LOCTITE ABLESTIK EMI 8880S

Data Package Conformal EMI Shielding Material

November, 2017

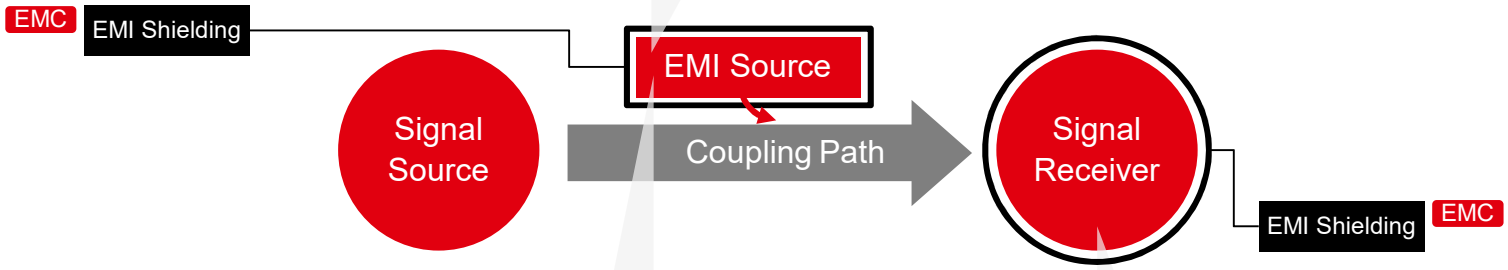
Agenda

- EMI Shielding Introduction
- Spray Solution Value Proposition and Technology Introduction
- Application Process Flow and Parameters
- Material Physical Properties
- Material Performance
- Material Reliability
- Summary

Electromagnetic Interference and Compatibility

Electromagnetic Interference (EMI)

- Unwanted signal (noise) emitted by electrical circuits carrying rapidly changing signals.
- Operational disruption of electronic devices when in the vicinity of an electromagnetic field caused by another device.



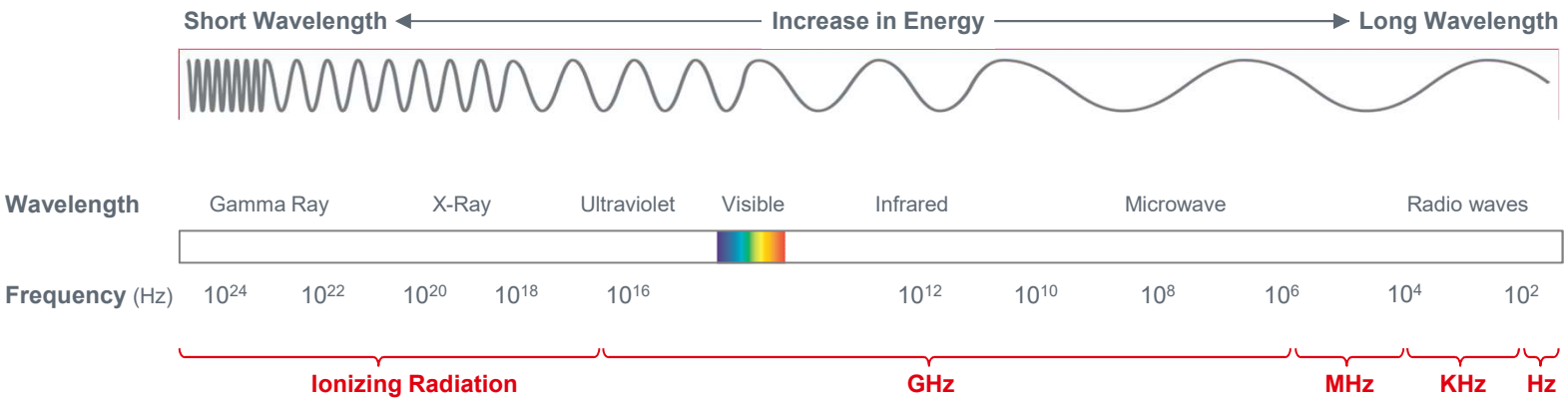
EMI Emission Examples

- High-speed clocking signals
- Digital noise from processors
- Digital power supplies (higher switching frequencies)
- Transmission interferences
- Buses, interconnects and networking interfaces

EMI Impact Examples

- Performance degradation of receiver signal processing circuits
- Unintended operation or malfunctions of electromechanical equipment, circuits, components
- Voltage breakdown or burnout of components and antennas

Electromagnetic Spectrum is a Limited Natural Resource



Examples of Typical Wireless Communication:	**Wireless**	**Wi-Fi (802.11b/g/n/ac)**	**Bluetooth**	**4G Cellular (LTE, WiMax)**	**5G**
	• 500MHz+	• 2.4~5GHz	• 2.4~2.485 GHz	• 0.7~2.7GHz	• 6GHz+

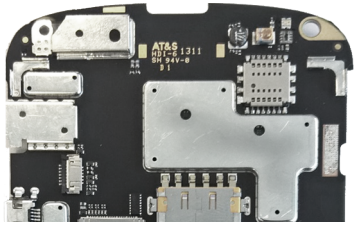
- The EM spectrum is a limited natural resource that must be maintained to allow reliable radio frequency communications.
- EMC regulatory bodies regulate and enforce EMC compliance with national or international standards such as International Electrotechnical Commission (IEC), Federal Communications Commission (FCC), Verband Deutscher Electrotechniker (VDE), International Special Committee on Radio Interference (CISPR), Comité Européen de Normalisation (CEN) and more.

Electronics EMI Shielding Progression

Board Level Moving to Package Level

Board Level Shielding

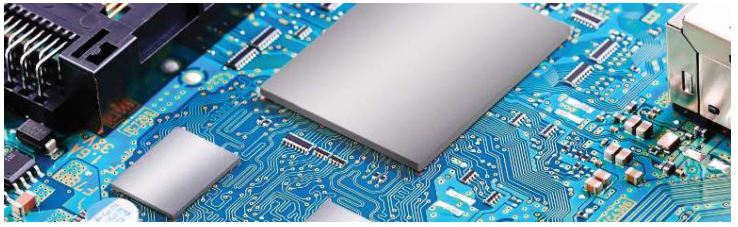
- Conductive enclosures soldered on the board



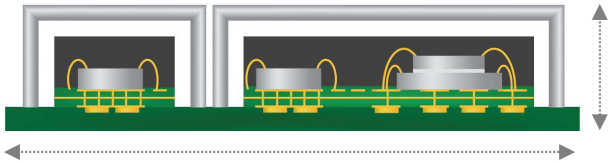
Requires large board space adding weight and thickness to the design with complex re-workability.

