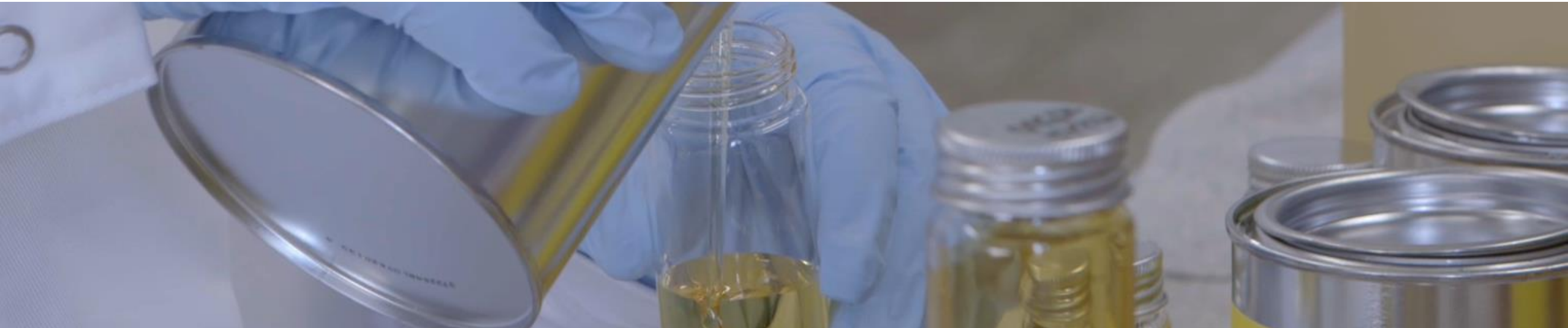
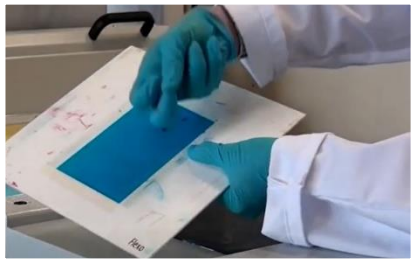
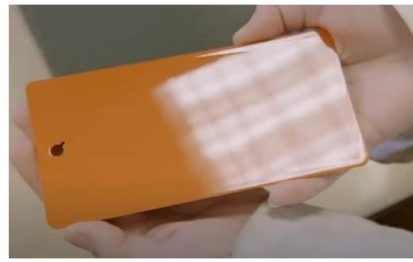
CONFORMAL COATINGS BY DUAL CURE



Jonathan Shaw, Marcus Hutchins, Jennifer McClung





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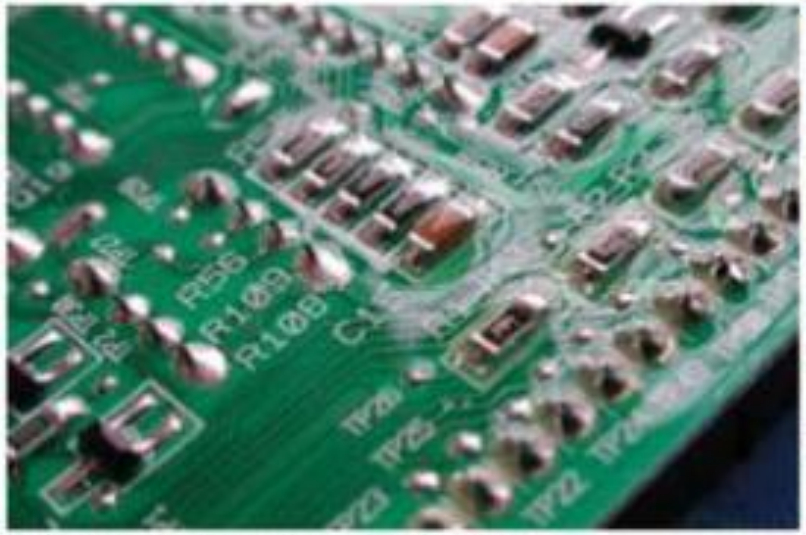
What Are Conformal Coatings

