POWDER COATING SUMMIT
SEPTEMBER 8-9, 2022

Unique Catalyst for Low Temperature Cure Epoxy Powder Coatings

September 9, 2022

KING INDUSTRIES SPECIALITY CHEMICALS

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Coatings TS&D Group

Introduction

Powder Coatings

- **Alluring Technology:**
  - Reduced VOC Emissions
  - Ability to Recycle Overspray
  - Exceptional Film Mechanical Properties

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- **Alluring Technology:**
  - Reduced VOC Emissions
  - Ability to Recycle Overspray
  - Exceptional Film Mechanical Properties

- **Need For Continued Innovation:**
  - Relatively New Technology
  - Review of History & Today's Market → **Need for LTC Capabilities**

Shorten Cure Time

Reduce Oven Temps

Powder History

Time Line

Powder History

NEW

- *Shell Chemicals*
- *Dry Blends*

1st Thermoset Powder

1950s

Powder History

- *Shell Chemicals*
- *Dry Blends*

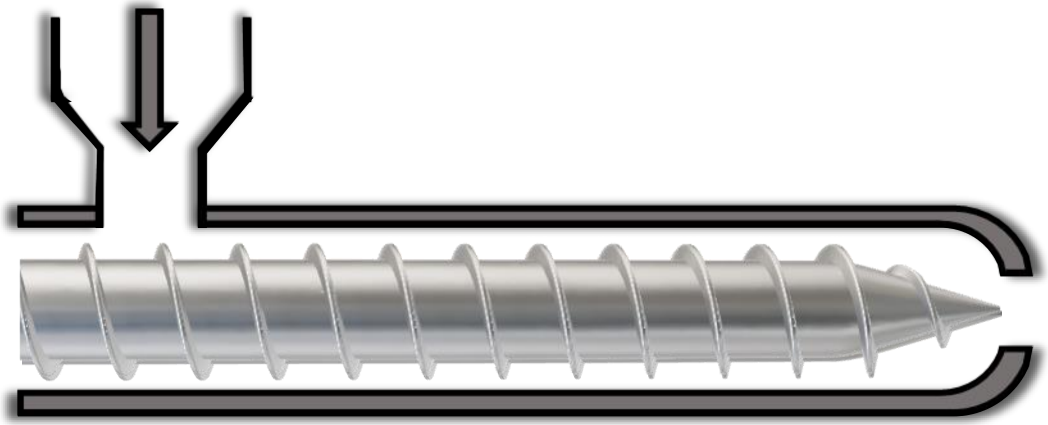
1st Thermoset Powder

1950s

1960s

Extrusion Methods

- *Extrusion Developed*
- *Reproducibility*



Reproducibility

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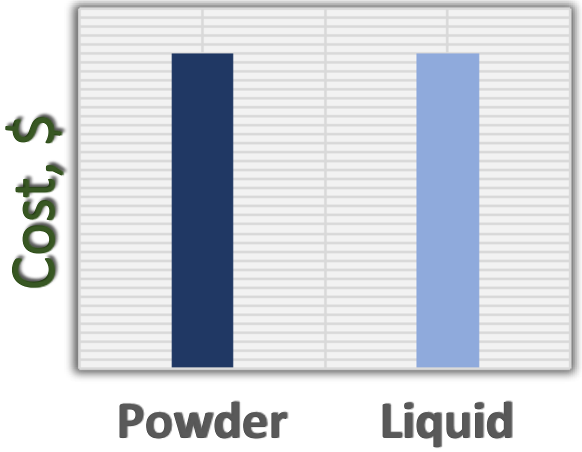
Competitive Price

- *Comparable to Liquid*
- *“Oil Shock”*
- *Clean Air Act*



Powder History

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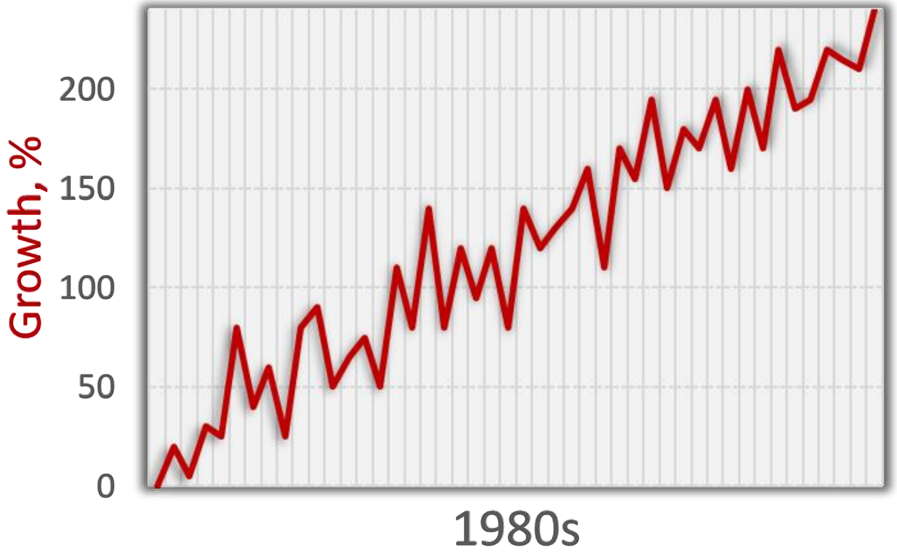
1980s – Evident Growth

- *Thermoset Coatings*
- *~240% Growth*



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- *Major Appliances*
- *Industrial Machinery*
- *Auto. Components*

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1950s — 1960s — 1970s — 1980s — **1990s**

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Overall Limitations:

- High Bake Temperatures
- Conventional Systems: ≥200°C

Implications:

- High Energy Costs
- Substrate Limitations

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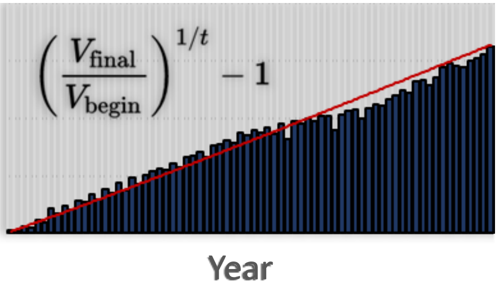
Bake Temperatures
≥200°C

2010s – Continued Growth
- *~6% Coatings Market*
- *$10.6-11.6B*
- *ACE Applications*

Powder History



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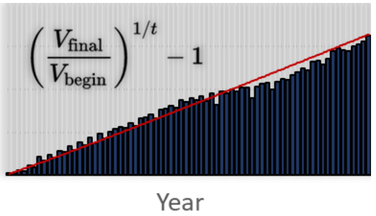
2020s – Large Estimated Growth
- 5.4% CAGR by 2026
- Total $15B

Powder History



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- *Major Appliances*
- *Industrial Machinery*
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Several Markets Emerge

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- *Total $15B*

Large Estimated Growth

1980s

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ident Growth

ermoset Coatings
40% Growth

Bake Temperatures
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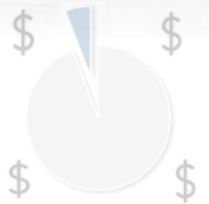


Overall Limitations:

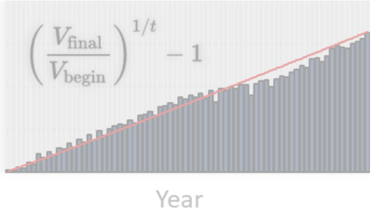
- High Bake Temperatures ***Still***
- Conventional Systems: ≥190°C

Implications:

- High Energy Costs
- Substrate Limitations

Powder History

Bake Temperatures ***Still*** High ≥190°C



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Bake Temperatures ≥200°C

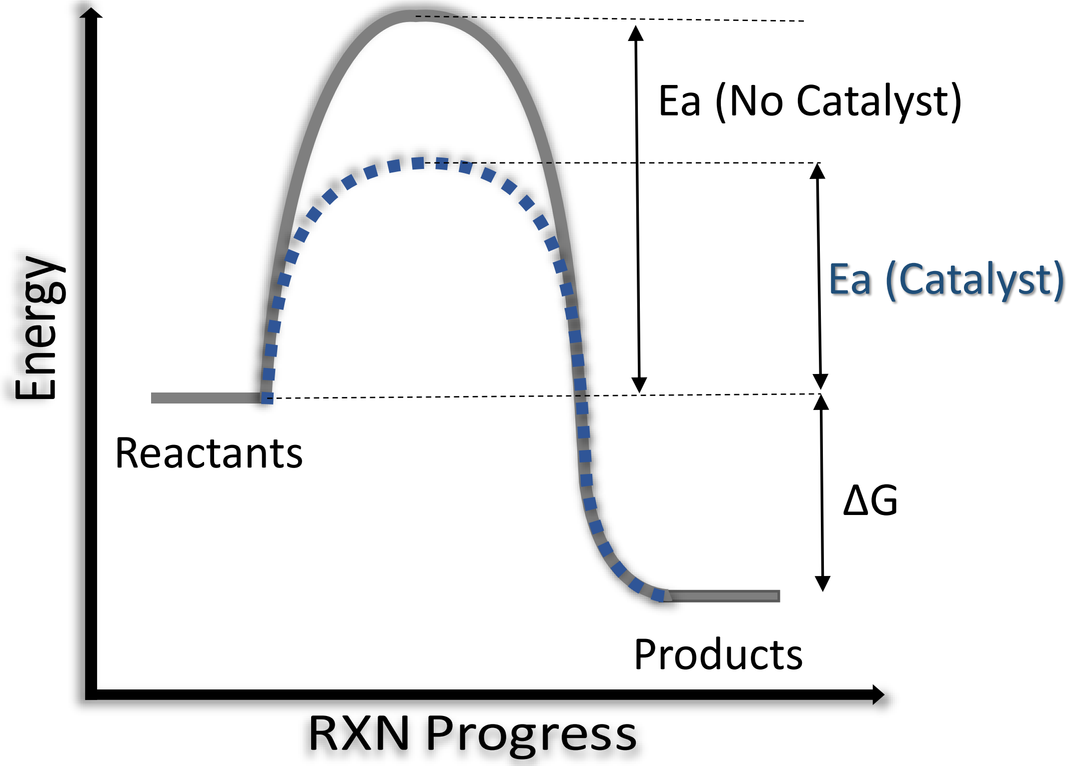
Powder History

1950s 1960s 1970s 1980s 1990s 2010s 2020s

1990s
Bake Temperatures
≥200°C

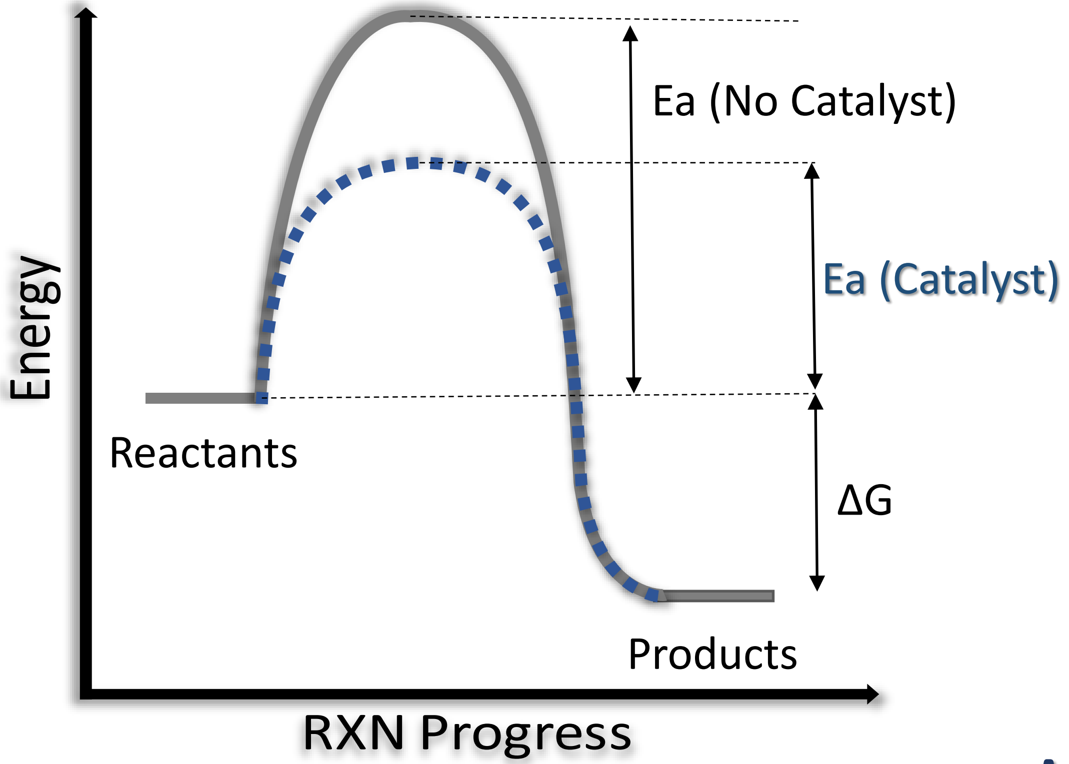
2020s
Bake Temperatures ***Still*** High
≥190°C

Conventional Systems



Approach: Catalysis

Overall Objectives

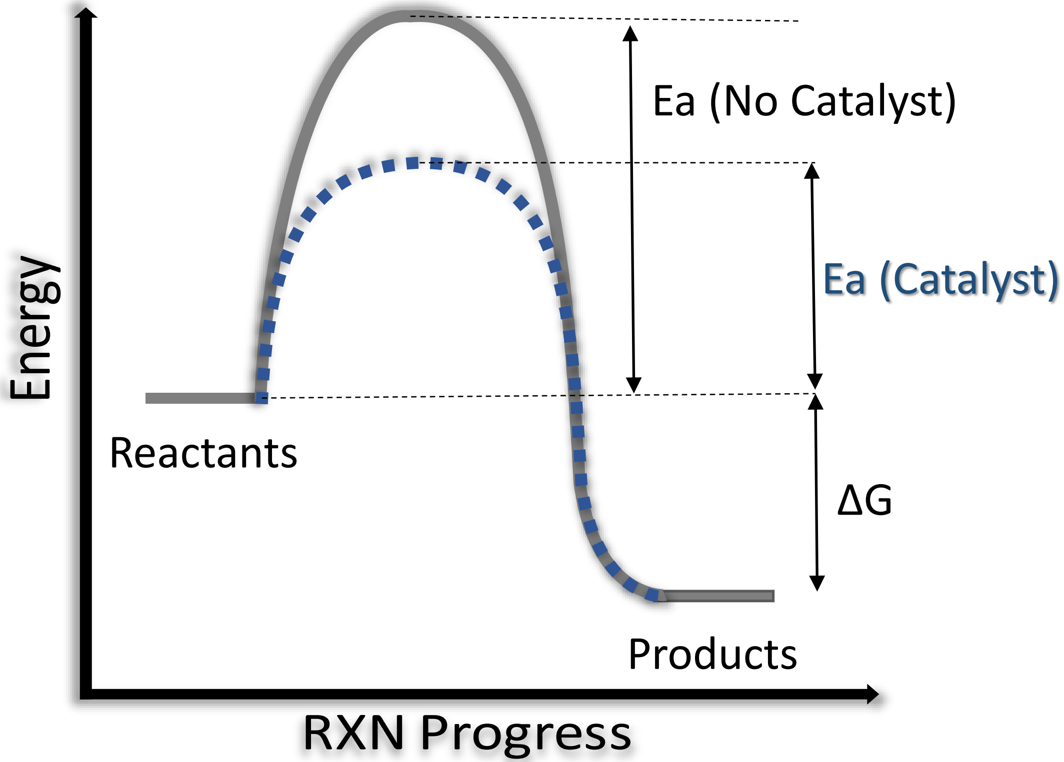


Approach:
Catalysis

- **Low Temperature Cure (LTC):**
  - Increase Efficiency
  - Reduce Energy Costs
  - Environmental Awareness
  - Heat Sensitive Substrates