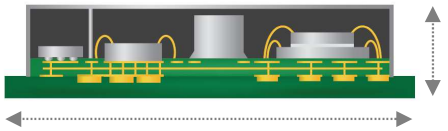
Package Level Shielding

- Conductive materials integrated into the package



Enables higher board density, design flexibility, simplified BOM for smaller, thinner, lighter device designs





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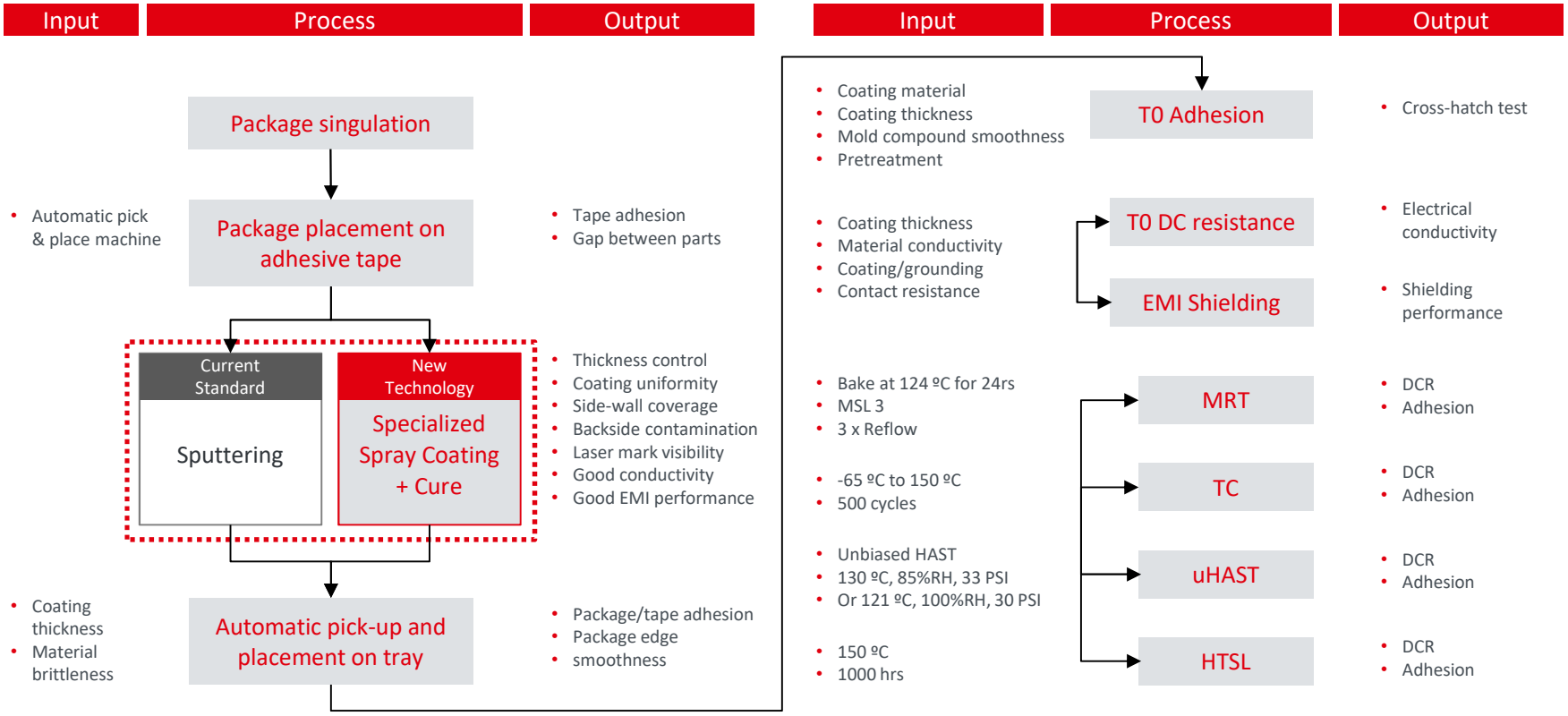
Package Level EMI Shielding Processing Flow



Specialized Spray vs. Sputtering

Material + Application

	Sputtering	Henkel Practical Solution: Specialized Spraying
Capital Investment	High	Low
Equipment Footprint	Large	Small
Equipment Maintenance Requirement	Strict and regular	Low
Process	Complicated, vacuum, need cooling	Simple, no vacuum, RT process
Throughput (UPH)	Low	High
Substrate Surface Quality Control	Tight. Requires specific surface treatment	Less sensitive to surface contamination
Easy Scalability	Low	High
Technology Awareness	High	New
Top Coating Thickness Control	Good	Good
Sidewall Coating Coverage	30~40% of top	50~60% of top
EMI SE / Electrical Performance	Good	Good
Coating Material Selection	Restricted selection (metal, alloy)	Flexible metal and polymer selection

Good Moderate Poor

Specialized Spray vs. Conventional Spray

Material + Application

			Henkel Practical Solution	
		Conventional Spray		Specialized Spray
Spray technology		Air spray		Ultrasonic spray
Atomization technology		Air pressure		Ultrasonic energy
Atomized droplet size		Micron		Submicron-Micron
Supported coating thickness (µm)		10 ~ >30µm		3 ~ >30µm
Sidewall coverage (vs. top)		10~50%		50~60%
Droplet uniformity		Poor		Good
Uniform thin coating (<10µm)		No		Yes
Coating uniformity		Poor		Good
Viscosity		<600cps		<600cps
Throughput (UPH)		High		High (~40 carriers per hour)
HVM availability		Commercial		Commercial
Equipment cost		Low		Low

Good Moderate Poor

Atomizing Spraying Technology

Ultrasonic Spray Atomization

Henkel Material | **Spray Technology Agnostic**

Compatible with Various Spray Technologies

- Henkel materials are compatible with all types of spray equipment.
- Atomizing spray technology provides most advantages for package level EMI shielding.

Ultrasonic Spray Coating Technology

- Ultrasonic energy atomizes material into small droplets
  - Droplet size is related to material and ultrasonic energy
  - Droplets are finer and more uniform than from conventional air spray
- Air pressure sprays and shapes the droplet configuration

Note Henkel can provide test data and recommendations on optimal spray technologies for various applications, however, Henkel does not directly sell or distribute spray machines.