Conformal Coatings protect electronic PCB (printed circuit boards) from moisture and contaminants

- Prevent short circuits and corrosion of components and solder joints
- Minimize dendritic growth and electromigration of metal between conductors
- “Conform” to the contours of the PCB, protecting the board and extending its service life
- Accomplish all of the above at thin coating thicknesses (mils)



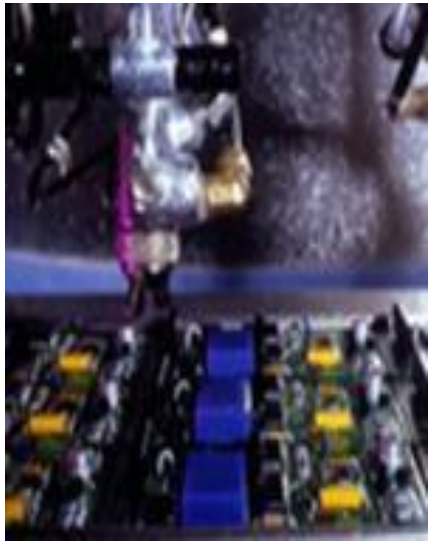
Whirlpool Dishwasher PCB

Ford Engine Control Module

Conformal Coatings Application Methods

Dip Coating

Flow or Brush Coating



Spray Coating

Select coating

Conventional Conformal Coatings Chemistries

Acrylic
- Ease of rework
- Simple drying process
- Good moisture resistance
- High fluorescence level
- Ease of viscosity adjustment

Epoxy
- Useful to about 150 °C
- Harder durometer, abrasion resistance
- CTE closer to epoxy PCB substrate
- Higher Tg
- Good dielectric properties

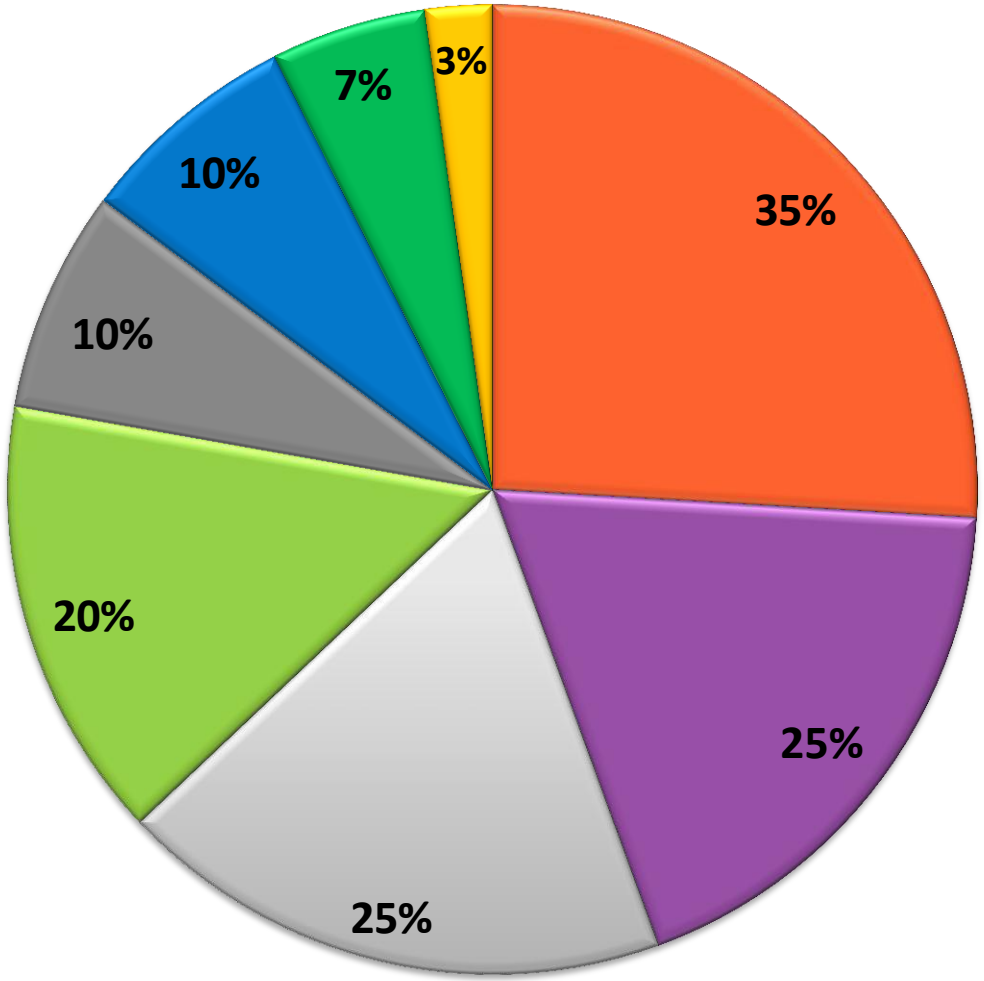
Polyurethane
- Good dielectric properties
- Good moisture resistance
- Solvent resistance
- Less reversion potential
- Abrasion resistance