Maintain Growth of Powder Coatings Market

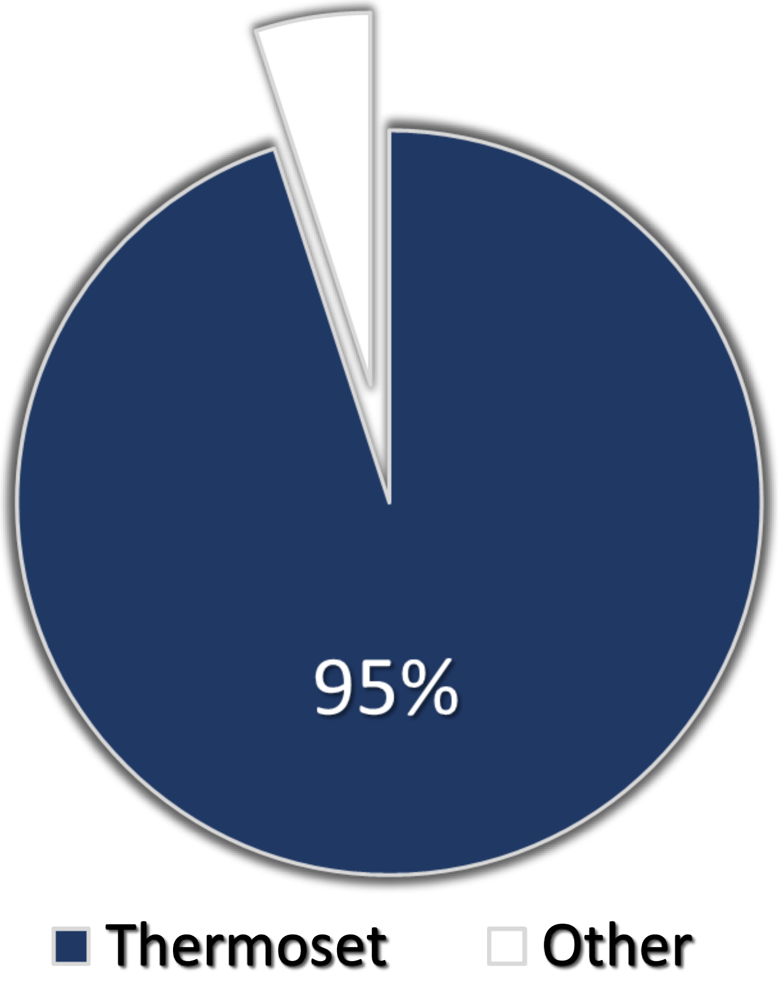
Overall Objectives



Approach: Catalysis

Naming Convention	%Active	Appearance
Catalyst LC	80	Clear, Light Straw-color Liquid
Catalyst PC	56	White, Free-Flowing Powder

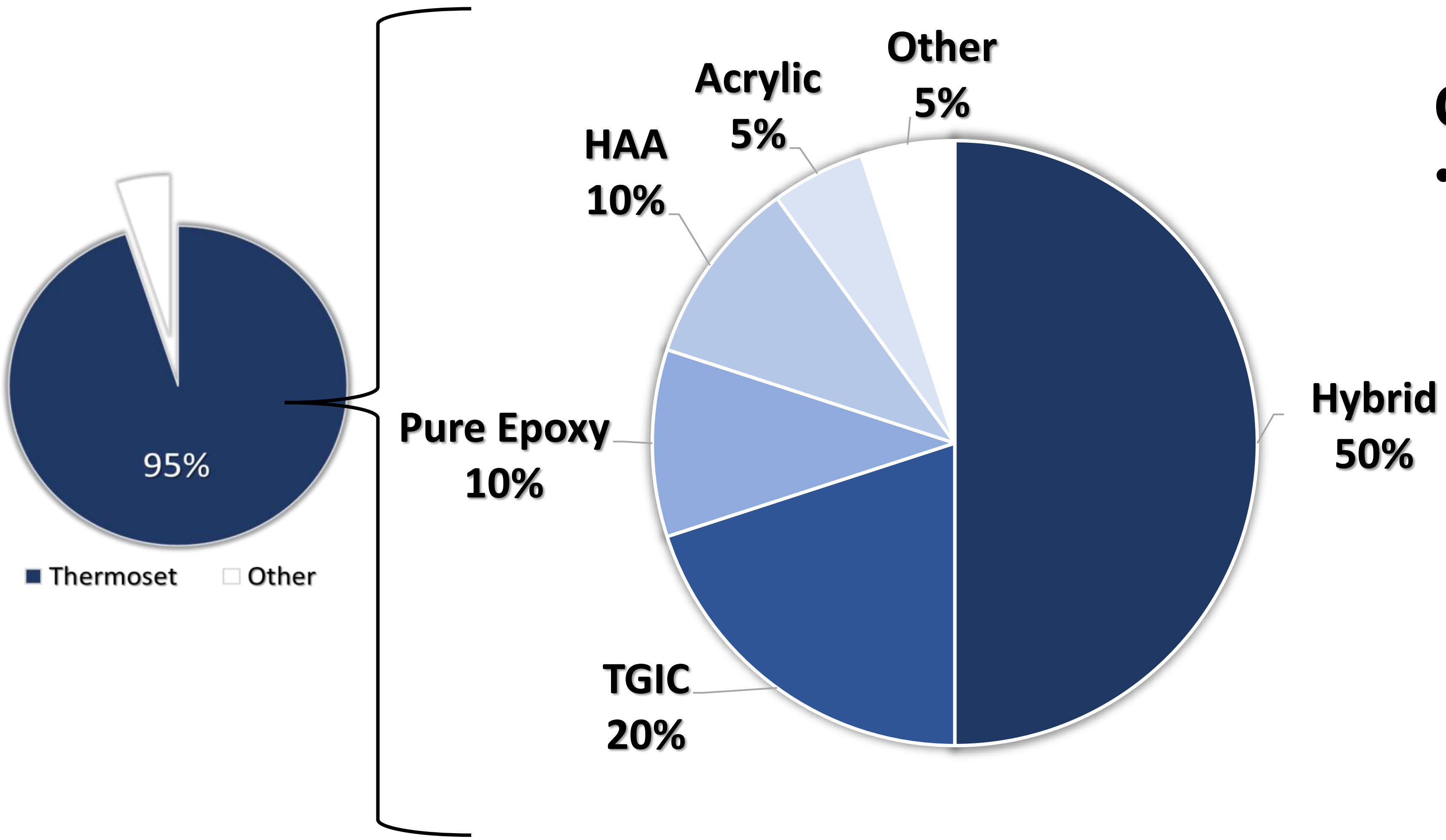
Thermoset Technologies



Current Market:

- ~95% Thermoset

Thermoset Technologies



Current Market:

- ~95% Thermoset
  - **Polyester/BPA Hybrid** – 50%
  - **Polyester/TGIC** – 20%
  - Polyester/HAA – 10%
  - **Pure Epoxy** – 10%
  - **Acrylic/GMA** – 5%
  - Other – 5%

Thermoset Technologies

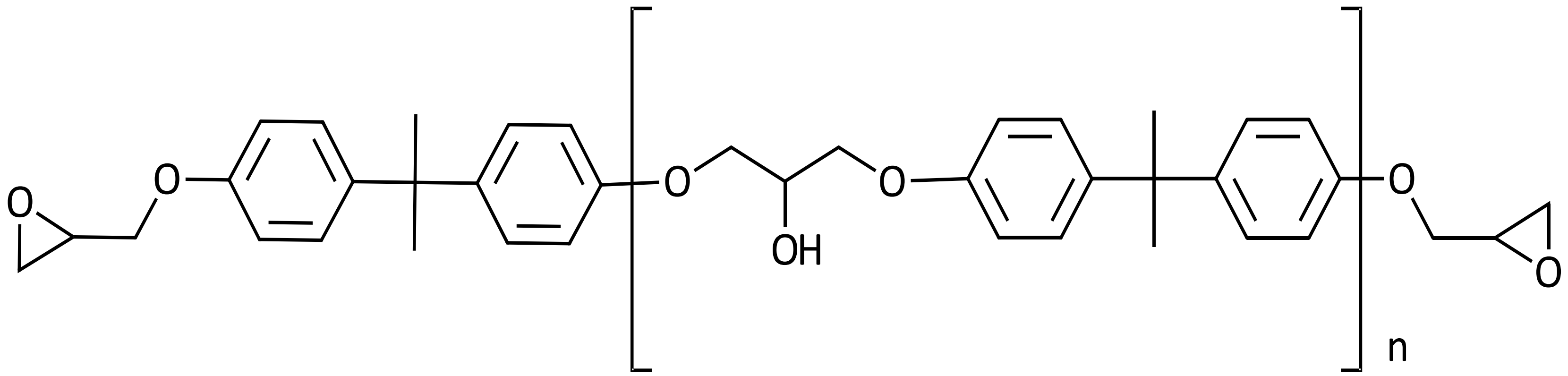
Polyester/BPA Hybrid

- Carboxyl Functional Polyester Resin
- Bisphenol-A Diepoxide

Polyester/TGIC

Acrylic/GMA

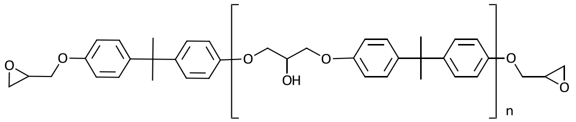
Pure Epoxy



Bisphenol-A (BPA) Diepoxide, $n \geq 0$

Thermoset Technologies

Polyester/BPA Hybrid



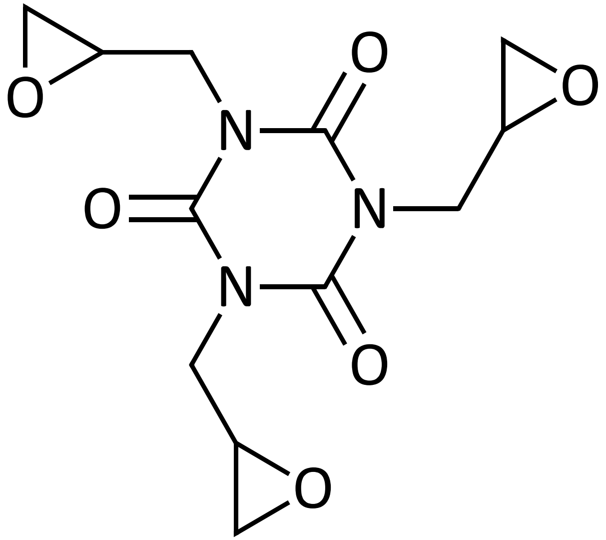
Bisphenol-A (BPA) Diepoxide,
n ≥ 0

Polyester/TGIC

- Carboxyl Functional Polyester Resin
- Trifunctional Epoxide Crosslinker

Acrylic/GMA

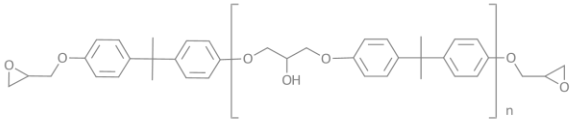
Pure Epoxy



Triglycidylisocyanurate
(TGIC)

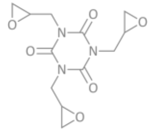
Thermoset Technologies

Polyester/BPA Hybrid



Bisphenol-A (BPA) Diepoxide, n ≥ 0

Polyester/TGIC

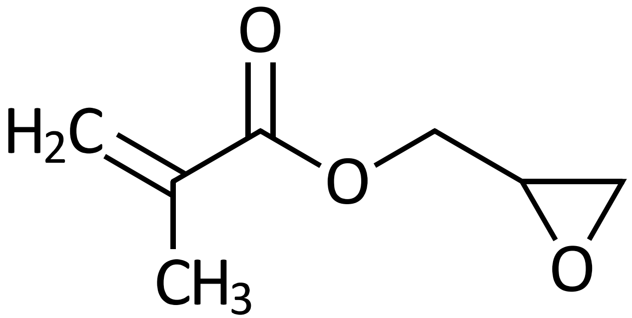


Triglycidylisocyanurate (TGIC)

Acrylic/GMA

- Carboxyl Functional Acrylics
- Epoxy Functional Acrylics
  - Glycidyl methacrylate (GMA) Acrylics

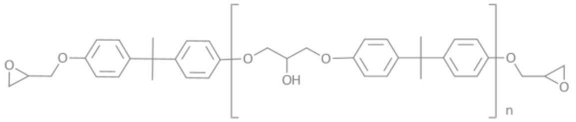
Pure Epoxy



Glycidyl methacrylate (GMA) monomer

Thermoset Technologies

Polyester/BPA Hybrid



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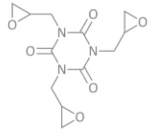
Polyester/TGIC



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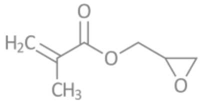
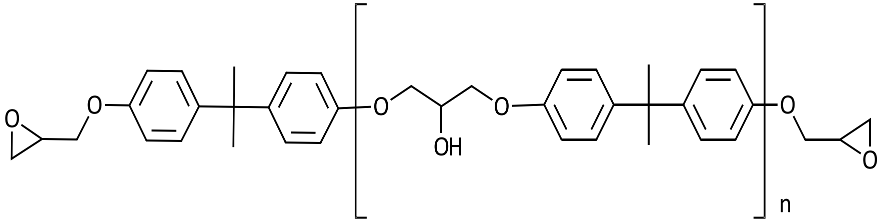


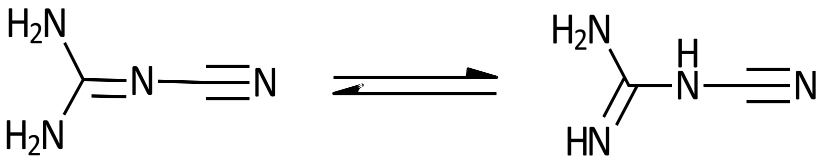
Glycidyl methacrylate (GMA) monomer

Pure Epoxy

- BPA Epoxy
- No Acrylic or Polyester
- Amine Functional Hardeners
  - DICY
  - Dihydrazide
  - Benzoguanamine



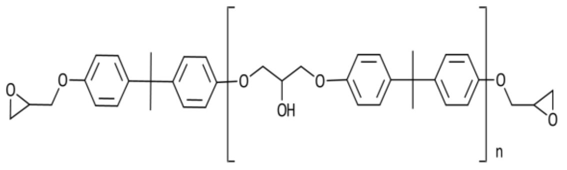
Bisphenol-A (BPA) Diepoxide, n ≥ 0



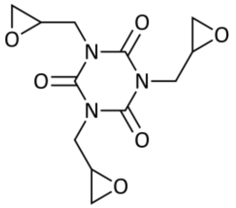
Dicyandiamide (DICY)

Thermoset Technologies

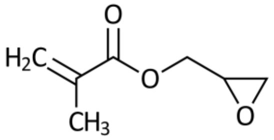
Polyester/BPA Hybrid	Polyester/TGIC	Acrylic/GMA	Pure Epoxy



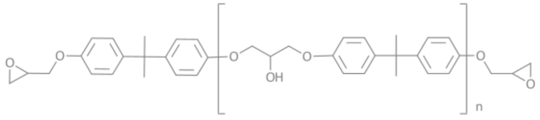
Bisphenol-A (BPA) Diepoxide, n ≥ 0



Triglycidylisocyanurate (TGIC)

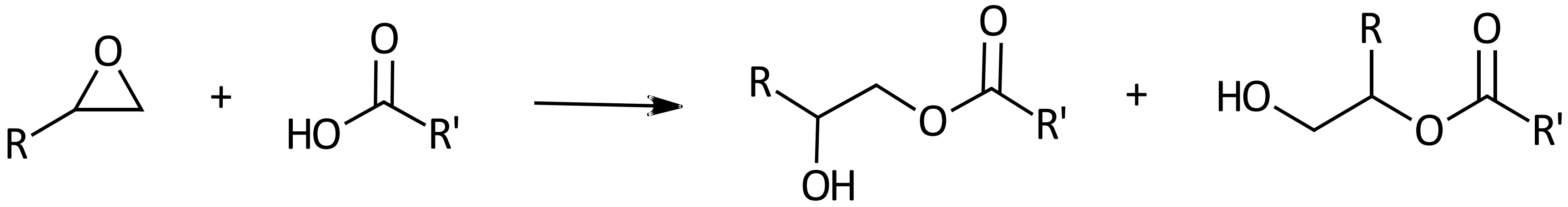


Glycidyl methacrylate (GMA) monomer



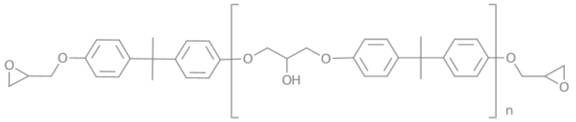
Bisphenol-A (BPA) Diepoxide, n ≥ 0

RXN of Epoxide and Carboxylic Acid –> 1° and 2° OH Functional Esters



Thermoset Technologies

Polyester/BPA Hybrid



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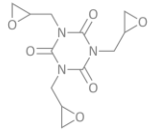
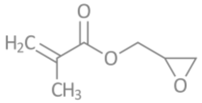


