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Packaging Strategy for High Voltage and High Shock Environments

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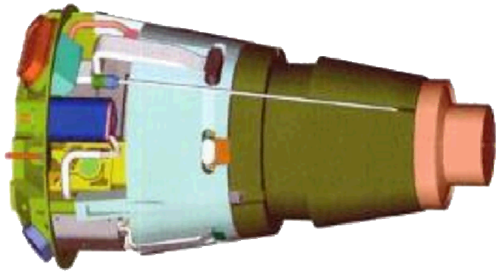
Outline

- Problem Statement
- Background
  - Current Packaging Strategy
  - High Voltage Breakdown
- Approach
  - New Packaging Strategy
- Testing and Validation
  - High Voltage Testing
  - Contact Angle Testing
  - Dielectric Strength Testing
  - Adhesion Characterization
- Conclusions
- Future work



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Problem Statement

It is the intent of this study to develop a new packaging strategy that will eliminate the cumbersome design issues associated with the legacy encapsulation packaging strategy currently used in high voltage, high impact applications.

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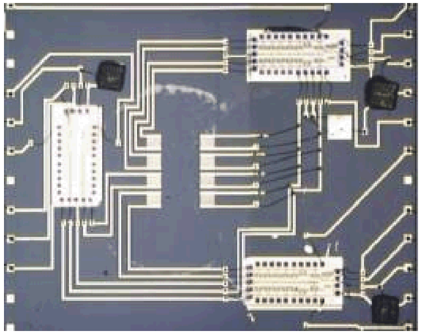
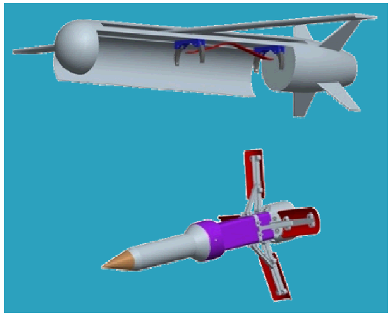
Background

- What are we packaging?
  - Electronic components on Printed Circuit Boards (PCBs)



- Where are PCBs used?
  - Everywhere
  - Compact
  - Low and high voltage
  - Multi-layer traces and components

- Why do we packaged PCBs?
  - Operating environment
  - Coated
  - Fastened
  - Encapsulated



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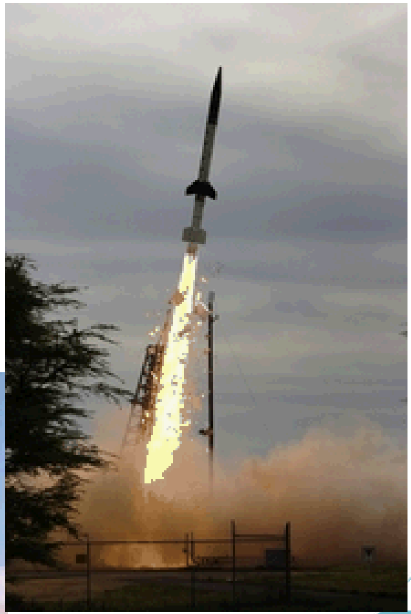
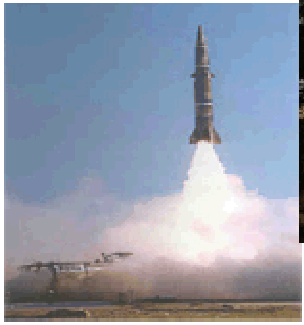
Background

- Sandia's Current Packaging Strategy for High Voltage High Impact Environments
  - Utilizes an epoxy encapsulant
    - Filled system – Glass Micro Balloons
  - Pros
    - Prevents electrical breakdown
    - Provides impact protection
  - Cons
    - Thermal stresses
    - Rework is difficult
    - Heavy





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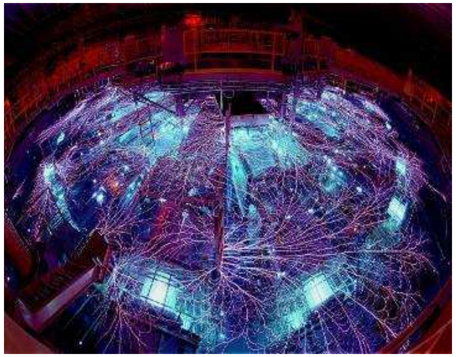
Background



- 3 types of high voltage breakdown
  - Internal discharge
  - Surface discharge
  - Corona discharge
- Goal is to improve packaging strategy while preventing breakdowns
  - Strong dielectric
  - Adheres well
  - Complete coverage
- Investigate conformal coatings

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Approach

- New Packaging Strategy
  - Coat with a Conformal Coating
  - Package with a Foam

  - Pros Coating
    - Prevents electrical breakdown
    - Provides component protection
    - Rework is feasible

  - Pros Foam
    - Provides impact protection
    - Rework is still feasible
    - Light 4lbs instead of 65lbs

  - Pros Combination
    - Can optimize coating and foam combinations for operating environment

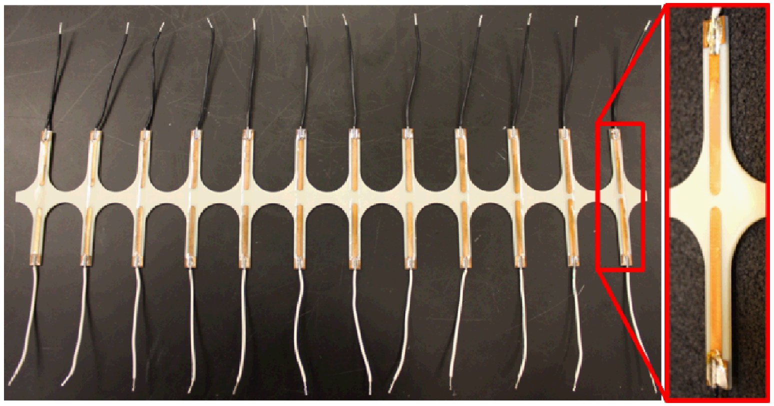
Developing New Strategy

- Coatings
  - Selected Coatings
    - Commercial
    - In House
  - Application Techniques
    - Brush
    - Syringe
    - Spray
    - Vapor Deposition

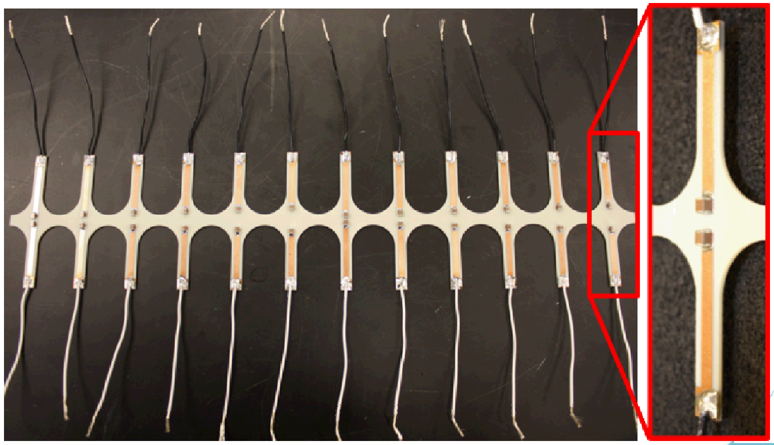
Material	Form	Cure	Intended Use	Tg (°C)
828/DEA	2 Part liquid	Thermal	Adhesive/Encapsulant	71
HA-84	1 Part liquid	UV and Thermal	Coating	85
Dymax X-617-11-1	1 Part liquid	UV	Coating	65
Humiseal UV40	1 Part liquid	UV and Thermal	Coating	45
Uralane 5750	2 Part liquid	Thermal	Adhesive	-60
Dymax 9481	1 Part liquid	UV and Thermal	Coating	65
Dymax 984	1 Part liquid	UV and Thermal	Coating	69
Dymax 920557	1 Part liquid	UV and Thermal	Coating	80
828/D230	2 Part liquid	Thermal	Adhesive	70
TurboCoat	1 Part Aerosol	RT	Coating	53
Fine-L-Kote	1 Part Aerosol	RT	Coating	45
Masterbond UV15	1 Part liquid	UV	Coating	125
Parylene C	1 Part solid	Vapor Deposition	Coating	90
Emcast 1902	1 Part liquid	UV	Coating	63
Emcast 1910	2 Part liquid	UV and Thermal	Coating	63
828/DEA w/ 4% Cabosil	2 Part liquid	Thermal	Adhesive/Encapsulant	71
Cytec EN4/EN11 w/ 4% Cabosil	2 Part liquid	Thermal	Adhesive	-60
828/GMB/DEA	2 Part liquid	Thermal	Adhesive/Encapsulant	71