Silicone
- Stable over wide temperature range (-40 °C to 200 °C)
- Flexible, provides dampening and impact protection
- Good moisture resistance
- High dielectric strength
- Low surface energy for better wetting

Parylene
- Excellent uniformity regardless of part geometry
- Chemical inertness
- Minimal added mass and low outgassing
- Low environmental impact process
- Low dielectric constant

Amorphous Fluoropolymer
- High glass transition temperature
- Low surface energy
- Low water absorption
- Solvent resistance
- Low dielectric constant

Trends & Drivers: *Unmet needs learned from Voice Of the Market in different sub-segments*



- Price
- Cure Speed
- Adhesion / Wettability
- Dark Cure
- Ease of Rework
- Thermal Capability
- Whisker Mitigation
- By Products

What	Which Means
Dark Cure	cure in shadow areas under circuits
Cure Speed	dry time to handle
Adhesion/Wettability	adhere and wet out to solder and dirty surfaces
Whisker Mitigation	eliminate tin whisker growth
Ease of Rework	strip and recoat coating
By Products	chemical byproducts from curing

Trends & Drivers: Unmet needs in general

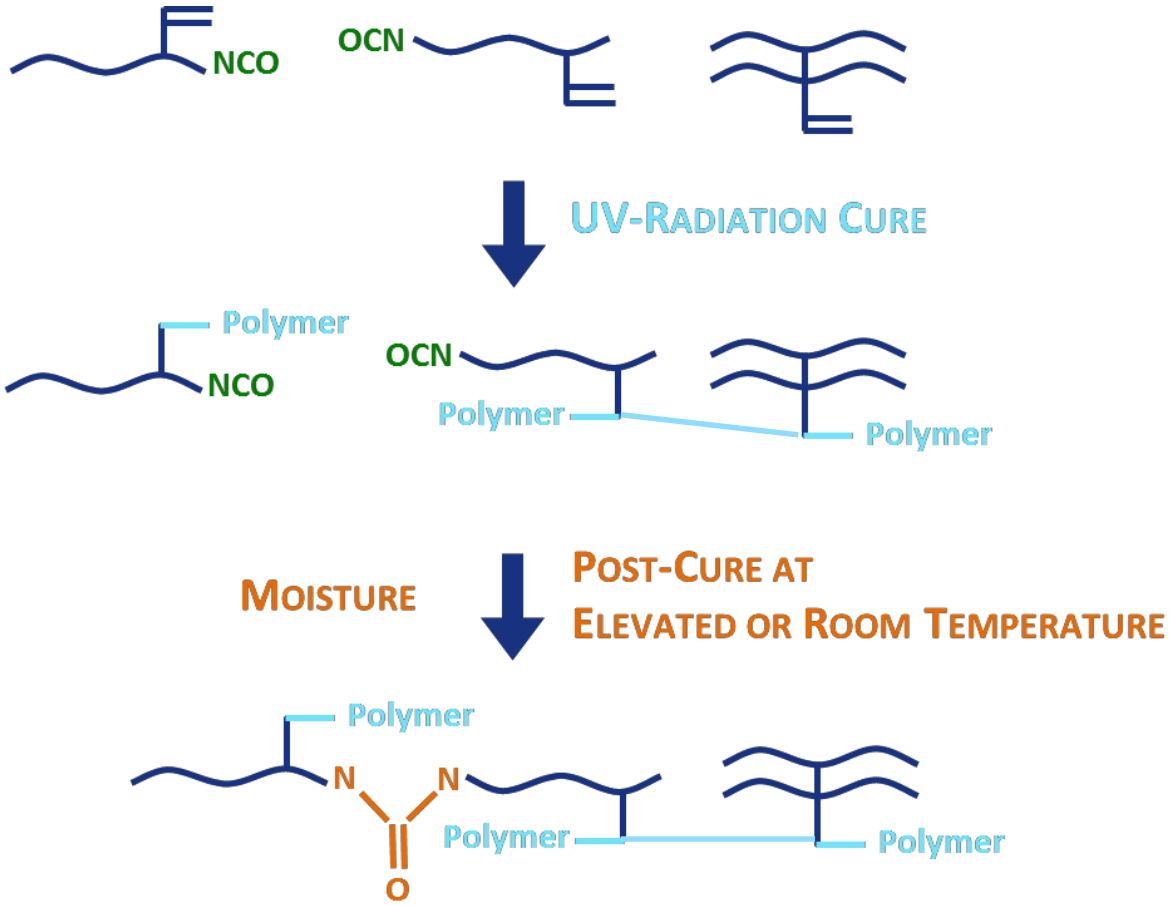
- Higher flexible resins that withstand thermal shock test (Resistance within broader temperature range)
- Need for faster curing coatings
- Need for more automated and high volume production
- Improved ease of application
- Improved adhesion to substrates

Allnex Solutions for the Conformal Coatings Market

- 1K Dual Cure (acrylate plus moisture Cure)
  - Resins with acrylate plus isocyanate functionality that can be cured with UV to give handleable films, but will continue to react with moisture to give good cure in shadow areas that were not cured via UV. For example, areas beneath some of the components on the circuit board

- 2K Dual Cure (acrylate plus NCO/OH cure)
  - Resins with acrylate plus isocyanate functionality in conjunction with resins with acrylate plus hydroxyl functionality that can be cured with UV to give handleable films, but will continue to react with each other to give good cure in shadow areas that were not cured via UV.