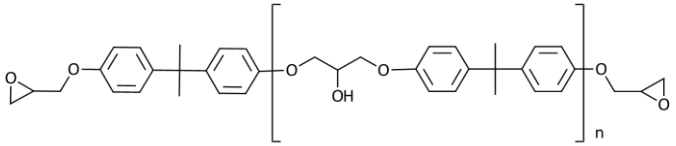
Triglycidylisocyanurate (TGIC)

Acrylic/GMA



Glycidyl methacrylate (GMA) monomer

Pure Epoxy



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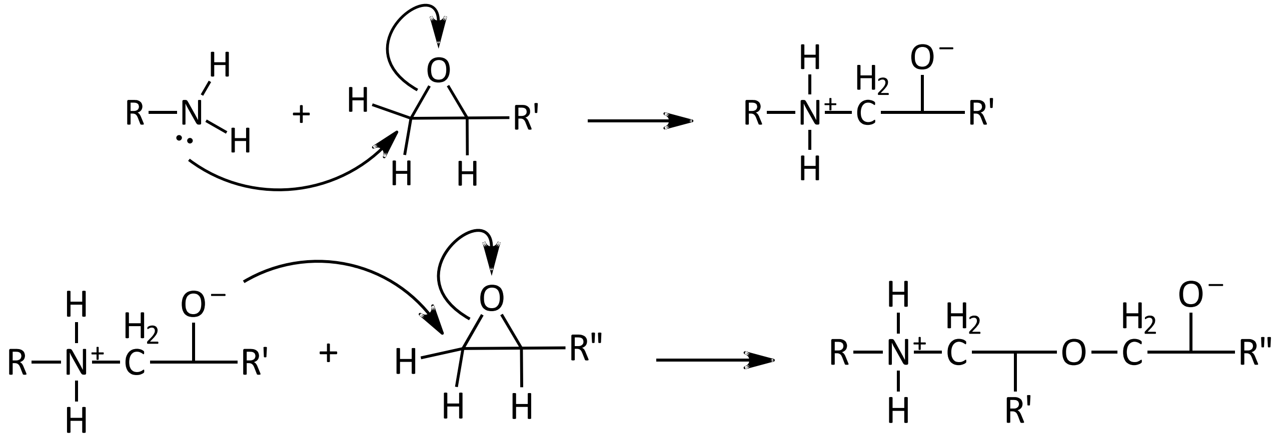
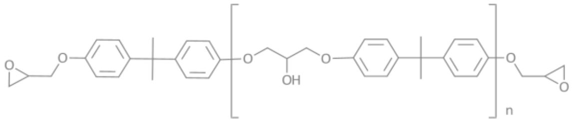


- Epoxy/Amine Polymerization

Thermoset Technologies

Polyester/BPA Hybrid	Polyester/TGIC	Acrylic/GMA	Pure Epoxy



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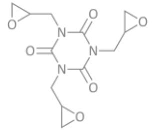

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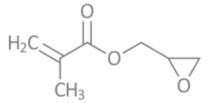

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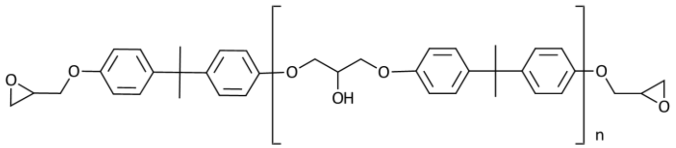

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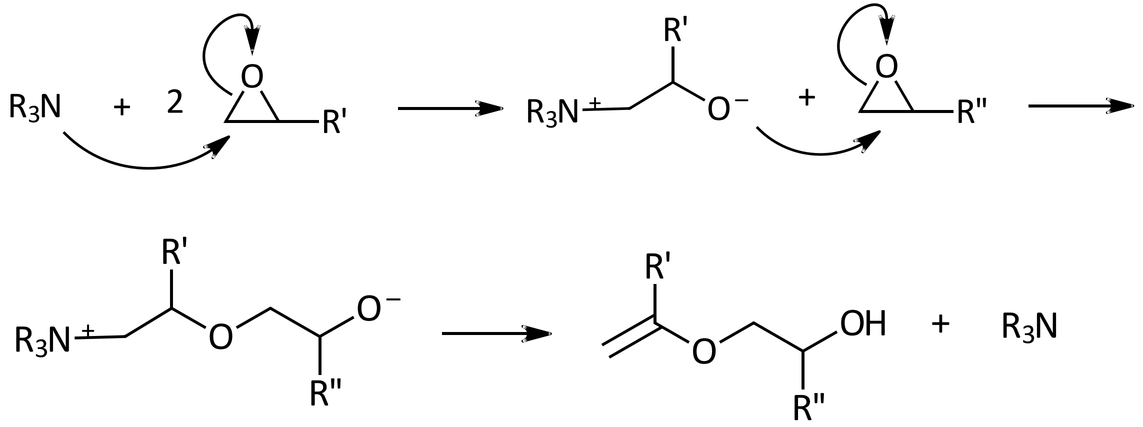
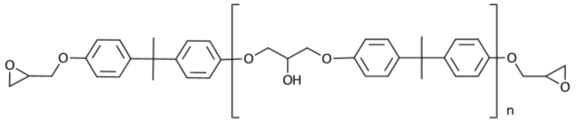


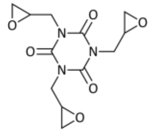
- Epoxy/Amine Polymerization
- Epoxy Homopolymerization
  - Often Catalyzed with 3° Amine

Thermoset Catalysis

Polyester/BPA Hybrid	Polyester/TGIC	Acrylic/GMA	Pure Epoxy



Bisphenol-A (BPA) Diepoxide, $n \geq 0$



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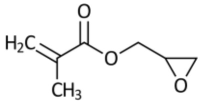

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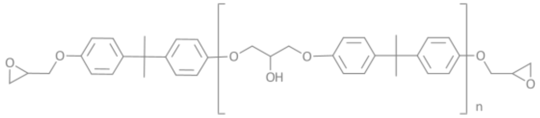
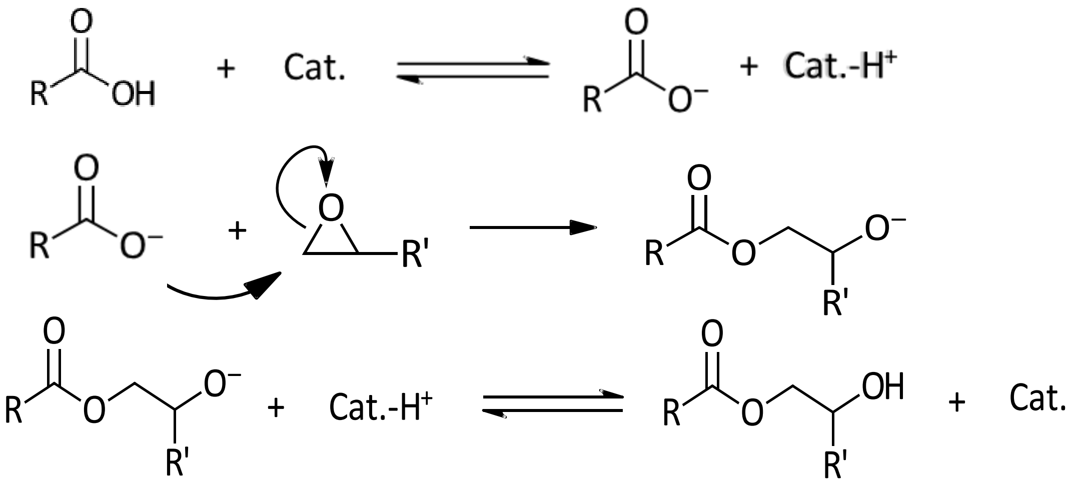


Base catalysis most effective



Thermoset Catalysis

Suitable Catalysts for Epoxy/Carboxy RXN

Base catalysis most effective

Family	Chemical
Tertiary amines	Benzyldimethylamine (BDMA) 2-methylimidazole (2-MI) 1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU) Tetramethyl Guanidine (TMG) Octyldimethylamine (ODMA) Decyldimethylamine (DDMA)
Quaternary bases (Ammonium & Phosphonium)	Benzyl trimethylammonium bromide (BTAB) Tetrabutyl ammonium bromide (TBAB) Tetrabutyl phosphonium bromide (TBPB)
Metal compounds	Zinc chelates Zinc-Amine Zinc octoate Bismuth-Amine

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Metal compounds	Zinc chelates Zinc-Amine Zinc octoate Bismuth-Amine

Limitations/Issues:

Performance:

- Appearance
- Yellowing
- Storage Stability

Handling, Safety, and Regulatory:

- Several Concerns

Thermoset Catalysis

Limitations/Issues:

Handling, Safety, and Regulatory

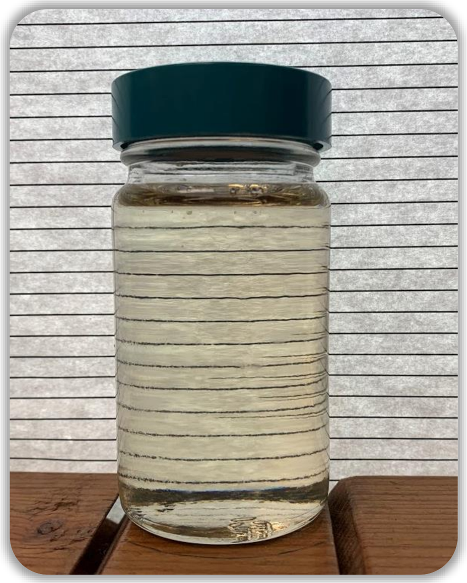
	Liquids	Flammability	Corrosive	Single Exposure Respiratory	Acute Toxicity	Reproductive Concerns	Aquatic Hazards	Halogenated	Carcinogen Risk
Benzyldimethylamine (BDMA)	X	X	X		X		X		
2-methylimidazole (2-MI)			X		X	X	X		X
1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU)	X	X	X		X				
Tetramethyl Guanidine (TMG)	X	X	X		X				
Octyldimethylamine (ODMA)	X		X		X		X		
Decyldimethylamine (DDMA)	X		X		X		X		
Benzyl trimethylammonium bromide (BTAB)				X			X	X	
Tetrabutyl ammonium bromide (TBAB)							X	X	
Tetrabutyl phosphonium bromide (TBPB)					X	X	X	X	
Zinc chelates	X								
Zinc-Amine	X								
Zinc octoate	X								
Bismuth-Amine	X								

Catalyst LC & PC

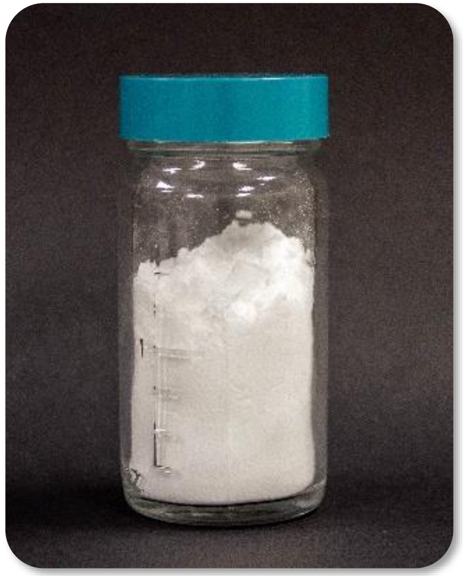
Naming Convention	%Active	Appearance
Catalyst LC	80	Clear, Light Straw-color Liquid
Catalyst PC	56	White, Free-Flowing Powder

Catalysts for Epoxy Powder Coatings:

- Safe and Easy to Handle
- LTC Capabilities
- Achieve Good Chemical Resistance and Impact Resistance
- Better Film Appearance than Conventional Materials



Catalyst LC



Catalyst PC

Experimental

Pure Epoxy	Acrylic	BPA Hybrid	TGIC
Experiment I – Epoxy Homopolymerization	**Experiment II –** Acrylic/GMA	**Experiment III –** Polyester/BPA	**Experiment IV –** Polyesteramide/TGIC

Experimental

Experiment I –
Epoxy Homopolymerization

Experiment II –
Acrylic/GMA

Experiment III –
Polyester/BPA

Experiment IV –
Polyesteramide/TGIC

Experimental

Experiment I –
Epoxy Homopolymerization

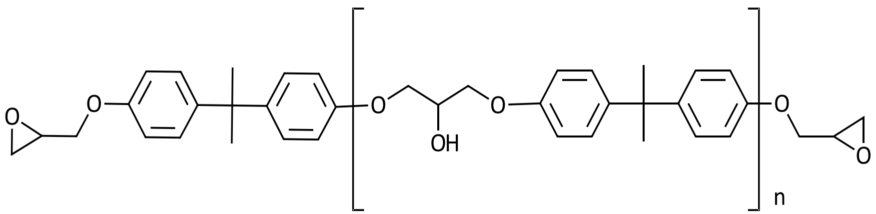
Experiment II –
Acrylic/GMA

Experiment III –
Polyester/BPA

Experiment IV –
Polyesteramide/TGIC

- **Catalyst LC**

- Demonstrate Capabilities of Accelerating Homopolymerization of BPA-type Epoxy.
- Liquid Materials

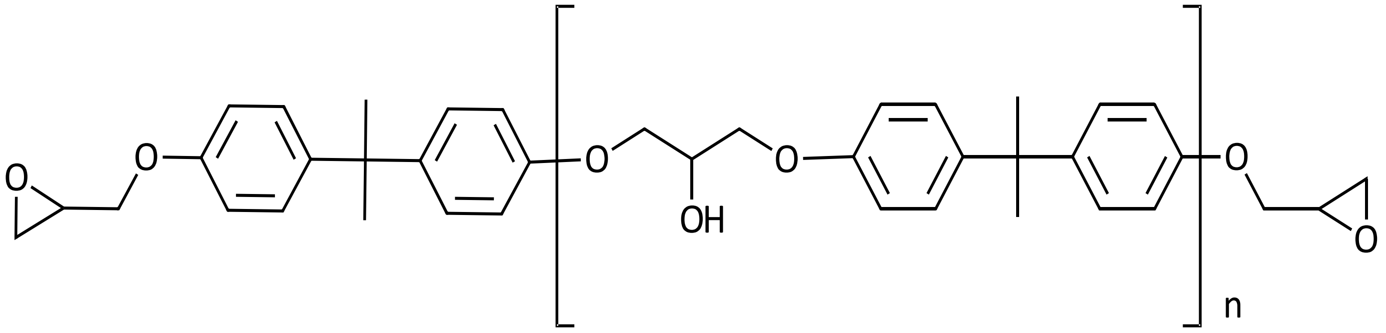


Bisphenol-A (BPA) Diepoxide,
n ≥0

Experiment I –
Epoxy Homopolymerization

Formulation

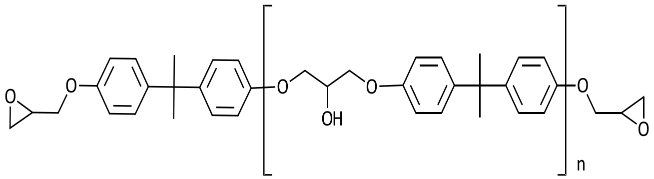
Material	Description	%
Epoxy Resin	BPA type resin, EEW 182- 192 g/eq	100.00
TOTAL		100.00
%Total resin solids (TRS)	100	



