1,5-Pentanediol Diacrylate, a Bio-based Alternative for UV Curable Coatings

Coatings Trends & Technologies (CTT)
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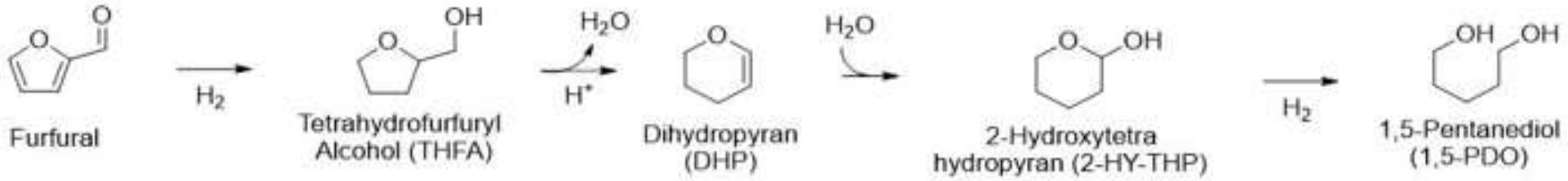
Agenda

- Background
- Synthesis
- PDDA Properties
- Applications – Simple
  - Simplified Wood Coatings
- Applications – Advanced
  - UV Flooring
  - EAPPC (Plastic Coating)
  - Fiber Optic Coating
  - Automotive Spray Coating
  - UV Screen Print Coating
- Summary

Advantages Using Bio-Based Materials

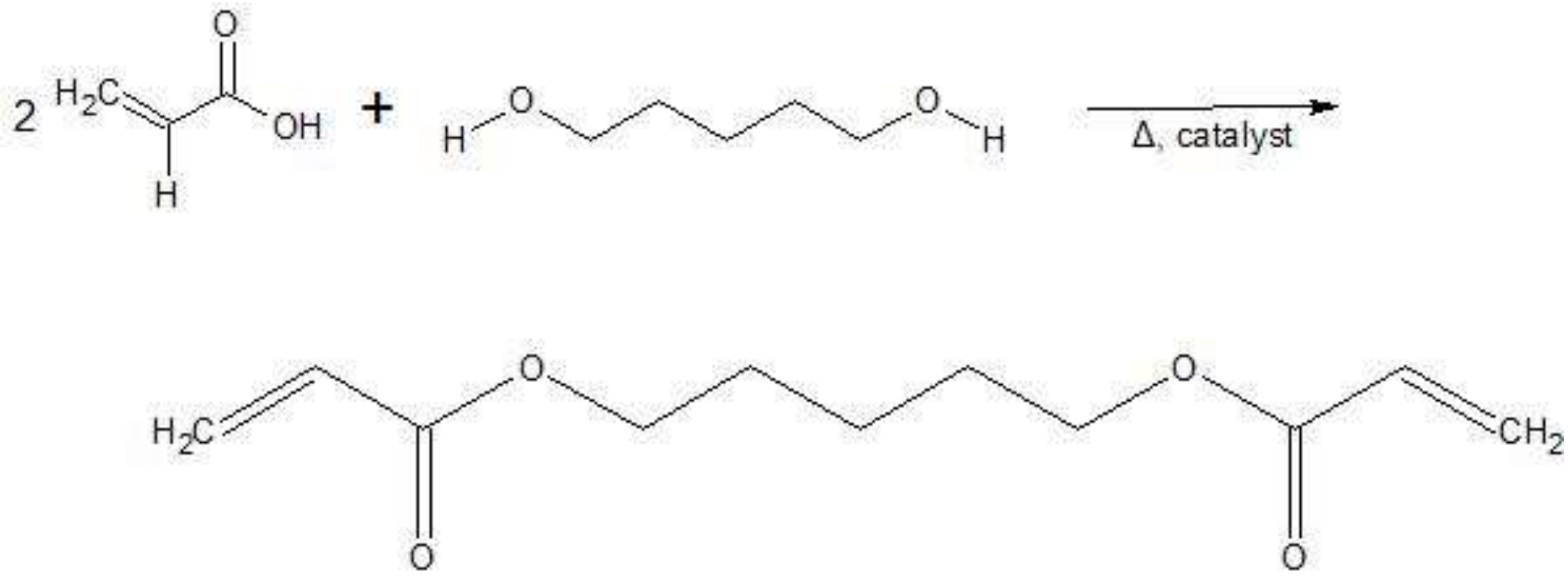
- Derived from renewable sources
- Minimum impact on the environment
- Availability
- Potentially competitive costs

