Active and passive devices embedded in laminate-based multilayer board

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Outline

- **Background and Motivation**
  - Demands of miniaturization both wiring board and discrete package
  - Fujikura's Embedded Die Technology (WABE Technology) combined with WLP and FPC Technology
- **Passive Embedded Process by WABE Technology**
  - Electrode adoption
  - Embedded passive component
- **Fabrication process**
  - Wafer Level Packaging for embedding applications
  - Multilayer polyimide wiring board process
- **Fabricated results**
- **Reliability**
  - Environmental test
  - Bending test
- **Additional option**
  - Thermal enhancement
  - RF capability
- **Conclusion**

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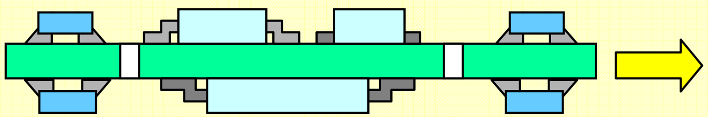
Background

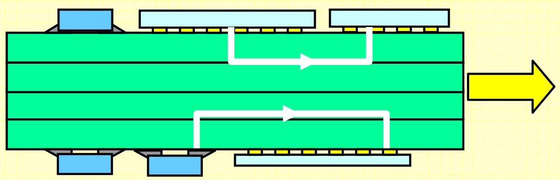
- Miniaturization of electronic equipments
  →Wiring Boards and Discrete Packages

Wiring Board

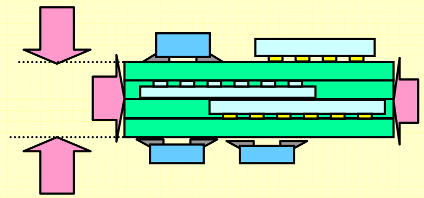
Double-sided Board
(Mounting space)



Multi-Layer Board
(Wiring space embedded)

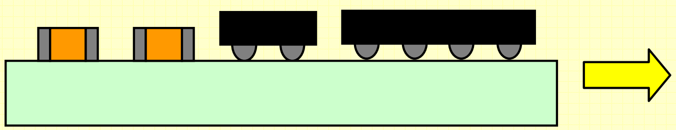


IC Embedded Board

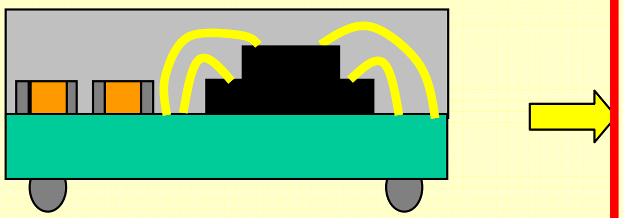


IC
Embedded

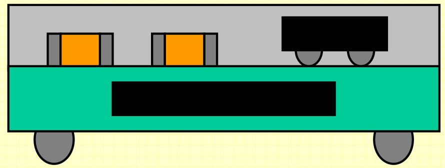
Discrete Package (SiP)



Discrete SMT



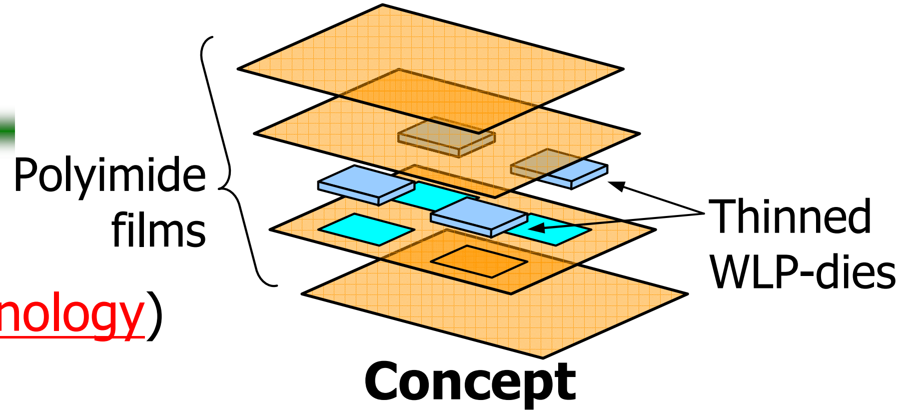
SiP
(Stacked Die)



