CNSL Epoxy Curing Agents and Polyols: Excellent Bonding Strength on Plastics and Composite

Cardolite Marketing
Jan. 2017

Cardolite

Contents

- Introduction of materials
  - Phenalkamides, Polyamides
  - Phenalkamines
  - CNSL Polyols
- Plastic bonding
- Composite bonding

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Assembly of automotive interior

Automotive hood composite bonding

Plastic bonding

Composite honey comb panel bonding

Headlamp plastic bonding: PC,PP, PBT

Metal-composite plastic bonding for aerospace

Non-metal Bondings

Introduction

- Non- metal substrates
  - Plastics: ABS, Nylon, PC, PVC, Acrylic, PE, PP
  - Composite: Carbon fiber reinforced epoxy(CFRP)
- Adhesive systems
  - Epoxy adhesives: Polyamides (NT-1544, NT-1542), Phenalkamides (LITE 3040, LITE 3060, LITE 3025, GX-3090), Phenalkamines (NC-558, NX-5607, NX-2009, LITE 2002)
  - Polyurethane adhesives: Polyols (GX-9005, LITE 9001, GX-9008)
- Pretreatments
  - Sand paper polish + Alcohol rinse

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Product	Color (Gardner)	Viscosity (cPs) @25°C	25°C Dry Hard (hr)	5°C Dry Hard (hr)	AHEW	Gel time (min)	Technology
LITE 2002	10	450	6	20	104	51	Phenalkamine
NC-558	17	900	10	22	95	40	Phenalkamine
NX-2009	7	370	4	12	95	31	Phenalkamine
NX-5607	10	2489	2	9	95	14	Phenalkamine
LITE 3040	≤10	5000	7.3	29	118	110	Phenalkamide
LITE3060	≤10	800	5	17.5	104	40	Phenalkamide
LITE 3025	≤10	35000	7	29	103	200	Phenalkamide
GX-3090	7	518	4.3	19.2	69	45	Phenalkamide
NT-1544	≤10	10000	9.4	36	97	211	Polyamide
NT-1542	≤8	40000	9.4	34.5	103	208	Polyamide

Product	Viscosity (cPs) @25°C	Hydroxyl equivalent weight	OH Functionality	Technology
LITE 9001	2000	320	4.3	Polyol
GX-9005	3000	330	3.2	Polyol
GX-9008	3500	178	3	Polyol

Cardolite Offerings:QC Data

CNSL Epoxy Curing Agents and Polyols: Plastic Bonding

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Curing agents	Lap shear strength on plastics(MPa)													
	ABS	Failure Mode	Nylon	Failure Mode	PC	Failure mode	PVC	Failure mode	Acrylic	Failure mode	PE	Failure mode	PP	Failure Mode
LITE 3060	3.4	CF/AF	2.2	CF/AF	3.5	CF/AF	3.0	CF/AF	2.6	CF/AF	1.8	CF/AF	1.9	CF/AF
LITE 3040	3.6	CF/AF	2.7	CF/AF	**4.9**	SF	3.1	CF/AF	**3.4**	CF/AF	1.6	CF/AF	2.0	CF/AF
GX-3090	3.6	CF/AF	2.2	CF/AF	4.6	SF	2.8	CF/AF	3.1	SF	1.4	CF/AF	1.7	CF/AF
LITE 3025	3.3	CF/AF	2.6	CF/AF	4.0	CF/AF	3.0	CF/AF	2.4	CF/AF	**2.1**	CF/AF	2.0	CF/AF
NT-1544	3.6	CF/AF	**2.8**	CF/AF	3.7	SF	**3.5**	SF	3.4	SF	1.9	CF/AF	**2.1**	CF/AF
NT-1542	3.9	SF	2.0	CF/AF	3.7	CF/AF	3.4	SF	2.8	SF	1.6	CF/AF	2.1	CF/AF

-Cured with Liquid epoxy(EEW=190) at 40°C/16hr
-Substrate pretreatment: sand paper polish+ Ethanol clean
-Failure Mode: CF: Cohesive failure, AF: Adhesive failure SF: substrate failure

✓Overall LITE 3040 and NT-1544 show better bond strength on plastics

Phenalkamides vs Polyamides

Curing agents	Lap shear strength on plastics(MPa)													
	ABS	Failure Mode	Nylon	Failure Mode	PC	Failure mode	PVC	Failure mode	Acrylic	Failure mode	PE	Failure mode	PP	Failure Mode
NC-558	3.9	CF/AF	**2.4**	CF/AF	**5.3**	SF	3.0	CF/AF	**3.7**	SF	1.6	CF/AF	1.9	CF/AF
NX-5607	**4.1**	CF/AF	2.2	CF/AF	3.5	CF/AF	**3.2**	CF/AF	2.8	SF	1.7	CF/AF	*2.3*	CF/AF
NX-2009	3.5	SF	2.3	CF/AF	2.4	CF/AF	3.0	CF/AF	2.7	SF	**1.8**	CF/AF	**2.3**	CF/AF
LITE2002	**4.1**	CF/AF	2.3	CF/AF	5.0	SF	**3.2**	CF/AF	3.2	SF	1.5	CF/AF	1.9	CF/AF