Developing New Strategy

- Test Coatings Electrically
  - Test Geometry
    - Flat traces
    - 12 gaps
    - Ranging from .01 to .52 inches



    - Components
    - 6 gaps-repeated
    - Ranging from .05 to .425 inches



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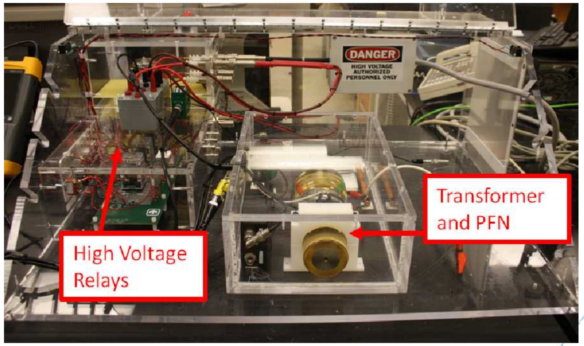
Developing New Strategy

- Apply load to test geometry
  - High Voltage Safety Box

- AC Test System
  - 20 to 100 kV range
  - Test Procedure
    - Start at 20kV
    - Applied a13µs pulse
    - Stepped up in ~10kV increments
    - Finish at max of 100 kV

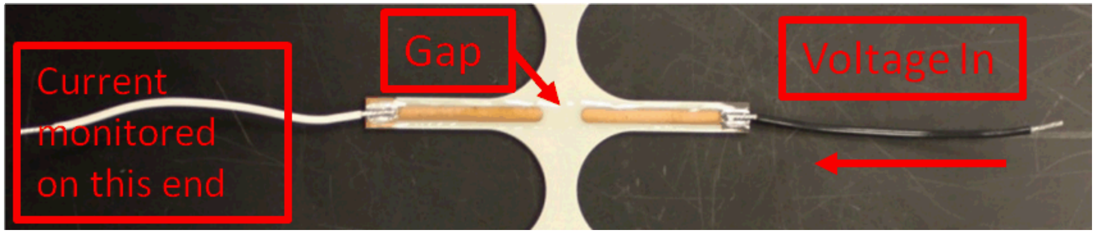


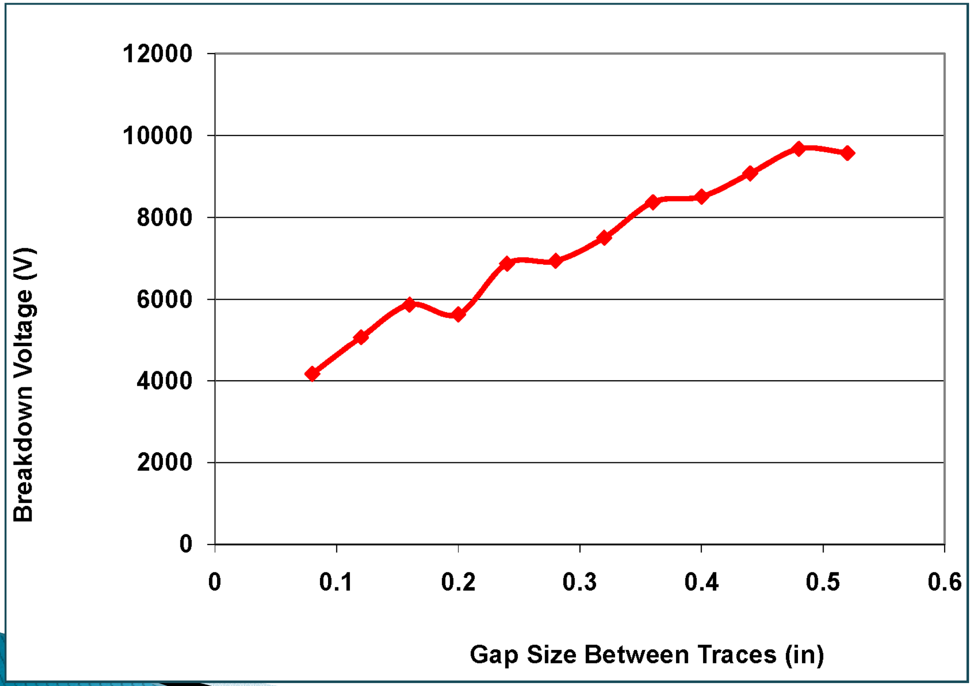
- DC Test System
  - 0 to 20 kV range
  - Test Procedure
    - Start at 1kV
    - Applied for 10 seconds
    - Stepped up in 1kV increments
    - Finish at max of 20 kV

- Labview Interface

Initial Electrical Testing

- Detecting breakdowns across a gap





- Flat trace geometry
- No coating

- Breakdown voltage vs. Gap in ambient air

- Baseline established

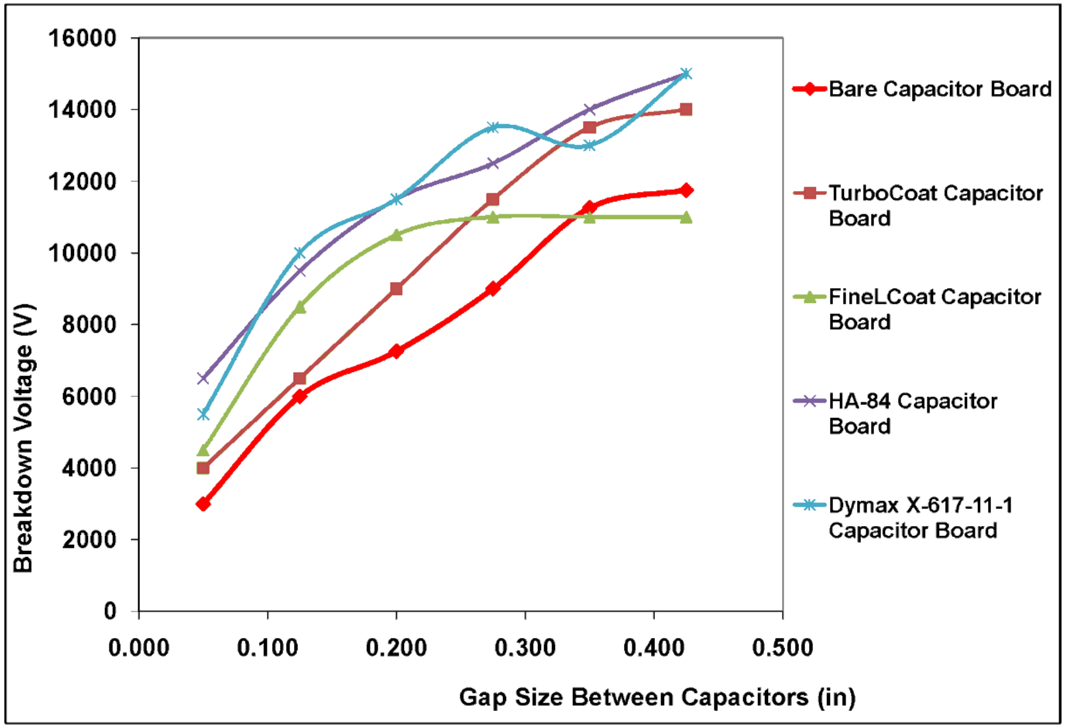
Initial Electrical Testing

- Coatings on flat trace geometry
  - .01 to .52 inch gaps
- Applied coatings
  - Brush
  - Syringe
  - Aerosol
- DC test
- Outperformed DC system
  - Except aerosol coatings
    - 1 coat, thin

Coating	Thickness (in)	Gap Size (in)	Breakdown Voltage (Volts)
None	N/A	0.010	900
Humiseal UV40	0.021	0.010	>20000
Uralane 5750 Hand applied	0.011	0.010	>20000
HA-84 Brushed on (2 coats)	0.042	0.010	>20000
Dymax X-617-11-1	0.017	0.010	>20000
Dymax 920557	0.030	0.010	>20000
Fine-L-Kote	0.007	0.010	9000
Turbo-Coat	0.006	0.010	18000