Ultrasonic Spray Atomization

Process, Parameters, and Advantages

Parameters

- Ultrasonic frequency
- X-Y-Z motion
- Spray head height
- Spray head angle
- Spray speed
- Flow rate / pressure
- Interval + Pass

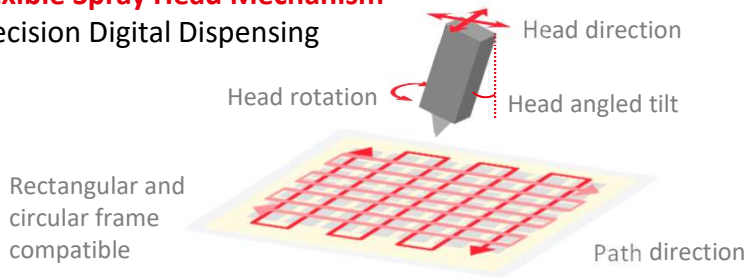
Key Advantages

- Tight thickness control (single µm level)
- Room temperature in air process
- Low material wastage (precision coating)
- No cooling required
- No special surface treatment required
- Adjustable parameters + angle for sidewall
- No moving parts in head for stable liquid delivery

Dual spray head system

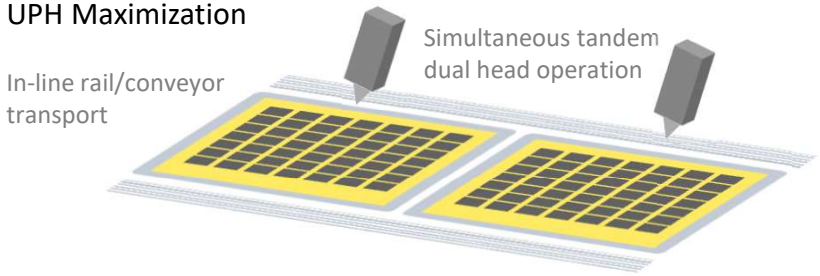
Flexible Spray Head Mechanism

Precision Digital Dispensing



Prism 800 Dual Spray Head System

UPH Maximization



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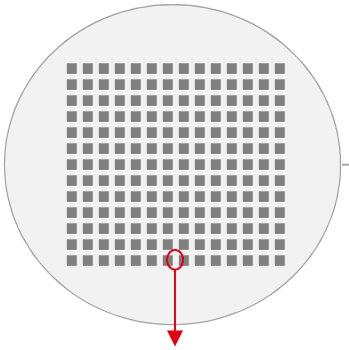
Spray Processing Flow

Lamination Format



Note: Tests were done using a ring carrier. However, square or rectangular carriers are recommended for actual production to maximize UPH.

Materials / Input
- Die size: Multiple size molded substrate
- Dicing Tape

Lamination
- Manual placement on to dicing Tape
- Gap: 1 mm

Spray Coating
- Equipment: USI Prism 800
- Spray Head: CAT ILDS 35 KHz
- Material : LOCTITE ABLESTIK EMI 8880S

Cure
- Equipment: Oven
- Cure Conditions: 175°C for 1 hour

Coating Thickness & Quality Measurement
- Cross-section, SEM, visual inspection

Spray Coating Parameters

Parameter	Standard Value
Flow rate*	0/8-3ml/min
Spray pitch	10 mm
Speed*	400 mm/sec
Air pressure	400 KPa
Z-height	40 mm
Head angle*	30 degrees
# of passes	4

Spray Processing Key Parameters

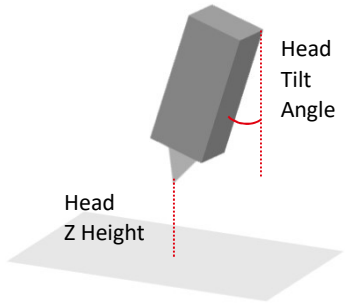
Parameters for Full Four Sidewall Coverage

Software-Controlled Spray Parameters

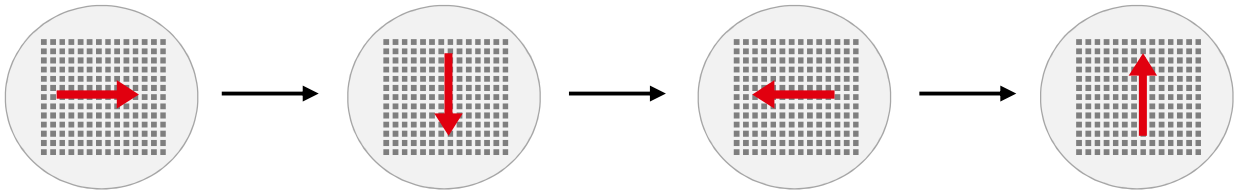
Parameter	Type	Standard Value
Flow rate	Variable	0.8 – 3 ml/min
Speed		200 – 600 mm/sec
Spray Pitch	Constant	10 mm
Air Pressure		400 K Pa
Z-height		40 mm
Head angle		30°
Spray Direction (# of Pass)		4

Used for coating thickness control

Spray Head Parameters



Spray Head Directions For 4 Sidewall Coverage



Curing Parameters

Curing Equipment and Conditions	
Oven	Convection oven
Atmosphere	Air
Oven Preheat Condition	Preheat to 175°C
Cure Profile	1hr at 175°C in preheated oven

Storage and Handling

	Conditions	Time
Storage	-40°C	1 year
Work Life	25°C	24 hours
Open Time	25°C	8 hours

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Material Properties

LOCTITE ABLESTIK EMI 8880S

Physical Properties	
Material Name - Commercial	LOCTITE ABLELSTIK EMI 8880S
Technology	Electrically Conductive
Application Method	Spray
Filler Type	Proprietary Ag filler
Volume Resistivity (Ω·cm)	7.9×10^{-6}
Coating Thickness Range (µm)	3 ~ 10
Rec. Dried Coating Thickness (µm)	4±1
Viscosity, 5rpm (cps)	550
Thixotropic Index	1.3
Curing Condition	175ºC, 1 hour, in air
Permeability	1
Shielding Effectiveness (dB)	90
Adhesion on EMC (Cross hatch) ASTM	5B
Compatible Surface	MC

Key Features

- Designed for spray coating
- High bulk conductivity
- Flexible coating thickness
- Excellent adhesion on untreated epoxy mold compound surface (and other materials)
- Thermal cured material

