Mechanical Properties and Adhesion of Various Conformal Coatings

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Abstract

Conformal coatings can be used to mitigate tin whisker growth on tin-rich surfaces, for which its mechanical properties and adhesion will play a crucial role. In this study, various types of conformal coatings were investigated under different curing conditions to measure mechanical properties and coating adhesion to tin surface. FTIR was used to examine the degree of curing of the coating. Mechanical properties of the film were evaluated by universal testing machine and micro-hardness tester. Also, adhesion of the coating was determined by a cross-cut tape peeling test.

Research Overview

Conformal coatings that are often used to prevent the board from corroding can effectively mitigate the needle-like tin whisker growth.

Advantage
- Reduce the tin whisker growth rate
- Trap the tin whisker
- Protecting against
  - Humidity and chemical environment

Types
- Acrylic (AR)
- Silicone (SR)
- Polyurethane (PU)
- Polyurethane Acrylate (PUA)

Conformal Coating

PRODUCT NAME	RESIN	CURING TYPE	COATING METHOD	VISCOSITY (cps)
1B31 [1]	AR	Thermal Curing	Spray Coating	197 ± 15
HFAC200H [2]	AR	Thermal Curing	Spray Coating	360
1C51 [1]	SR	Thermal Curing	Doctor Blade method	590 ± 100
URC200D [2]	PU	Thermal Curing	Spray Coating	240
PC18M [3]	PU	Moisture Curing	Doctor Blade method	350
Arathane5750 [4]	PU	Thermal Curing	Doctor Blade method	A – 50, B – 600
PC40UMF [3]	PUA	UV & Moisture Curing	Doctor Blade method	250
UV40 [1]	PUA	UV & Moisture Curing	Doctor Blade method	650 ± 150
Dymax 9483 [5]	PUA	UV & Moisture Curing	Doctor Blade method	690

[1] Humiseal ; [2] Electrolube ; [3] Henkel ; [4] Huntsman ; [5] Dymax

UV Curing System Informatio: Bulb Intensity: 4800 μW/cm^2 at 15 inches ; Wavelength – 365 nm (UVA)

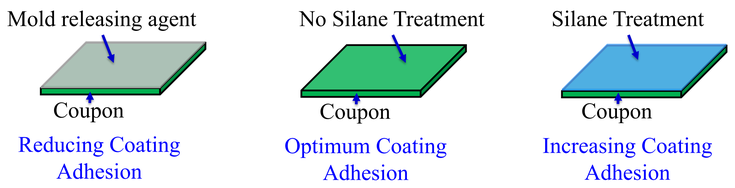
Characterization

Chemical Structure
- FT-IR spectroscopy using attenuated total reflection (ATR) mode

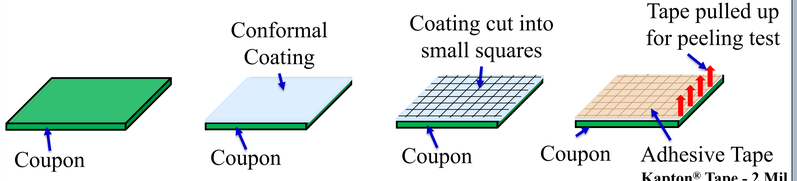
Mechanical Properties
- Tensile testing (modified from ASTM D882) with Instron
  - Sample dimension : 2.5 in x 0.5 in
  - Gauge length : 0.5 in
  - Displacement rate : 0.05 in/min
- Hardness testing with Vickers hardness testing
  - Load : 10 gf
- Adhesion testing with cross-cut tape peel test

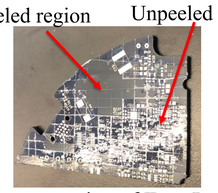
Instron Tester

Engineering coupon-coating interface property



Adhesion Test – Cross-cut Tape peel test





Representation of Tape Peel Test

$$\text{Peeled-off Percent} = \frac{Number\ of\ peeled - off\ squares}{Total\ number\ of\ squares}\ X\ 100$$

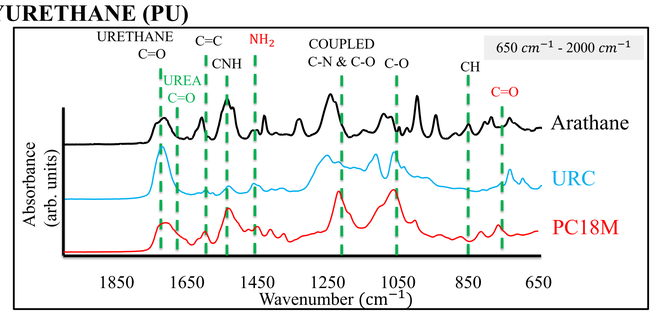
Peeled-off Percent	0%	0-5%	5-15%	15-35%	35-65%	>65%
ASTM D3359 Class	5B	4B	3B	2B	1B	0B