-Cured with Liquid epoxy(EEW=190) at 40°C/16hr
-Substrate pretreatment: sand paper polish+ Ethanol clean
-Failure Mode: CF: Cohesive failure, AF: Adhesive Failure SF: substrate failure

✓Phenalkamines, i.e. NC-558 and LITE 2002, show good bond strength on ABC, PC and PP
✓NX-2009 exhibits favorable bond strength on PE and PP that are low surface energy plastics

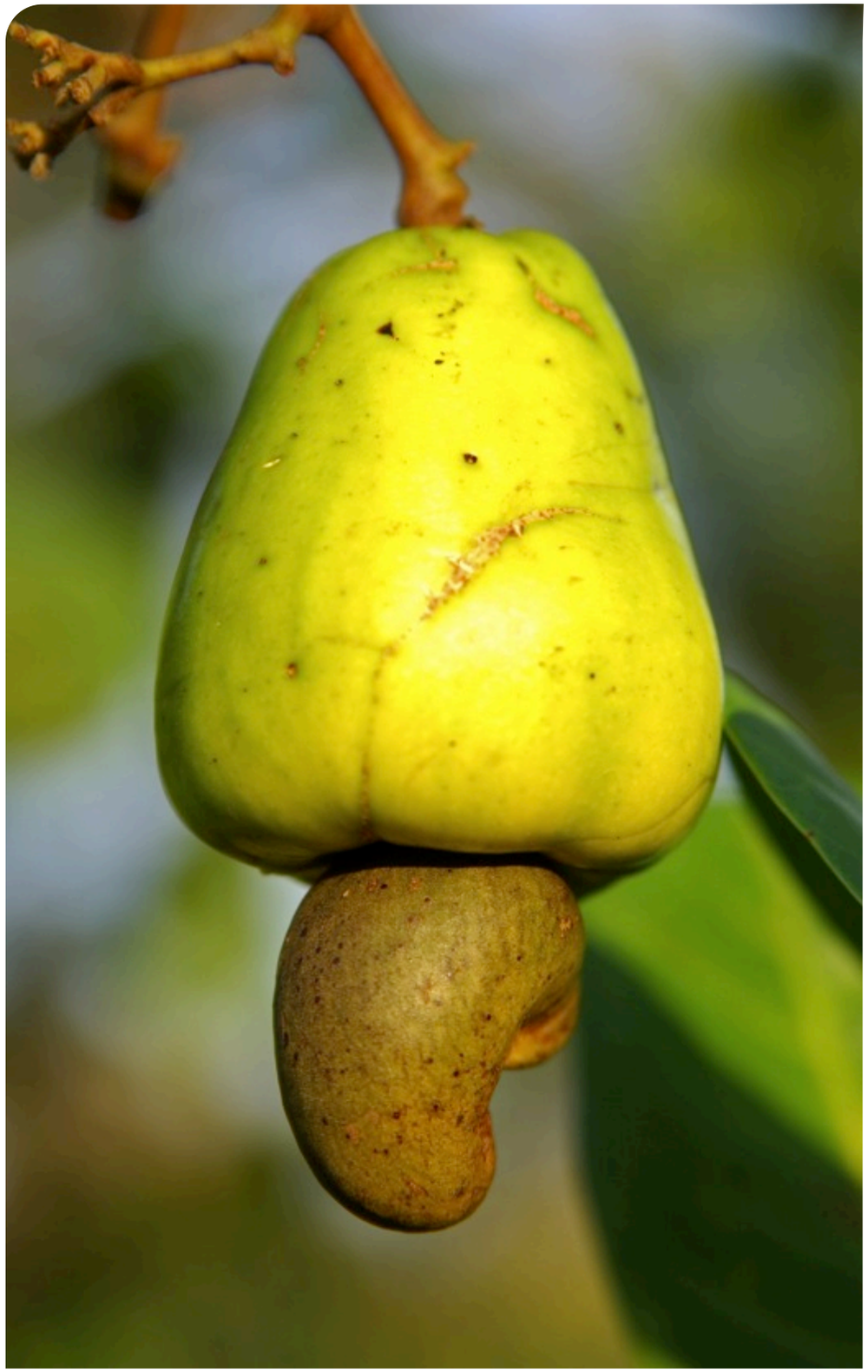
Phenalkamines

Polyols	Lap shear strength on plastics(MPa)													
	ABS	Failure Mode	Nylon	Failure Mode	PC	Failure mode	PVC	Failure mode	Acrylic	Failure mode	PE	Failure mode	PP	Failure Mode
GX-9005	4.1	CF/AF	2.7	CF/AF	4.9	CF/AF	4.0	CF/AF	3.2	CF/AF	1.4	CF/AF	1.8	CF/AF
LITE 9001	4.1	CF/AF	1.9	CF/AF	3.3	CF/AF	2.3	CF/AF	3.0	CF/AF	1.4	CF/AF	1.6	CF/AF
GX-9008	4.6	SF	2.1	CF/AF	NA		NA		NA		NA		1.4	CF/AF

-Cured with polymeric MDI at NCO index 100
-Substrate pretreatment: sand paper polish+ Ethanol clean
-Failure Mode: CF: cohesive failure, AF: Adhesive failure SF: substrate failure

✓GX-9005 shows good bond strength on Nylon and PVC
✓GX-9008 exhibits excellent bond strength on ABS

Polyols



Summary

- Various products including phenalkamide, phenalkamine, polyamide, and polyol are evaluated for plastics bonding
- Best suitable product for each plastics has been determined. It seems that performance of bond strength is heavily dependant on substrates
- In this study, we evaluated epoxy technology and polyurethane technology. In general epoxy base system showed higher bond strength than polyurethane system
- Tested products covers wide range of viscosities, cure speed, mechanical properties for various application needs

CNSL Epoxy Curing Agents and Polyols: Composite Bonding

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Curing agents	Lap shear strength, MPa	Failure Mode	Cure conditions