Bisphenol-A (BPA) Diepoxide, n = 0

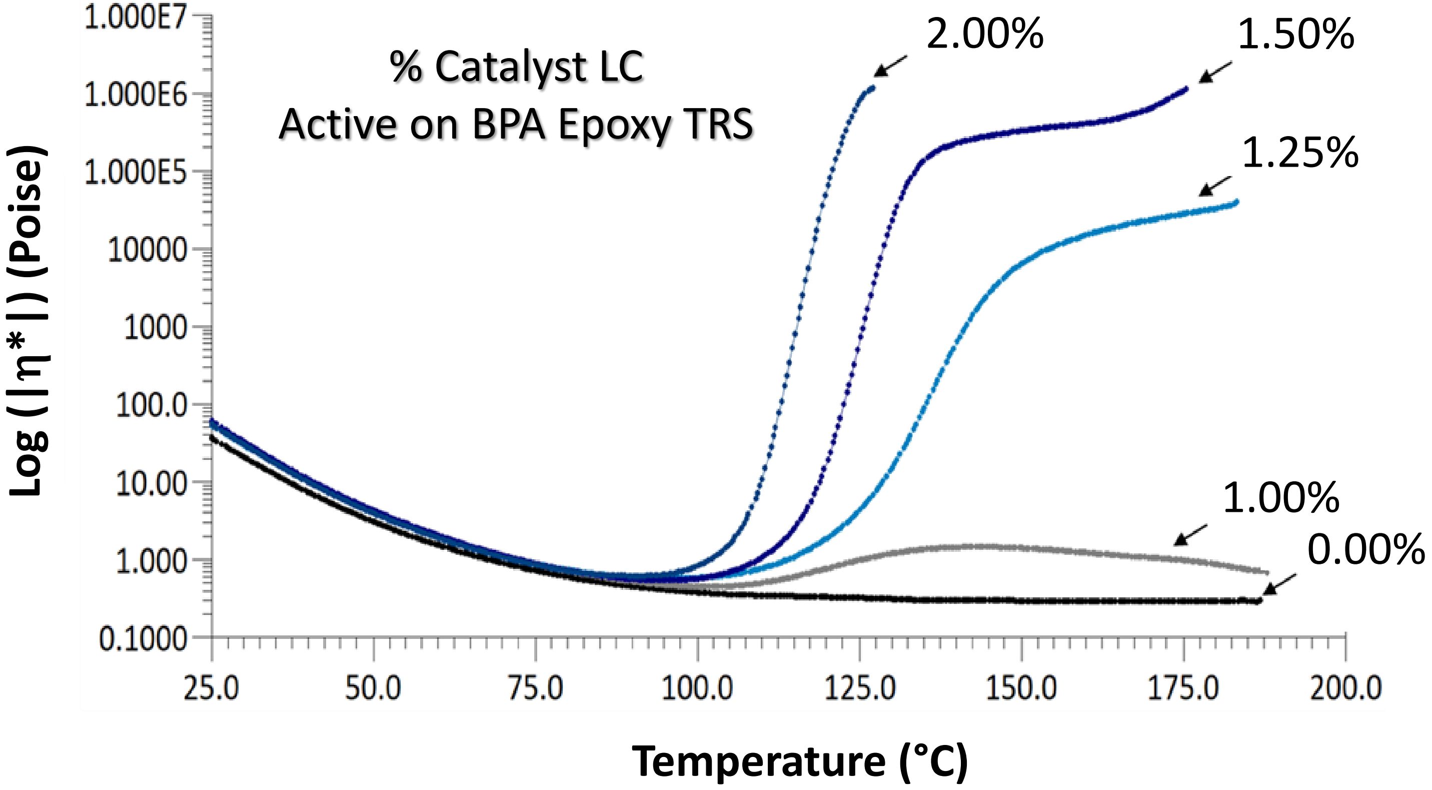
Experiment I –
Epoxy Homopolymerization

Gel Temperatures



AR 2000 Rheometer – Pelteir Plate – 20mm Steel Plate

Temperature Ramp: 2.5°C / min – 25-188°C

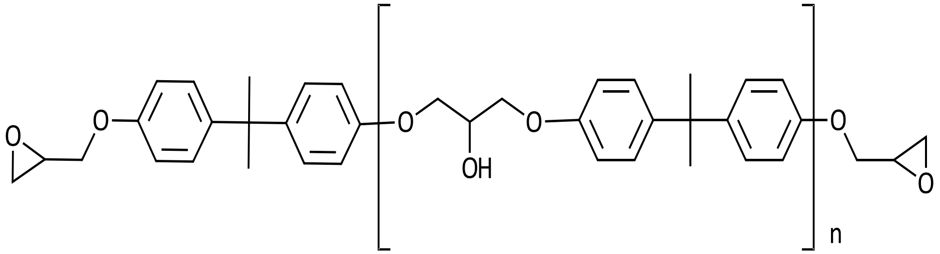


Experiment I –
Epoxy Homopolymerization

Gel Temperatures

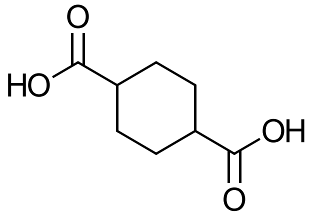
AR 2000 Rheometer – Pelteir Plate – 20mm Steel Plate

Temperature Ramp: 5°C / min – 25-188°C + Isotherm



Bisphenol-A (BPA) Diepoxide,

n = 0



1,4-Cyclohexanedicarboxylic Acid (CHDA)

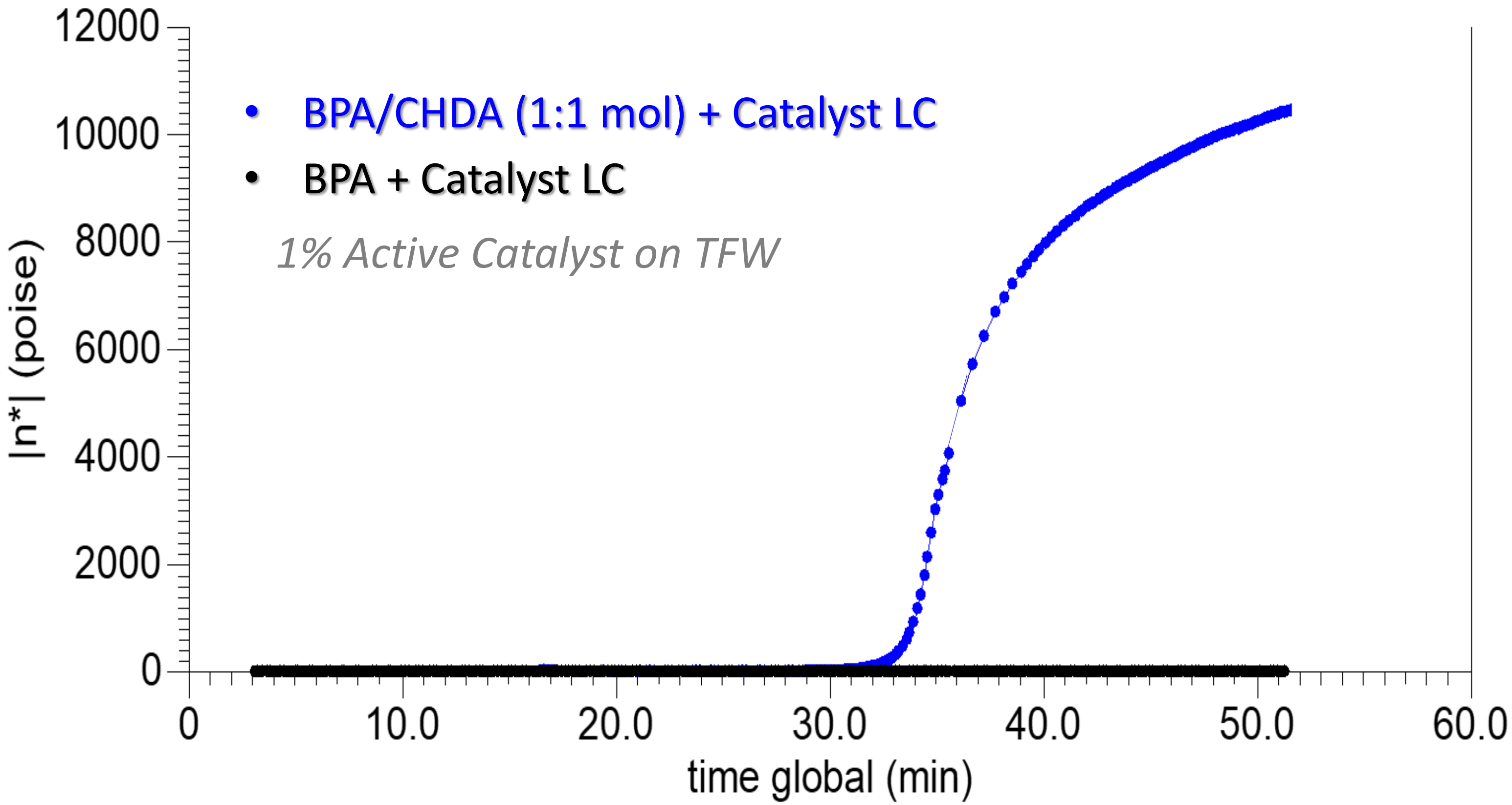
Nucleophile

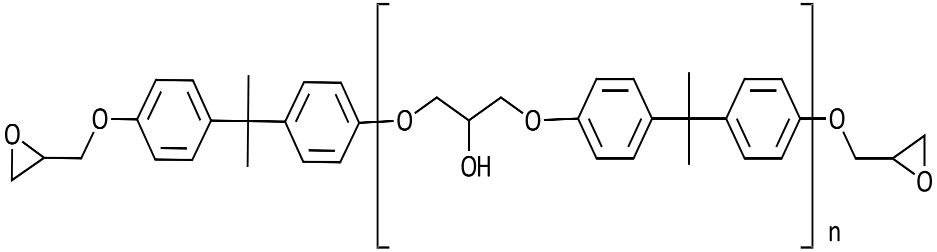
Experiment I –
Epoxy Homopolymerization

Gel Temperatures

AR 2000 Rheometer – Pelteir Plate – 20mm Steel Plate

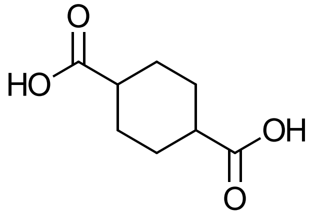
Temperature Ramp: 5°C / min – 25-188°C + Isotherm





Bisphenol-A (BPA) Diepoxide,

n = 0



1,4-Cyclohexanedicarboxylic Acid (CHDA)

Nucleophile

Experimental

Experiment I –
Epoxy Homopolymerization

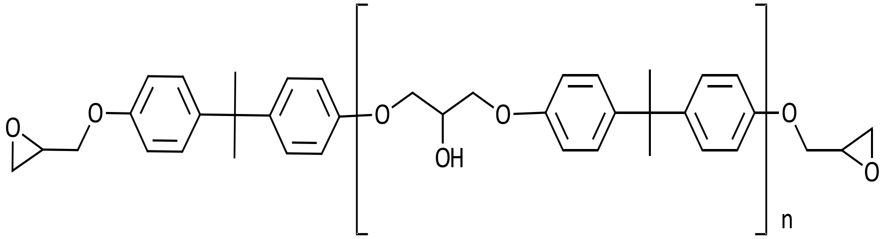
Experiment II –
Acrylic/GMA

Experiment III –
Polyester/BPA

Experiment IV –
Polyesteramide/TGIC

Conclusions:

- **Catalyst Accelerates Epoxy Homopolymerization of BPA-Type Epoxy**
- Useful for Pure Epoxy Systems
- More Effectively Promotes Epoxy/Carboxy RXN



Bisphenol-A (BPA) Diepoxide,
n = 0

Experimental

Experiment I –
Epoxy Homopolymerization

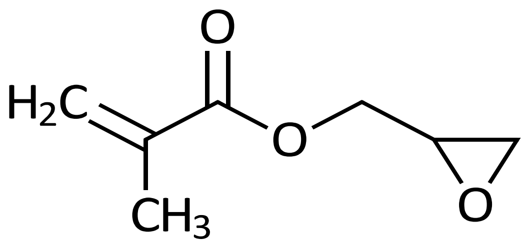
Experiment II –
Acrylic/GMA

Experiment III –
Polyesteramide/TGIC

Experiment IV –
Polyester/BPA

- **Catalyst LC**

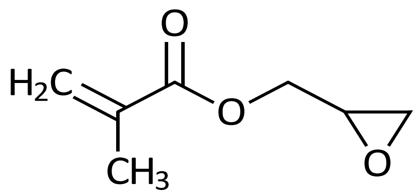
- Carboxyl Functional Acrylic Resin with GMA-Type Epoxy
- SB and Powder Systems
- Gel Temperature / Cure Evaluations



Glycidyl methacrylate (GMA) monomer

Experiment II –
Acrylic/GMA

Formulation



2K SB Clear Acrylic/GMA

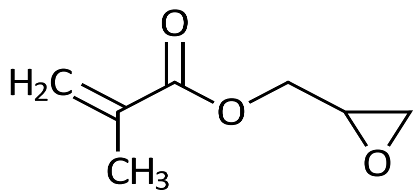
Component	Material	Description	%
Acid Component	**Acrylic resin**	**Carboxyl functional acrylic, AV 148 mg KOH/g**	31.10
	Xylene	Solvent	15.10
	PM acetate	Solvent	15.10
	n-Butyl acetate	Solvent	7.50
	Silane flow additive	Polyester modified dimethylsiloxane	0.20
Epoxy Component	**Epoxy resin**	**Glycidyl methacrylate (GMA), EEW 300 - 350 g/eq**	14.00
	Xylene	Solvent	6.80
	PM acetate	Solvent	6.80
	n-Butyl acetate	Solvent	3.40
TOTAL			100.00

Total Resin Solids (TRS) = 45%

Acrylic/GMA on TRS = 69 / 31

Experiment II –
Acrylic/GMA

Formulation



Powder Acrylic/GMA

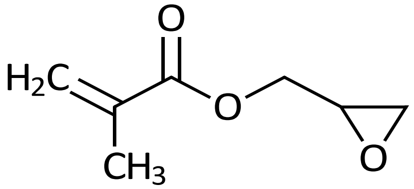
Material	Description	%
Acrylic resin	Carboxyl-functional acrylic, AV 148 mg KOH/g	69.00
Epoxy resin	Glycidyl methacrylate (GMA), EEW 300 - 350 g/eq	31.00
TOTAL		**100.00**

Total Resin Solids (TRS) = 100%

Acrylic/GMA on TRS = 69 / 31

Experiment II – Acrylic/GMA

Powder Rheology Method

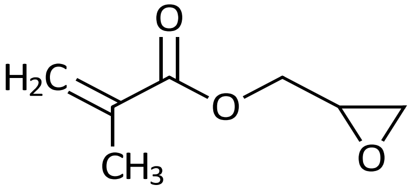


Powder Acrylic/GMA

Powder Disc Prepared using Cylindrical Pellet Press (left)

Experiment II –
Acrylic/GMA

Powder Rheology Method



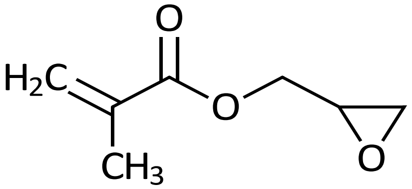
Powder Acrylic/GMA

Powder Disc Prepared using Cylindrical Pellet Press (left)

–3 Piece Press

Experiment II –
Acrylic/GMA

Powder Rheology Method



Acrylic/GMA Powder

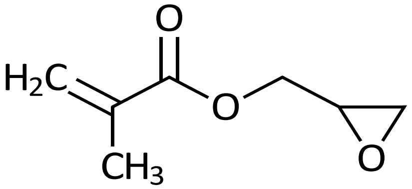
Powder Disc Prepared using Cylindrical Pellet Press (left)

–3 Piece Press

1) Fine Powder Poured into Press

Experiment II –
Acrylic/GMA

Powder Rheology Method



10,000 N

Acrylic/GMA Powder

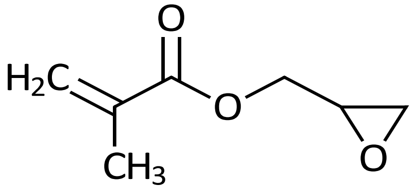
Powder Disc Prepared using Cylindrical Pellet Press (left)