IC Embedded SiP

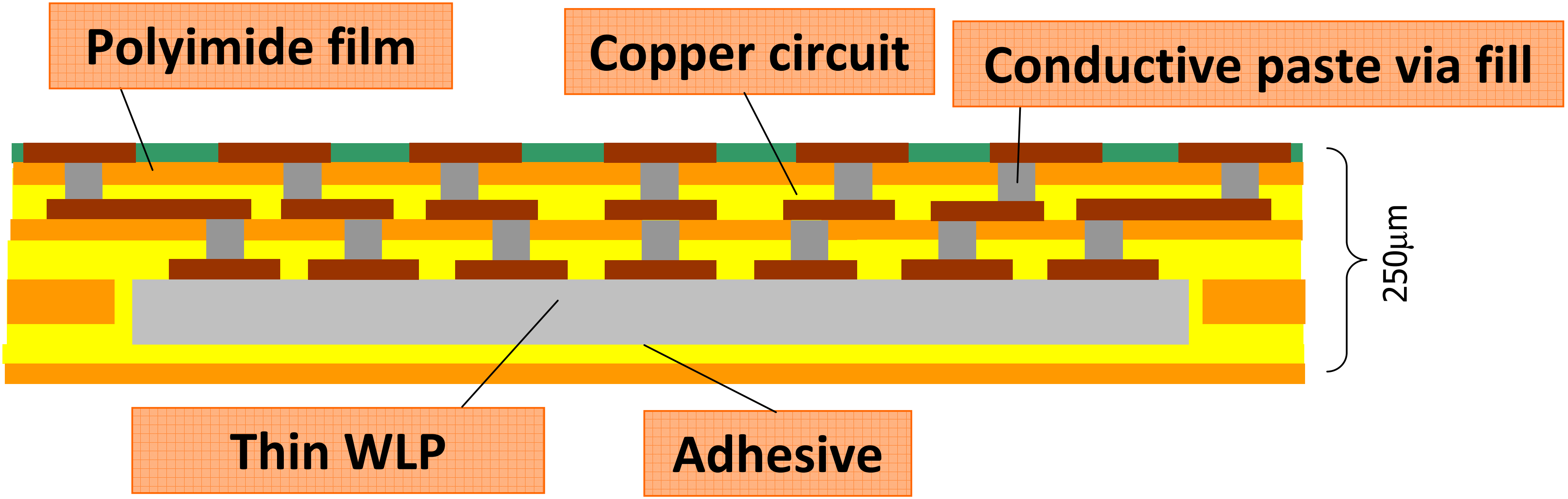
Embedded Die Technology

WABE Technology™



WLP + FPC = WABE Technology™

(Wafer And Board level device Embedded Technology)



(1) Thin WLP → **Ultra thin profile**

(2) Flex based multilayer wiring board → **Low cost process**

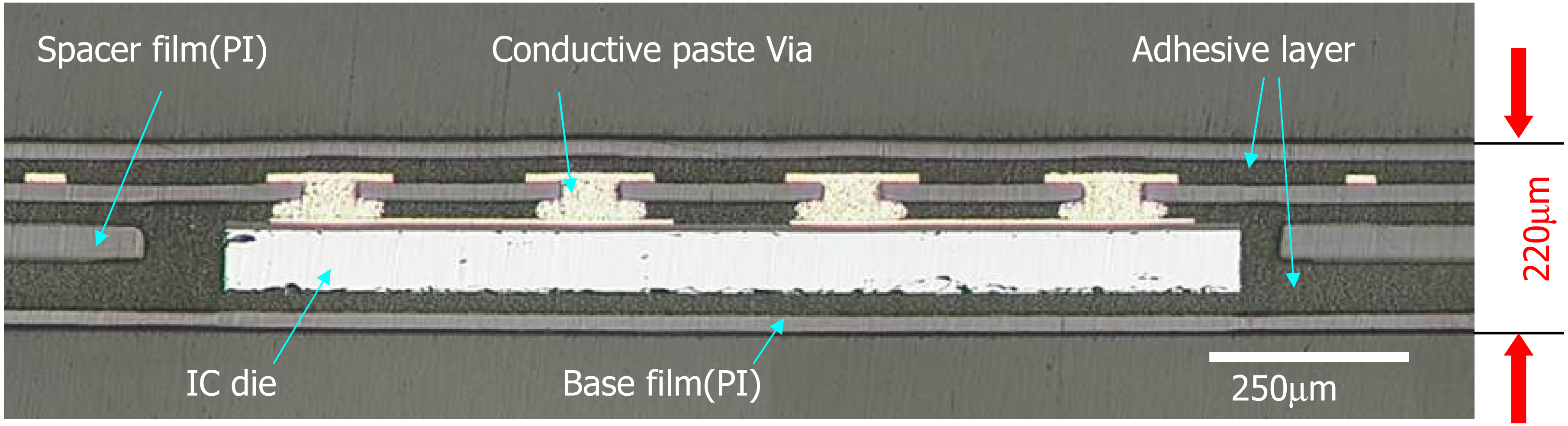
(3) Conductive paste for Z-connection → **One step lamination**