allnex Solutions for the Conformal Coatings Market - 1K Moisture Cure



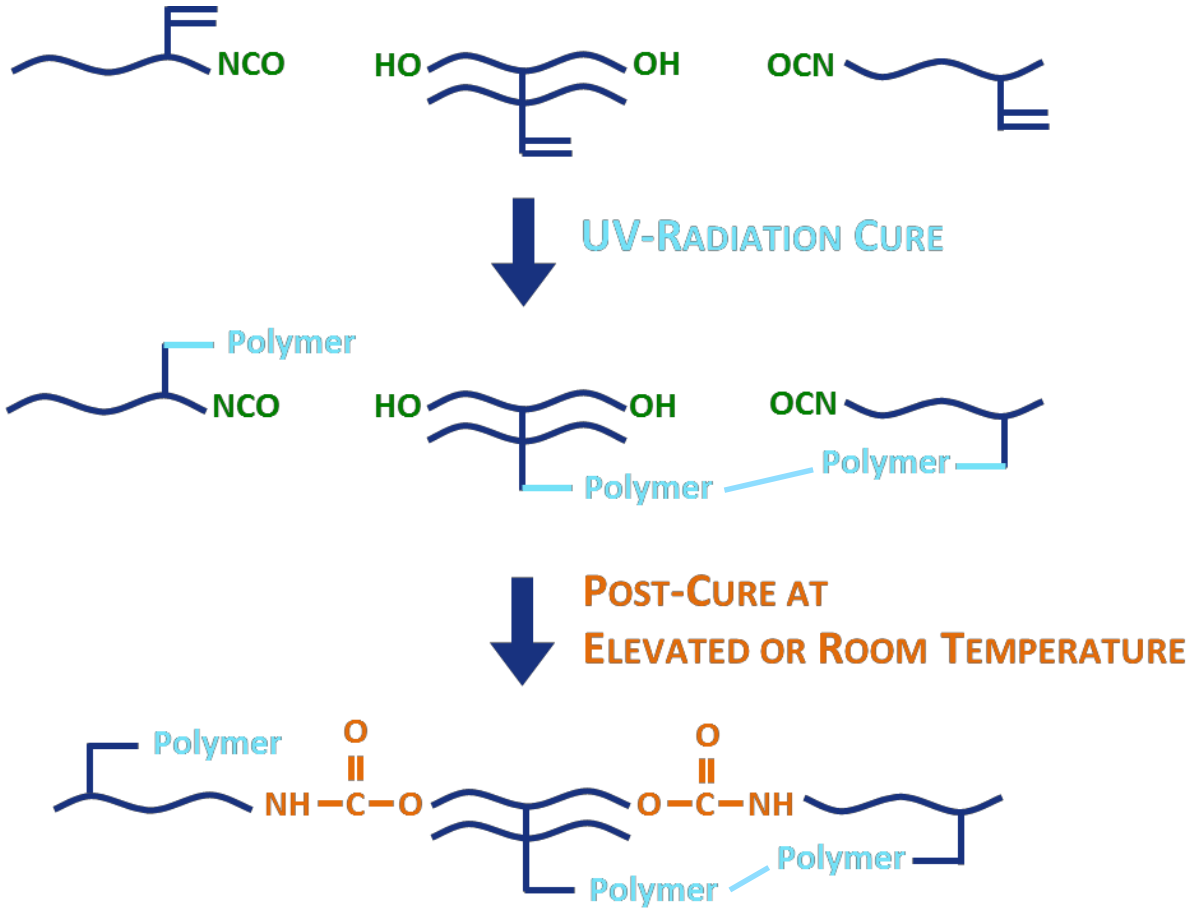
- Formulation is a blend of acrylate and acrylate/NCO functional resins/diluents
- Initial UV curing reaction produces a tack-free, handleable film
- Moisture cure reaction takes place with temperature or time. Shadow areas become cured. Final film properties are generated.

allnex Solutions for the Conformal Coatings Market - 1K Moisture Cure SPF

Raw Material	Description (acrylate / NCO func / % NCO)	A	B	C
EBECRYL® 4510	Aliphatic urethane acrylate (1 / 2 / ~13)	100		45
EBECRYL 4396	Aliphatic urethane acrylate (0.8 / 2.2 / ~7.5)		50	50
BuAc	Solvent			5
IBOA	1f Hydrophobic diluent	60	60	60
HDDA	2f diluent	20	20	20
Photoinitiator	Curing agent	5	5	5
Viscosity @25°C, cP		500	700	

- Films using EB 4396 are more flexible vs. films from EB 4510
  - Backbone structure
  - Lower %NCO leads to fewer urea bonds when moisture cured
- A catalyst can be added to decrease cure time of moisture cure reaction (e.g. DBTDL)

allnex Solutions for the Conformal Coatings Market - 2K Dual Cure



- Formulation is a blend of acrylate/OH and acrylate/NCO functional resins/diluents
- Initial UV curing reaction produces a tack-free, handleable film
- NCO/OH reaction takes place with temperature or time. Shadow areas become cured. Final film properties are generated.