–3 Piece Press

1) Fine Powder Poured into Press
2) Powder Pressed with 10,000 N Force

Experiment II –
Acrylic/GMA

Powder Rheology Method



<u>Acrylic/GMA Powder</u>

Powder Disc Prepared using Cylindrical Pellet Press (left)

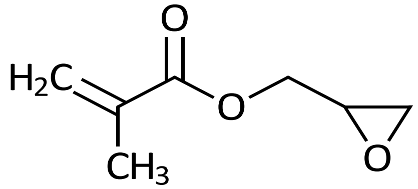
–3 Piece Press

1) Fine Powder Poured into Press
2) Powder Pressed with 10,000 N Force
3) Disc Ejected From Bottom of Pellet Press

Powder Disc

Experiment II –
Acrylic/GMA

Powder Rheology Method

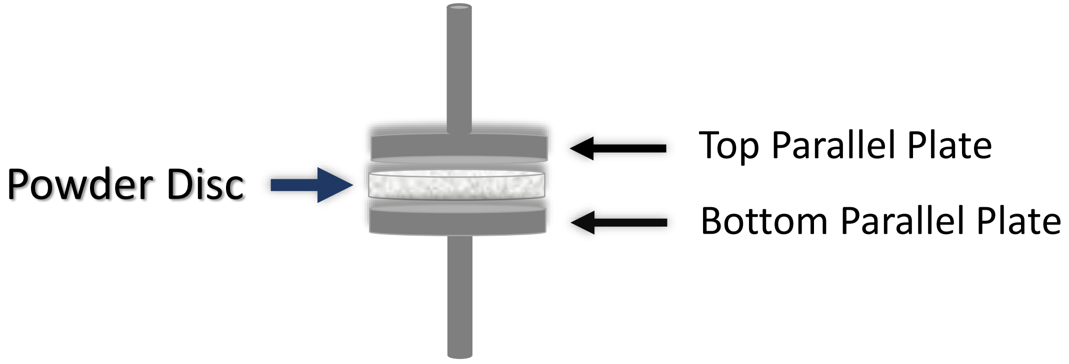


<u>Acrylic/GMA Powder</u>

Powder Disc Prepared using Cylindrical Pellet Press (left)

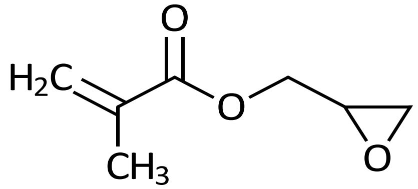
–3 Piece Press

1) Fine Powder Poured into Press
2) Powder Pressed with 10,000 N Force
3) Disc Ejected From Bottom of Pellet Press
4) Disc Placed Between Parallel Plate Geometry and Evaluated for Gel Time via Oscillation Tests



Experiment II –
Acrylic/GMA

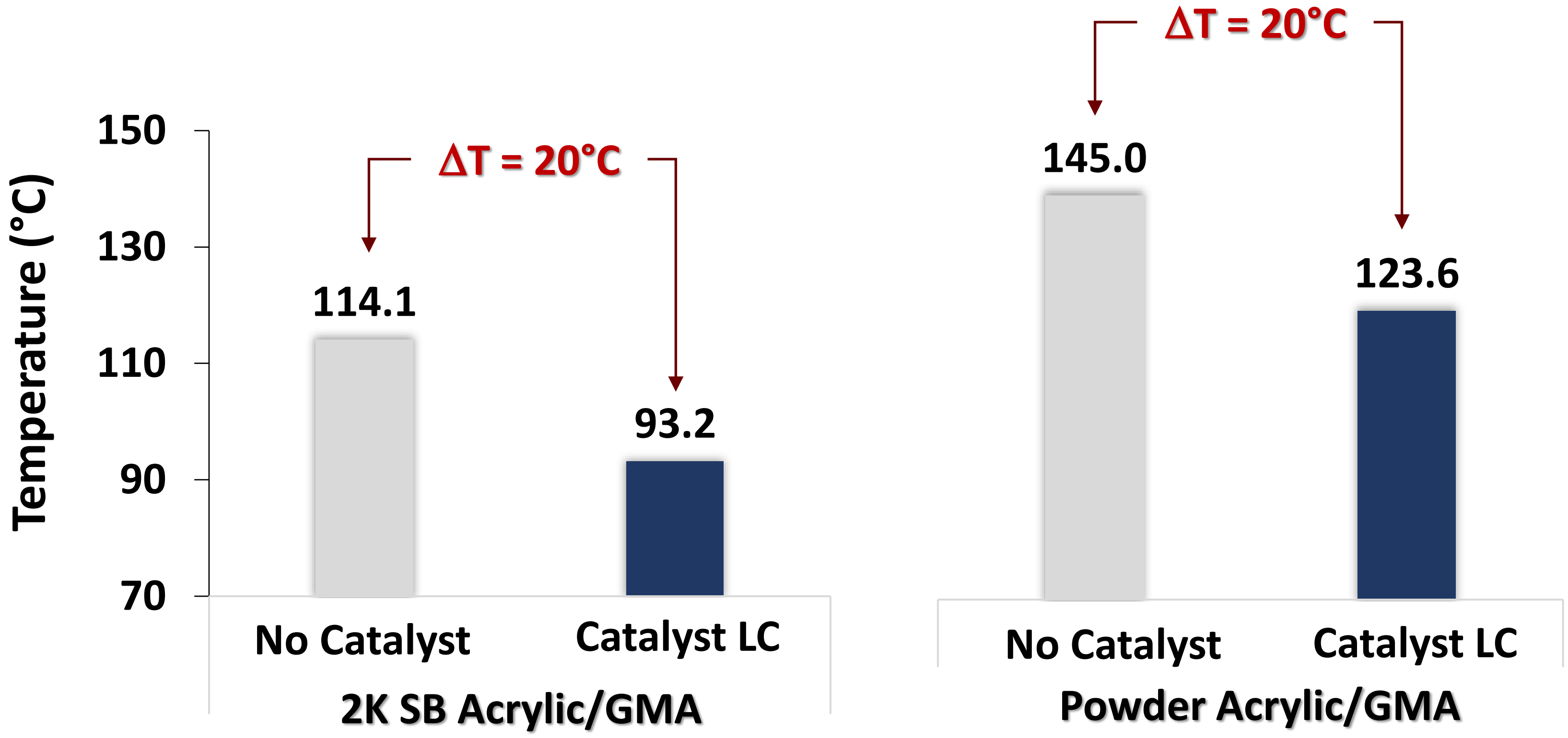
Gel Temperatures



AR 2000 Rheometer

Temperature Ramp = 1°C / min

1% Active Catalyst on TRS



POWDER COATING SUMMIT SEPTEMBER 8-9, 2022

KING INDUSTRIES SPECIALTY CHEMICALS

Experimental

Experiment I –
Epoxy Homopolymerization

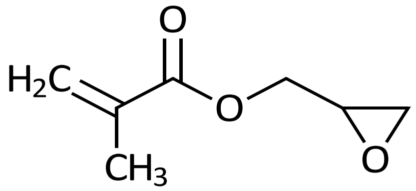
Experiment II –
Acrylic/GMA

Experiment III –
Polyesteramide/TGIC

Experiment IV –
Polyester/BPA

Conclusions:

- **Catalyst is Highly Active in GMA-Type Acrylic Systems**
  - Accelerates Crosslinking Reaction
  - Carboxyl Functional Acrylic/GMA-Type Diepoxide
- Significantly Reduces Gel Temperature:
  - Acrylic SB and Powder Systems



Glycidyl methacrylate (GMA) monomer

Experimental

Experiment I – Epoxy Homopolymerization

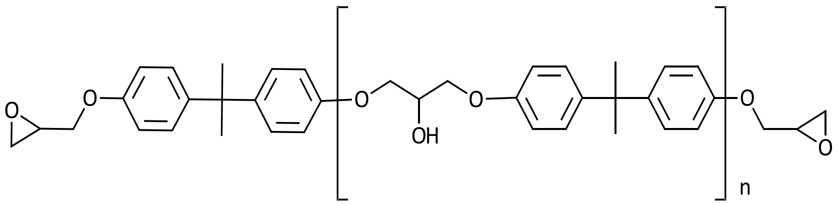
Experiment II – Acrylic/GMA

Experiment III –
Polyester/BPA

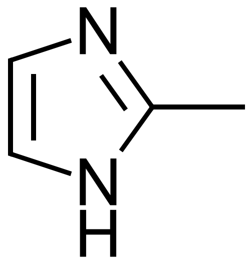
Experiment IV– Polyesteramide/TGIC

- **Catalyst PC**

- White Polyester/BPA Hybrid (70/30)
- Gel Times
- Film Performance & LTC Capabilities:
  - 170°C and 140°C PMT
- Comparisons vs. 2-MI

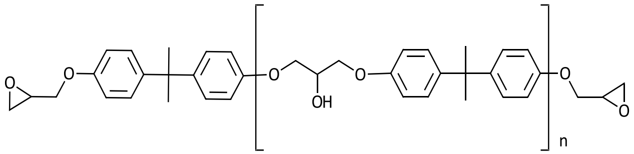


Bisphenol-A (BPA) Diepoxide, $n \geq 0$



Experiment III – Polyester/BPA

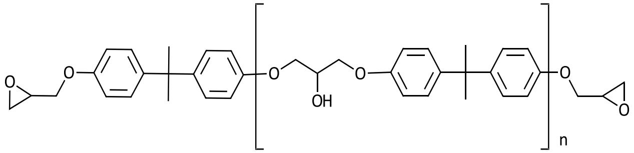
Formulation



Material	Description	%
Polyester resin	Carboxyl-functional polyester, AV 35 mg KOH/g	45.50
Epoxy resin	BPA type resin, EEW 182 - 192 g/eq	19.50
TiO_2	Titanium dioxide	17.38
$BaSO_4$	Barium sulfate extender	15.82
Surface agent	Polyacrylate surface agent	1.50
Benzoin	Degassing agent	0.30
TOTAL		**100.00**
%Total resin solids (TRS)	65	
Polyester/BPA on TRS	70 / 30	

Experiment III – Polyester/BPA

Formulation

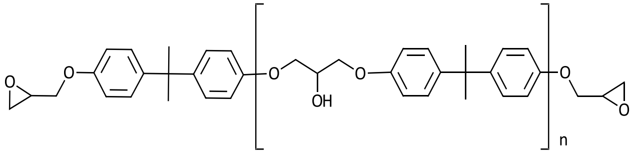


Material	Description	%
Polyester resin	Carboxyl-functional polyester, AV 35 mg KOH/g	45.50
Epoxy resin	BPA type resin, EEW 182 - 192 g/eq	19.50
TiO_2	Titanium dioxide	17.38
$BaSO_4$	Barium sulfate extender	15.82
Surface agent	Polyacrylate surface agent	1.50
Benzoin	Degassing agent	0.30
TOTAL		**100.00**
%Total resin solids (TRS)	65	
Polyester/BPA on TRS	70 / 30	

- No catalyst
- 2-Methylimidazole
  - 1% as Supplied = 1% Active
- Catalyst PC
  - 1% as Supplied = 0.56% Active
  - 1.79% as Supplied = 1% Active

Experiment III –
Polyester/BPA

Coating Preparation



Processing

- Raw Materials were premixed for 180 seconds:
  - 5 Kg Batch/Formulations
- Premix was added to extruder hopper
  - Extruded under standard conditions.
  - Maximum Zone 3 temperature of 105°C.
- Extrudate was flaked and ground using ACM
- Optimum particle size and distribution achieved using Ultrasonic Sieve (No. 140 Mesh)

Experiment III –
Polyester/BPA

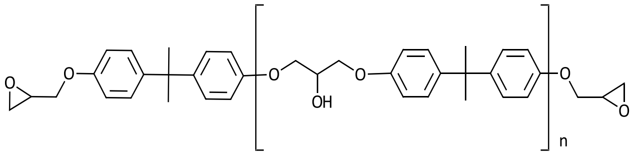
Film Preparation

- **Coatings Sprayed over $ZnPO_4$ CRS**
  - **Spray Gun:** Gema Optiflex Pro
  - **Gun Voltage:** 65 kV

- **Films Cured in Conventional Oven**
  - **Temperatures:** 170°C & 140°C
  - **Dwell Time:** 15 min PMT
  - **DFT =** ~2.8 mil

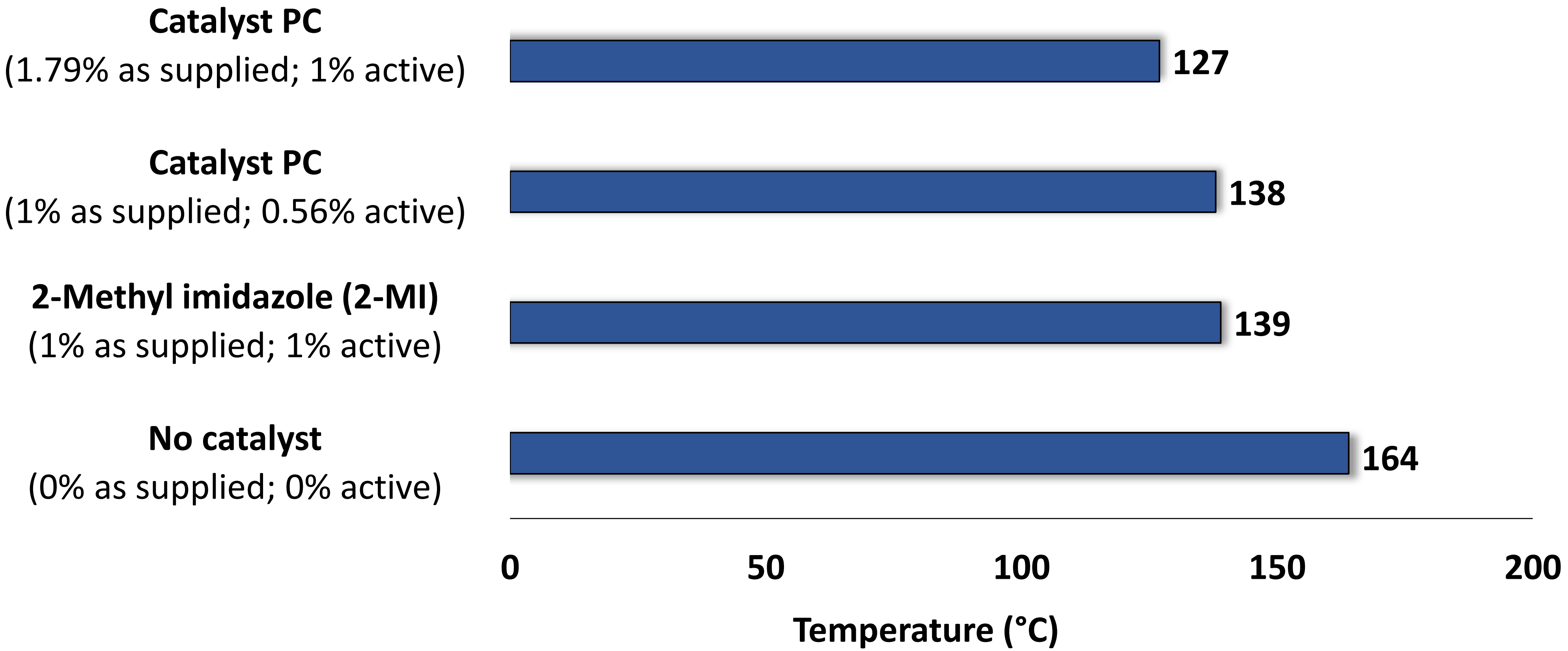
Experiment III – Polyester/BPA

Gel Temperatures



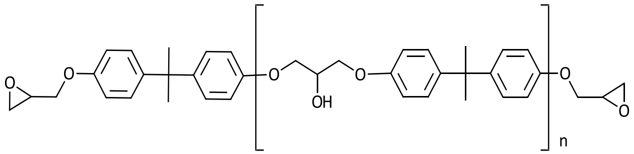
AR 2000 Rheometer – ETC – Parallel Plates