Ultra Thin Profile

Minimal Package/Board Thickness

- Thinned WLP die and film based structure
→ **Ultra thin profile**

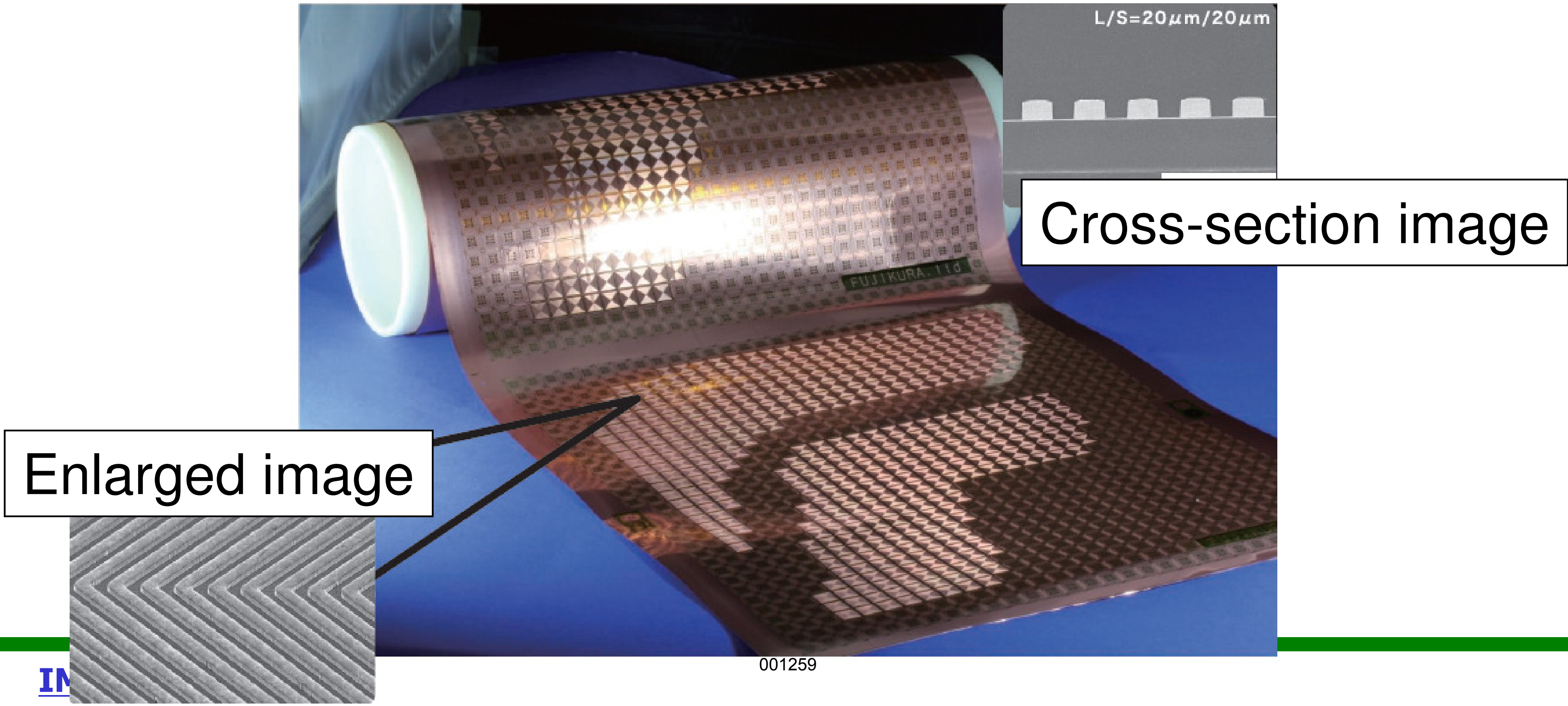
Body Thickness = 220μm (4 polyimide layers)