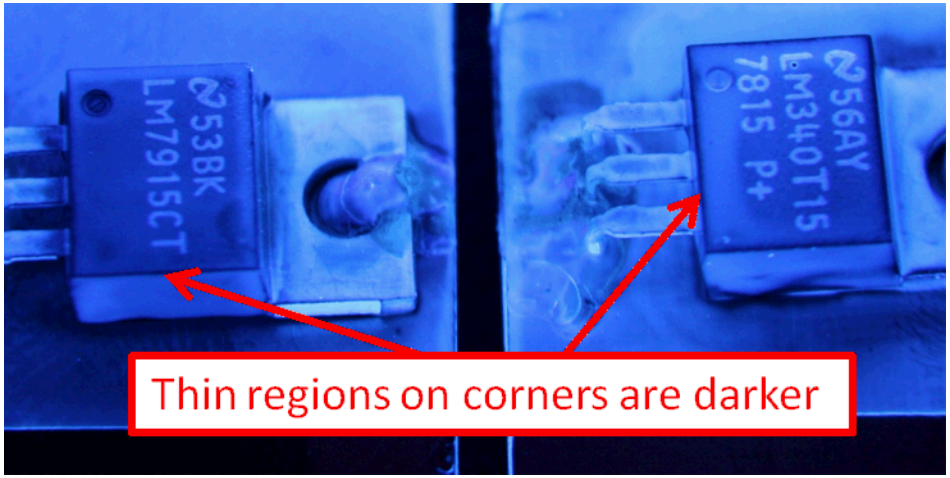
Initial Component Electrical Testing

- Component Geometry
- Uncoated Board
- Select Coatings Applied
  - HA-84 and Dymax >20kv on flat trace
  - Aerosol- 3 coats
- DC System Testing
- Protruding Geometries with sharp edges present issues



Coating Sharp Edges

- Address corner coverage
  - Aerosol coatings in 3 coats
    - Fluoresce under UV light



- Components are a challenge
  - Sharp Corners
    - Thin coverage
    - High electrical field concentration

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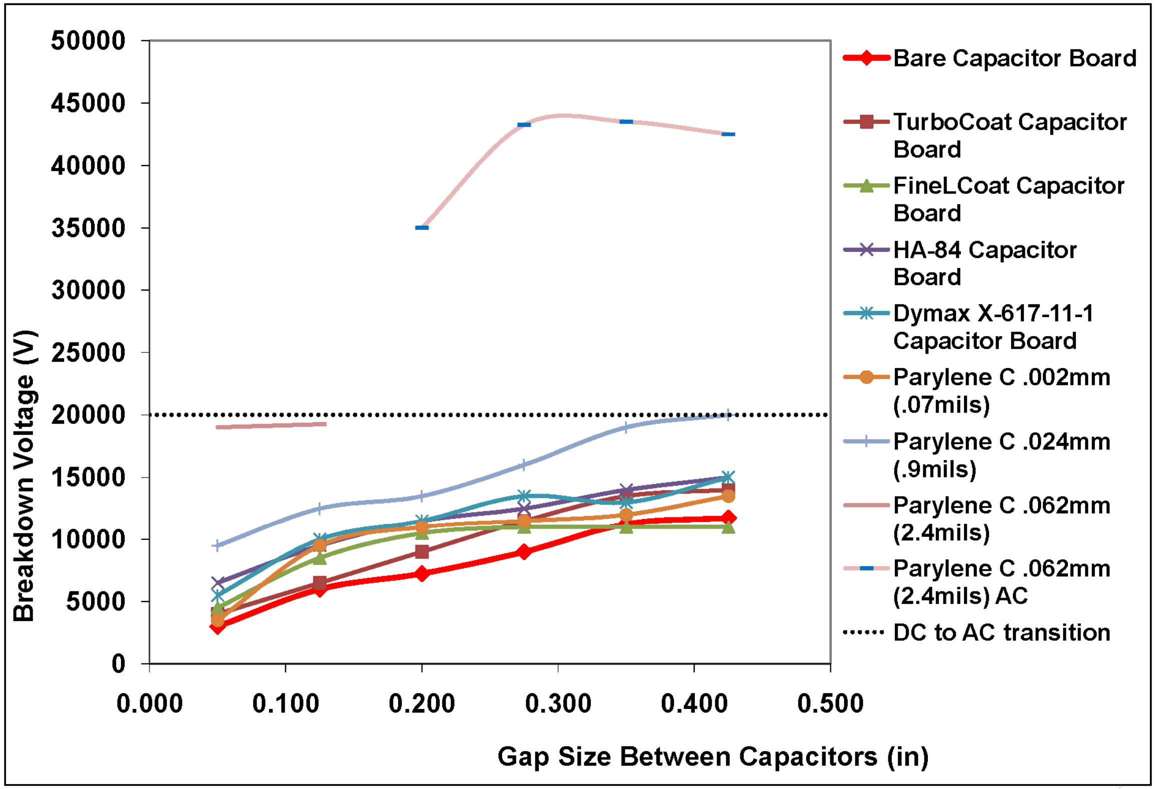
Uniform Coating on Protruding Geometries

- Prove corners can be protected
  - Parylene C
  - Vapor deposition applies uniformly to all surfaces
  - Applied in 3 coating thicknesses



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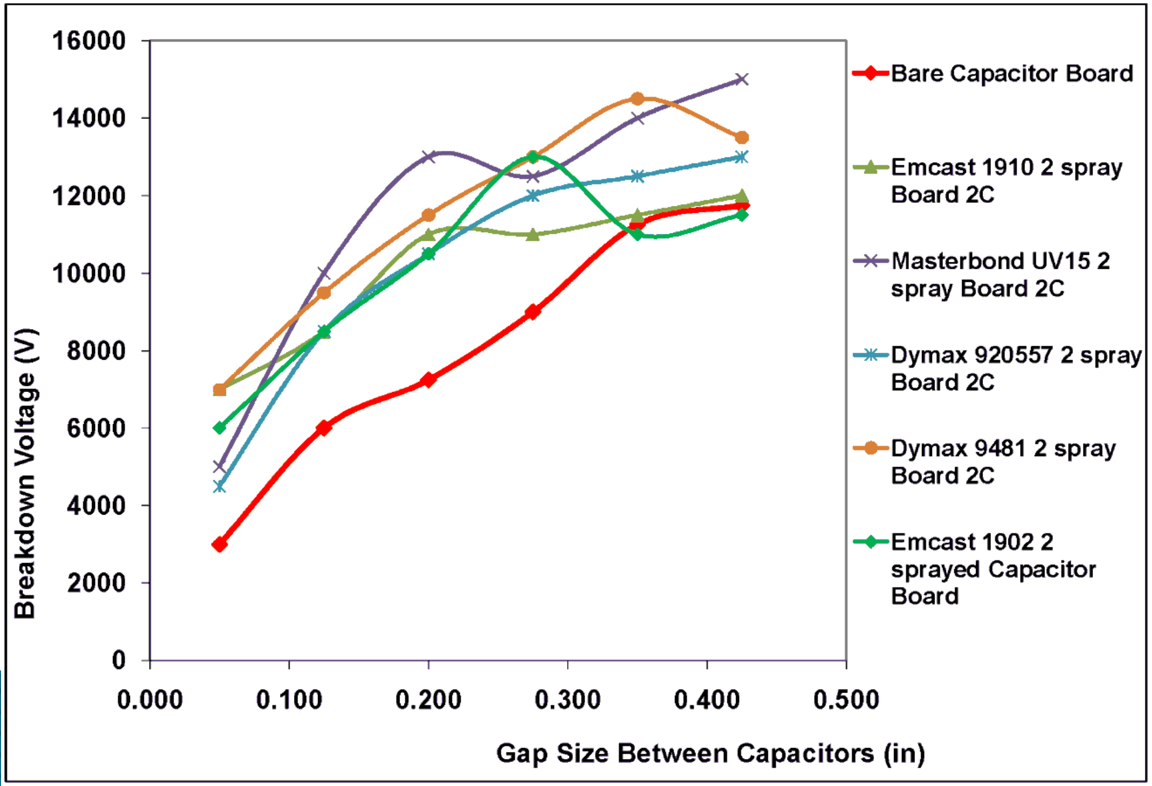
Spray Coating Development

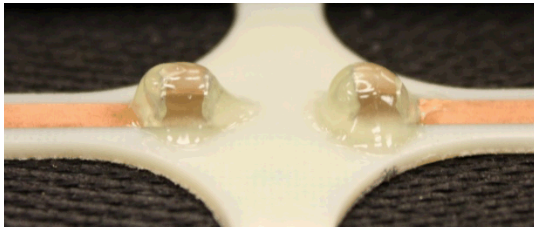
- Corners can be protected
  - Uniform coverage