allnex Solutions for the Conformal Coatings Market - 2K Dual Cure SPF

SPF 1	Raw Material	Description	
Part A	EBECRYL® 1200	OH functional acrylated acrylic	38.9
	Photoinitiator	Curing agent	2.5
Part B	EBECRYL 4510	NCO functional urethane acrylate	45.8
	BuAc	Solvent	8.5

SPF 2	Raw Material	Description	
Part A	EBECRYL 8210	OH functional acrylated acrylic	36.7
	IBOA	Hydrophobic monomer	10.0
	Photoinitiator	Curing agent	3.0
Part B	EBECRYL 4396	NCO functional urethane acrylate	30.3
	IBOA	Hydrophobic monomer	20.0

allnex Solutions for the Conformal Coatings Market – Pot Life

- Pot life refers to the time it takes for a reactive system to reach a state where processing, quality, and/or performance is impeded making the mixture no longer suitable for use

- Pot life indictors:
  - Viscosity doubling from original viscosity
  - Mixture no longer fluid
  - Performance results are no longer predictable after a period of time

- Pot life factors
  - Catalyst, reactant concentrations
  - Temperature

allnex Solutions for the Conformal Coatings Market – Pot Life

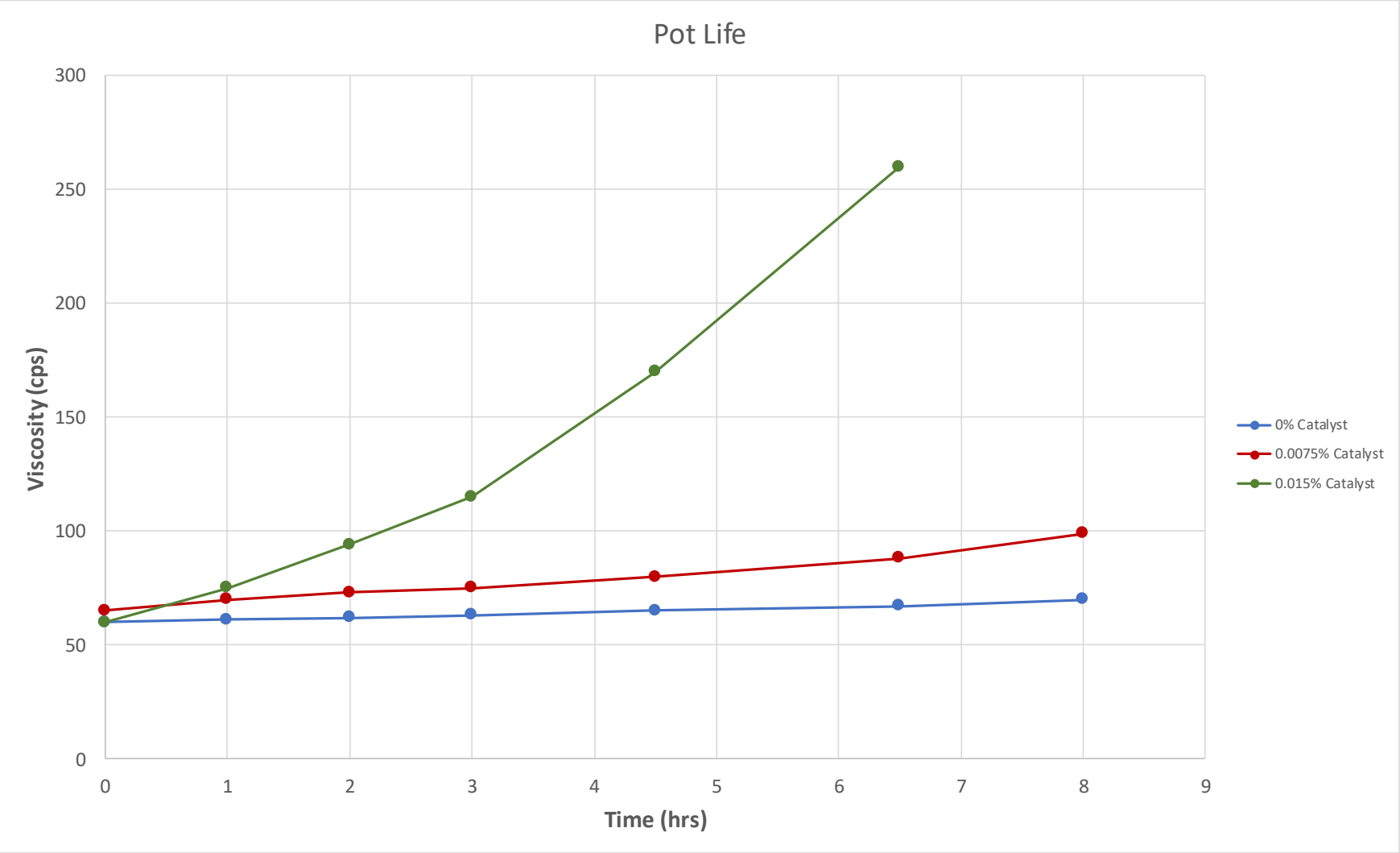
Component I	wt.
EBECRYL® 1200	26.7
HDDA	2.4
Butyl acetate	10.3
MODAFLOW® 9200	0.35
Photoinitiator (hydroxy-cyclohexylphenylketone)	2.9
Catalyst (DBTDL)	0.015