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Spray Coating Performance

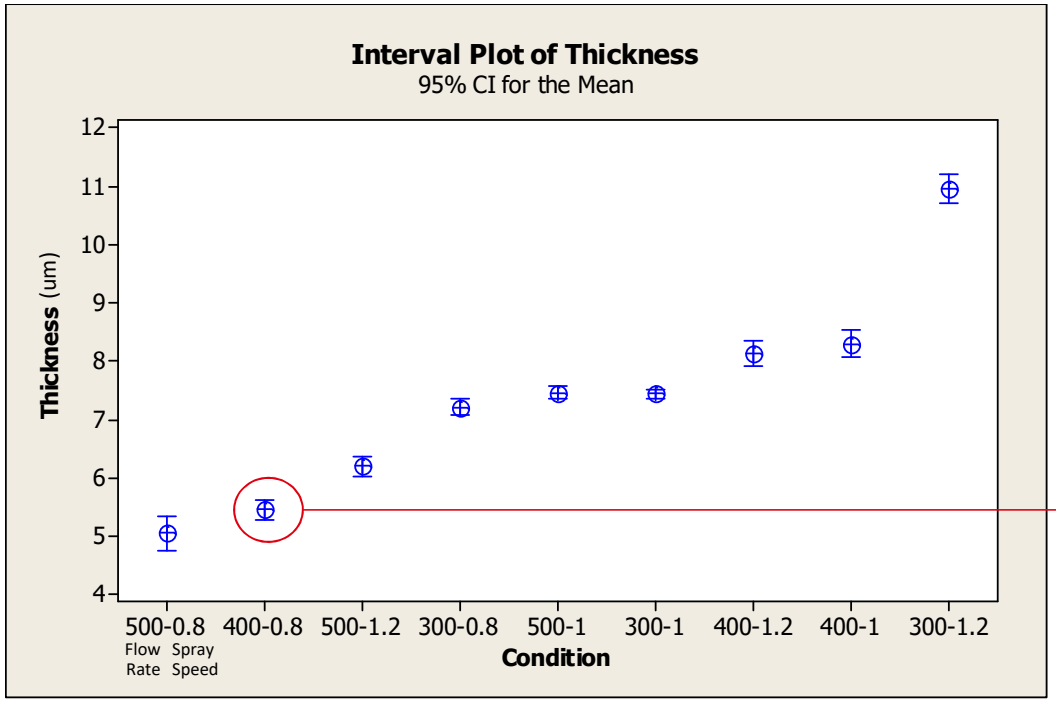
Spray Coating Process DOE

Objective: To evaluate how different parameters within the machine effects material thickness after cure.

Leg	Flow Rate (ml/min)	Spray Speed (mm/sec)
1	0.8 ml/min	300 mm/sec
2	1 ml/min	300 mm/sec
3	1.2 ml/min	300 mm/sec
4	0.8 ml/min	400 mm/sec
5	1 ml/min	400 mm/sec
6	1.2 ml/min	400 mm/sec
7	0.8 ml/min	500 mm/sec
8	1 ml/min	500 mm/sec
9	1.2 ml/min	500 mm/sec

Spray Coating Performance

Thickness & Uniform vs. Coating Parameters

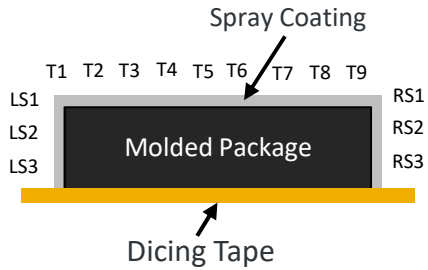


- Uniform coating was observed for all the spray parameters.
- Standard parameter for 5 µm top thickness.

Spray Coating Performance

Thickness Uniformity vs. Spray Coating Parameters

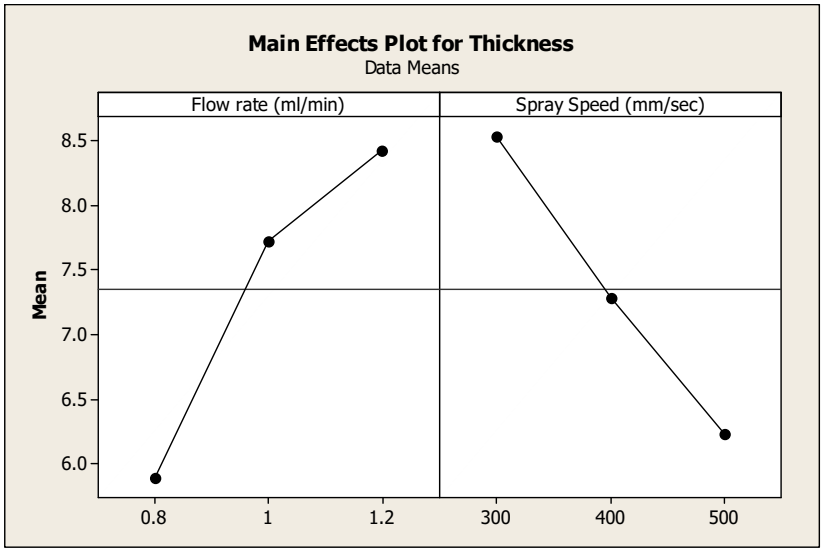
Leg	Condition	Left Side			Top						Right Side		
		LS1	LS2	LS3	T4	T5	T6	T7	T8	T9	RS1	RS2	RS3
1	300-0.8	3.2	3.2	3.2	7.3	8	7	7	7	7	3.2	3.2	3.2
2	300-1	4.2	3.2	3.2	7.4	7.4	7.4	8	7.4	7.4	4.2	3.2	3.2
3	300-1.2	5.3	5.3	4.2	11.5	11.5	11.5	11.5	10.5	10.5	5.3	5.3	3.2
4	400-0.8	3.2	2.1	2.1	5.3	5.3	5.3	5.3	5.3	5.3	3.2	2.1	2.1
5	400-1	4.2	3.2	3.2	8.4	8.4	8.4	8.4	8.4	7.4	4.2	3.2	3.2
6	400-1.2	4.2	3.2	3.2	7.4	7.4	8.4	8.4	8.4	7.4	4.2	3.2	3.2
7	500-0.8	4.2	3.2	3.2	4.2	4.2	4.2	4.2	5.3	5.3	3.2	3.2	3.2
8	500-1	3.2	3.2	3.2	7.4	7.4	7.4	7.4	7.4	7.4	3.2	3.2	3.2
9	500-1.2	2.1	2.1	2.1	6.3	6.3	6.3	6.3	6.3	6.3	2.1	2.1	2.1

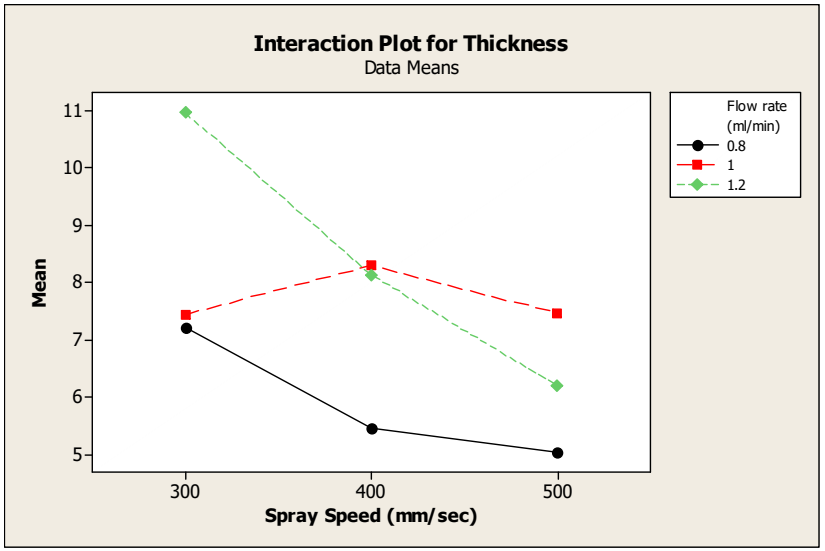


- Different points of the left, top, and right sides were measured.
- Uniform coating on both top and side wall for all the spray parameters.