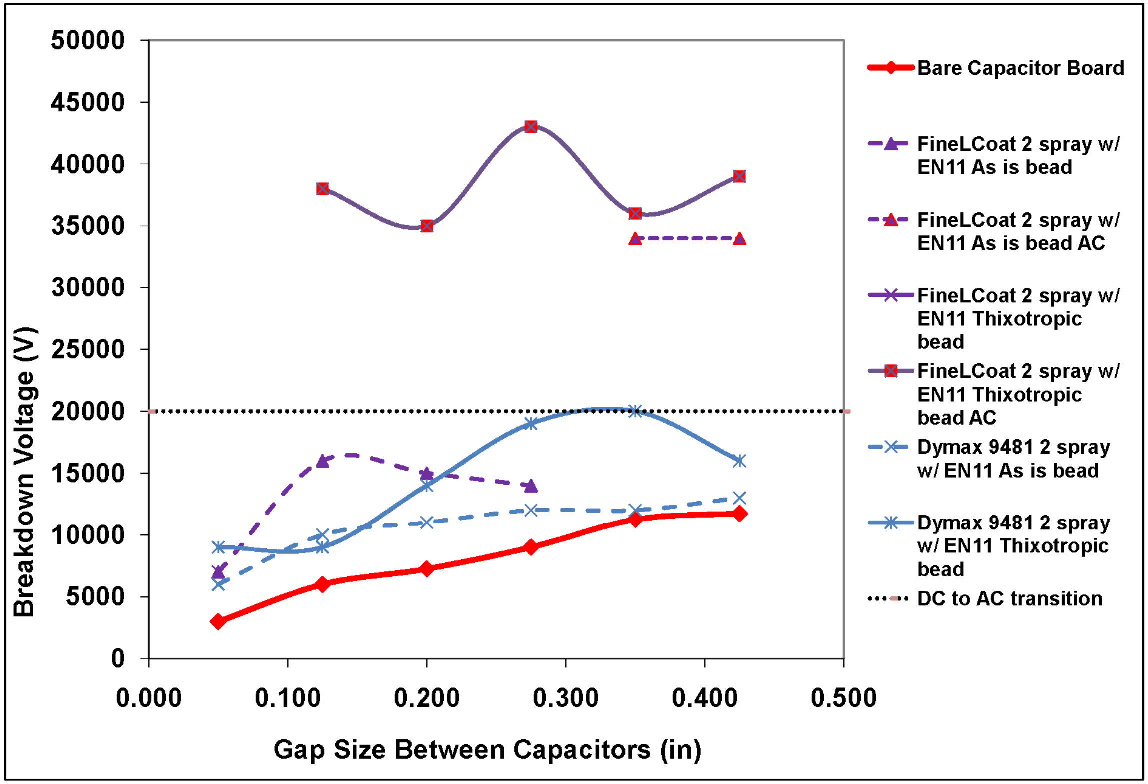


- Spray coating technique developed
- Coatings down selected to spray capable materials
- Sprayed component test boards
- DC tests- still breaking down

Bead Coating Development

- Apply bead coat to high voltage components
  - EN11 in two versions
    - As is – dashed line
    - Thixotropic – solid line





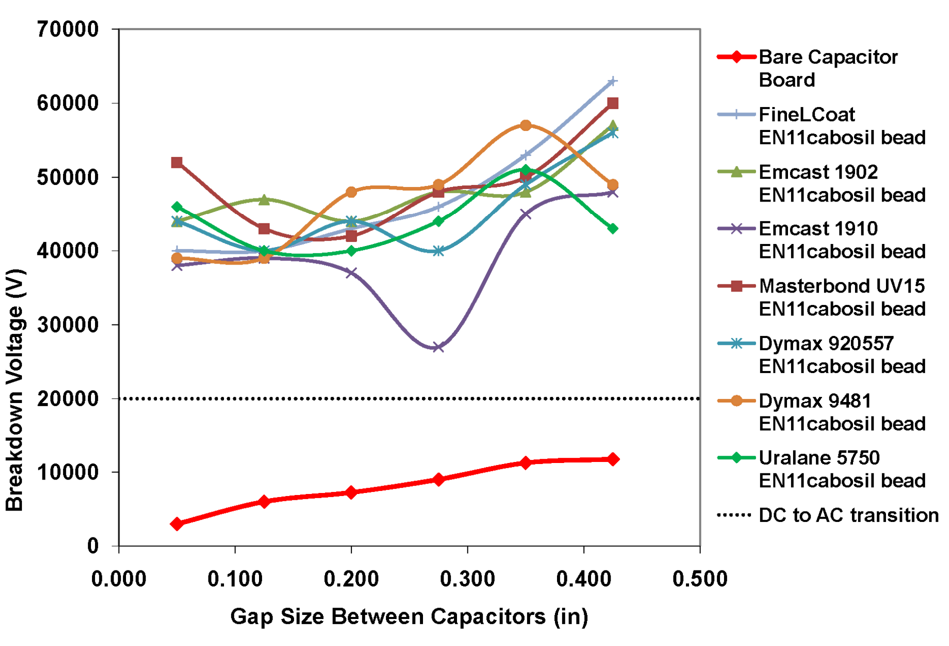
- Thixotropic outperforms As is
- Uniform coverage critical