Component II	wt.
EBECRYL 4510	33.0
Butyl acetate	20.55

NCO:OH = 1.05

Solid content ~52 %

allnex Solutions for the Conformal Coatings Market – Pot Life



allnex Solutions for the Conformal Coatings Market – Properties vs. t, T

Part A	wt. %
EBECRYL®1200	53.4
HDDA	4.8
Butyl acetate	20.6
MODAFLOW® 9200	0.7
1-hydroxy-cyclohexylphenyl-ketone	5.8
DBTDL	0.03

Part B	wt. %
EBECRYL 4510	66.0
Butyl acetate	41.1
Sum:	192.3

- Parts A&B are mixed just before application

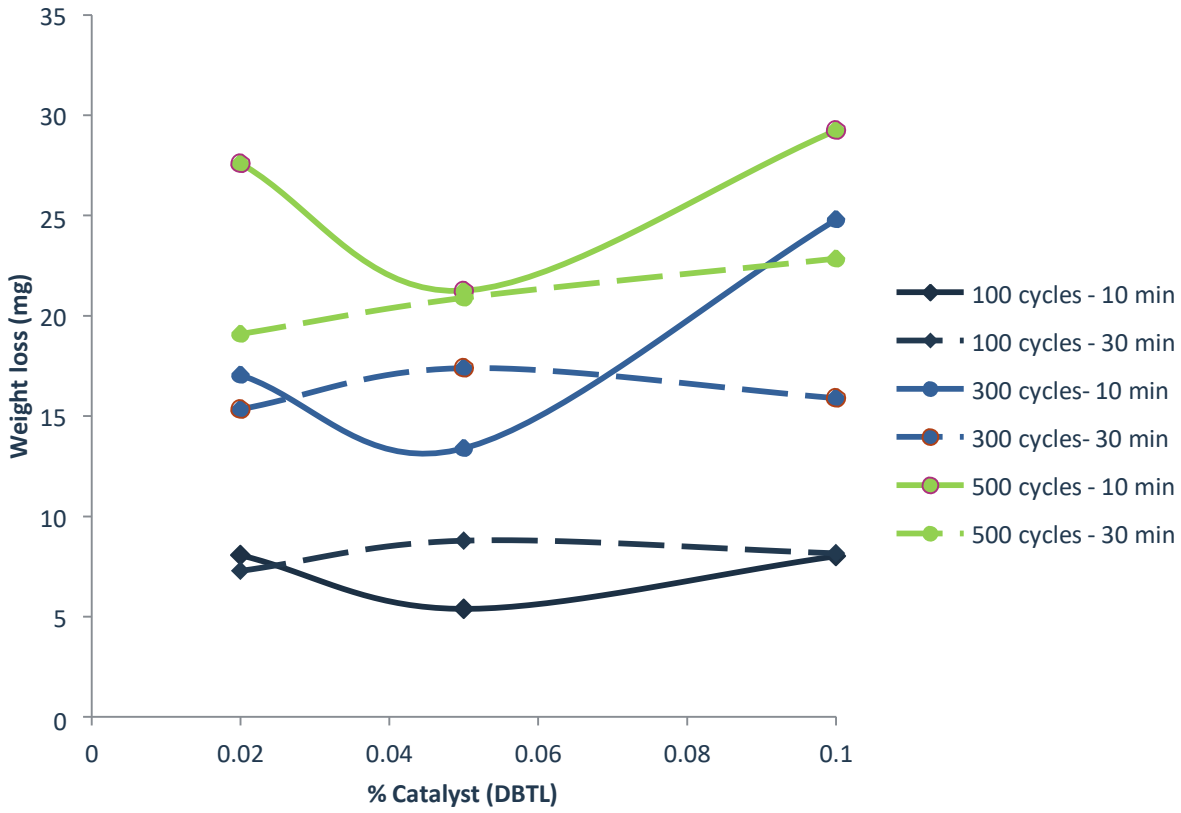
- Viscosity 25 sec. DIN 4 @ 23°C
- Solids content ~52 %
- Pot life ~5 hours