Spray Coating Performance

Coating Thickness Main Effect and Interaction Plot



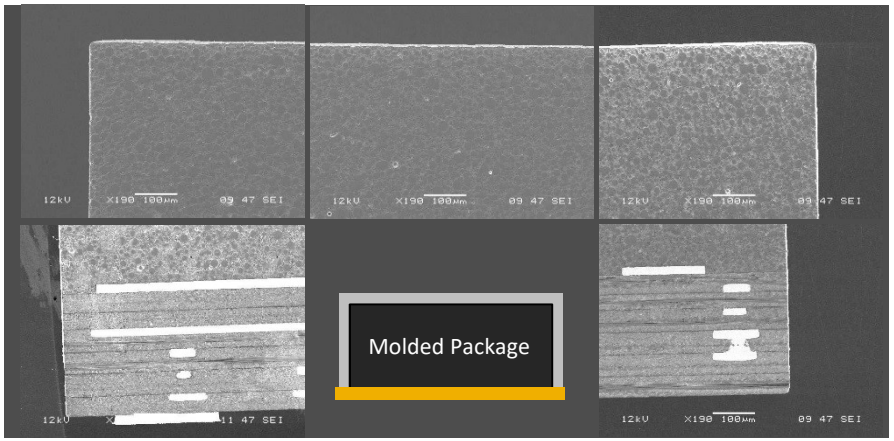


- Flow rate and spray speed have a significant impact on coating thickness. As flow rate increases thickness increases, and as spray speed increases thickness decreases.

Spray Coating Quality

Recommended Spray Parameters for Different Thicknesses

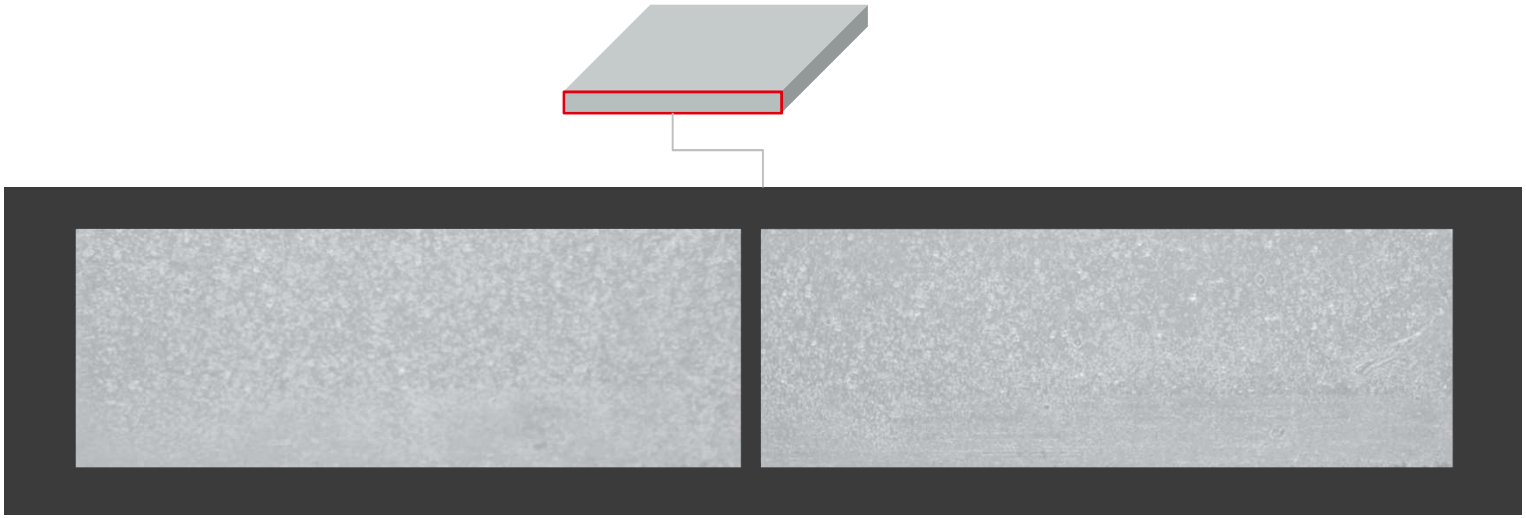
Spray Parameters		Thickness Results	
Spray Speed	Flow rate	Top thickness	Side thickness
400	0.8	5 µm	3 µm
500	1.2	6 µm	3 µm
300	0.8	7 µm	3.5 µm
400	1.2	8 µm	4 µm
300	1.2	10 µm	5 µm



- Uniform coating and thickness on both top and side walls.

Spray Coating Performance

Package Sidewall Coverage

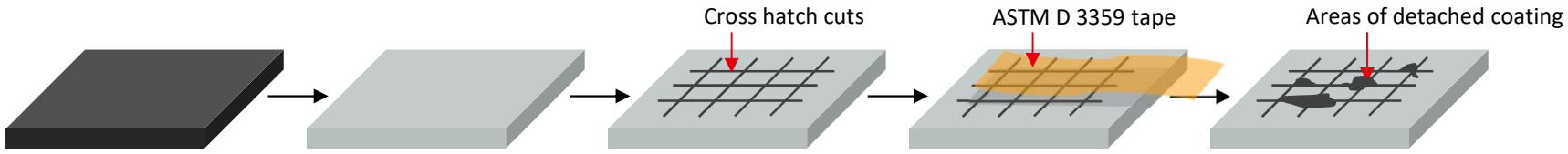


- All coated packages shows good coverage on all sides.

Adhesion Performance

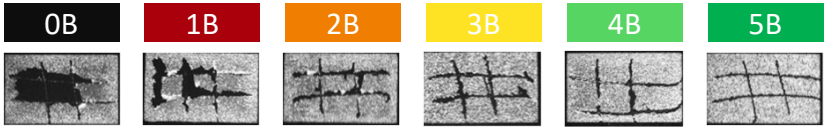
Adhesion Testing Process Flow

Cross Hatch Test



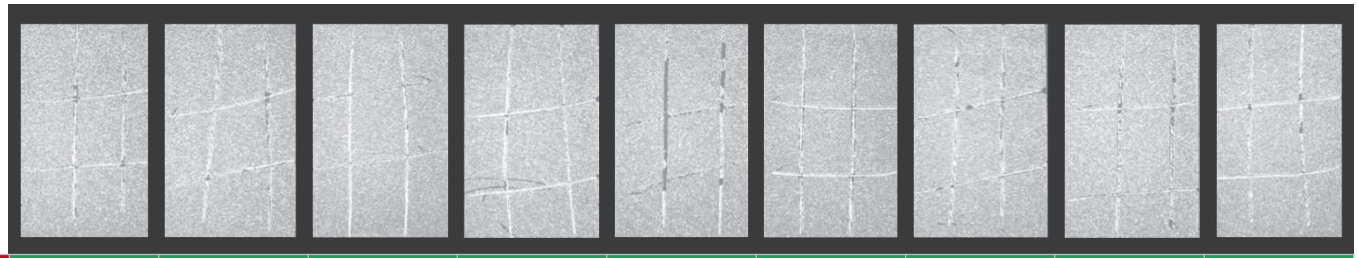
- EMC molded part
- EMC molded part with coating
- EMC molded part with coating and cross hatch cuts
- EMC molded part with coating and cross hatch cuts
- Use adhesive tape to pull off coating