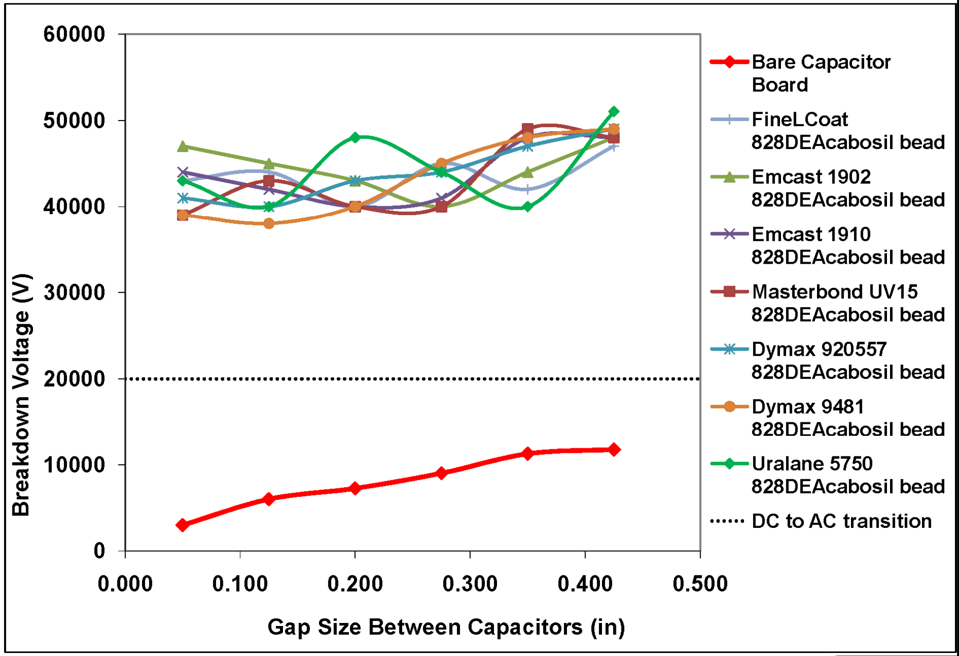
Bead Coating Strategy

- Bead Coat High Voltage Components
  - Two types of bead material

- EN11 thixotropic
  - Low Tg

- 828/DEA thixotropic
  - High Tg





- Breakdown protection 40 to 65kV

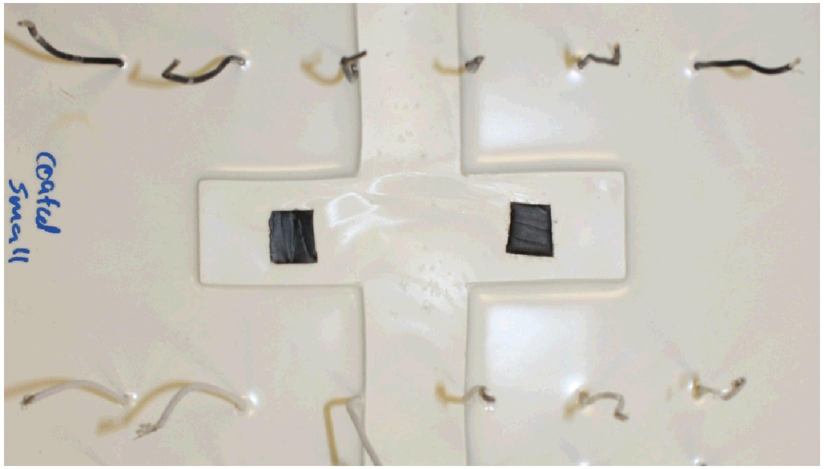
New vs. Legacy Packaging Strategy

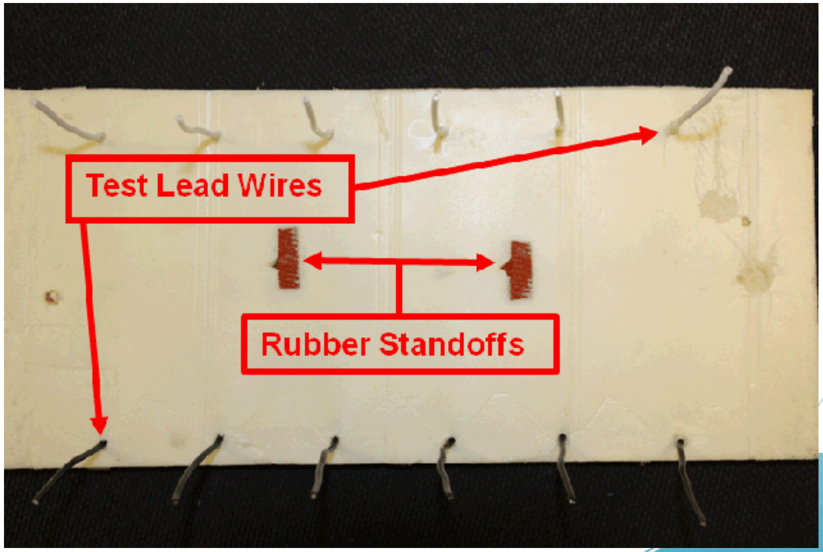
- Compare

- Epoxy encapsulant
    - 828/GMB/DEA

  vs.
- Foam encapsulant
    - PMDI foam

- Three board configurations for each packaging strategy
    - Uncoated capacitor board
    - Coated capacitor board
    - Coated and bead capacitor board





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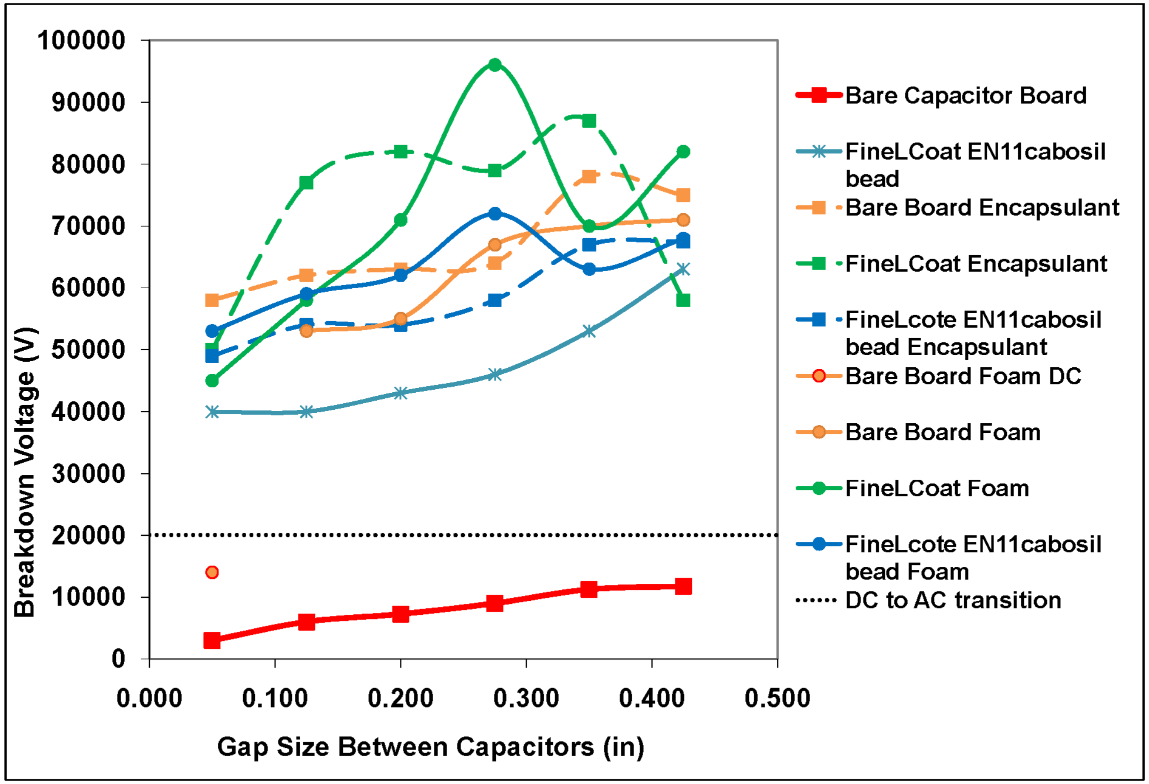
New vs. Legacy Electrical Testing Results

- Epoxy Encapsulant
  vs.
- Foam Encapsulant

- Comparable Breakdown Voltages

- Foam alone
  - Provide mechanical rigidity
  - Skin acts as a dielectric

- New strategy is electrically capable and equivalent



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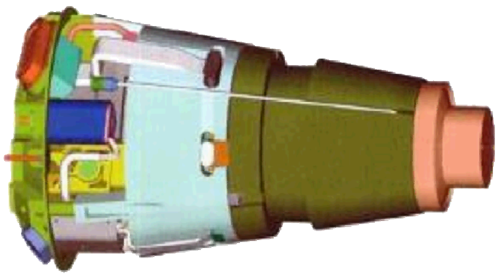
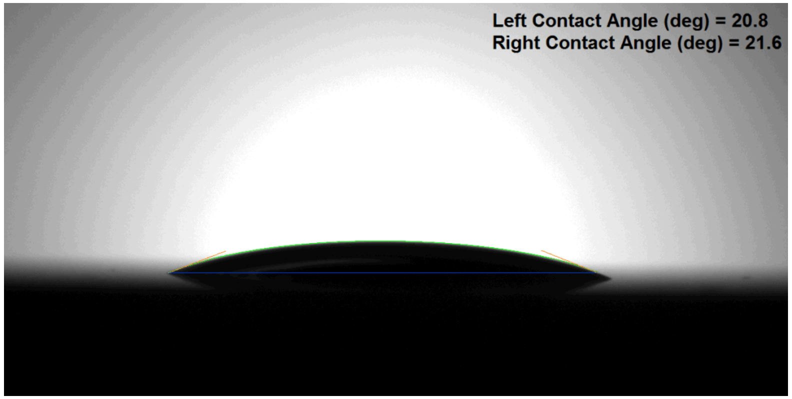
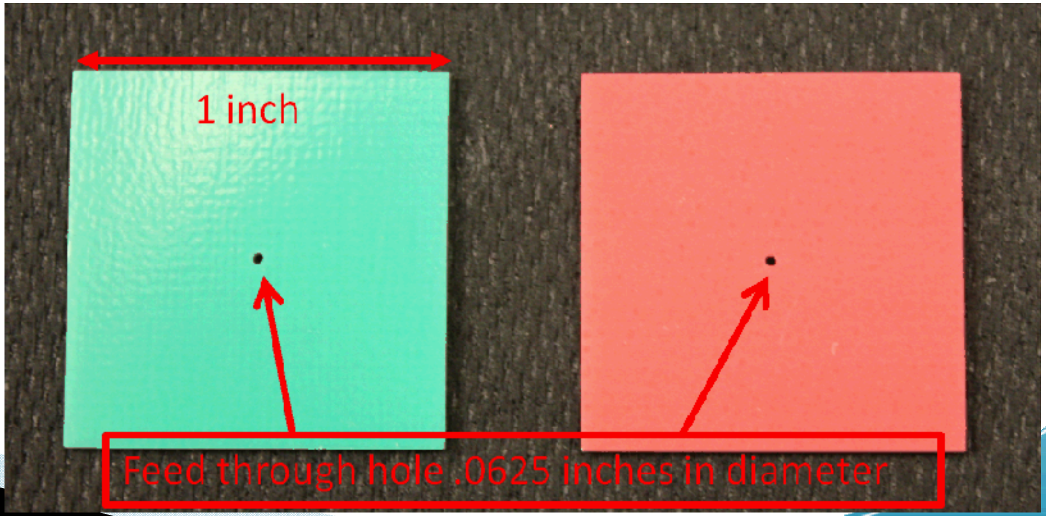
- Future work



Contact Angle Testing

- Two types of solder mask
  - Screen Printed Red Enthone
  - Spray Applied Green Taiyo
- Feed-Through-Goniometer
- Contact angle vs. time