1,5 – PDO Synthesis



Corn cob waste – 144 Million tons/year globally

PDDA Synthesis

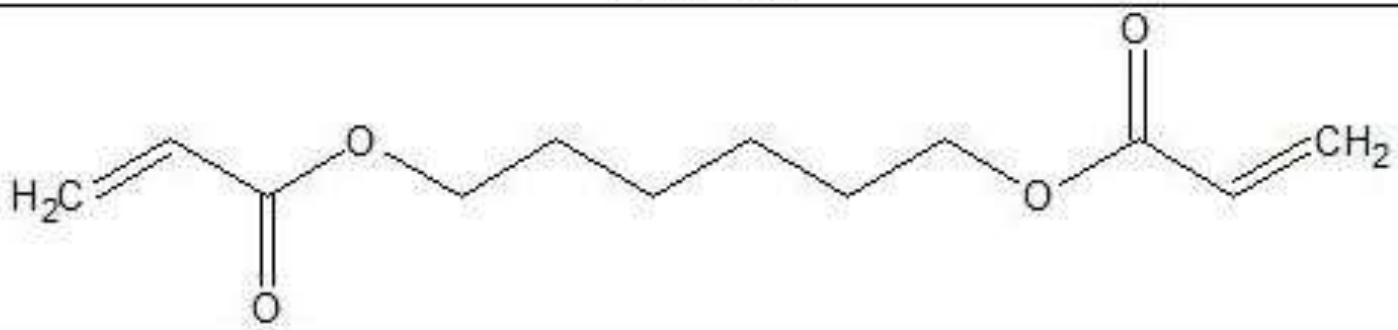


PDDA Properties (Developmental)

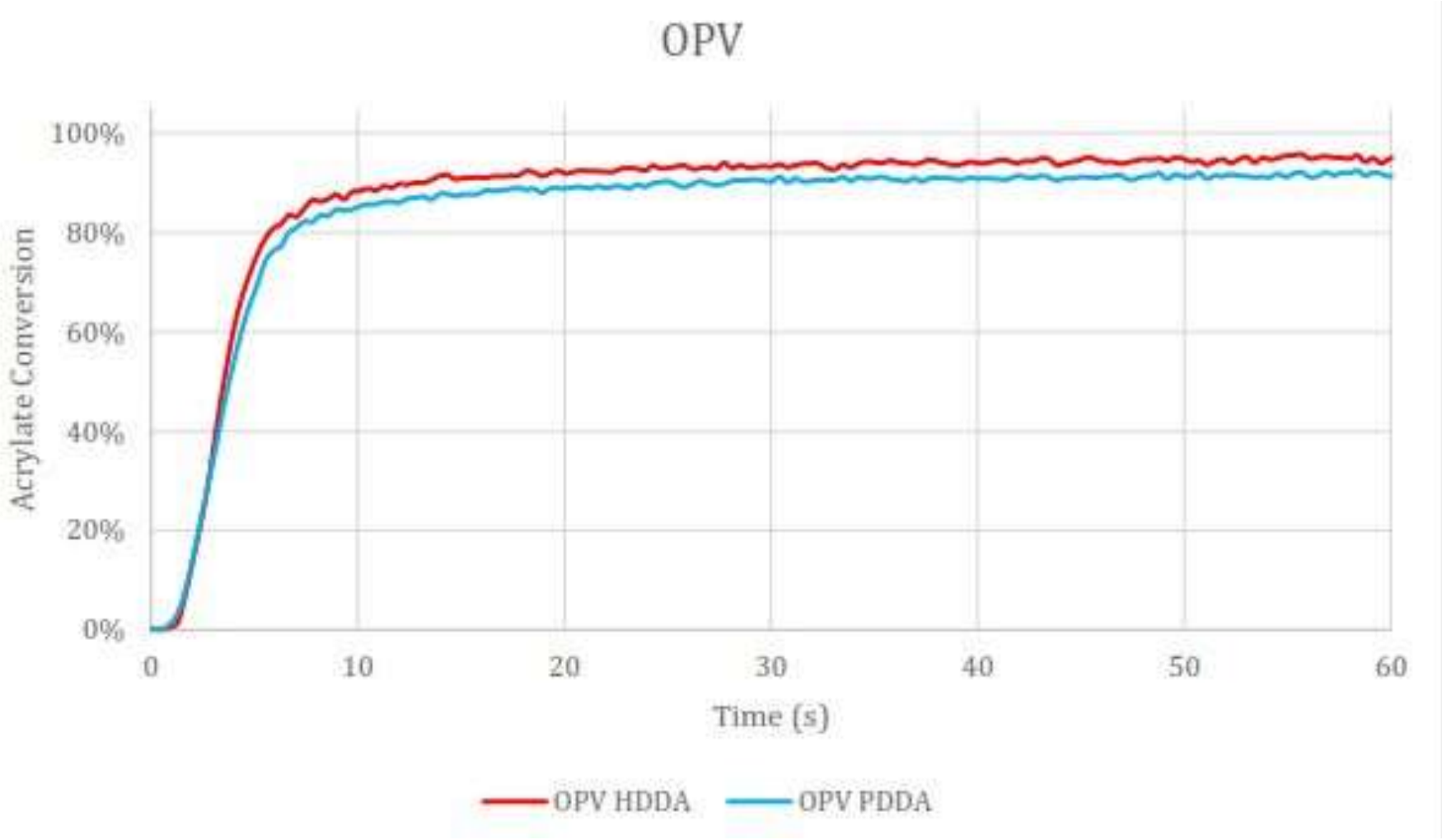
Property	PDDA	HDDA
Viscosity @ 100 rpm (cps)	27	15
Density g/ml	1.03	1.01
T_g Based on Tan Delta	85.7	88.7
Acid Value mg KOH/g	5*	<0.1

