivity – Oligomer Functionality

Urethane acrylate, 3f	57	
DPGDA	18	
Urethane acrylate, 6f		75
Booster Resin	20	20
Phosphine oxide PI	5	5
Viscosity (mPa.s)	2000	1400
Reactivity-Finger Nail Resistance (m/min)	1x 10	1x 40

Application : 30 µ on Leneta
Cured with 8W /cm^2 395nm LED at 1cm substrate lamp distance, LED "in-line" with the substrate (22cm)

Higher surface reactivity is obtained with higher functional oligomers

Reactivity - Summary

Effect of Increasing… on formulation reactivity		Coating thickness	Monomer dilution	Booster Resin	Oligomer Function-ality
Formulation reactivity	Higher Lower	↑	↓	↑	↑

e.g. a 30µ hard coating will be easier to cure than a 5µ flexible coating

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    Gloss, Yellowing

    Stain resistance
  - **Pigmented Coatings**
- **Conclusions**

Gloss

Urethane acrylate, 3f	60
DPGDA	40
Booster Resin	20
Phosphine oxide PI	5
Silica matting agent, wax treated	8
Silica matting agent, untreated	2
Polypropylene wax	2
Viscosity, 25°C, mPa.s	2150
Reactivity – Finger Nail Resistance (m/min)	2 x 5
Gloss (60°)	65

Application : 30-35 µ on Leneta
Cured with 8W /cm^2 395nm LED at 1cm substrate lamp distance, LED "in-line" with the substrate (22cm)

Yellowing

	Hg (80W/cm)	LED	LED
Urethane acrylate, 3f	85	85	65
DPGDA	10	10	10
Booster Resin			20
Benzophenone/α-hydroxy ketone (50/50) PI	5		
Phosphine oxide PI		5	5
Yellowing, b-value 24 h (initial)	0 (1.4)	/	0.5 (2.8)
Reactivity Finger Nail resistance (m/min)	1x 25	4x5 NOK	1x 5

Application : 30µ by Barcoater on Leneta paper
*Curing : LED 8W/cm² 395 nm, 1cm distance from substrate to LED (**perpendicular** orientation)*

Application Program

	Hg (80W/cm)	LED
Urethane acrylate, 3f	85	65
DPGDA	10	10
Booster Resin		20
Benzophenone/α-hydroxy ketone (50/50) PI	5	
Phosphine oxide PI		5
Viscosity (mPa.s)	10,100	4,020
Acetone DR	>100	>100
Eosine, red dye (16 hours)	4	1
NH_3, 10% (16 hours)	5	5
Mustard (16 hours)	1	1
Ethanol 50% (16 hours)	5	5

Application : 30µ by Barcoater on Leneta paper
*Curing : LED 8W/cm² 395 nm, 1cm distance from substrate to LED (**perpendicular** orientation)*

Very similar results, except for the eosine resistance

Pigmented systems

Urethane acrylate, 3f	45	35	25
DPGDA	10	10	10
Booster Resin	20	20	20
TiO_2	20	30	40
Phosphine oxide PI	5	5	5
Viscosity (mPa.s)	*3620*	*3520*	*3540*
30-35 µ, Finger Nail Resistance (m/min)	1 x 5	1 x 10	1 x 15
Yellowing, immediately after cure, b-value	2.7	2.5	2.2

Application : 30-35 µ on Leneta
Cured with 8W /cm^2 395nm LED at 1cm substrate lamp distance, LED "in-line" with the substrate (22cm)

Good surface & deep curing possible
in white pigmented systems

Conclusions

- The Booster Resin Approach is about transforming UV formulations into LED curable formulations

- This approach is also valid for other low energy curing UV technologies (e.g. UV-A cure)

- The Booster Resin is a co-resin and replaces part of the UV oligomers in the formulation

- Application results have shown that the Booster Resin is very effective in increasing reactivity of UV LED curing systems.

- UV LED technology opens opportunities for new applications.

- Further development will be necessary to achieve specific application requirements

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Thank you for your attention !