IEEE Build-Up Substrate Symposium (BUSS)

Substrate Materials for Advanced Packaging

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Resonac Corporation

May 2nd, 2024

Today's Contents

1. Corporate Introduction

2. Introduction for Core & Prepreg for Advanced Package Substrate
   - Motivation and Challenges in Semiconductors
   - Resonac's Proposal for Market Requirement
   - Low CTE Materials
   - Super Flat Cores

3. Future Technology Roadmap

Today's Contents

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   - Super Flat Cores

3. Future Technology Roadmap

January 2023: Resonac was Born

RESONAC 4

Showa Denko

Showa Denko Materials
(Former Hitachi Chemical)

RESONAC
Chemistry for Change

January 2023: Resonac was Born

RESONAC 5

Resonate
共鳴する・響き渡る

× **Chemistry**の「C」

RESONAC
Chemistry for Change

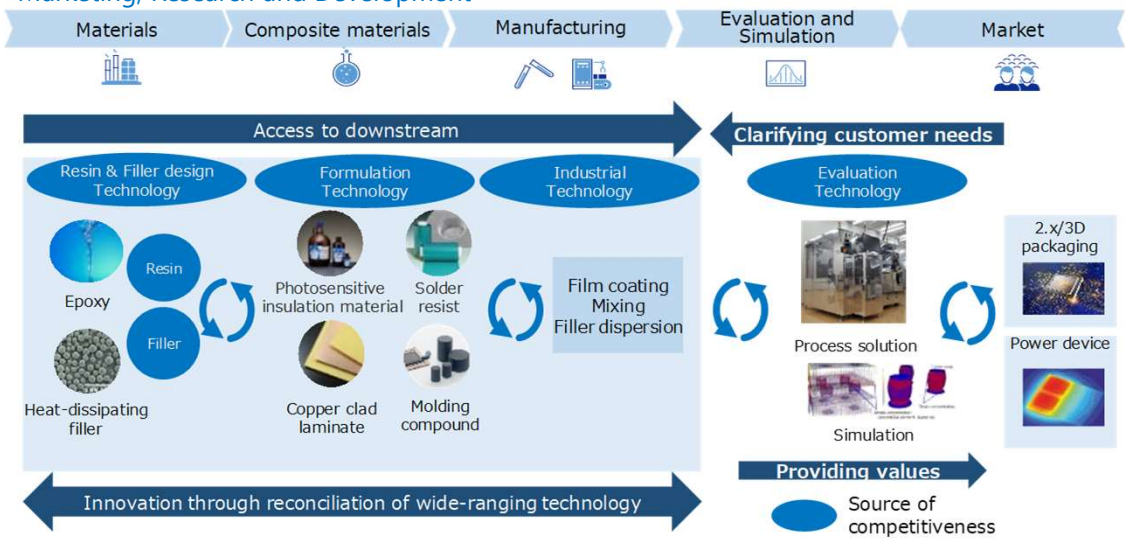
共創型化学会社

Co-Creative Chemical Company

Strategy to Establish Competitive Advantage

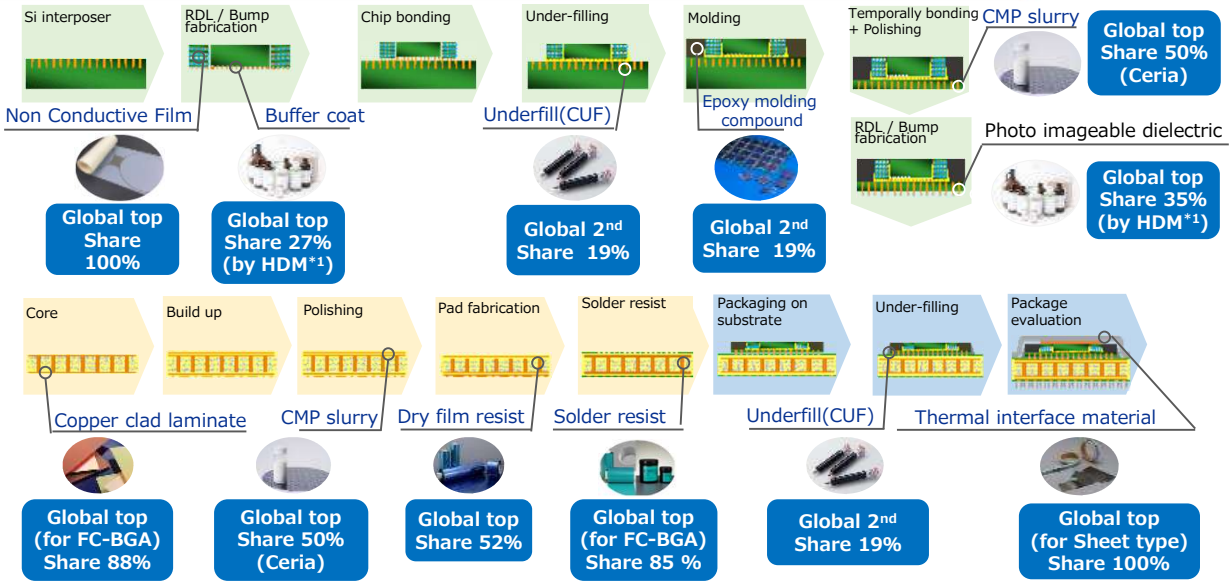
RESONAC 6

- Marketing, Research and Development -



Material Lineup for 2.xD & 3D Package [*Overall Share]

RESONAC 7



*1 : Share of Buffer coat and Photosensitive insulating material by HD Microsystems, *2 : Global market shares are based on data gathered by RESONAC