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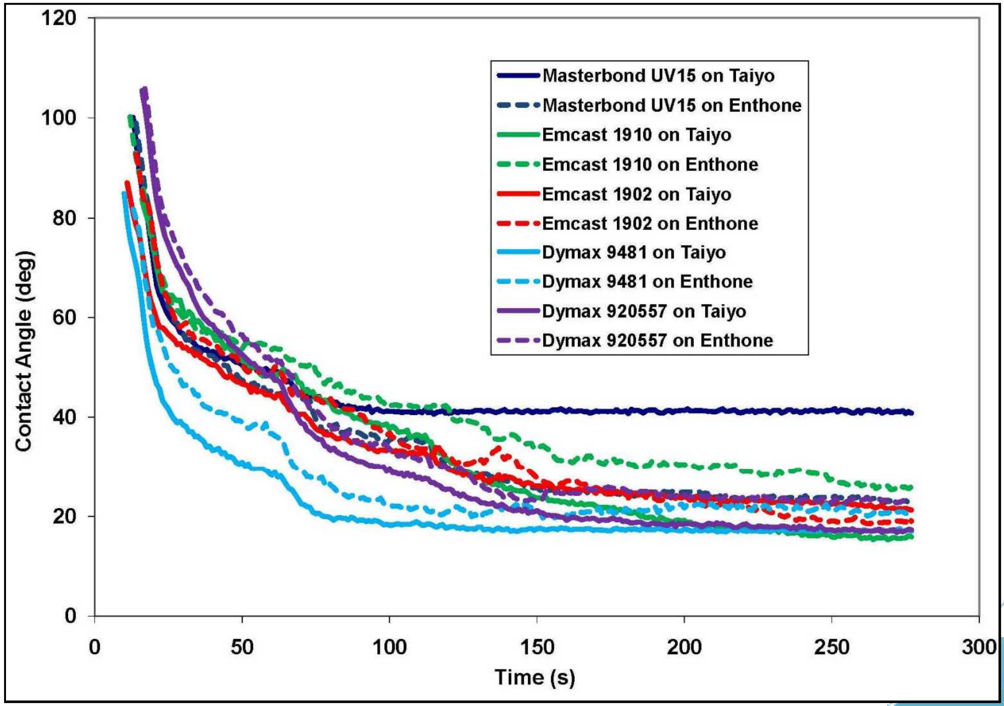
Contact Angle Results

- Contact angle vs. time
- Red solder mask results are dashed lines
- Green solder mask results are solid lines

- Equilibrium is reached in 3 minutes

- All coatings capable of wetting solder mask surfaces

- Green Taiyo solder mask preferred class



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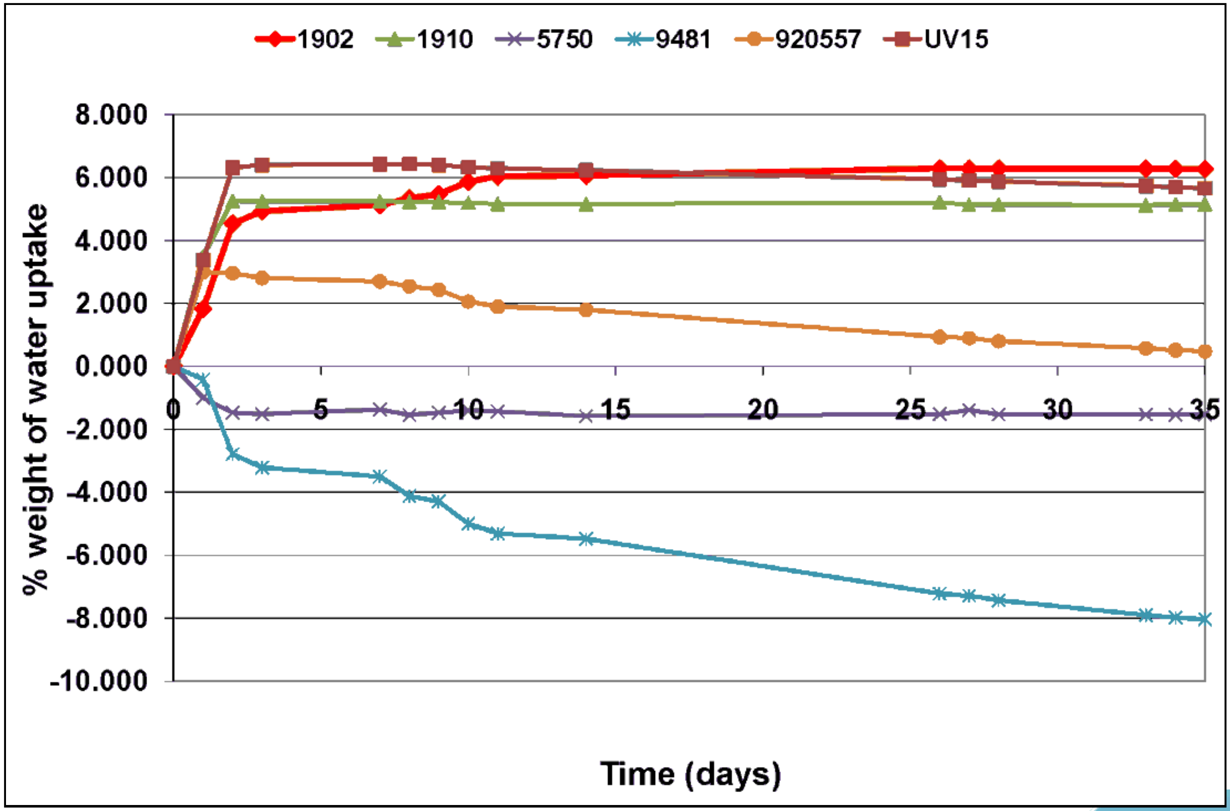
Water Uptake Study

- Package for operating environment – Humid
  - Square plaques of bulk material
  - Submersed in 70°C DI water
  - Monitored weight for 35 days



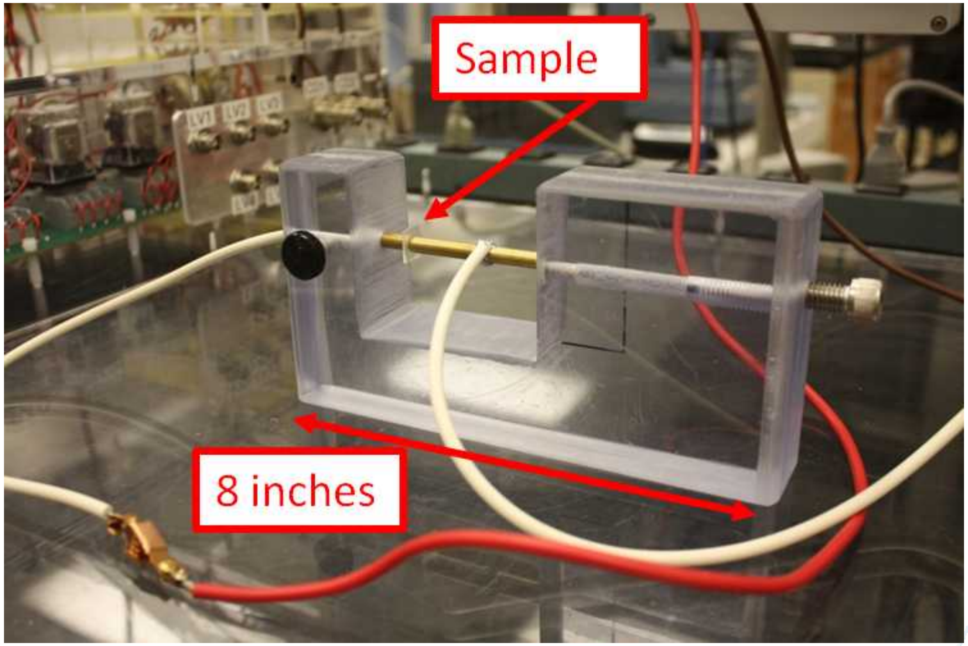
- Strong activity in 5 days
- Either absorb or resist water
- Saturated in about 10 days
- Continued weight loss

Dielectric Strength Testing

- Bulk dielectric strength of coatings

- Square plaques of bulk material
- Submersed in 70ºC DI water
- Monitored weight gain for two weeks