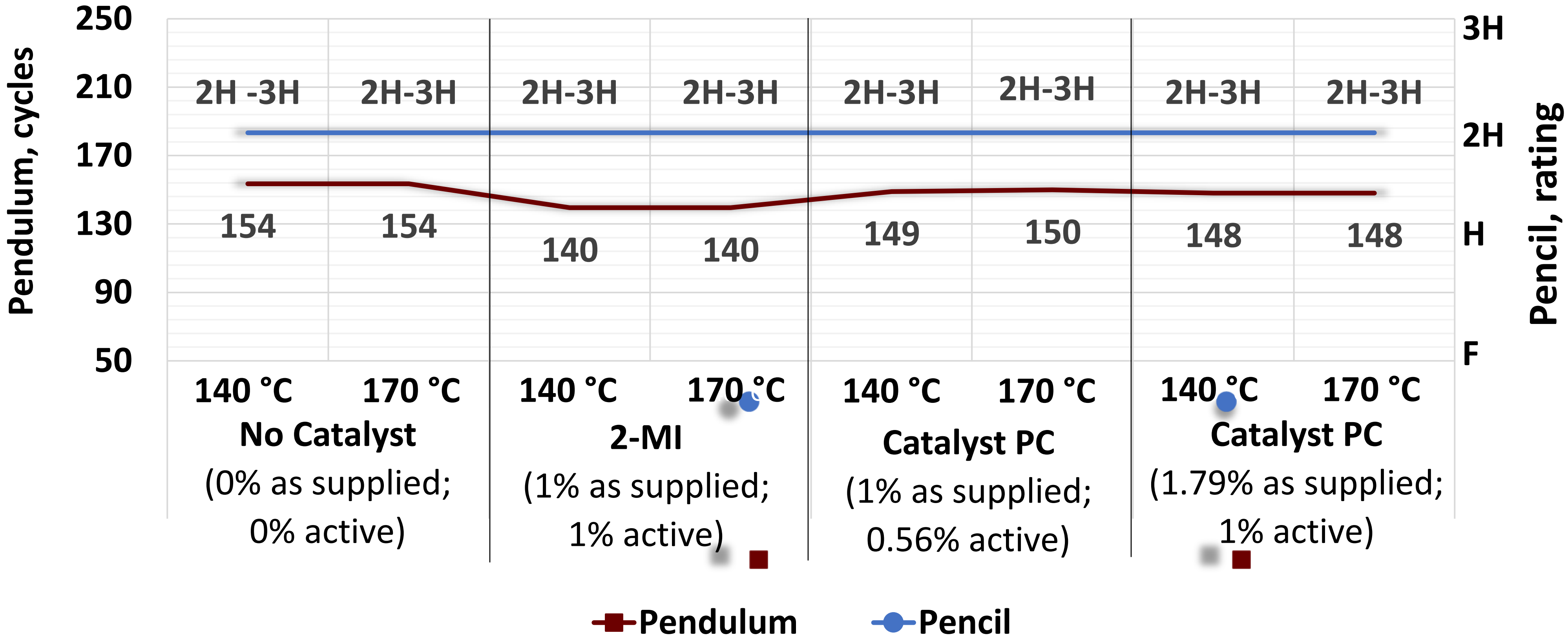
Temperature Ramp: 5°C / min – 20 - 200°C



Experiment III –
Polyester/BPA

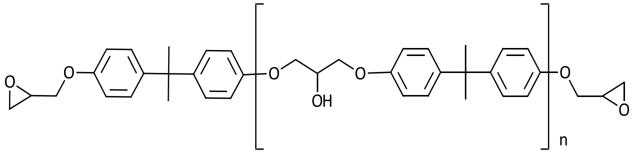
Film Hardness

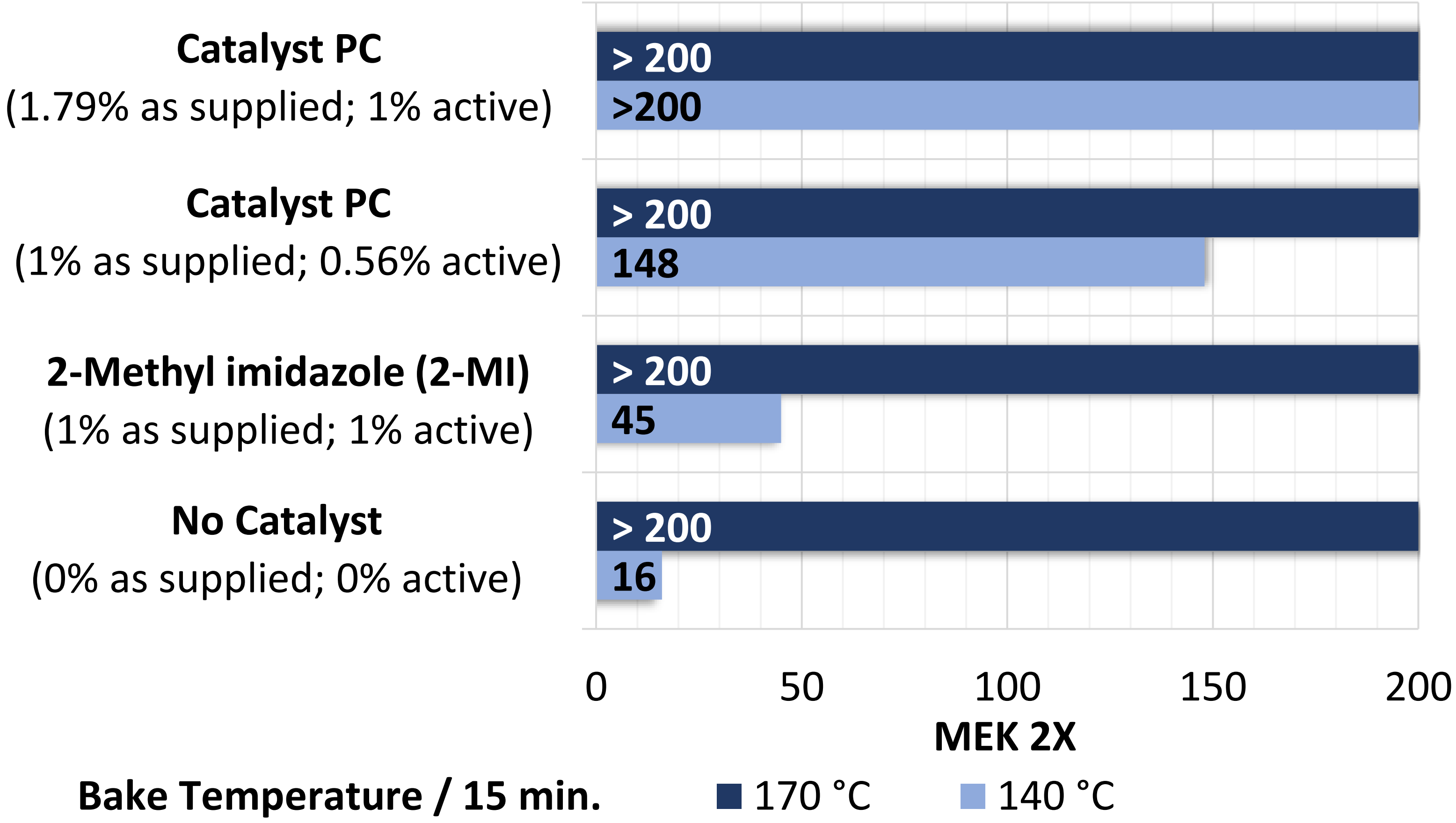




Experiment III –
Polyester/BPA

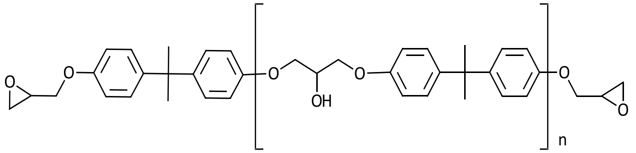
Cure Response: *MEK Resistance*



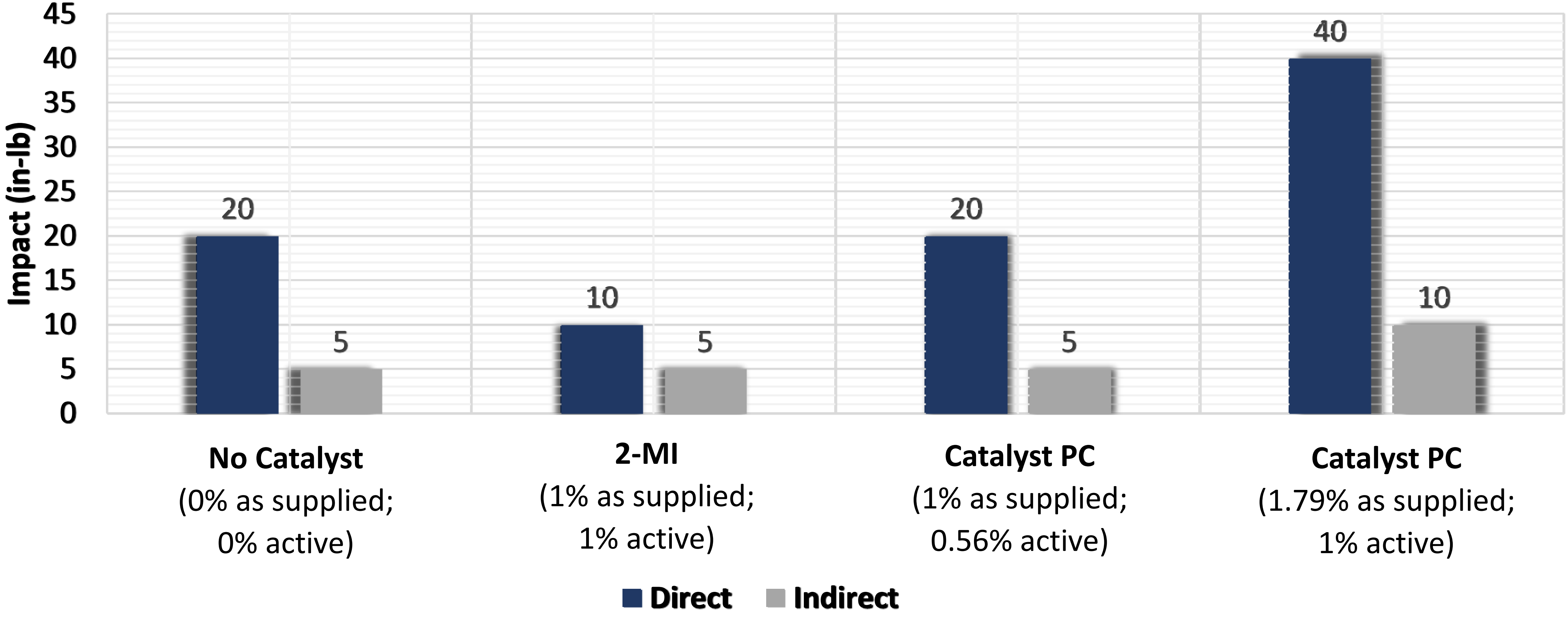


Experiment III –
Polyester/BPA

Impact Resistance



140°C/15min



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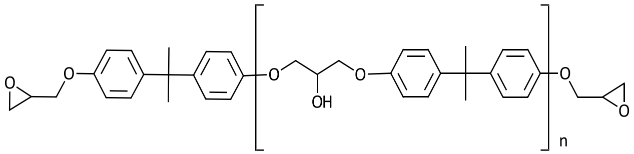
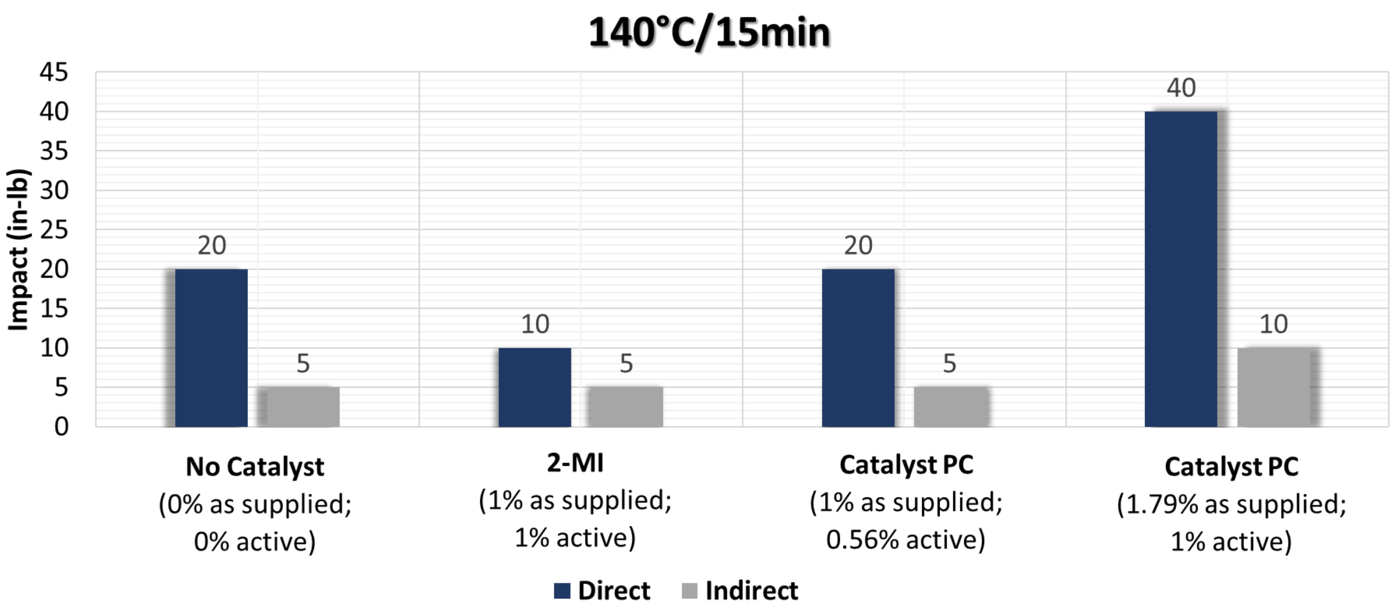
Experiment III – Polyester/BPA

Impact Resistance





Fail @ 20 in-lb

1% 2-MI
(1% Active)

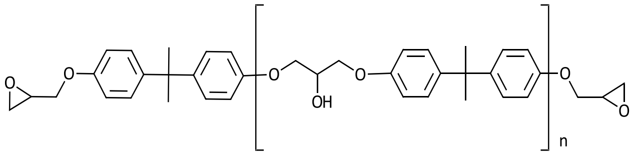
Pass @ 40 in-lb

1.79% *Catalyst PC*
(1% Active)