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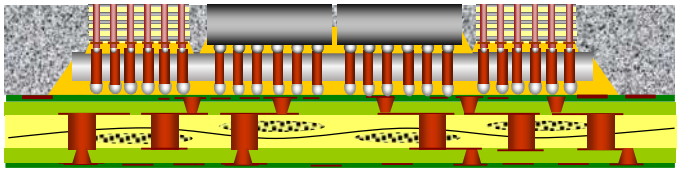
Motivation and Challenges in Semiconductors

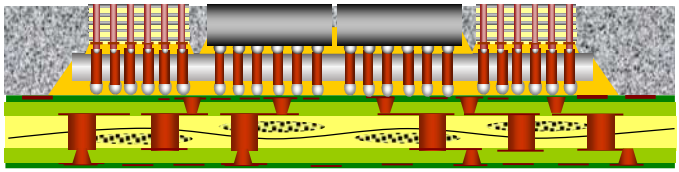
RESONAC 9



Motivation	Approach	Challenges
High Speed	HSIO on Substrate	Signal Loss ➔ Electrical Property, Body size
Large Capacity of Data Processing	Multi-Core on Die, Large Die ➔ Yield, Manufacturing Cost	Complex Assembly ➔ Chiplet ➔ Power Delivery ➔ Large Body Size
Low Power Consumption	Narrow Pitch ➔ Bump Pitch Scaling	High Density Circuit

Resonac's proposal for Large Size Substrate

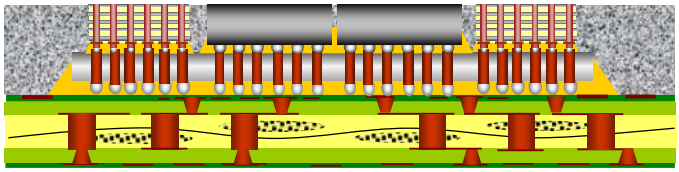
RESONAC 10



Challenge in Semiconductors	Requirement To Substrate	Breakthrough During Substrate Process	Proposal / Solution From Material Stand-point
Large body size	Low Warpage High Yield	Warpage Control Shrinkage Control	Low CTE, High Modules Shrinkage Accuracy
High density circuit	Narrow pitch	Fine L/S Fabrication Narrow pitch TH	High Drill-processability
Electrical property	Signal Integration	Pattern, PKG Design	Low Dk/Df
Power delivery	More efficiency Power Delivery	Embedded Multi-layer core (MLC structure)	Super FLAT Core High Resin flow Prepreg