Good Adhesion ⟶ Poor Adhesion

Results and Discussion

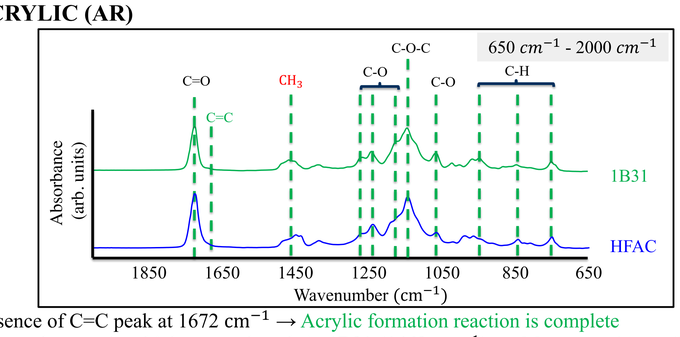
FT-IR (ATR)

POLYURETHANE (PU)



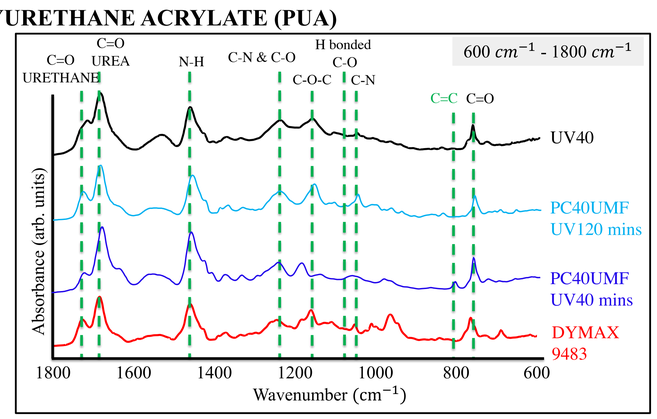
- Absence of C=O peak at 1643 cm^{-1} → No urea (by-product) formation
- Dominant C=C (1596 cm^{-1}) and CH (814 cm^{-1}) peak in PC18M → Presence of aromatic group (Hard segment)

ACRYLIC (AR)



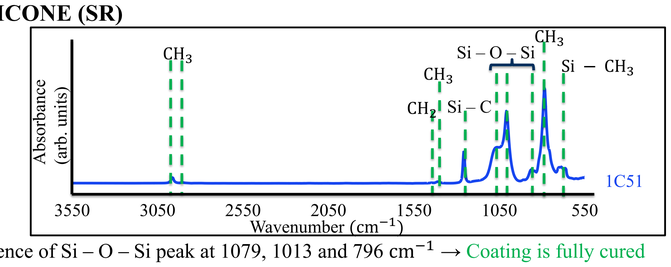
- Absence of C=C peak at 1672 cm^{-1} → Acrylic formation reaction is complete
- CH_3 peak moved to higher wavelength in 1B31 (1463 cm^{-1}) → More stretching of methyl group

POLYURETHANE ACRYLATE (PUA)



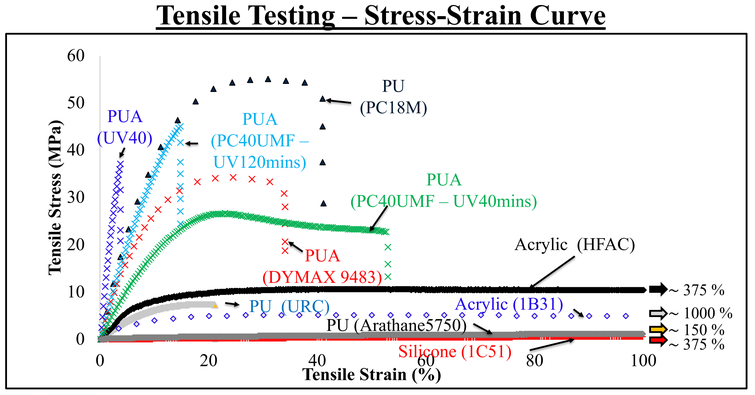
- Presence of C=C peak at 809 cm^{-1} in PC40UMF 40mins cured → Coating is partially cured
- Shifting of C = O (Urethane) peak to 1708 cm^{-1} in UV40 → More brittle than other PUA

SILICONE (SR)