Flex Printed Circuit Technology

Roll to roll process

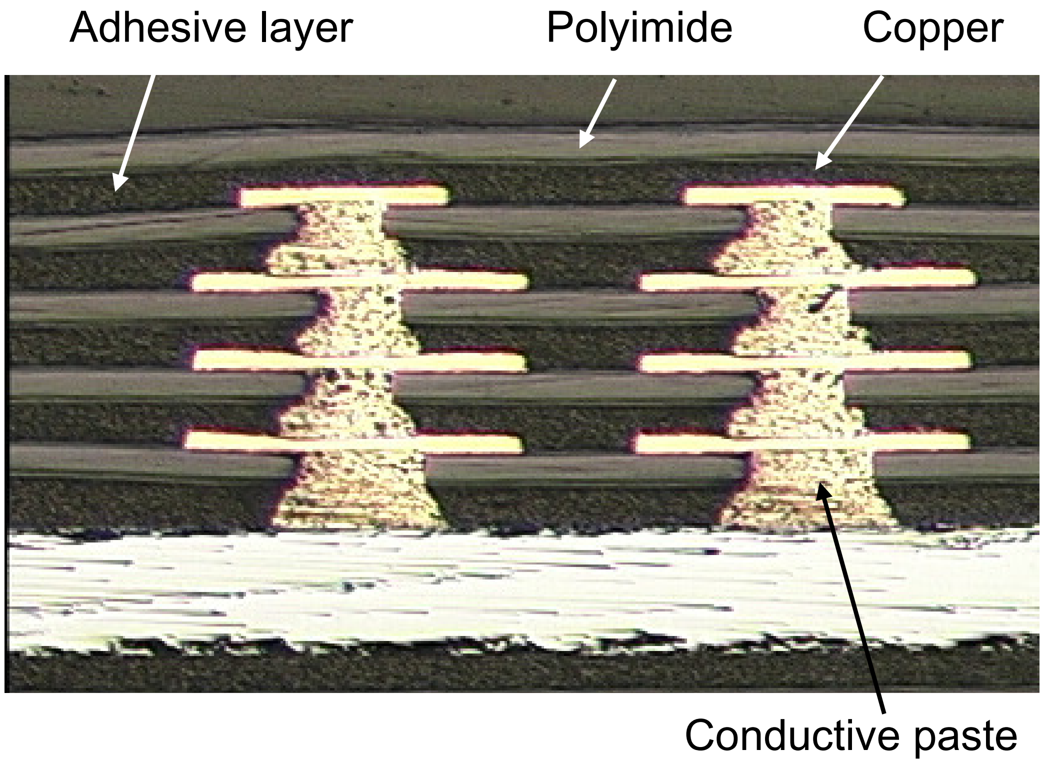
- Based on a mature, high volume flex technology (WW 2nd)
- Roll to roll process (max.500mm width) → Cost effective



Via Structure with conductive paste

Conductive paste for Z-connection

Via is filled by conductive paste → One step lamination

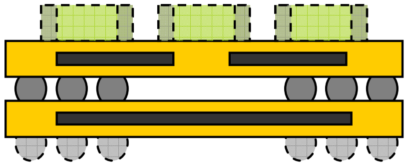


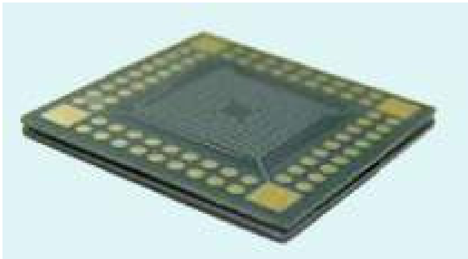
After curing
(Cross section)

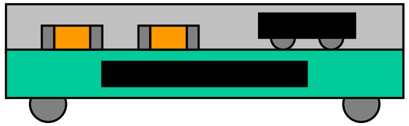
Applications of WABE Technology™

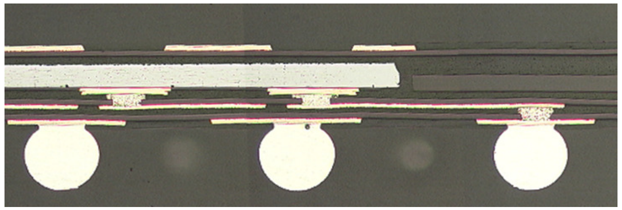
Semiconductor Package
(Fan-out, Package on Package)