140°C Cure

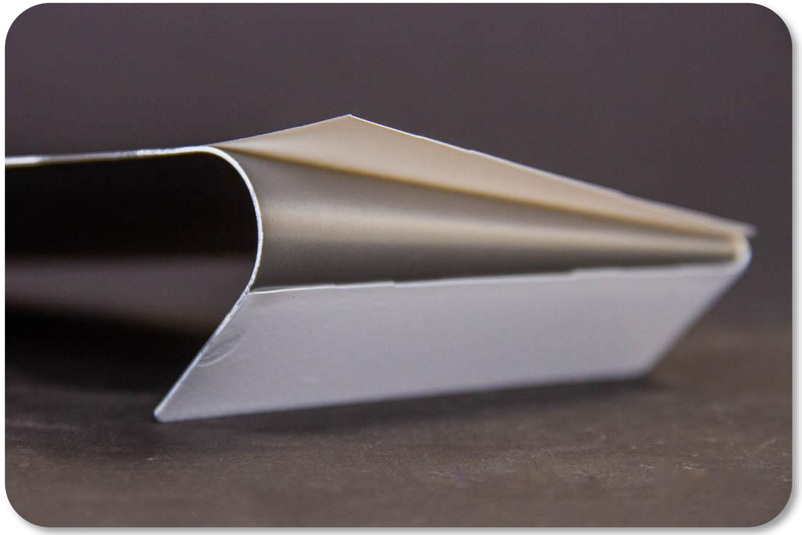
Experiment III –
Polyester/BPA

Mandrel Bend



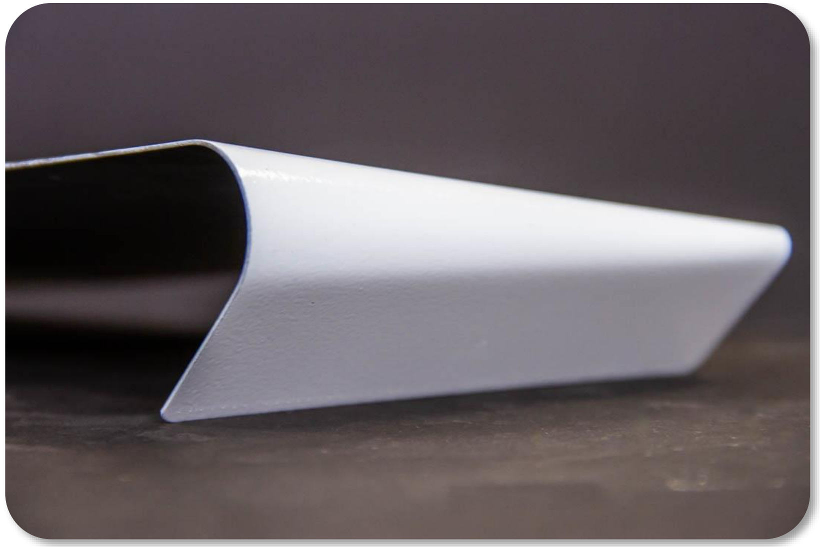
Mandrel Bend

Fail



1% 2-MI
(1% Active)

Pass

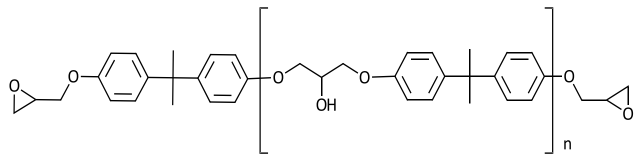


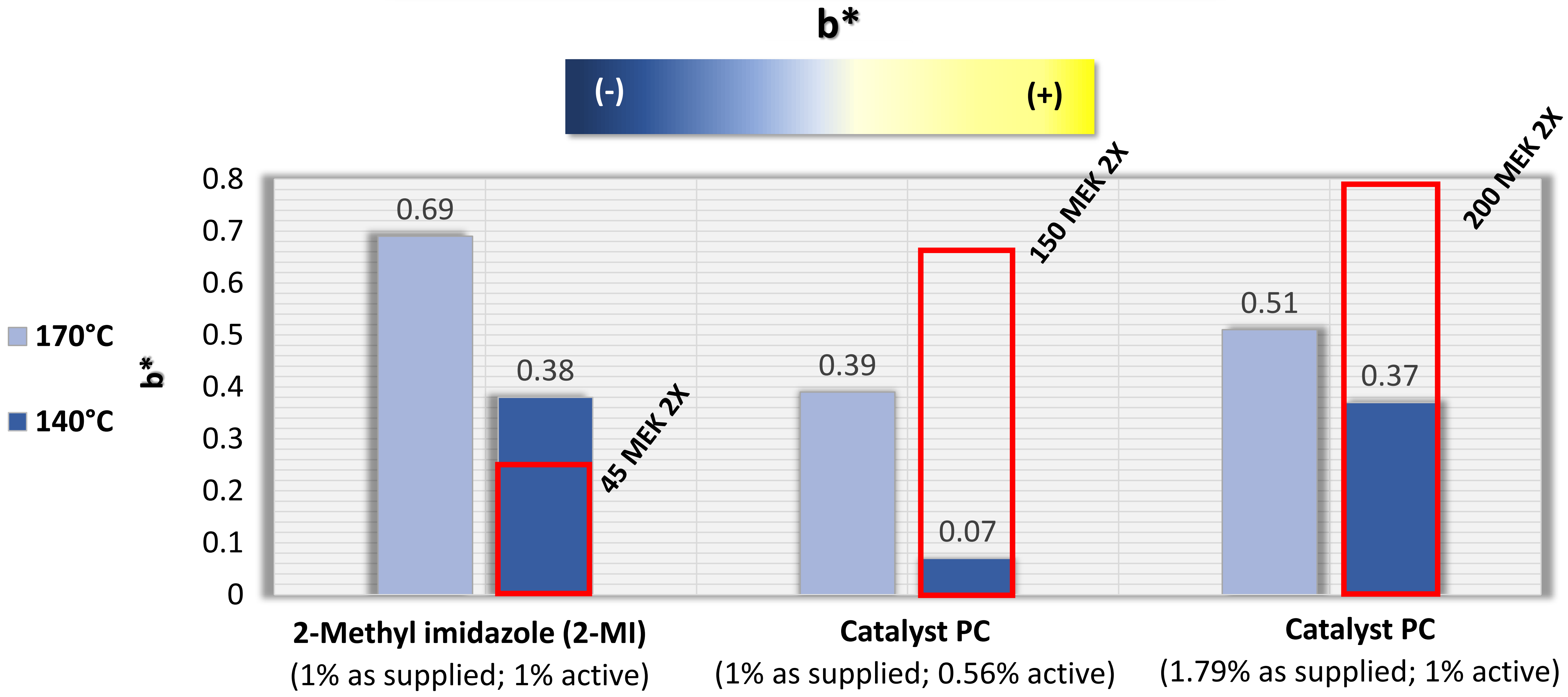
1.79% *Catalyst PC*
(1% Active)

140°C Cure

Experiment III – Polyester/BPA

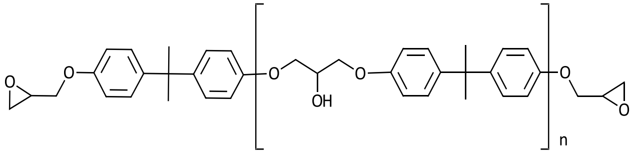
Color: Yellowing



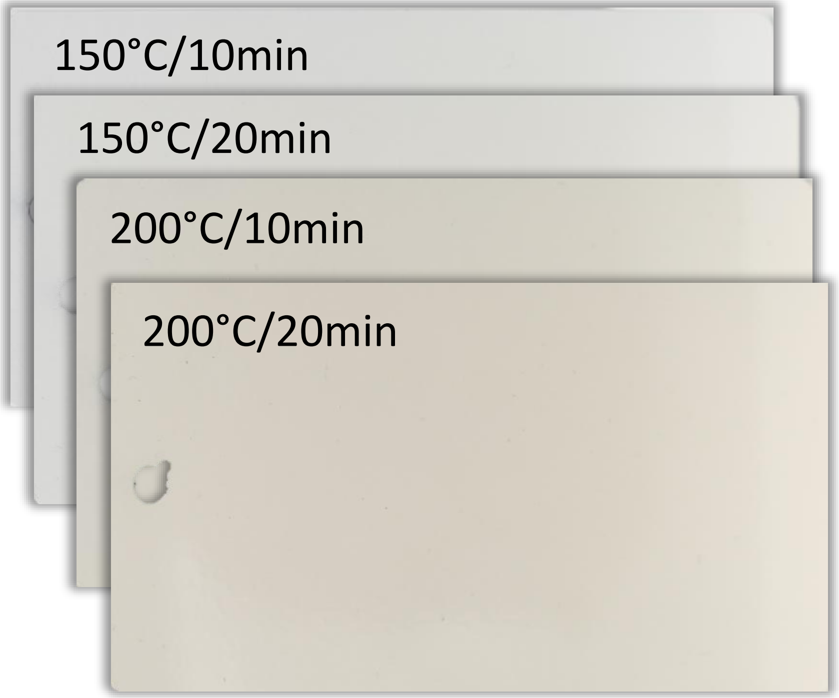


NEW STUDIES:
60/40 Hybrid

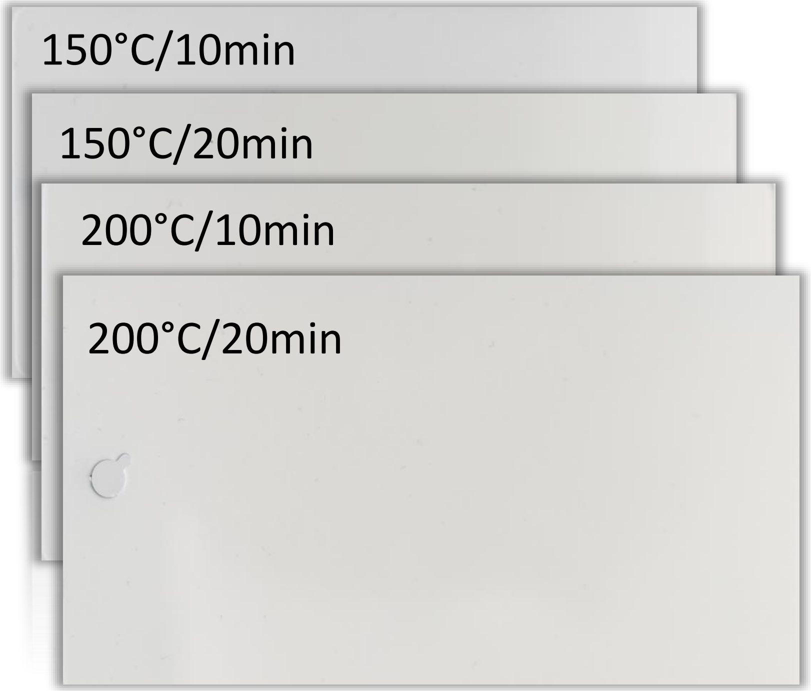
Color: Yellowing



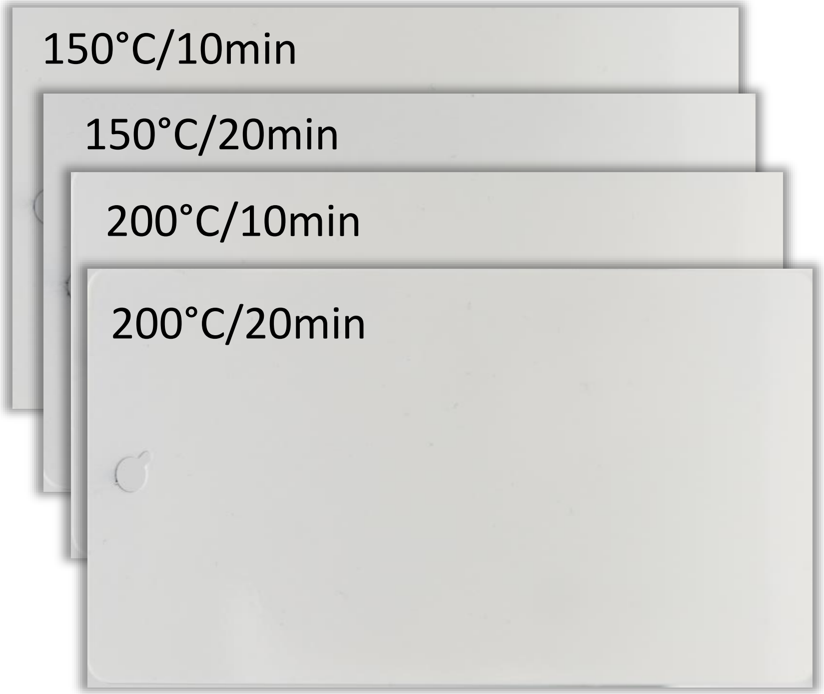
0.68% 2-Methyl Imidazole



0.68% Catalyst PC

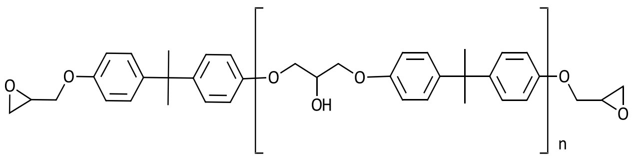


1.20% Catalyst PC



NEW STUDIES:
60/40 Hybrid

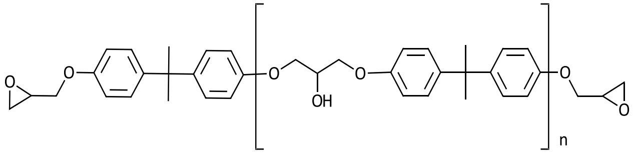
Color: Yellowing



0.68% 2-Methyl Imidazole | **0.68% Catalyst PC** | **1.20% Catalyst PC**

NEW STUDIES:
60/40 Hybrid

Color: Yellowing



b*

200°C/20min

0.68% 2-Methyl Imidazole

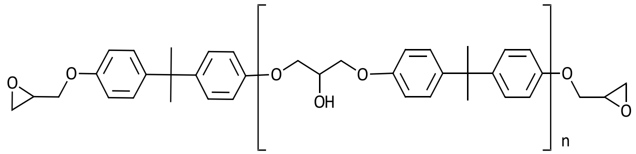
b* = 5.71
20°, 60° = 90.8, 100

1.20% Catalyst PC

b* = 1.51
20°, 60 = 93.5, 101

Experiment III –
Polyester/BPA

Heat Aged Stability



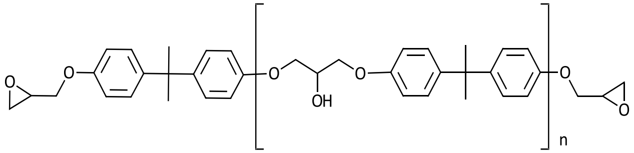
Storage Stability

50°C Storage

Formulation	Initial	1 Month+
No Catalyst (0% active; 0% as supplied)	Free-flowing powder	Free-flowing powder
2-Methyl Imidazole (1% as supplied; 1% Active)	Free-flowing powder	Free-flowing powder
Catalyst PC (1.79% as supplied; 1% active)	Free-flowing powder	Free-flowing powder
Catalyst PC (1% as supplied; 0.56% active)	Free-flowing powder	Free-flowing powder

Experiment III –
Polyester/BPA

Experimental



Experiment I –
Epoxy Homopolymerization

Experiment II –
Acrylic/GMA

Experiment IV–
Polyesteramide/TGIC

Experiment III –
Polyester/BPA

Conclusions:

- **Catalyst PC is Highly Active in BPA Hybrids**
  - Accelerates Crosslinking Reaction
  - Carboxyl Functional Polyester/BPA-Type Diepoxides.
- 70/30 White Polyester/BPA Hybrid
- Superior to 2-MI
  - Compared on Equal Active and Equal as Supplied
  - Superior LTC
  - Less Discoloration
  - Better Gloss Properties
  - Cleaner SDS → Safer → Less Labeling in Manufacturing

Experimental

Experiment I –
Epoxy Homopolymerization

Experiment II –
Acrylic/GMA

Experiment III –
Polyester/BPA

Experiment IV –
Polyesteramide/TGIC

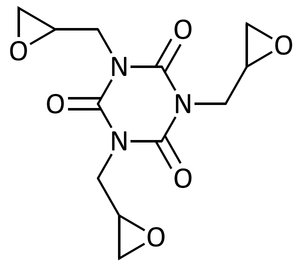
- **Catalyst PC**

- White Polyesteramide/TGIC
  -Biobased Polyesteramide (soybean oil)

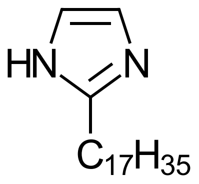
- Melt-Flow Rheology

- Film Performance & LTC Capabilities:
  — 135°C and 125°C PMT

- Comparisons vs. 2-heptadecyl-1H imidazole ('C17 Imidazole')

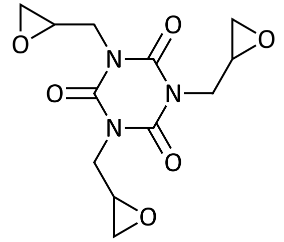


Triglycidylisocyanurate
(TGIC)



Experiment IV –
Polyesteramide/TGIC

Formulation



Material	Description	%
Polyester-amide resin	Carboxyl-functional resin, AV 35 mg KOH/g	61.55
TGIC	Triglycidyl isocyanurate, EEW 100 g/eq	6.84
Surface agent	Flow additive	1.00
Benzoin	Degassing agent	0.50
TiO_2	Titanium dioxide	30.10
TOTAL		**100.00**
%Total resin solids (TRS)	68.2	
Polyester/TGIC on TRS	90 / 10	