Resonac's proposal for Large Size Substrate

RESONAC 11



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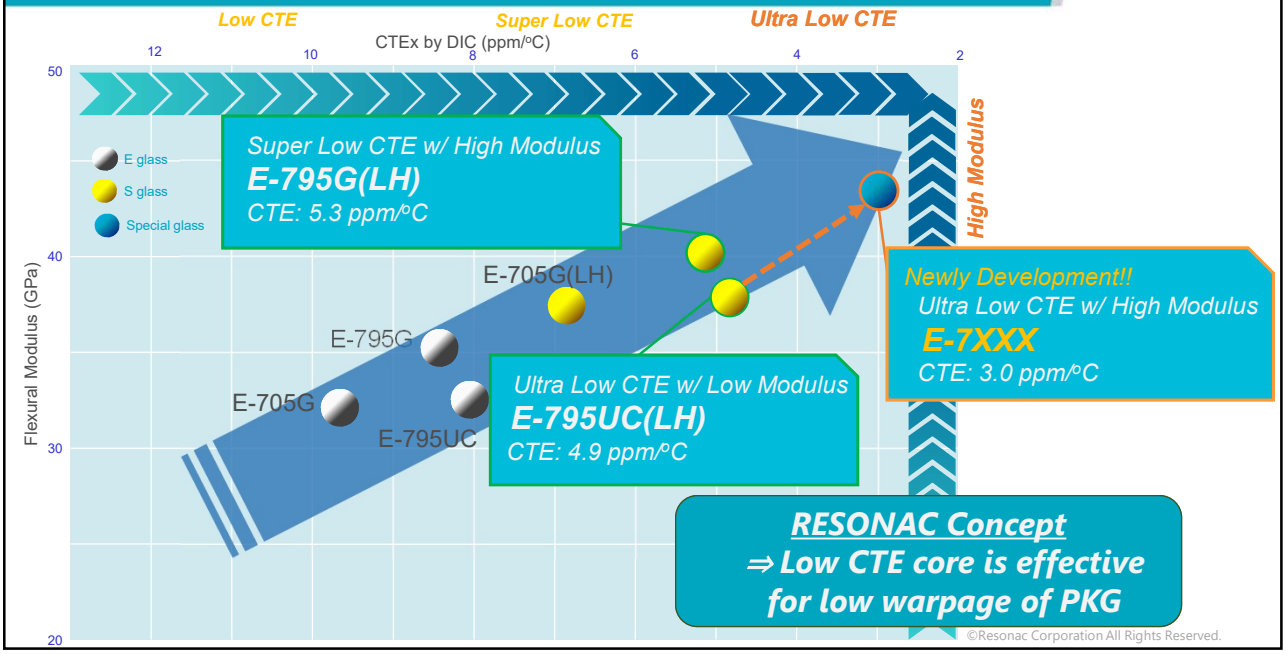
Material Development Direction

RESONAC 12



For Warpage Control [Material Properties, CTE]

RESONAC 13

Item	Conditions		E705G		E795G		E795UC	
			E705G	E705G(LH)	E795G	E795G(LH)	E795UC	E795UC(LH)
Glass type	Glass type		E	S	E	S	E	S
	Weave density		Std	HD	Std	HD	Std	HD
Tg	TMA	°C	260	260	280	280	280	280
	DMA		300	300	330	330	330	330
CTE (Comp.)	α1 (X)	ppm/°C	9.5	7.2	8.0	5.6	7.5	4.9
	α2 (X)		1.1	1.0	1.0	1.0	1.0	1.0
CTE (DIC)	140-180°C	ppm/°C	9.6	6.9	8.5	5.5	8.1	4.9
	180-220°C		10.3	7.2	8.9	6.0	8.0	4.9
Peel Strength	12 μm	kN/m	0.9	0.9	0.7	0.7	0.7	0.7
Flexural Modulus	A	GPa	33	38	36	41	33	38
Dk	1 GHz	-	4.5	4.2	4.4	4.2	4.2	4.0
Df	1 GHz	-	0.008	0.008	0.006	0.006	0.009	0.009

*1; For 800 μm thickness
*2; Dk/Df measured by SPDR method.

For Warpage Control [Warpage Simulation]

RESONAC 14

➢ Warpage Simulation Results with Each Material Set and Thickness Variation

- Simulation method: 3D elastic analysis
  ΔWarpage: Difference between 25 °C and 260 °C
  Benchmark: 705G(LH) 800μm
- Simulation model
  - Substrate: 5-2-5 construction
  - Package size: 60 x 60 mm
  - Die size: 25 x 25 mm
  - Die height: 725 μm
  - Bu thickness: 30μm
  - Underfill thickness: 80 μm (CEL-C-3730S-012L3-20)
  - SR thickness: 20μm (SR7300)
  - Cu thickness: 18μm
  - Cu coverage: 80%

Core thickness (μm)	ΔWarpage index				
	705G(LH)	795G(LH)	795UC	795UC(X)	795UC(LH)
200	2.04	1.88	2.17	2.05	1.87
400	1.55	1.36	1.70	1.56	1.33
600	1.23	1.04	1.38	1.24	1.00
800	**1.00**	0.82	1.15	1.01	0.78
1000	0.83	0.67	0.97	0.84	0.63
1200	0.71	0.56	0.83	0.71	0.51
1400	0.61	0.47	0.72	0.62	0.43
1600	0.53	0.41	0.64	0.54	0.36

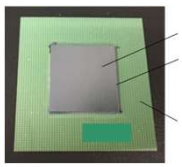
Warpage Performance in Thickness Variation can be simulated by RESONAC Technology.