System in Package
(Sensor, RF, High Power)

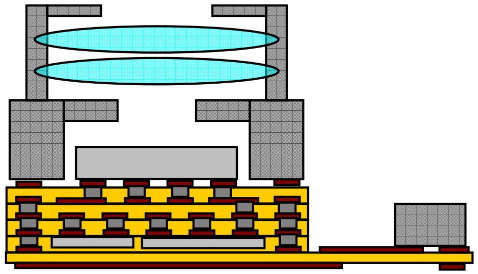


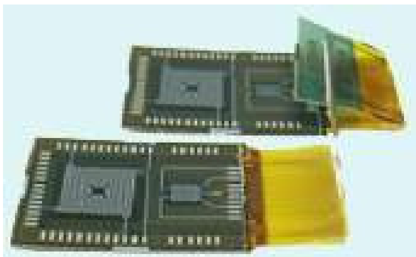


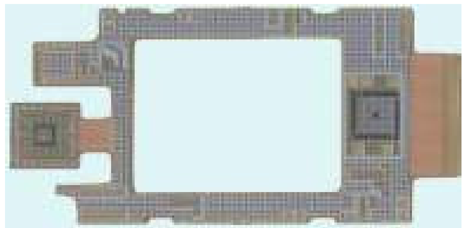


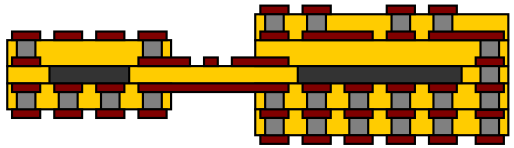


FlipChip International









Module Substrate
(Partially multi-layer)

Embedded Rigid-Flex

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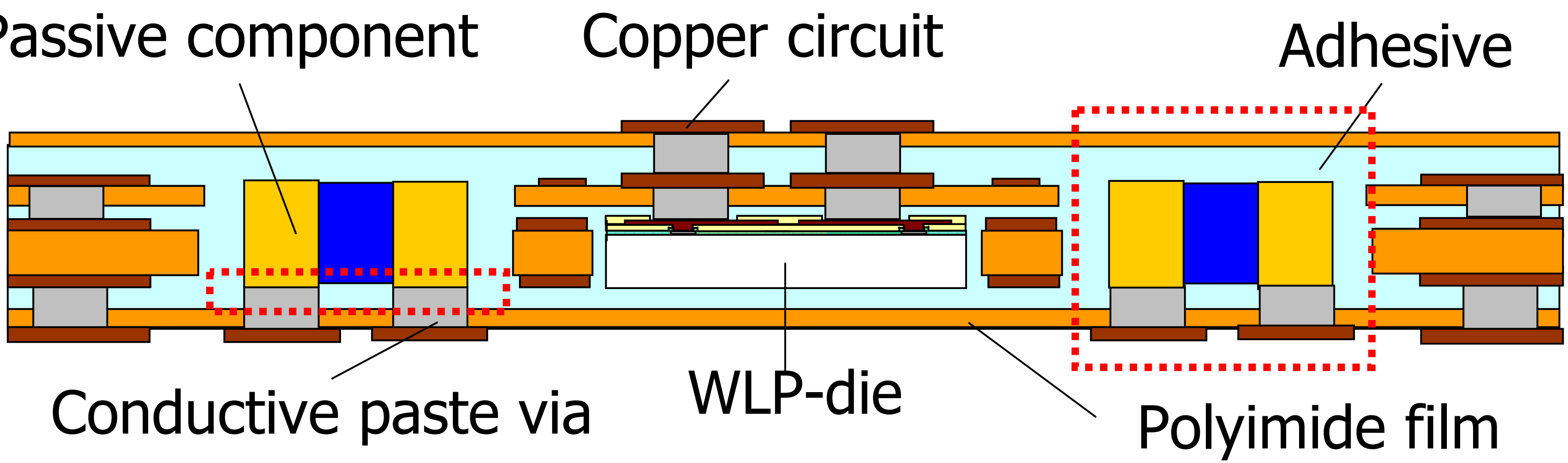
Passive & Active WABE Technology™