- Target dry film thickness (DFT): 20 g/m²
- 10' - 30' @ 80°C: flash off and thermal curing*
- UV curing: 2 x 10 m/min. with 120 W/cm Hg lamp (1200 mJ/cm²)
- Test done after 1 week storage at RT

* may be adjusted by the amount of catalyst to the requirements of the line/machine as seem earlier

allnex Solutions for the Conformal Coatings Market – Properties vs. t, T

Impact of thermal cure time (10 min/30 min at 80°C) and catalyst amount: ABRASION



Surprisingly, neither time nor catalyst amount seems to impact abrasion performance significantly

allnex Products for Dual Cure

NCO Functional Acrylates*

Products	Dilution	Acrylate Functionality	Isocyanate Functionality	Viscosity at 25°C approx. mPas	NCO content % on supply form	Color
EBECRYL 4150	-	1	2	9000	12.8	< 150 APHA
EBECRYL 4250	-	3.4	1.4	2000	5	< 100 APHA
EBECRYL 4396	-	1	2.2	14000	7.5	< 150 APHA
EBECRYL 4510	10 BA	2	2	17000	7	< 100 APHA
EBECRYL 4765	45 EA	2	2.5	125	4.3	< 100 APHA
EBECRYL 4950	20 BA	3		1700	6.2	< 100 APHA

OH Functional Acrylates*

Products	Dilution	Acrylate Functionality	OH Value on supply form	Viscosity at 25°C approx. mPas	Tack Free after evaporation	Color
EBECRYL 1200	45 BA	-	110	3000	Yes	< 5 Iodine
EBECRYL 1205	52 BA	-	75	1000	Yes	< 1
EBECRYL 4900	40 BA	2	28	1500	Yes	< 1
EBECRYL 8210	-	3.5	80	4000	No	< 2

* non-exhaustive list, and future developments ongoing

allnex Solutions for the Conformal Coatings Market – Conclusions

- allnex dual cure resins can provide a foundation for the development of Conformal Coatings
- allnex isocyanate functional acrylate resins can be used in dual cure to give good coatings properties and good cure in shadow areas through moisture curing of the isocyanate
- allnex isocyanate functional acrylates can be combined with hydroxy functional acrylates to give good coatings properties and good shadow cure through the NCO/OH reaction
- UV curable dual cure coatings deliver
  - Dark cure - cure in shadow areas under components
  - High cure speed- improved dry time to handle
  - Adhesion/wettability – wet out and adhere to solder, components
  - Whisker migration – can mitigate tin whisker growth

THANK YOU FOR YOUR ATTENTION!

ANY QUESTIONS?

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