For Warpage Control [Warpage Evaluation]

RESONAC 15

➢ Warpage Performance with RESONAC Low CTE Cores

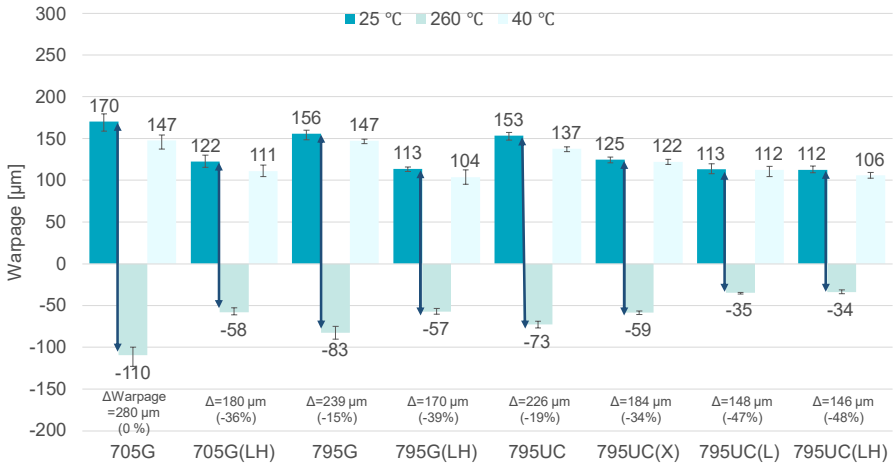
TV construction (2-2-2)



Convex

Concave

- Substrate: 2-2-2 construction
- Package size: 40 x 40 mm
- Chip size: 20 x 20 mm
- Chip height: 775 µm
- Core thickness: 1000 µm
- Bu thickness: 30 µm
- Underfill: CEL-C-3730series
- SR thickness: 19µm (SR-FA)
- L1,2,5,6: 18 µm Cu 80%
- L3,4: 12 µm Cu 80%



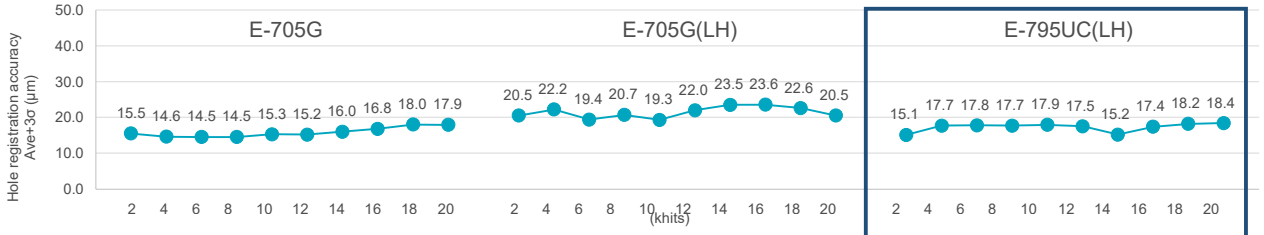
E795UC(LH) has the Best Warpage Performance in he Evaluation

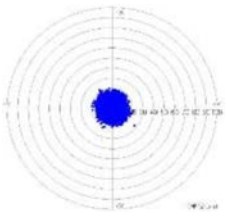
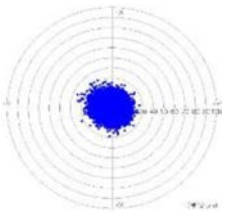
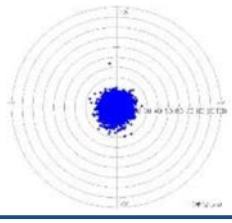
For Fine Pitch Scaling [Drilling Performance, φ0.135 mm]