NT-1544	19.4	CF	40°C/16h+60°C/4h
NT-1542	17.5	CF	40°C/16h+60°C/4h
LITE3040	15.8	CF	40°C/16h+60°C/4h
LITE3060	16.0	CF	40°C/16h+60°C/4h
LITE3025	15.4	CF	40°C/16h+60°C/4h
GX-3090	14.8	CF	40°C/16h+60°C/4h
NC-558	18.1	CF	40°C/16h+60°C/4h
LITE 2002	17.3	CF	40°C/16h+60°C/4h
LITE 2402	17.0	CF	40°C/16h+60°C/4h+120°C/2h
NX-5607	14.4	CF	40°C/16h+60°C/4h
NX-5608	14.8	CF	40°C/16h+60°C/4h

-Composite substrate: Carbon fiber reinforced epoxy(Dicy based prepreg)
-Epoxy curing agents are cured with Liquid epoxy(EEW=190)
-Substrate pretreatment: Sand paper polishing and IPA clean

✓The composite substrate used has shown excellent strength and has not displayed any substrate failure
✓Most of CNSL based epoxy curing agents display greater than 15MPa bond strength
✓NT-1544 and NC-558 has shown the best bond strength on composites

Epoxy Adhesives

Curing agents, cured with Liquid epoxy(EEW=190)	Lap shear strength, MPa	
	Carbon fiber reinforced epoxy substrates: Sand paper polish+IPA clean	Sand blasted Steel
NT-1544	19.4	23
NT-1542	17.5	23
LITE3040	15.8	23
LITE3060	16.0	18.4
LITE3025	15.4	23
GX-3090	14.8	14.7
NC-558	18.1	21
LITE 2002	17.3	15
LITE 2402*	17.0	20.3
NX-5607	14.4	18
NX-5608	14.8	16
Cure conditions	40°C/16h+60°C/4h *40°C/16h+60°C/4h+120°C/2h	40°C/16hr *40°C/16h+60°C/4h+120°C/2h

✓ Overall bond strength on sand blasted steel is greater than those on the composite

Metal vs Composite bonding

Polyol	Lap shear strength, MPa	Failure mode	Cure conditions
GX-9005	5.7	CF	40°C/16h+60°C/4h
LITE 9001	5.6	CF	40°C/16h+60°C/4h
GX-9008	15.4	CF	40°C/16h+60°C/4h

-Composite substrate: Carbon fiber reinforced epoxy(Dicy based prepreg)
-Cured with Polymeric MDI isocyanate, NCO index=100
-Substrate pretreatment: Sand paper polishing and IPA clean