Embedding passive components

Key point → Robust connection between passive and conductive paste

Electrode of embedded passive component

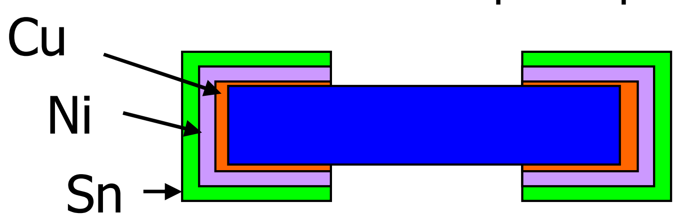
Key point for robust connection

- Form alloy between passive component's electrodes and conductive paste

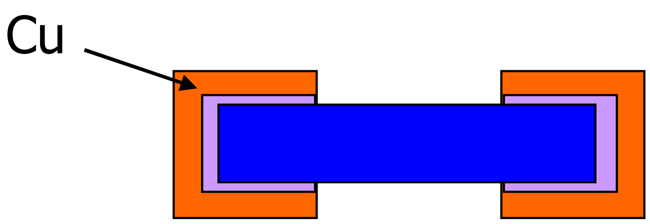
Evaluate the alloy layer between the conductive paste and two types of passive component's electrodes, Cu/Ni/Sn and Cu

Cu/Ni/Sn electrode

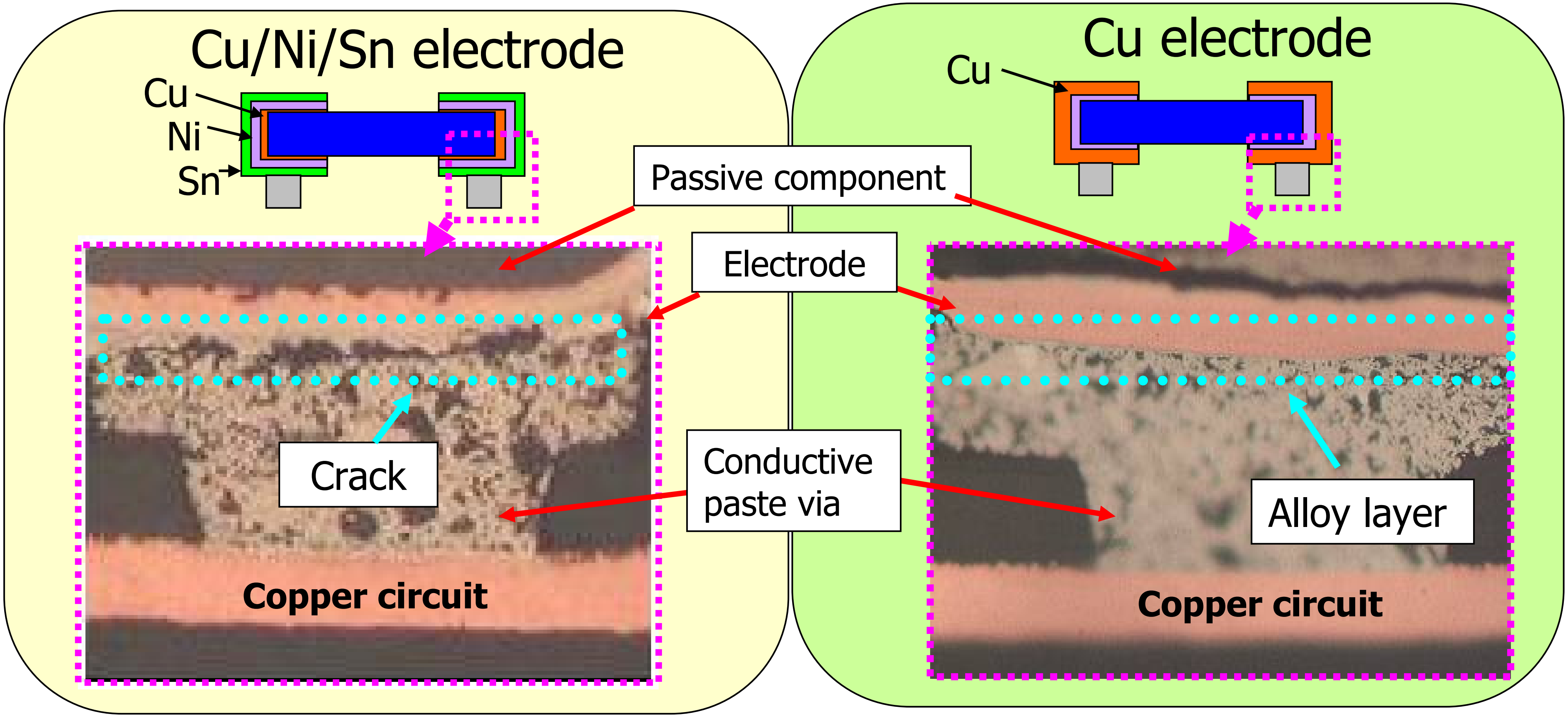
(Standard electrode of chip components)