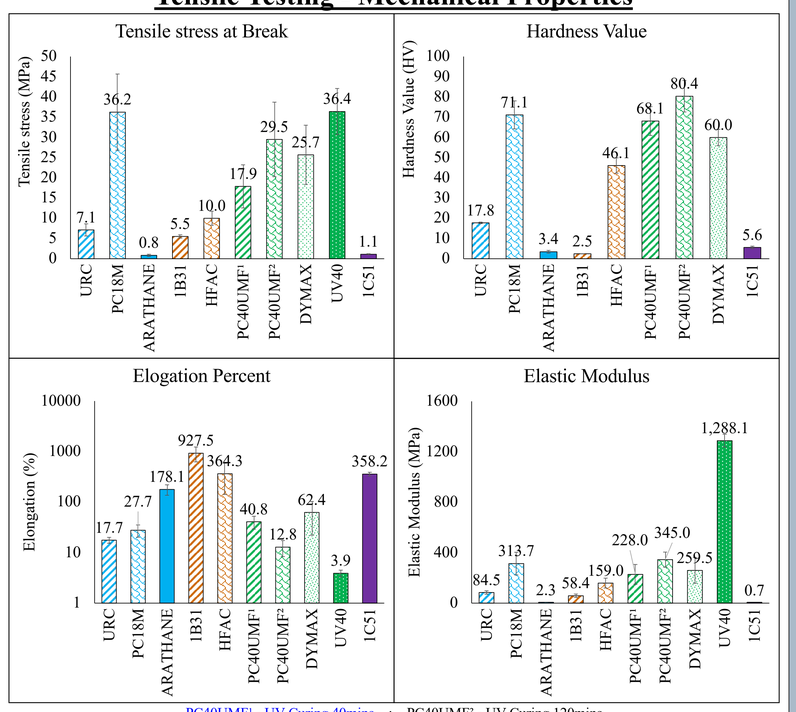
- Presence of Si – O – Si peak at 1079, 1013 and 796 cm^{-1} → Coating is fully cured

Tensile Testing – Stress-Strain Curve



- PUA (UV40) is the most brittle coating
- Acrylic (1B31) has the highest elongation percent
- PU (PC18M) & PUA (PC40UMF- partial UV cure) show good strength/ductility combination

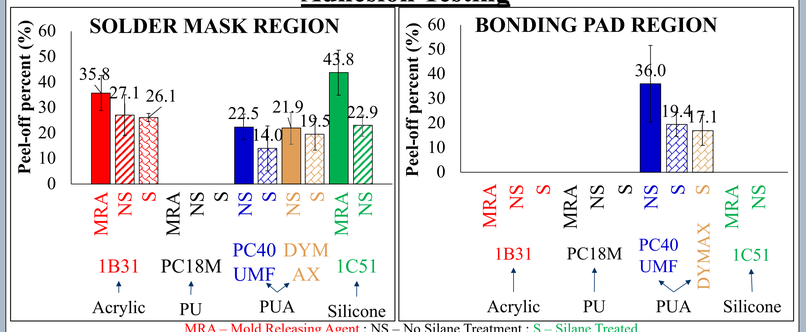
Tensile Testing - Mechanical Properties



PC40UMF¹ - UV Curing 40mins ; PC40UMF² - UV Curing 120mins

- Most ductile conformal coating : 1B31 (AR)
- Most brittle conformal coating : Humiseal UV40 (PUA)
- Soft conformal coatings : Arathane (PU), 1B31 (AR) and 1C51 (SR)

Adhesion Testing



- PC18M (PU) shows excellent adhesion to solder mask and (Au-Pd) bonding pad region
- 1C51 (SR) with mold releasing agent shows highest peel-off percent
- PU, Acrylic and Silicone showed excellent adhesion strength in bonding pad region

Summary

Mechanical Properties
- Polyurethane (PU) Conformal Coating
  - PC18M showed higher strength
  - Arathane 5750 is a soft PU coating with > 175% elongation
- Acrylic (AR) Conformal Coating
  - 1B31 showed highest elongation percentage (> 900% elongation)
- Silicone (SR) Conformal Coating
  - 1C51 is a soft conformal coating with high elongation (> 350% elongation)
- Polyurethane Acrylate (PUA) Conformal Coating (Dual UV/moisture Cure System)
  - DYMAX and PC40UMF UV40mins have similar mechanical properties
  - Full UV curing (120 mins) of PC40UMF makes the coating harder and brittle

Adhesion Properties
- Adhesion of PC18M is excellent in both the solder-mask and bonding-pad
- Silane treatment improved the adhesion of PC40UMF (PUA) in the bonding pad
- Acrylic, PU and Silicone coating did not peel-off from the bonding-pad region

Future Work

- Make the PC18M (Hard - PU), Arathane 5750 (Soft - PU), 1B31 (High elongation - AR), 1C51 (Soft- SR), PC40UMF and Dymax (Dual curing system) coatings on the board coupons for HTHH treatment (2500 hours)
- Tin whisker growth monitoring & Coating adhesion and degradation evaluation
- Compare the performance of SR/AR/PU/PUA coating with that of parylene coatings

Acknowledgement

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