✓ GX-9008 shows excellent bond strength on epoxy carbon composite substrate

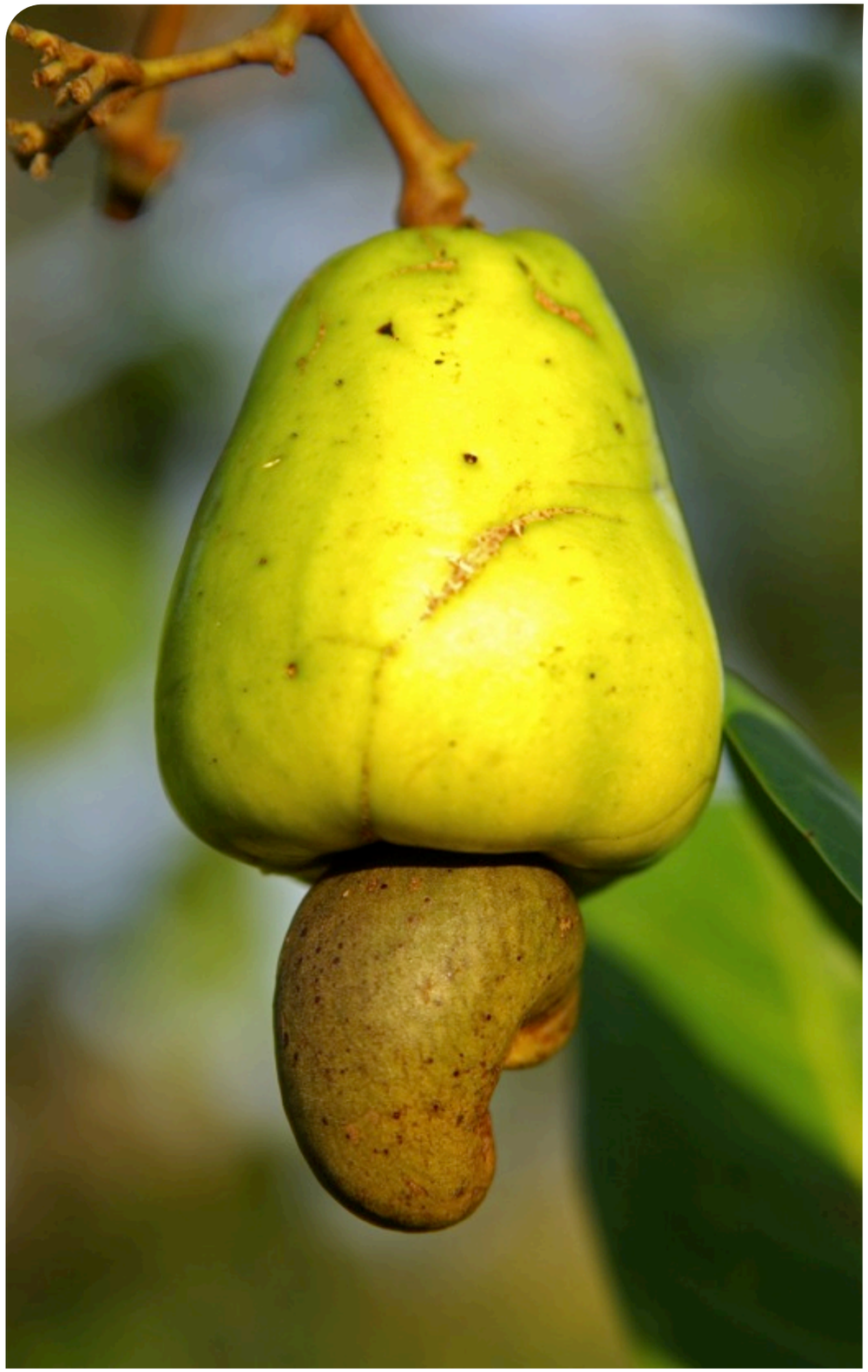
Polyurethane Adhesives

Components	A	1B	2B
NPEL128	80		
MX125	20		
LITE 3040		50	14
Jeffamine D230			21
Coupling agent-amine functional		3	3
Silverbond 602		20	20
Fumed silica-HL380		6	7
Total, wt	100	79	65

NEPL128: Liquid epoxy, EEW=190
MX 125: Kaneka toughener(25% core shell rubber in unmodified, liquid epoxy resin based on Bisphenol-A)

Formulations, wt	Lap Shear Strength, MPa		
	Carbon fiber reinforced epoxy	Steel	Aluminum
A/1B=100/79	17	26.5	22.3
A/2B=100/65	21.0	26.1	27.0

Formulated Systems



Summary

- Various products including phenalkamide, phenalkamine, polyamide, and polyol are evaluated for composite substrate
- Best bond strength is achieved from NT-1544 and NC-558
- Formulated systems using LITE 3040 demonstrated excellent bonding on various substrates including steel, aluminum, CFRP(carbon fiber reinforced epoxy polymer)