Representative Adhesion Results



Adhesion Performance

Initial Adhesion vs. Coating Thickness

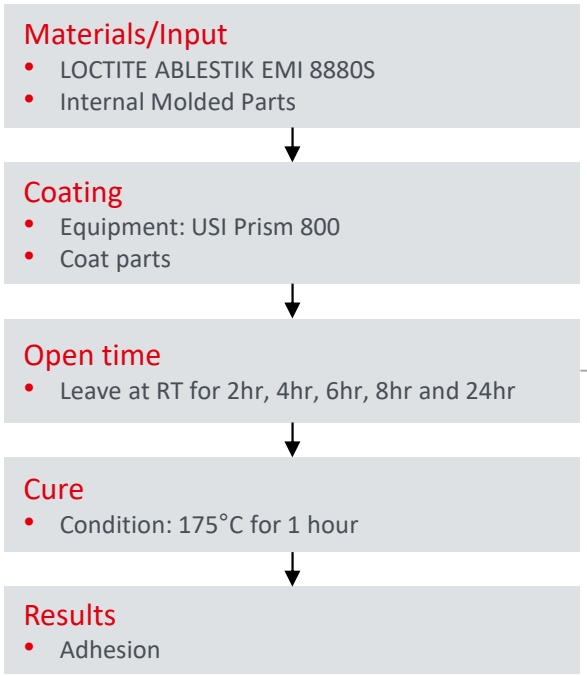


Adhesion	5B	5B	5B	5B	5B	5B	5B	5B	5B
Thickness (um)	7	7.5	10	5	8	8	5	7.5	6
Flow rate (ml/min)	0.8	1	1.2	0.8	1	1.2	0.8	1	1.2
Spray Speed (mm/sec)	300			400			500		

- All of the recommended coating conditions and thicknesses tested provide 5B adhesion results.

Open Time Performance

Testing Flow



Open Time

Refers to time interval after spray coating and before curing

Open Time Performance

Adhesion Results

Adhesion	5B	5B	5B	5B	5B
Thickness (um)	5	5	5	5	5
Open Time	Initial	2 hours	4 hours	6 hours	8 hours

- Up to 8hr opening time has no significant on adhesion.

Material Stability Performance

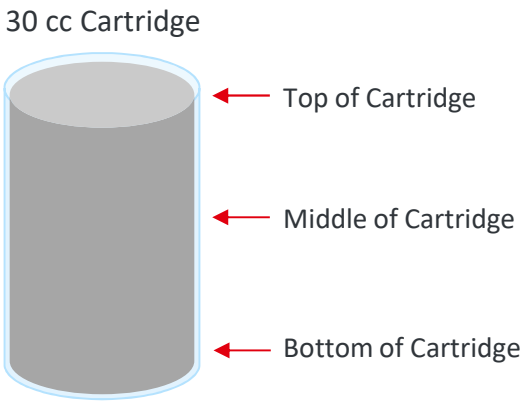
Testing Flow

Materials/Input
- LOCTITE ABLESTIK EMI 8880S
- Internal molded parts

Coating
- Equipment: USI Prism 800
- Coat full cartridge at different times

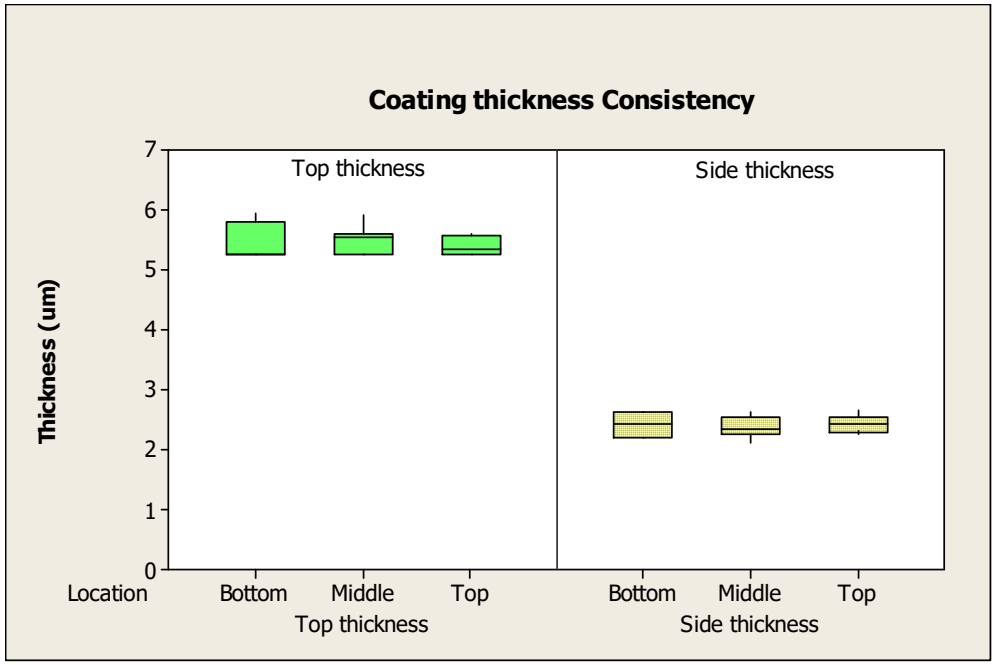
Cure
- Condition: 175°C for 1 hour

Results
- Cross-section, adhesion



Material Stability

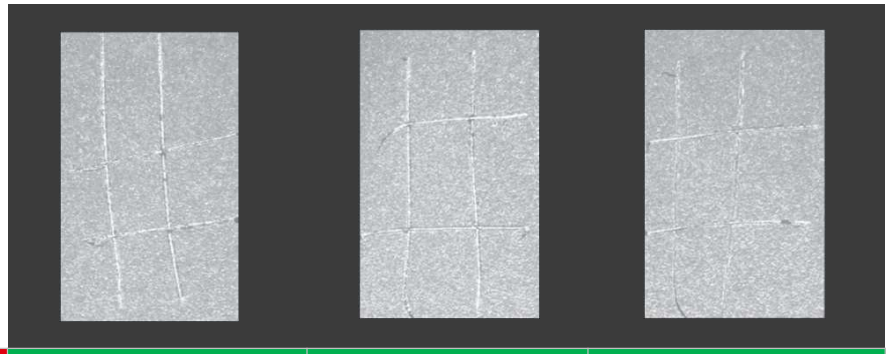
Coating thickness consistency

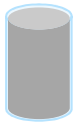


- Coating thicknesses of the package coated with the materials from different locations of the cartridge are consistent
- This indicates material is stable without stirring during spray