RESONAC 16

➢ Mechanical Drilling Performance

*t1.0 mm w/ 12µm Cu, 2 panels stack, φ0.135mm



Item	E-705G	E-705G(LH)	E-795UC(LH)
Hole Position			

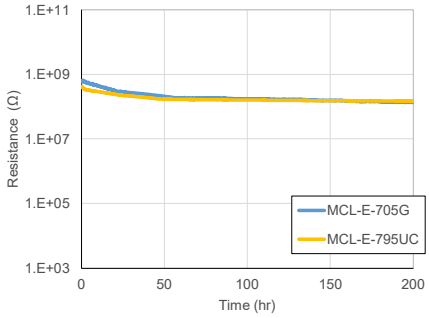
E795UC(LH) has Better Hole Registration Accuracy than E705G(LH)

For Fine Pitch Scaling [Reliability of Through Hole]

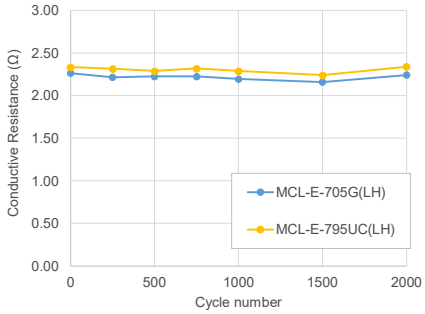
RESONAC 17

➢ Reliability Testing Results for Narrow Pitch Through Hole

【B-HAST】
- Thickness: 1.01 mm
- TH diameter: 150 μm
- Wall to Wall: 100 μm
- Condition: 130 ºC/85 %RH/3.5 V



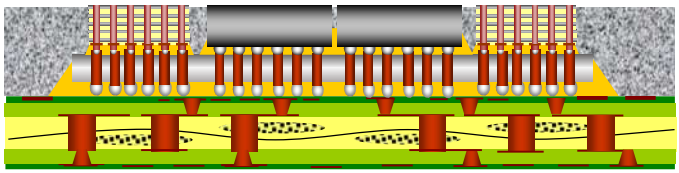
【Thermal Cycle Test】
-Thickness: 1.01 mm
-TH diameter: 150 μm
-Wall to Wall: 150 μm
-Condition: -55 ºC/30 min ⇔ 125 ºC/30 min



RESONAC Materials show the excellent reliability with Narrow Pitch Through Hole.

Resonac's proposal for Large Size Substrate

RESONAC 18



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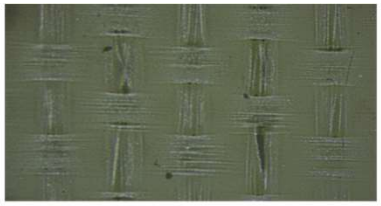
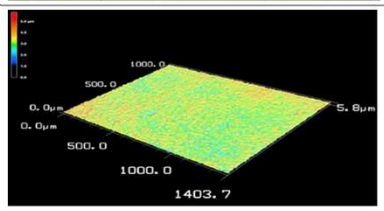
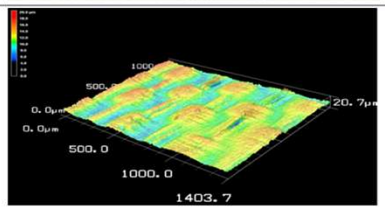
Technology of Super Flat Core & Prepreg

RESONAC 19

■ Feature
- Smooth surface
- Good filing capability
- Small thickness variation
- Stable dimension change

Item	TYPE-F	Current-type
Prepreg surface		
Laser micro scope (KEYENCE, VK-X100)		