CNSL Curing Agents for Epoxy Grout and Adhesive Formulations

Cardolite Corporation
Jan. 2017

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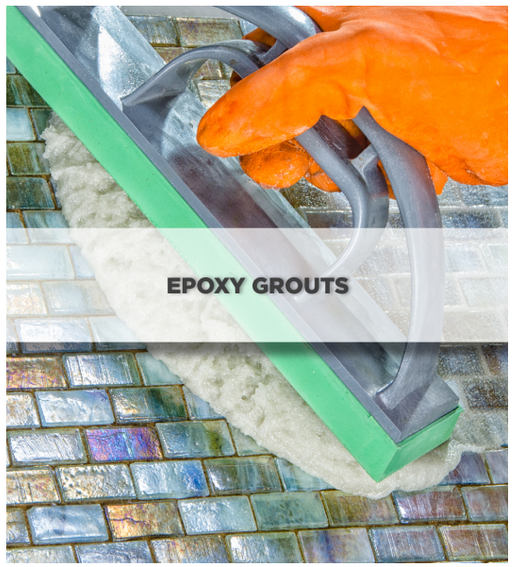
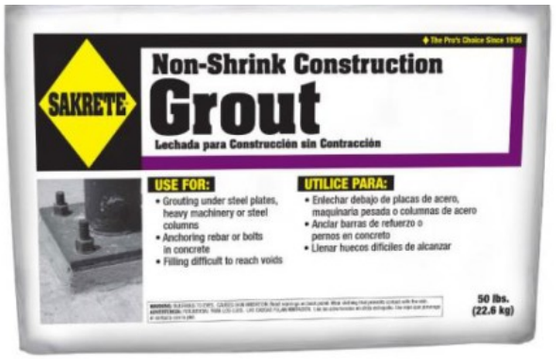
Content

- Waterborne NX-8101
  - Tile grout and adhesives
- Phenalkamines/Phenalkamides
  - Fast strength development construction adhesive, NX-5608
  - Grout: cost effective, NX-2003D
  - Grout: high strength, GX-3090

Grout: is a fluid form of concrete used to fill gaps. It is used in construction to embed rebars in masonry walls, connect sections of pre-cast concrete, fill voids, and seal joints such as those between tiles.

- Tiling grout
- Flooring grout
- Resin grout
- Non-shink grout
- Structural grout





Type of Grouts

Clear System

Test items	Epon828/NX-8101
Lap shear strength(MPa) on steel	9.8 mps (1421 psi)
Shore D	74.3
Compressive strength (MPa)	33.0 mps (4786)
Tg(°C)	65.5
PHR	141
Pot life	60min
Mixed Viscosity at 25 °C(cps)	1850
Comments	Cured 9days at RT

Tile Grout/Adhesive I

Part A	Wt
NPEL128	7.3
XY748	1.3
NX-2026	1.7
A501	0.03
Betone 27	0.17
Cement	23.2
Total wt	33.7

Part B	Wt
NX-8101	10.93
A501	0.17
DI water	7.3
Silverbond602	36.8
100# sand	13.2
Total wt	68.4

NPEL128: Liquid epoxy(EEW=190)
NX-2026: Cardolite Cardanol
XY748: Aliphatic glycidyl ether
Cement: Portland cement (P.O 42.5R)
100# sand:100mesh Silica sand
A501: Air Release additive.

Tile Grout and Adhesive I: Test Results

Test items		NX-8101
Compression strength, MPa		53.7 mps *(7789 psi)
Shore D	1 day	77
	2 day	78
	7 day	80
Working time (minute)		>40
Viscosity		Paste

In the tile grout formulation, NX-8101 exhibits excellent compression strength and fast hardness development with extended working time

Tile Grout/Adhesive II

Part A	Wt
NPEL128	7.3
Ultra LITE 513	1.3
NX-2026	1.7
A501	0.03
Betone 27	0.17
Cement	23.2
Total wt	33.7

Part B	Wt
NX-8101	10.93
A501	0.17
DI water	7.3
Silverbond602	36.8
100# sand	13.2
Total wt	68.4

NPEL128: Liquid epoxy(EEW=190)
NX-2026: Cardolite Cardanol
Ultra LITE 513: Mono epoxy functional CNSL diluent
Cement: Portland cement (P.O 42.5R)
100# sand:100mesh Silica sand
A501: Air Release additive.