- Tested electrically



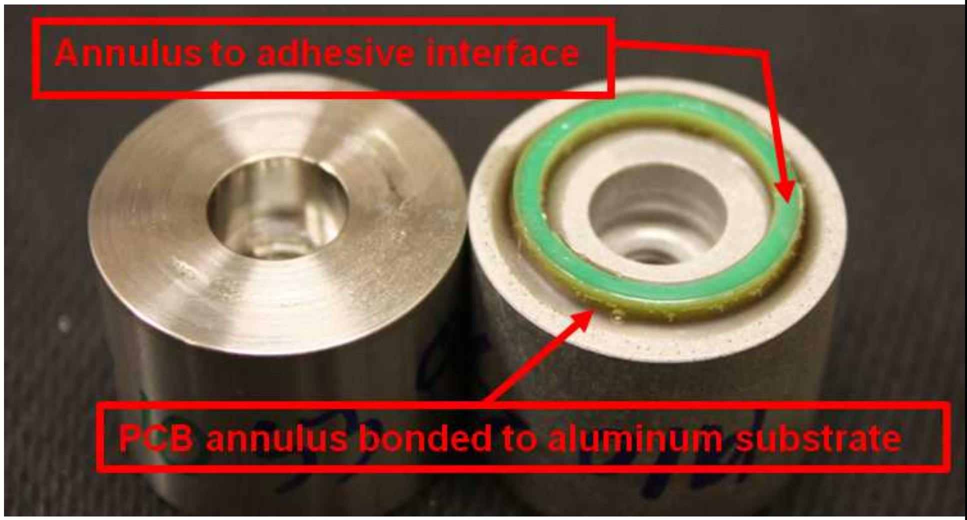
Dielectric Strength Results

- Unaged vs. 2 week aged dielectric strength
- Water does impact dielectric strength
- Coatings resistance to water maintain dielectric strength
- Customize coating selections based on operating environment

ASTM D149	Dielectric Strength unaged (V/mil)	Dielectric Strength 2wk 100%RH at 70C aged (V/mil)	% reduction in Dielectric Strength from 2wk 100%RH at 70C aged (V/mil)	% weight gain of water (g)
HA-84	2056	1250	39	2
Dymax X-617-11-1	1045	432	59	3
Humiseal UV40	1070	1100	approx 0	-1
Uralane 5750	1186	1214	approx 0	0
Dymax 9481	2167	1477	32	-3
Dymax 920557	1300	1379	approx 0	1
828/D230	1727	1577	9	2
Emcast 1902	2769	1200	57	1
Emcast 1910	1364	895	34	5

Napkin Ring Adhesion Testing

- Napkin Ring Geometry
  - Two substrates- S.S. and composite
  - Bonded together with an annulus of coating
  - Targeting PCB to coating interface



- Torsion tested
- Torque load at failure

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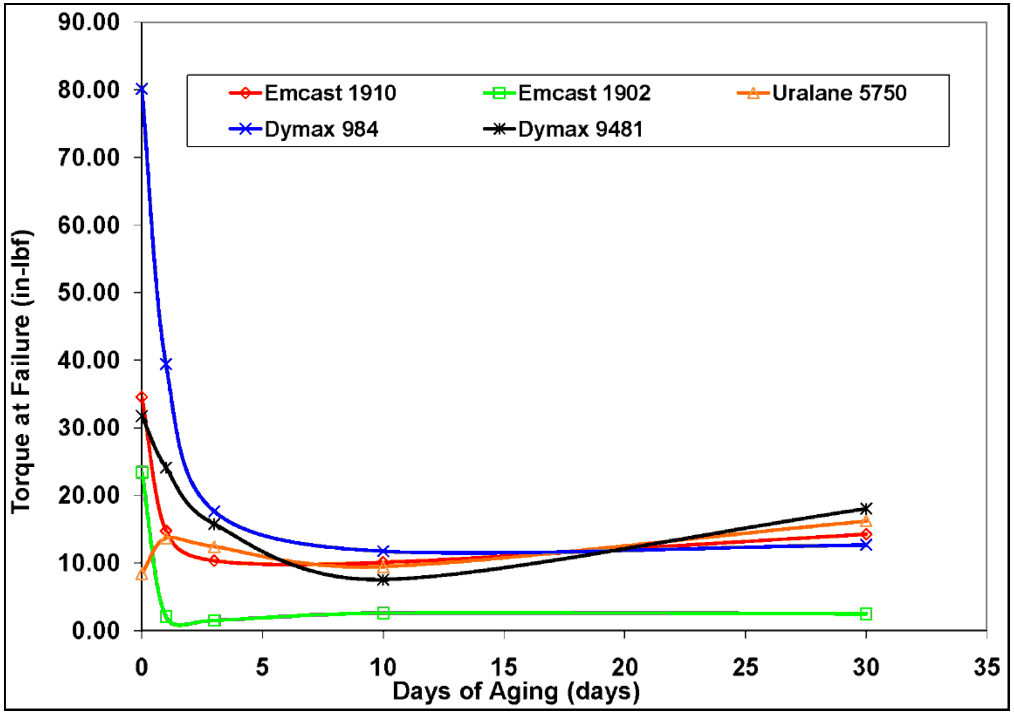
Napkin Ring Adhesion Results

- Aging Study
  - 70°C at ~100% RH
  - 0, 1, 3,10,30 day aging times
  - Two samples per configuration

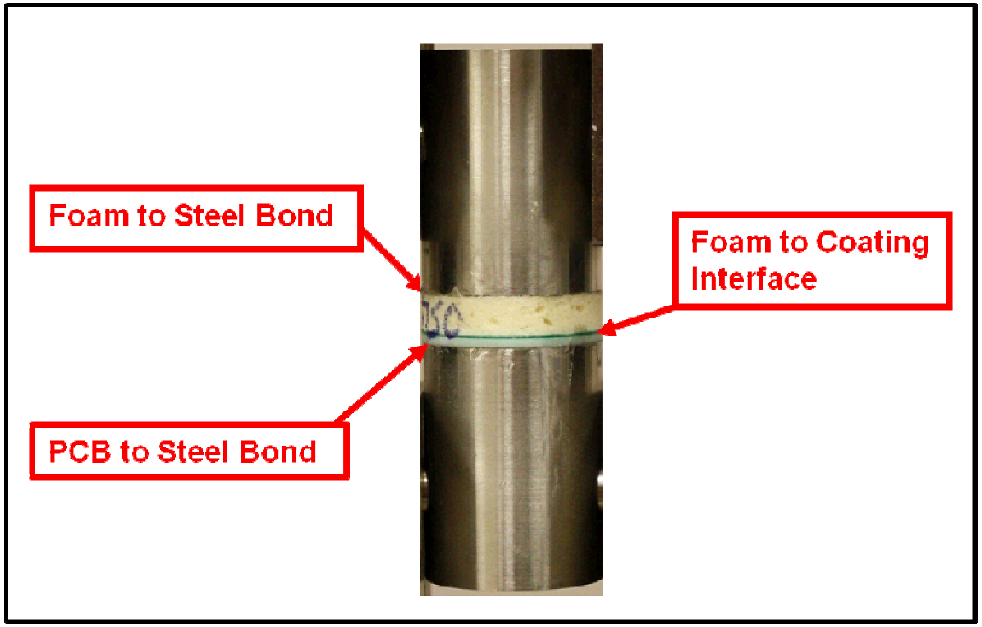


- All but 5750 experiences some loss in adhesion strength

- Compare to a 0 day 828/GMB/DEA napkin ring strength of 235 in-lb

Butt Tensile Adhesion Testing

- Butt tensile geometry
  - Two substrates and test interface
  - Foam adhesion cured directly on coating
  - Targeting PCB with coating to foam interface