Material Stability

Adhesion Consistency



Adhesion	**5B**	**5B**	**5B**
Thickness (µm)	5	5	5
Material	Bottom of cartridge	Middle of cartridge	Top of cartridge
			

- Adhesion of the package coated with the materials from different location of the cartridge is consistent.
- It indicates material is stable without stirring during spray

Processing Uniformity Performance

Testing Flow

Materials/Input
- LOCTITE ABLESTIK EMI 8880S
- Internal molded parts

↓

Coating
- Equipment: USI Prism 800
- Coat full wafer

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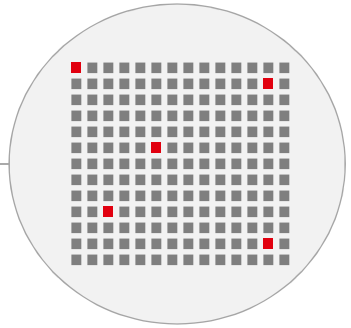
Cure
- Condition: 175°C for 1 hour

↓

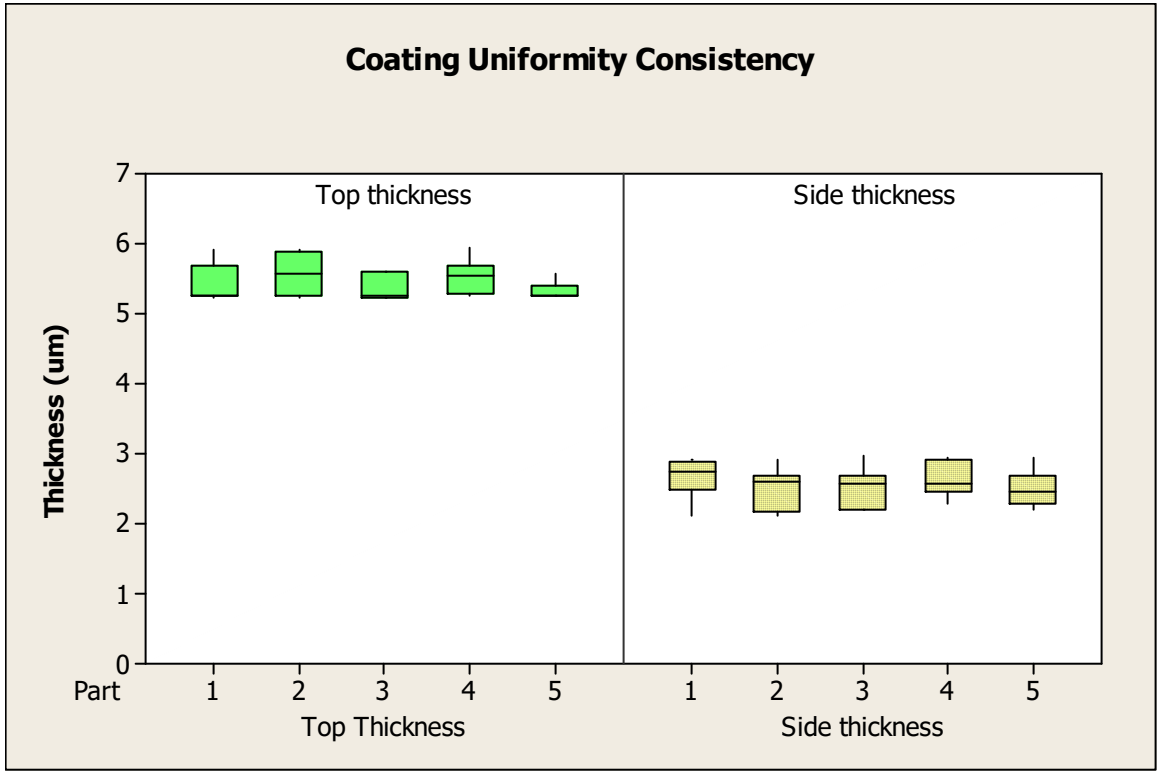
Results
- Cross-section, adhesion



Cross-section & Adhesion
5 parts chosen from random locations

Processing Uniformity Performance

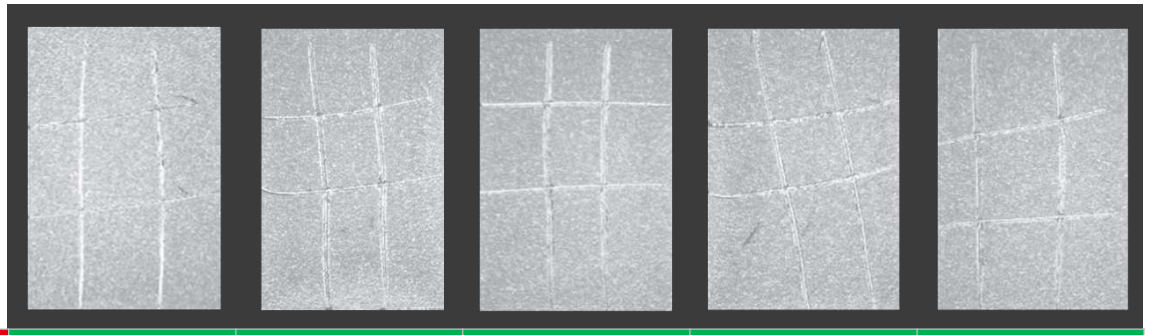
Coating thickness consistency



- Coating thickness of the package at different location on the carrier is consistent

Processing Uniformity Performance

Adhesion for Random Units



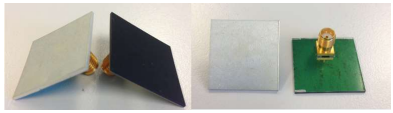
Adhesion	5B	5B	5B	5B	5B
Thickness (µm)	5	5	5	5	5
Chosen Unit	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5

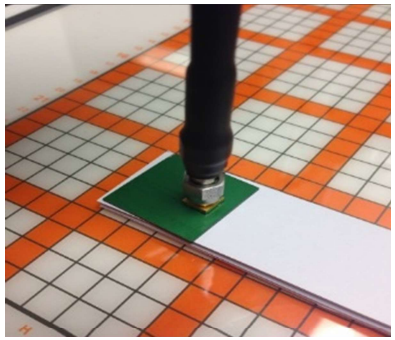
- Adhesion of the package at different location on the carrier is consistent

Material Performance

Shielding Effectiveness

Test Method





- Uses 1GHz and 5GHz antennae and a real-time EM scanner (designed for EMI pre-compliance and diagnostics).