Tile Grout/Adhesive II: Test Results

Test items		NX-8101
Compression strength, MPa		48.5 mps (7034)
Shore D	1day	75
	2day	80
	7day	80
Working time (minute)		>40
Viscosity		Paste

✓ Use of UL-513 instead of AGE offers comparable performance
✓NX-8101 shows good compression strength, hardness and long working time

Test items	Epon828/NX-5608	Epon828/NX-2003D	Epon828/GX-3090
Lap shear strength on steel (Mpa)	16 Mpi (2321 psi)	20 Mpi (2900 psi)	14.7 Mps (2132 Psi)
Tensile Strength(Mpa)	62 Mpa (8992 psi)	51 Mps (7396 psi)	56.8 Mps (8238 psi)
Compressive strength (Mpa)	92 Mpi (13,344 psi)	75 Mpi (10, 878 psi)	105.8 Mpi (15,345 psi)
Tg(°C)	99	79	98
PHR	50	50	36
Gel Time at 25 °C(min)	13	35	50
Mixed Viscosity at 25 °C(cps)	3770	3450	3650
Comments	Fast cure and high strength	Lower cost	High strength and longer working time

Clear Systems

Components	1A	1B	2A	2B	3A	3B
Epoxy resin(EEW=190)	43.7		28		32	
UL-513			2			
NX-5608		43.7		28		16
NX-2026						5
Bentone 27	2.2	0.5				
Silverbond 602	52.8	52.8				
CaCO3 powder			70	72	68	79
Fumed silica(HL380)	1.3	3				
Total(wt)	100	100	100	100	100	100

Test results	Lap shear, Mpa	Tensile strength, Mpa	Flexural strength, Mpa	Compression strength, Mpa	Tg, °C	Gel time(min) at 25°C, 100g	Lap shear, Mpa, at 3hr at 25°C
1A/1B=2:1	16.2	26.1	47.0	75.4	94.2	29	5.58
2A/2B=2:1 Low cost	14.2	18.8	35.5	62.1	92.1	34	4.36
3A/3B=1:1 Low cost	12.3	19.5	34.4	34.4	77.5	30	4.56

* Cure condition: 40°C/16hr

2K Epoxy: Construction Adhesives(Fast Strength Development)

Part A	Formulation, wt
Epoxy resin(EEW=190)	70
1,4 butanediol diglycidyl ether	30
Total	100
Part B	
NX-2003D	57
Part C	
Aggregate	471

Aggregate:Sikadur 42 MP Normal aggregate

Test items	Part A/B/C=100/57/471
Compression strength, Mpa	49.2
Tg, °C	48.1
Gel time at 250g at 25°C, min	88
Working time at 250g at 25°C, min	50
Flowability	Easy to flow

* Cure condition: 40°C/12hr + 60°C/4hr

2K Epoxy Grout I: Cost Effective

Part A	Formulation I, wt	Formulation II, wt	Formulation III,wt
Epoxy resin(EEW=190)	75	75	75
1,4 butanediol diglycidyl ether	25	25	25
Total	100	100	100
Part B			
GX-3090	40	40	40
Part C			
Sikadur 42 MP aggregate	560		
Silverbond 602(silica)		140	
Sands*+Silverbond 602			350

*Sand blend: 16#Sand/24#sand/40#sand=70/70/140

Test items	Formulation I, Part A/B/C=100/40/560	Formulation II, Part A/B/C=100/40/140	Formulation III, Part A/B/C=100/40/350
Compression strength at max, MPa, **cured at 60°C/24hr**	92	121	101
Tg, °C	74	74	74
Gel time at 250g at 25°C, min	95	95	95
Working time at 250g at 25°C, min	63	63	63
Flowability	Easy to flow	Easy to flow	Flowable

GX-3090 can achieve compression strength greater than 120MPa with selected filler, i.e Silica

2K Epoxy Grout II: High Strength

Potting (Casting/ Encapsulation)