* Process under development, this value will be significantly reduced.

PDDA/HDDA Structures

Monomer	Structure	CAS#
HDDA		13048-33-4
PDDA		36840-85-4

Cure Speed – PDDA vs HDDA (OPV - Overprint Varnish)



Formulations for Simplified Wood Coatings

Components	HDDA	PDDA
HDDA	46.1	
PDDA		46.1
Urethane Diacrylate	46.1	46.1
Amine Accelerator	4.9	4.9
CPK Photoinitiator	2.9	2.9

Test Results for Simplified Wood Formulations

Formulation	Viscosity (cPs)	Shore Hardness ASTM D2240-15	Tack-Free Belt speed (fpm)	Acrylate conversion (%) FTIR
HDDA	120	81.5 D	75	98.5
PDDA	120	81.5 D	75	96

Mechanical Properties

	Tensile (ASTM 638-14)			Flexural (ASTM D790)		
Formulation	Modulus (mPa)	Strength (mPa)	Elongation	Modulus (mPa)	Strength (mPa)	Deflection
HDDA	410	20	7%	300	20	15%
PDDA	490	22	8%	375	27	22%

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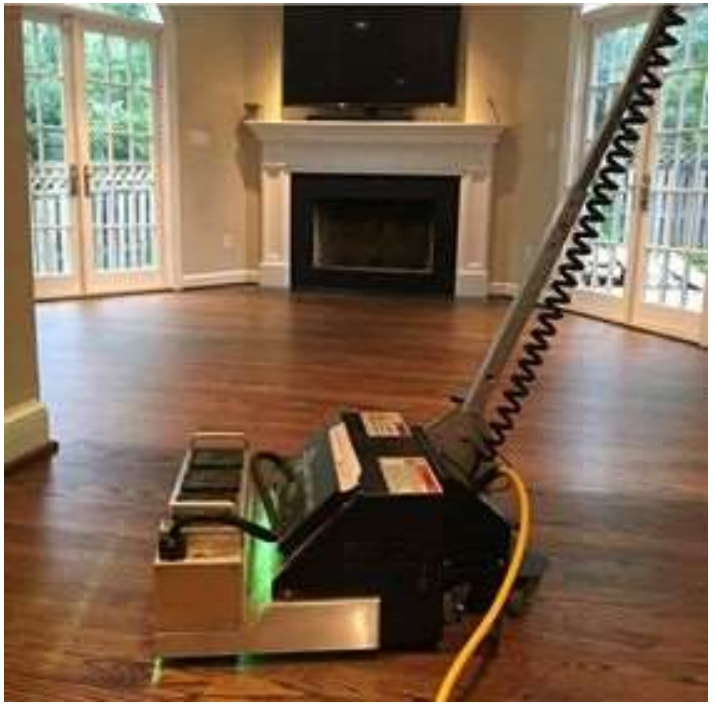
UV Flooring - Commercial Formulation

	HDDA	HD(EO)3DA	PDDA
Polyester Acrylate	12.6	12.6	12.6
Aliphatic Urethane Acrylate	25	25	25
PEA	10	10	10
TMPTA	4	4	4
IBOA	15	15	15
HDDA	14		
HD(EO)3DA		14	
PDDA			14
Stabilizer	0.1	0.1	0.1
Amine Synergist	3	3	3
Dispersion Aid	0.3	0.3	0.3
BP	3	3	3
BDK	1	1	1
Silica Powder	12	12	12