TYPE-F Technology can Uniformly Coat the Resin on the Glass Cloth

For Fine Pitch Scaling

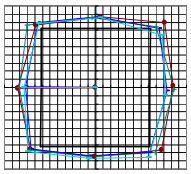
RESONAC 20

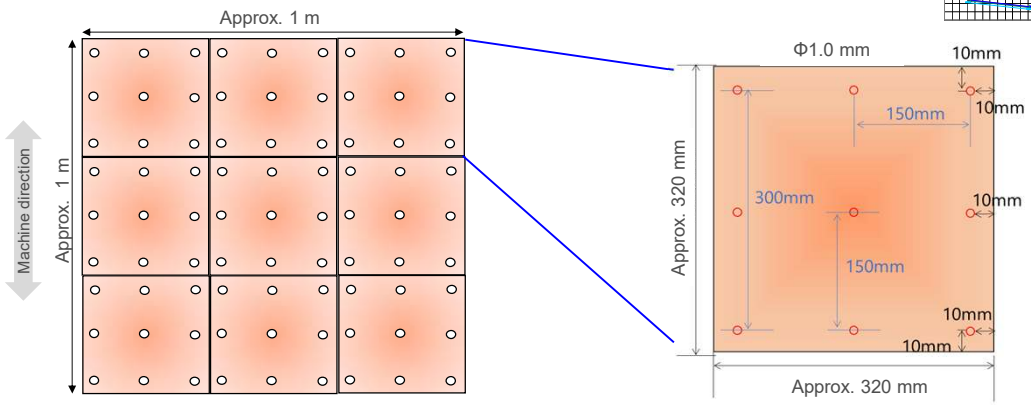
➢ Thermal Strain Measurement Method

■ Measurement method : MCL-E-795G(LH) 1.0 mm Core

1) Divided into 9 pcs from master size
2) φ1mm TH at even positions
3) Measure the distance between TH / TH
4) Perform heat treatment and measure the distance between TH and TH

◆Thermal strain data image
-Plot displacement as XY coordinates
（Magnification UP）

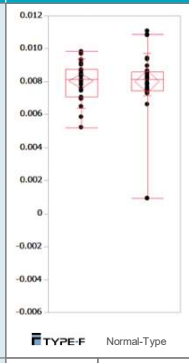
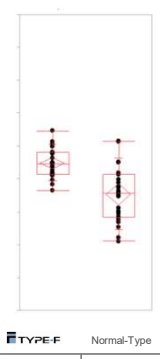
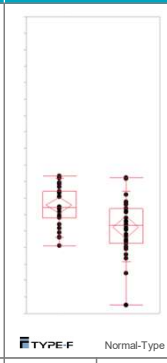
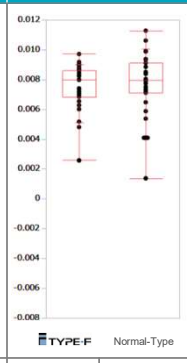
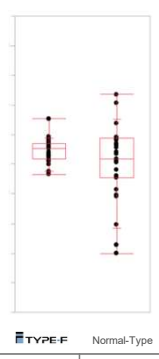
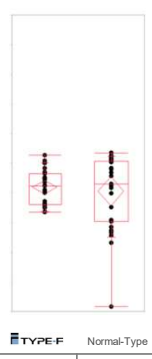




For Fine Pitch Scaling

RESONAC 21

➢ Dimension Stability Measurement Results [E795G(LH) TYPE-F]

Item	MD						TD					
	Et		E1		E2		Et		E1		E2	
Dimension change [%]												
Range (ppm)	46	99	36	61	42	77	71	99	37	107	38	104
σ	0.0011	0.0017	0.0009	0.0016	0.0012	0.0017	0.0015	0.0021	0.0008	0.0025	0.0011	0.0025

Process: (A)→E1(180 ºC/60 min)→E2(180 ºC/60 min), n =27

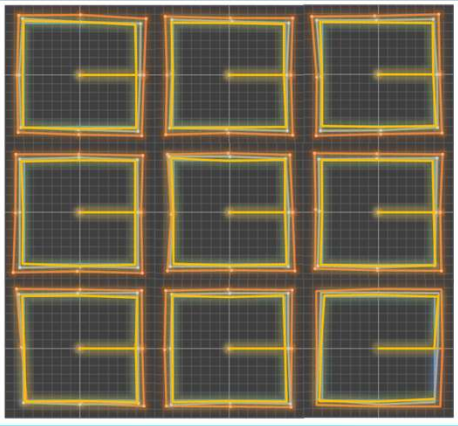
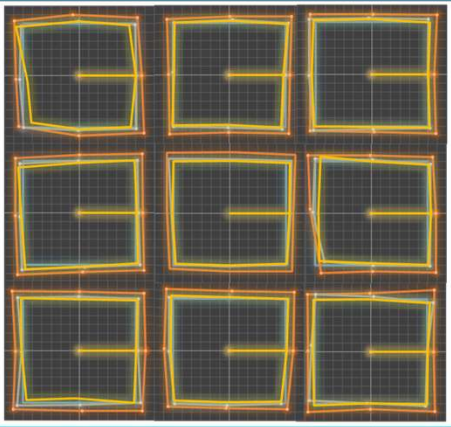
For Fine Pitch Scaling

RESONAC 22

➢ Dimension Change Regularity Confirmation [E795G(LH) TYPE-F]