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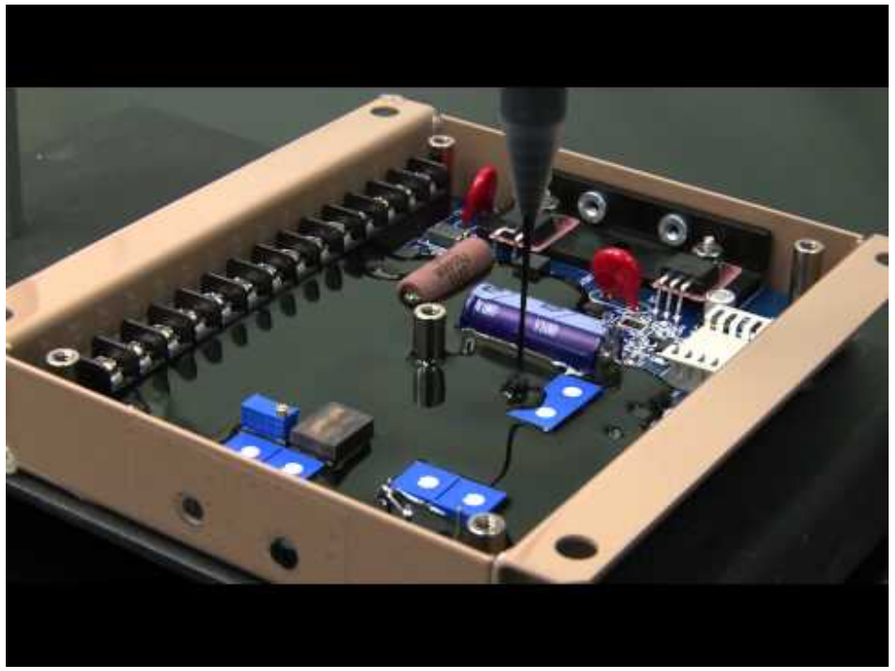
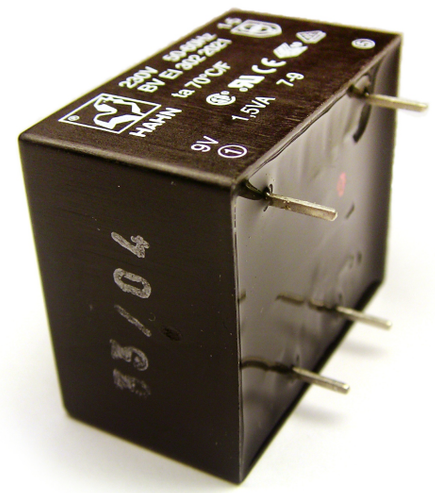




Potting is a process of filling a complete electronic assembly or construction materials with a solid or gelatinous compound for **resistance to shock and vibration, and for exclusion of moisture and corrosive agents**

Potting/Ecapsulation/Casting

Typical Applications/Requirement

- Potting Applications: Constructions, Electrical/electronics

- Requirements
  - Crack resistance/Thermal shock resistance
  - Low exotherm
  - High chemical resistance
  - Excellent water resistance
  - Excellent bond strength
  - Low chlorine content for electrical/electronics
  - Low viscosity

Commonly Used Curing Agents

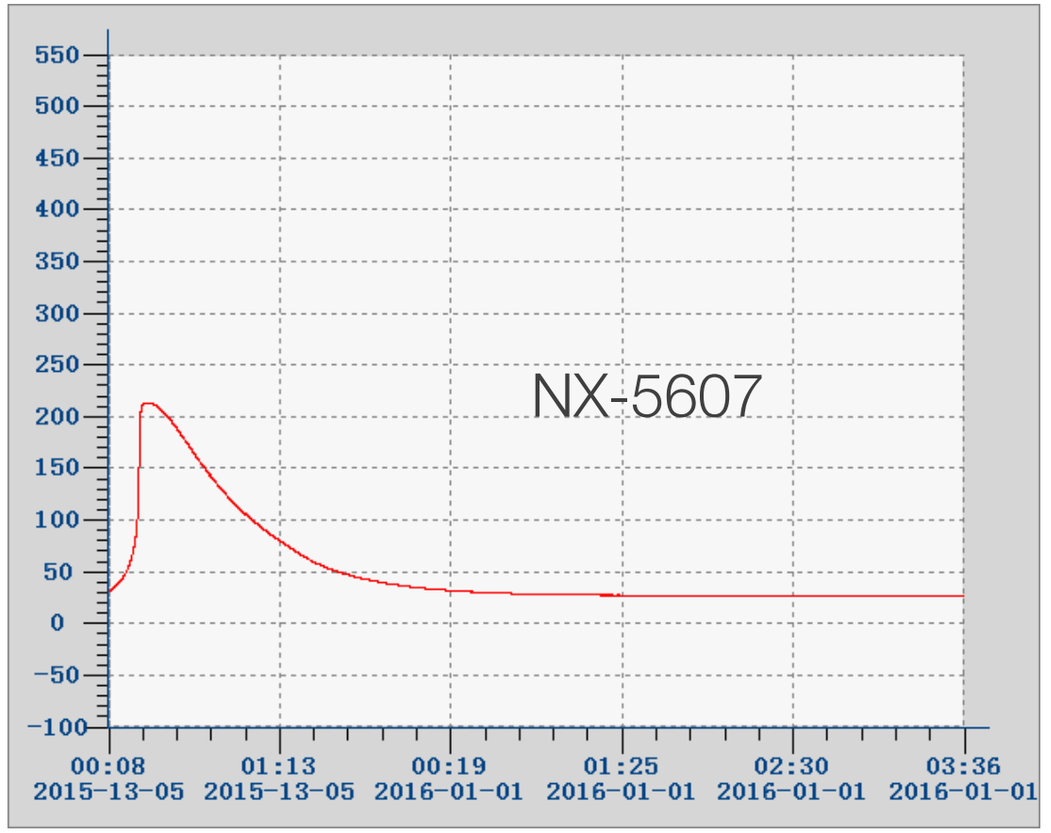
- DDM modifications
  - Good points: Low cost, good chemical resistance, long pot life.
  - Shortcoming: Bad color, health issue.
- Polyether amine D230
  - Good points: Low viscosity, long pot life, good toughness and color.
  - Shortcoming: Relatively high price. But currently its price is ok(~RMB23/kg).
- Polyamide
  - Good points: Good toughness, long pot life, price from local suppliers is ok.
  - Shortcoming: High viscosity.