UV Flooring - Test Results

	HDDA	HD(EO)3DA	PDDA
Viscosity @ 50 rpm (cps)	382	4830	356
Cure Speed (fpm)	50	50	50
Stain test Iodine/Bromothymal Blue	Pass/Pass	Pass/Pass	Pass/Pass
Stain Sharpie Wipe/ IPA Wipe	Pass/Pass	Fail/Pass	Fail/Pass
MEK double Rubs @ 850 mJ	52	91	50
Pencil Hardness	2H	2H	2H
Abrasion resistance steel wool	9	3	9
Rub tests 500 cycles	Failed	Failed	Failed
% cure @ 850 mJ (FTIR)	81	83	82

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Exterior Automotive Plastic Protective Coating (EAPPC)

	HDDA	HD(EO)3DA	PDDA
Aliphatic Urethane Acrylate	58.8	58.8	58.8
TMPTA	.09	.09	.09
HDDA	35		
HD(EO)3DA		35	
PDDA			35
Stabilizer	0.1	0.1	0.1
TPO	1	1	1
BDK	3	3	3
UV Absorber	0.5	0.5	0.5
HALS	0.5	0.5	0.5
Silicone Surfactant	1	1	1
Defoamer	.01	.01	.01

EAPPC - Test Results

	HDDA	HD(EO)3DA	PDDA
Viscosity @ 50 rpm (cps)	1020	1410	740
Cure Speed (fpm)	50	50	50
Stain test Iodine/Bromothymol Blue	Pass/Pass	Fail/Pass	Pass/Pass
Stain Sharpie Wipe/ IPA Wipe	Fail/Pass	Fail/Pass	Fail/Pass
MEK double Rubs @ 850 mJ	79	70	62
Pencil Hardness	HB	2B	H
Abrasion resistance steel wool	3	3	4
Rub tests 500 cycles	Passed	Passed	Passed
% cure @ 850 mJ (FTIR)	95	96	96

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Pencil Hardness	HB	2B	H
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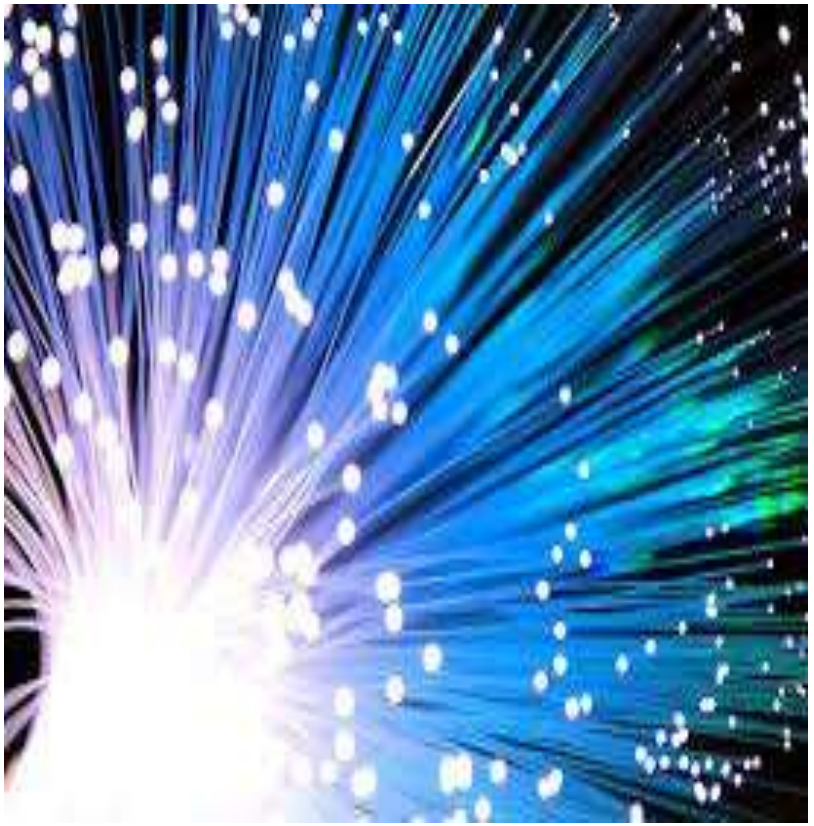
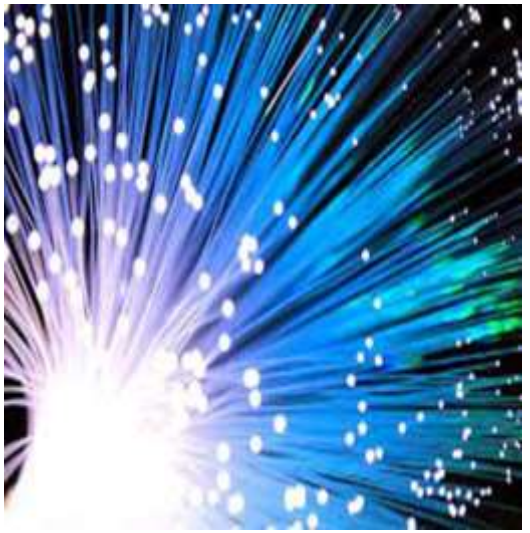
Fiber Optic Coating