- Tested in axial tension
- Stress at failure

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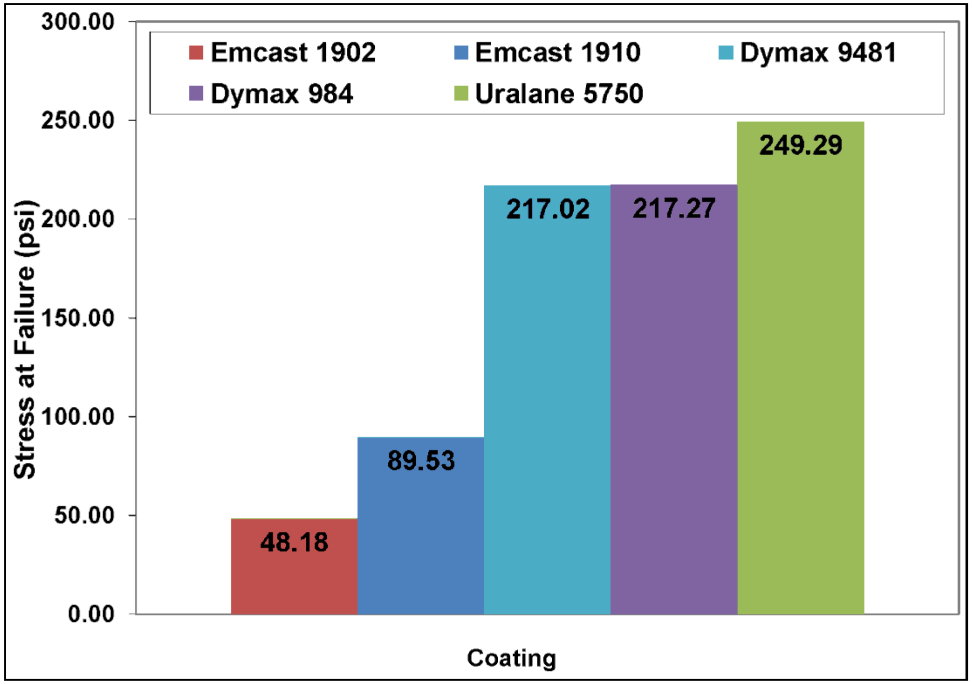
Butt Tensile Adhesion Results

- Two samples per configuration

- All failed at coating to foam interface



- Compare to 828/GMB/DEA strength of 5200 psi

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Conclusions

- Coating for flat traces and bead coating for protruding geometries can provide breakdown protection in the 40-65kV range depending on gap size
- The addition of foam can increase the electrical breakdown protection to 50-80kV range
- New packaging strategy vs. legacy packaging strategy
    - Equivalent from an electrical performance stand point
- Contact angle of coatings not impacted by type of solder mask
- Napkin ring and butt tensile adhesion strengths of coatings not as strong as legacy encapsulant, but adhesion is present
- Dielectric strength and adhesion can vary in a humid environment depending on the coating choice

Conclusions

- Approach was on target for the new packaging strategy
  - Coat with a conformal coating and bead coating
  - Package with a foam

  - Coating
    - Proven
    - Prevents electrical breakdown
    - Provides component protection
    - Still applicable
    - Rework is feasible

  - Foam
    - Proven
    - Prevents electrical breakdown
    - Still applicable
    - Can provide impact protection
    - Rework is still feasible
    - Light 4lbs instead of 65lbs

  - When Combined
    - Option of optimizing coating and foam combinations for operating environment

Future Work

- Larger test matrix to develop statistics
  - Would answer the question if polymers can be generalized in voltage breakdown strength
  - Age foam to asses its performance in a humid environment

- Develop a greater understanding for the behavior of the UV systems
  - adhesion differences between typical epoxy systems and the UV systems
  - Tg was measured on DSC, compare to TMA or DMA
  - Cohesive failure

- Test/Model packaging strategies in real applications for high voltage and high impact performance using combinations of coatings types and foam densities

Questions or Comments

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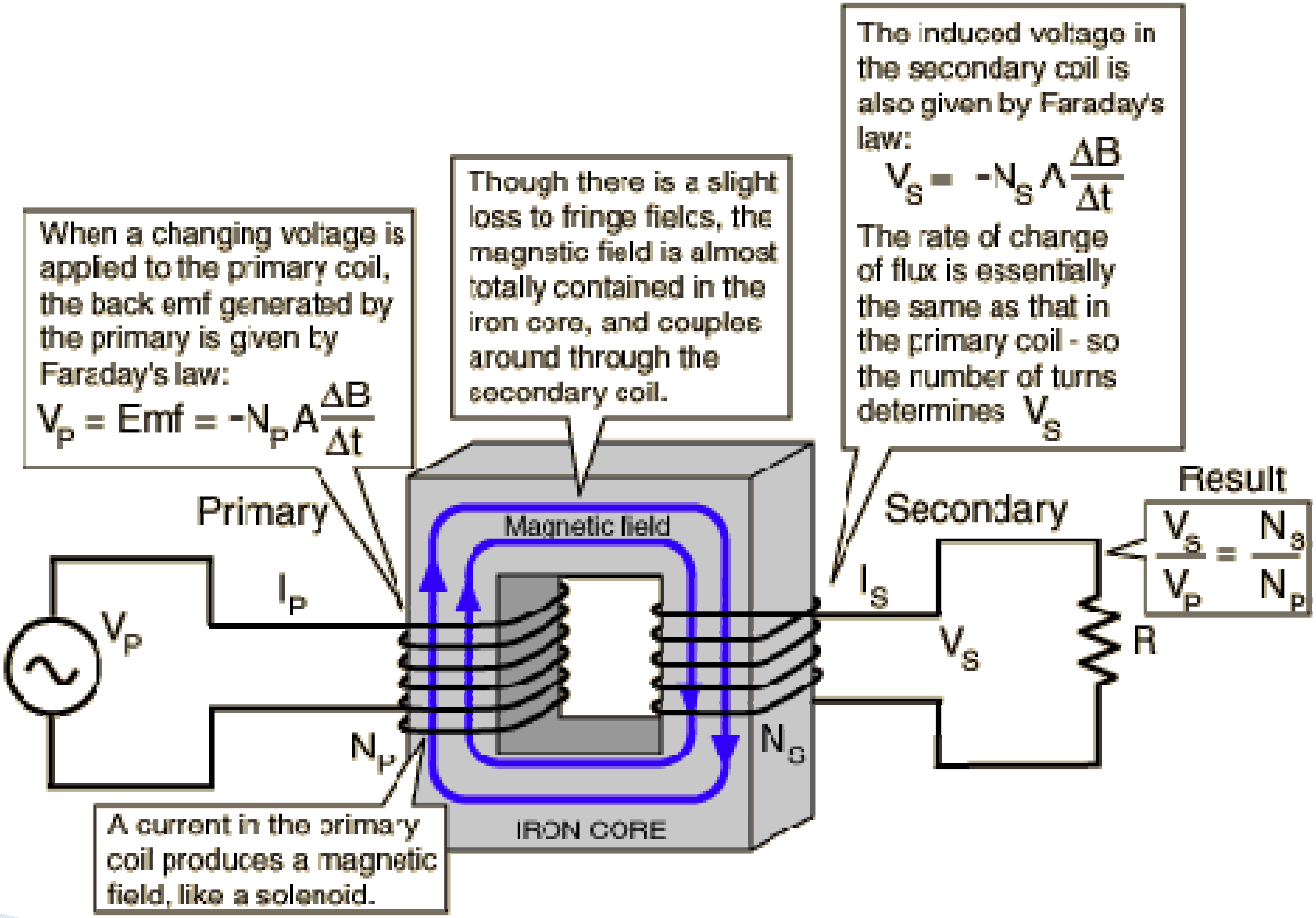
AC Test System -Transformer



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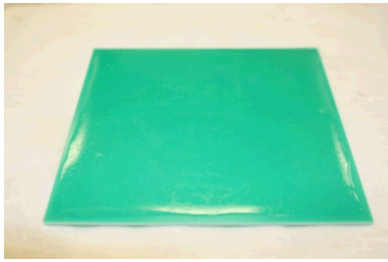
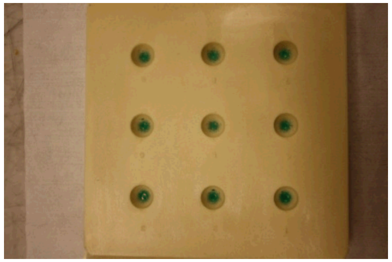
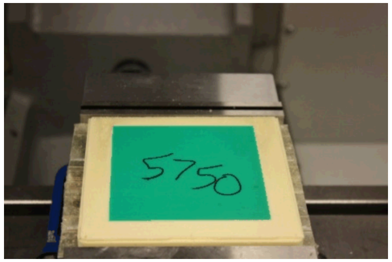
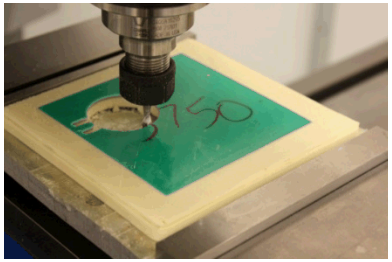
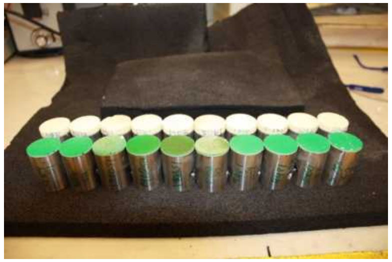
TBJ Test Coupon











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