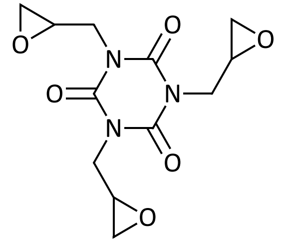
Experiment IV –
Polyesteramide/TGIC

Formulation & Film Preparation

- **Extruded, Pulverized, & Classified**
- **Coatings Electrostatically Sprayed over Bare CRS**
- **Films Cured in Conventional Oven**
  - **Temperatures:** 135°C & 125°C
  - **Dwell Time:** 15 min – 25 min PMT
  - **DFT =** ~3.0-4.0 mil

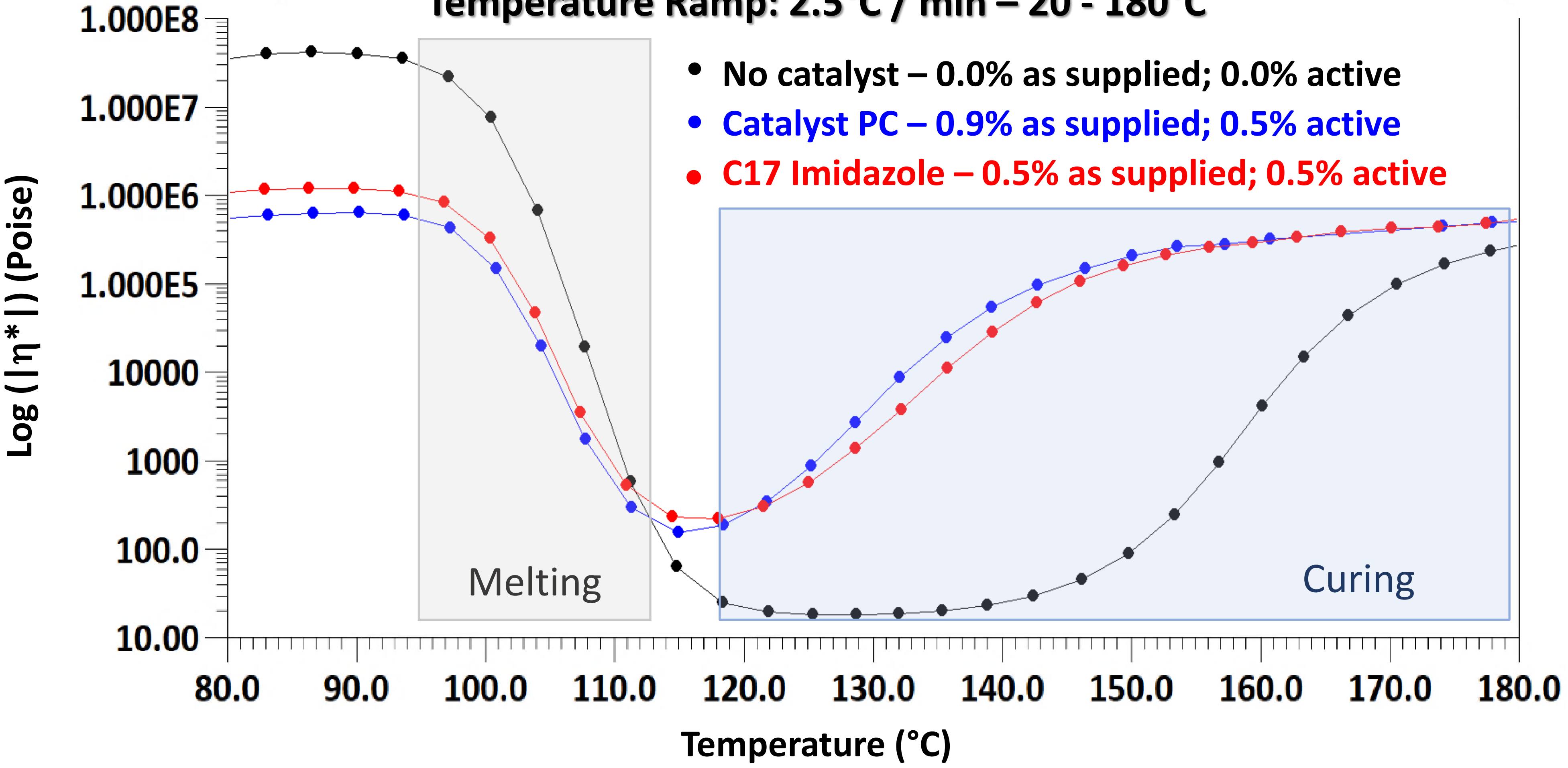
Experiment IV –
Polyesteramide/TGIC

Melt-Flow Rheology Profile



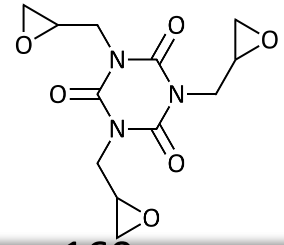
AR 2000 Rheometer – ETC – Parallel Plates

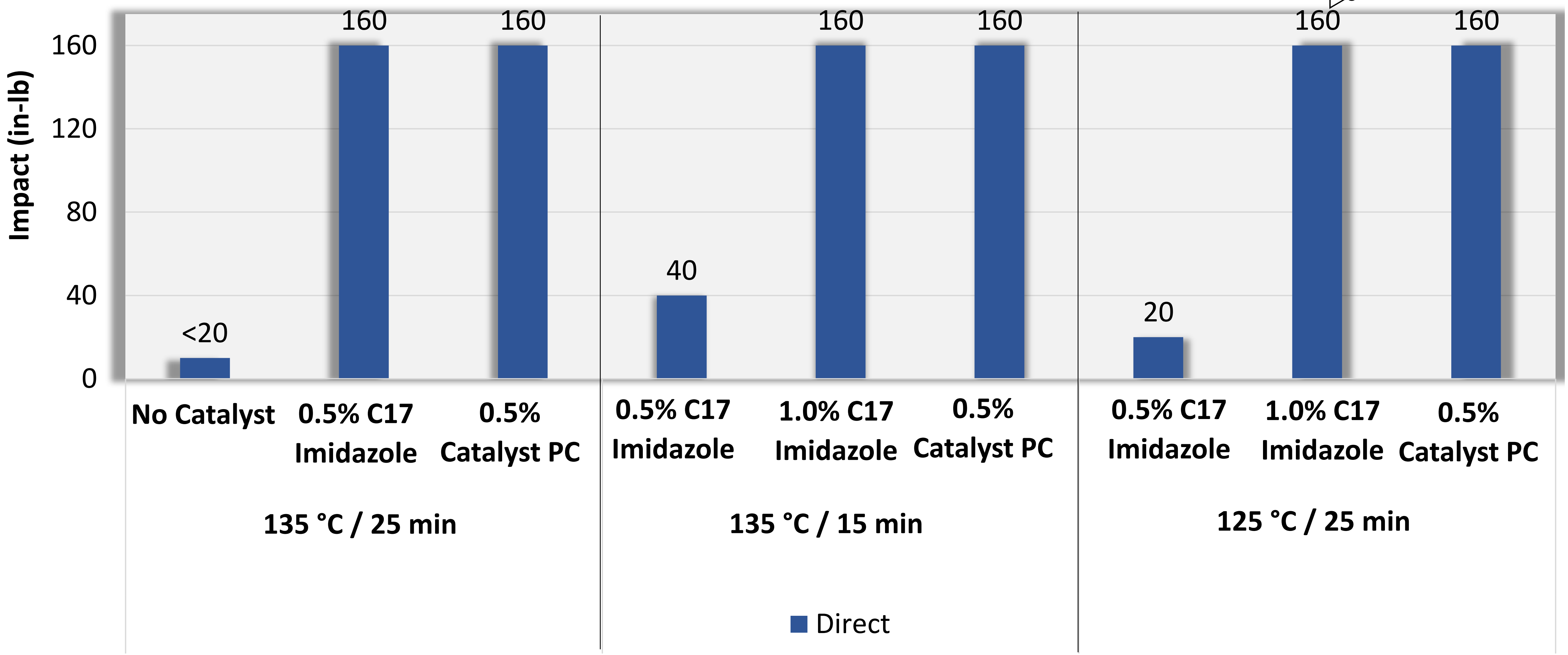
Temperature Ramp: 2.5°C / min – 20 - 180°C



Experiment IV –
Polyesteramide/TGIC

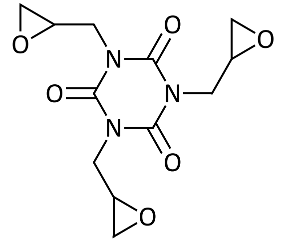
Impact Resistance

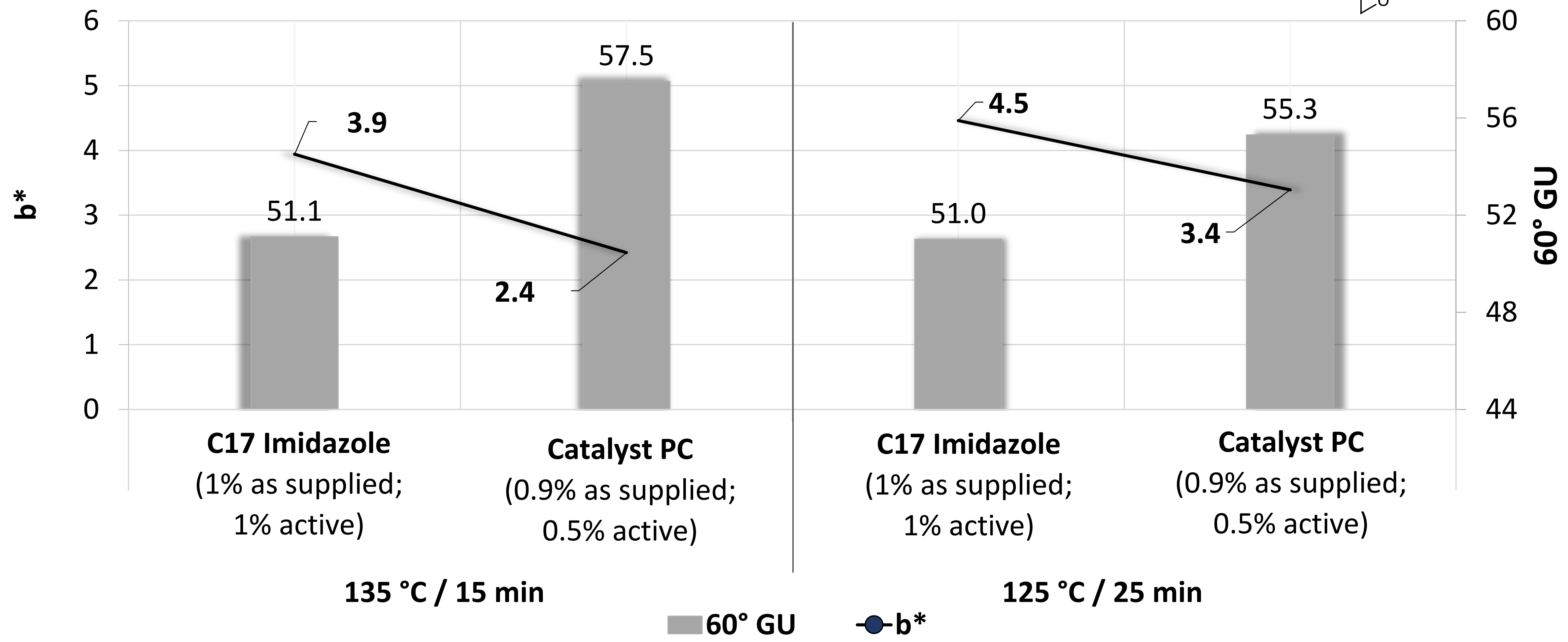




Experiment IV –
Polyesteramide/TGIC

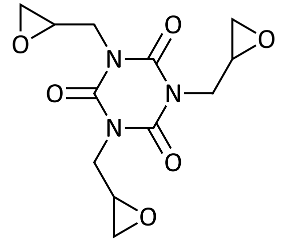
Appearance: Color and Gloss





Experiment IV –
Polyesteramide/TGIC

Heat Aged Stability



Storage Stability

50°C Storage

Formulation	Initial	1 Month+
No Catalyst (0% active; 0% as supplied)	Free-flowing powder	Free-flowing powder
2-Methyl Imidazole (1% as supplied; 1% Active)	Free-flowing powder	Free-flowing powder
Catalyst PC (0.9 as supplied; 0.5% active)	Free-flowing powder	Free-flowing powder

Experimental

Experiment I –
Epoxy Homopolymerization

Experiment II –
Acrylic/GMA

Experiment III –
Polyester/BPA

Experiment IV –
Polyesteramide/TGIC

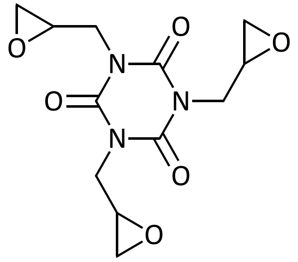
Conclusions:

- **Catalyst PC is Highly Active in TGIC Systems**
  - Accelerates Crosslinking Reaction
  - Carboxyl Functional Resins/TGIC Crosslinkers

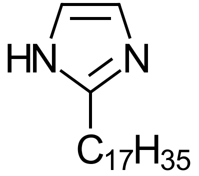
- White TGIC Powder Coating

- Good Melt-Flow Profile with Catalyst PC

- Superior to 2-Heptadecyl-1H-imidazole (‘C17 Imidazole’)
  - LTC with Lower Active Catalyst
  - Less Active Catalyst = Better Appearance
    - Less Discoloration
    - Better Gloss Properties



Triglycidylisocyanurate
(TGIC)



Experimental

Experiment I – Epoxy Homopolymerization

Experiment II – Acrylic/GMA

Experiment III – Polyester/BPA

Experiment IV – Polyesteramide/TGIC

Conclusions

- Catalyst PC & LC can be Used to Achieve LTC in a Variety of Epoxy Coatings.

- Accelerates Epoxy Homopolymerization
  - BPA-Type Epoxies
  - Pure Epoxy Formulations
- Promotes Nucleophilic Addition:
  - Carboxylic Acid + Epoxide
- Highly Active for Crosslinking RXN of Carboxyl Groups with:
  - GMA Epoxy Resins
  - Epoxidized BPA Resin
  - TGIC Crosslinkers

Experimental

Experiment I – Epoxy Homopolymerization	Experiment II – Acrylic/GMA	Experiment III – Polyester/BPA	Experiment IV – Polyesteramide/TGIC

Conclusions

- Catalyst PC & LC can be Used to Achieve LTC in a Variety of Epoxy Coatings.

<u>White Polyester/BPA Hybrid (70/30)</u>

- Superior to 2-MI
- LTC Response
  - Less Discoloration
  - Better Gloss Properties
- Equal Active and As Supplied

<u>White TGIC Crosslinked Coating</u>

- Superior to 2-heptadecyl-1H-imidazole
- LTC Response with Lower Active Catalyst
  - Less Discoloration
  - Better Gloss Properties

Experimental

Experiment I –
Epoxy Homopolymerization

Experiment II –
Acrylic/GMA

Experiment III –
Polyester/BPA

Experiment IV –
Polyesteramide/TGIC

Implications

- *Reduce Energy Consumption*
- *Improve Productivity*
- *Lower Active Catalyst Levels*
- *Better Performance*
- *Heat Sensitive Substrates*

Continue Growth of Powder Coatings Market

Acknowledgements

Contributions in Product Development

- Dr. Ravi Ravichandran
- Michael Emmet
- Dr. Steven Woltornist
- Dan Miller

Contributions in Powder Application & Testing

- Nathan Biller & Kevin Biller *(Chemquest-PCR)*
- Atman Fozdar *(Fozdar Dymanics)*
- Jeff Cafmeyer *(Battelle)*

Supporting Development of Bio-Based Resin

- United Soybean Board

For Permission to Present

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Opportunity to Present

POWDER COATING SUMMIT SEPTEMBER 8-9, 2022

PCI Paint & Coatings Industry

Coatings Trends & Technologies

Questions

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