■ Material: MCL-E-795G(LH) 1.0 mm Plot Displacement as XY Coordinates (Magnification UP x1000)

A Et E 1 E 2

TYPE-F	Normal-Type
	

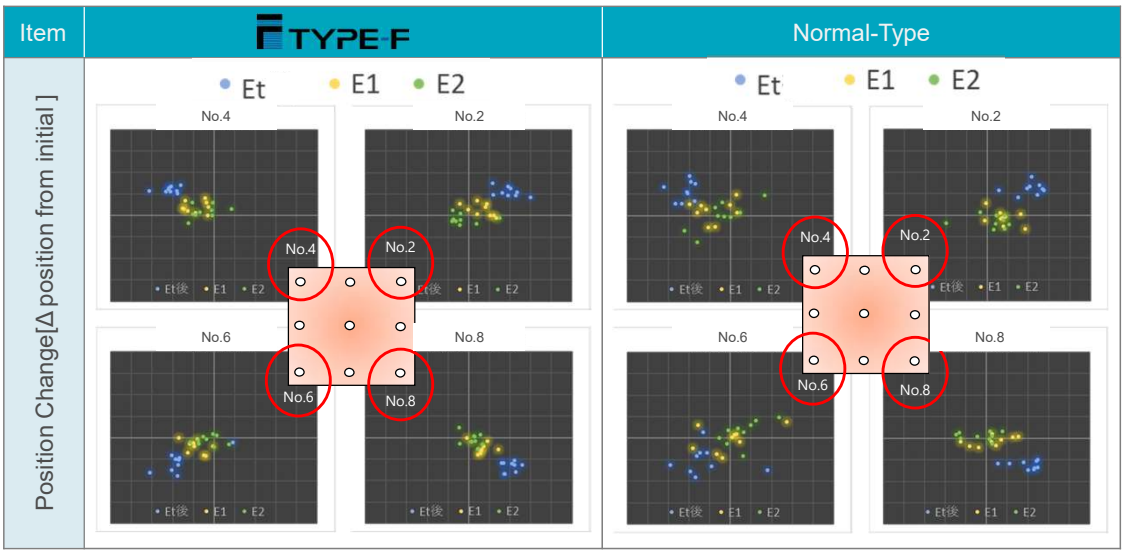
TYPE-F Technology Core has a Regular Pattern of Dimension Change during Each Process.

For Fine Pitch Scaling [Dimension stability]

RESONAC 23

➢ Dimension Change Regularity Confirmation [E795G(LH) TYPE-F]

N=9 sheets

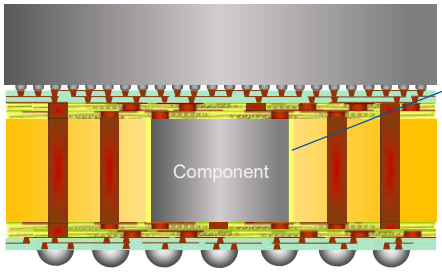


Concern of Flatness in Embedded Structure

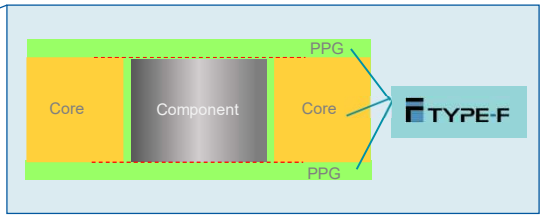
RESONAC 24

➢ Case Example

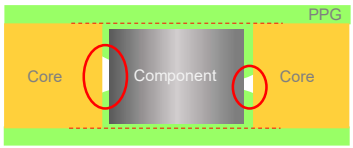
- Embedded structure in multi-layer core



– Is the thickness accuracy of core and components important for embedded structure?