Formulations	Water absorption(%) after 25°C/7day immersion	Tg, °C	Thermal shock, cycle times before crack	Peak exotherm temp, C	Time to peak exotherm temp, min	Lap shear strength, MPa	Tensile, MPa	Compression, MPa
Epon828:NX-5607=100:50	0.35	90	2	213.3	15	18	51	97
Epon828:NT-1544=100:50	0.54	106.7	2	44.1	167	23	57	86
Epon828:LITE 3040=100:55	0.51	70.4	2	95.7	112	23	52	77
Epon828:LITE 3060=100:55	0.62	77.9	2	180.5	37	18	66	89
Epon828:GX-3090=100:36.3	0.39	98.8	2	214.8	58	15	57	105
GX-9007:Desmodur 44V20L=100:40.3	0.21	18.3	8	67.8	69	10.7	17.3	-
LITE 9001:Desmodur 44V20L=100:41.6	0.21	54	8	81.9	37	9	11.2	-

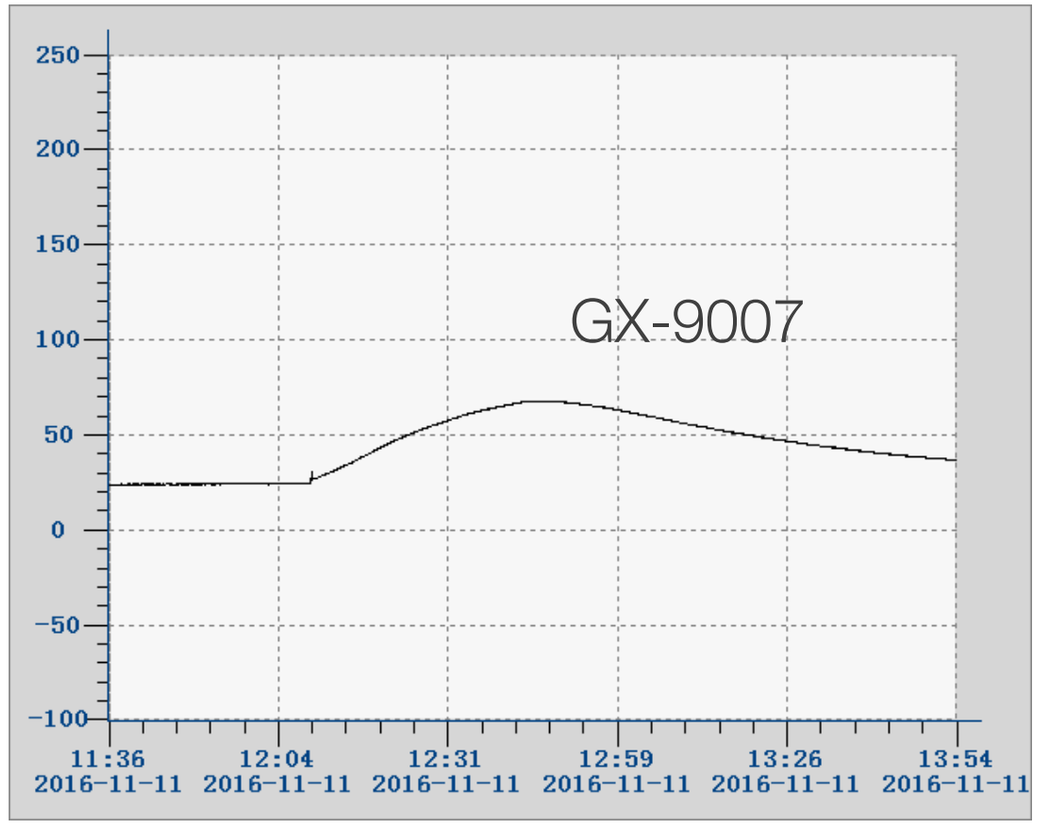
Thermal shock cycle: 120°C/2hr + -20°C/2hr
Exotherm study: 100g mass at 25°C
Lap shear substrate: sand blasted steel
Cure conditions: 40°C/16hr

Key Performance Comparison

Thermal Shock



Exotherm test



Test Items