Test Results

Method	Coating Speed	Flow rate	Top thickness	Side thickness	EMI Shielding Effectiveness at 5G	EMI Shielding Effectiveness at 1G
Sprayed	400	0.8	5 µm	3 µm	48.2	45.9
	300	0.8	7 µm	3.5 µm	48.2	45.2
	400	1.2	8 µm	4 µm	51.3	46.6
	300	1.2	10 µm	5 µm	52.7	47.8
Sputtered	N/A	N/A	3 µm	1 µm	43	41.2

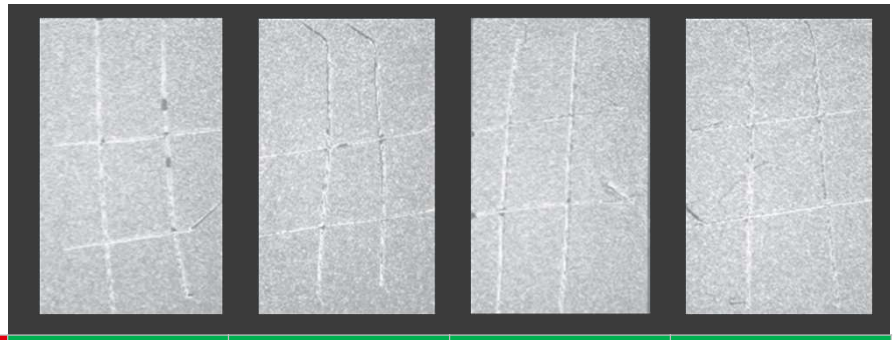
- All recommended coating parameters give better EMI performance than sputtering.
- The EMI performance is related with coating thickness.

Agenda

- EMI Shielding Introduction
- Spray Solution Value Proposition and Technology Introduction
- Application Process Flow and Parameters
- Material Physical Properties
- Material Performance
- Material Reliability
- Summary

Material Reliability

Adhesion Post Reliability Test – PCT

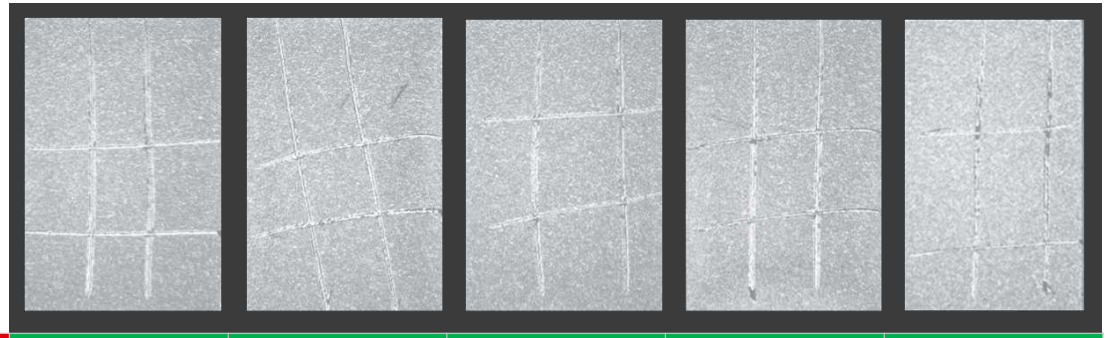


Adhesion	5B	5B	5B	5B
Thickness (µm)	5	10	5	10
Flow rate (ml/min)	0.8	1.2	0.8	1.2
Spray Speed (mm/sec)	400	300	400	300
Stage	Initial		Post- PCT	

- All units tested pass PCT testing.

Material Reliability

Adhesion Post Reliability Test – HTS testing (150°C)

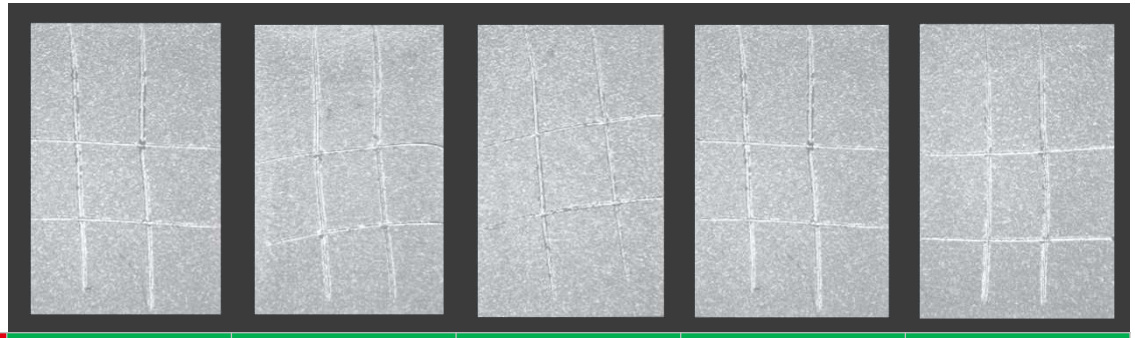


Adhesion	5B	5B	5B	5B	5B
Thickness (µm)	8	8	8	8	8
Flow rate (ml/min)	1.0	1.0	1.0	1.0	1.0
Spray Speed (mm/sec)	400	400	400	400	400
Stage	Initial	250 hours	500 hours	750 hours	1000 hours

- All units can withstand HTS testing up to 1000 hours with good adhesion.

Material Reliability

Adhesion Post Reliability Test – MSL3 + TCT (1000 cycles)



Adhesion	5B	5B	5B	5B	5B
Thickness (µm)	8	8	8	8	8
Flow rate (ml/min)	1.0	1.0	1.0	1.0	1.0
Spray Speed (mm/sec)	400	400	400	400	400
MSL3 + TCT	Initial	250 cycles	500 cycles	750 cycles	1000 cycles

- All units tested pass reliability up to TC-1000.

Agenda

- EMI Shielding Introduction
- Spray Solution Value Proposition and Technology Introduction
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Summary

Coating Capability

- LOCTITE ABLESTIK EMI 8880S achieves uniform top and sidewall coating for all the spray parameters tested
  - Spray speed and flow rate have significant effect on coating thickness and are the key parameters to adjust the coating thickness
  - 5-10um uniform coating can be achieved by adjusting flow rate and spray speed

Material Robustness

- LOCTITE ABLESTIK EMI 8880S shows 8 hours opening time. No significant adhesion drop was observed after 8 hours open time
- LOCTITE ABLESTIK EMI 8880S has no filler settlement in the cartridge and shows consistent performance for the whole cartridge without stirring.

Adhesion and EMI Shielding Performance

- All the LOCTITE ABLESTIK EMI 8880S parts tested show good adhesion and reliability performance
- LOCTITE ABLESTIK EMI 8880S shows equal or better EMI performance than sputtering at both 1GHz and 5GHz.