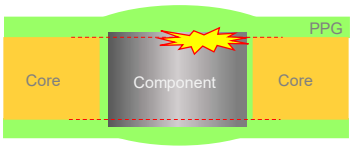


- Thickness: Core > Chip



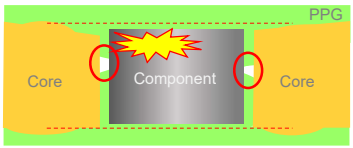
→ High filling volume
Can be optimized by PP adjustment

- Thickness: Core < Chip



→ Damage to Chip
Can be optimized
by thickness adjustment of Core/Chip

- Thickness: Large variation in core materials



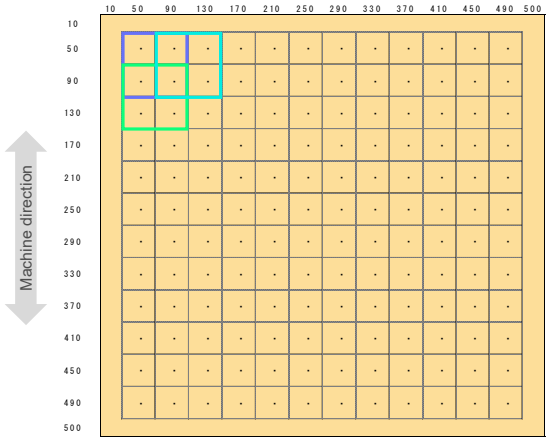
→ Large variation of filling volume
Damage to Chip
Should be high thickness accuracy of core

For Embedded Structure

RESONAC 25

➢ LTV Thickness Distribution Measurement Method

- Material: E705G t1.0 mm
- Measurement method



1) Panel size: 500x500mm
[Divided into 4 pcs from master sheet size Approx. 1 m^2]
2) Measured the thickness every 40 mm distances both vertical and horizontal direction by a micrometer

◆ Thickness distribution
All area：144 point
Center area：100 point
Edge area：44 point

◆CTV （Chip area thickness variation ）
Calculated the thickness difference between adjacent 4 points (Max – Min)
All area：121 point
Center area：81 point
Edge area：40 point

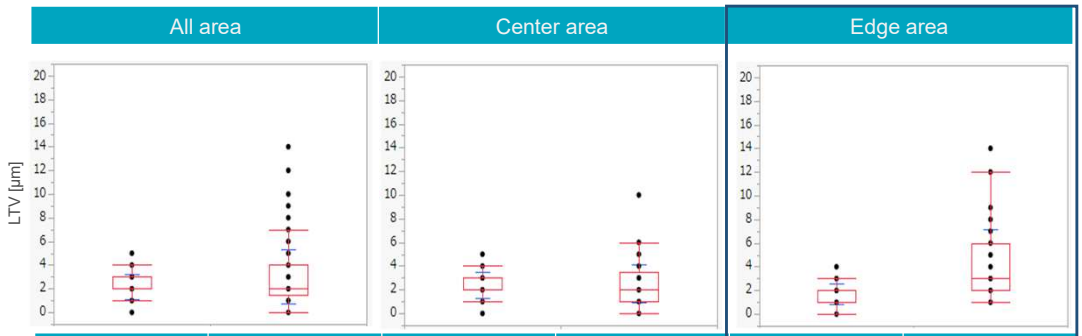
∗Calculated the thickness difference between 4 points

For Embedded Structure

RESONAC 26

➢ LTV Thickness Distribution Measurement Method

- Material: E705G t1.0 mm

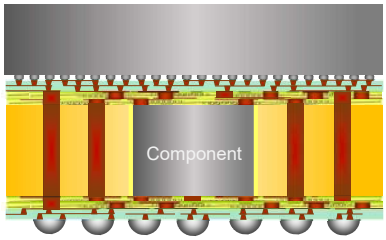


	TYPE-F	Normal-Type	TYPE-F	Normal-Type	TYPE-F	Normal-Type
LTV Ave [μm]	2.17	3.04	2.39	2.53	1.73	4.10
LTV Std. [μm]	1.07	2.31	1.09	1.64	0.88	3.04
LTV Max [μm]	5	14	5	10	4	14

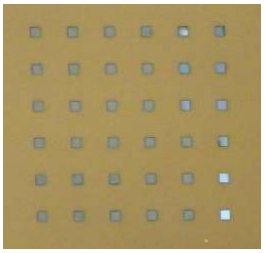
For Embedded Structure

RESONAC 27

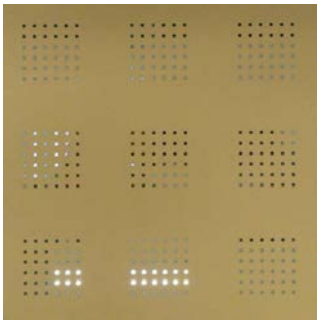
- Embedded structure in **M**ulti-**L**ayer **C**ore -



Die Mounting



Core Layer w/Cavity



Embedded Die Structure Evaluation Capability

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Chemistry for Change