	HDDA	PDDA
High MW Difunctional UA	45	45
Nonyl phenyl ethoxy acylate	30	30
HDDA	21	
PDDA		21
Stabilizer	0.1	0.1
TPO	.5	.5
Photoinitiator 184	3.4	3.4



Fiber Optic Coating -Test Results

	HDDA	PDDA
Viscosity @ 50 rpm (cps)	4451	4283
Cure Speed (fpm)	70	70
MEK double Rubs @ 850 mJ	26	27
Pencil Hardness	HB	2H
Gloss	29.6	56
Delta E	4.31	4.32
% cure @ 850 mJ (FTIR)	99	98.95



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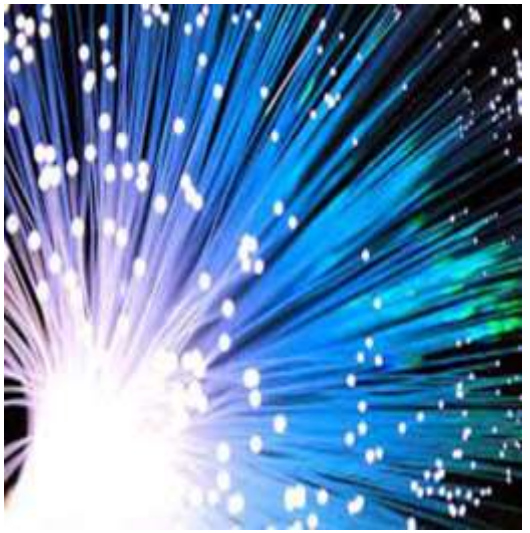

Automotive Spray Coating

	HDDA	PDDA
Aliphatic Urethane Acrylate	45	45
TMPTA	10	10
HDDA	37	
PDDA		37
TPO	.5	.5
Photoinitiator 184	4	4
UV Absorber	1	1
HALS	0.5	0.5
Silicone Surfactant	2	2

Automotive Spray Coating -Test Results

	HDDA	PDDA
Viscosity @ 50 rpm (cps)	305	470
Cure Speed (fpm)	70	70
MEK double Rubs @ 103 mJ	200	200
Pencil Hardness	8H	9H
Gloss	62	59
Delta E	4.41	4.29
% cure @ 103 mJ (FTIR)	92	93

Automotive Spray Coating -Test Results

	HDDA	PDDA
Viscosity @ 50 rpm (cps)	305	470
Cure Speed (fpm)	70	70
MEK double Rubs @ 103 mJ	200	200
Pencil Hardness	8H	9H
Gloss	62	59
Delta E	4.41	4.29
% cure @ 103 mJ (FTIR)	92	93

UV Screen Print Coating

	HDDA	PDDA
Epoxy in 25% TPGDA	40	40
TMPTA	20	20
HDDA	31	
PDDA		31
TPO	.5	.5
Photoinitiator 184	4	4
Defoamer	1	1
UV Absorber	1	1
HALS	0.5	0.5
Silicone Surfactant	2	2

UV Screen Print Coating -Test Results

	HDDA	PDDA
Viscosity @ 50 rpm (cps)	137	132
Cure Speed (fpm)	70	70
MEK double Rubs @ 103mJ	200	200
Pencil Hardness	8H	8H
Gloss	58.2	53.2
Delta E	4.35	4.6
% cure @ 103 mJ (FTIR)	85.5	84.11

Summary

- A new low viscosity bio-based UV Monomer is under development
- PDDA can be scaled up to commercial quantities
- PDDA will serve as a replacement monomer for a large range of UV curable coating applications
- Surprisingly, in some applications PDDA can bring improved properties even though it is a very close analog to widely used HDDA
- As the demand for raw materials that are bio-based or have increased renewable content grows, PDDA could serve to meet this demand

Acknowledgement

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Questions?

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Thank You!