Cu electrode



Comparison of electrode connections



Adopted embedded passives with Cu terminations for use in WABE Technology

Available Embedded Passive Capacitor w/Cu electrode

	Size (mm)	Thickness (mm)	Capacitance
C	0603	0.33	100p - 0.47uF
		0.15	0.01 - 0.1uF
	1005	0.33	0.47 – 2.2uF
		0.22	1 – 2uF
		0.15	10p - 0.22uF

Thin Profile → 0.15mm^t

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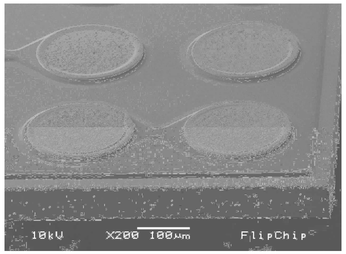
Fabrication Flow

Embedded IC

Wafer Level Packaging process

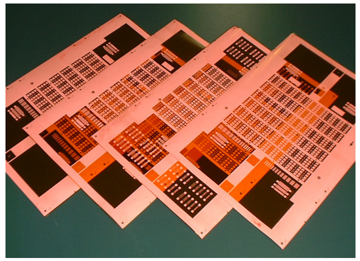
Forming RDL
Backgrinding (thinning)
Singulation



Wiring board

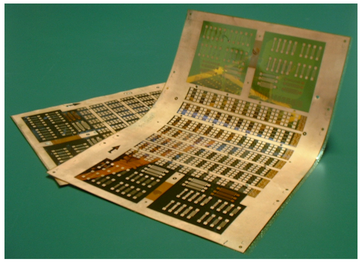
Flexible printed circuit process

Forming copper circuits
Opening via hole
Filling conductive paste

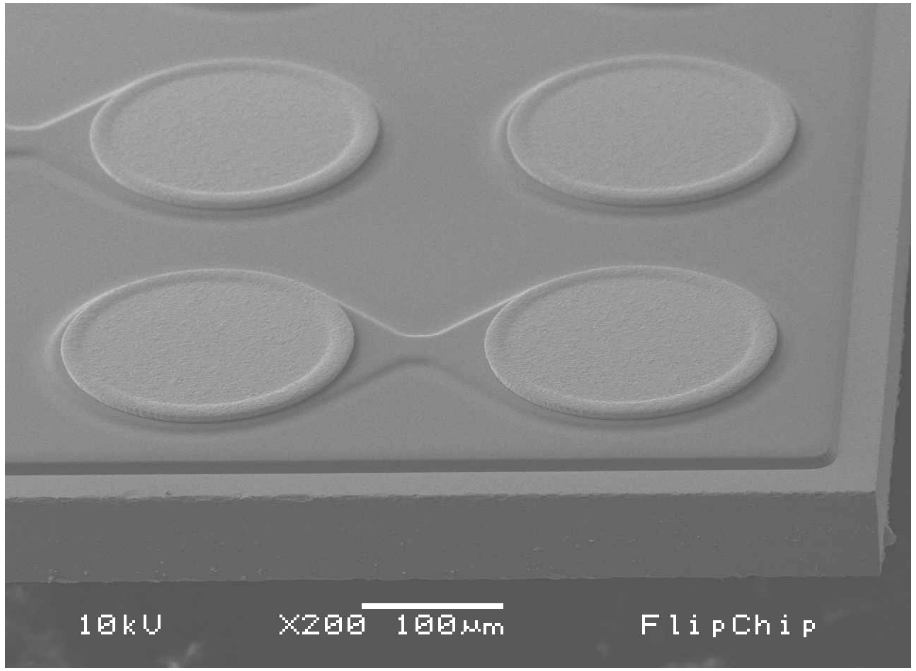


Co-laminating process

Stacking whole materials
Heating and Pressing



Embedded IC Preparation



EDC™
(Embedded Die Customization)

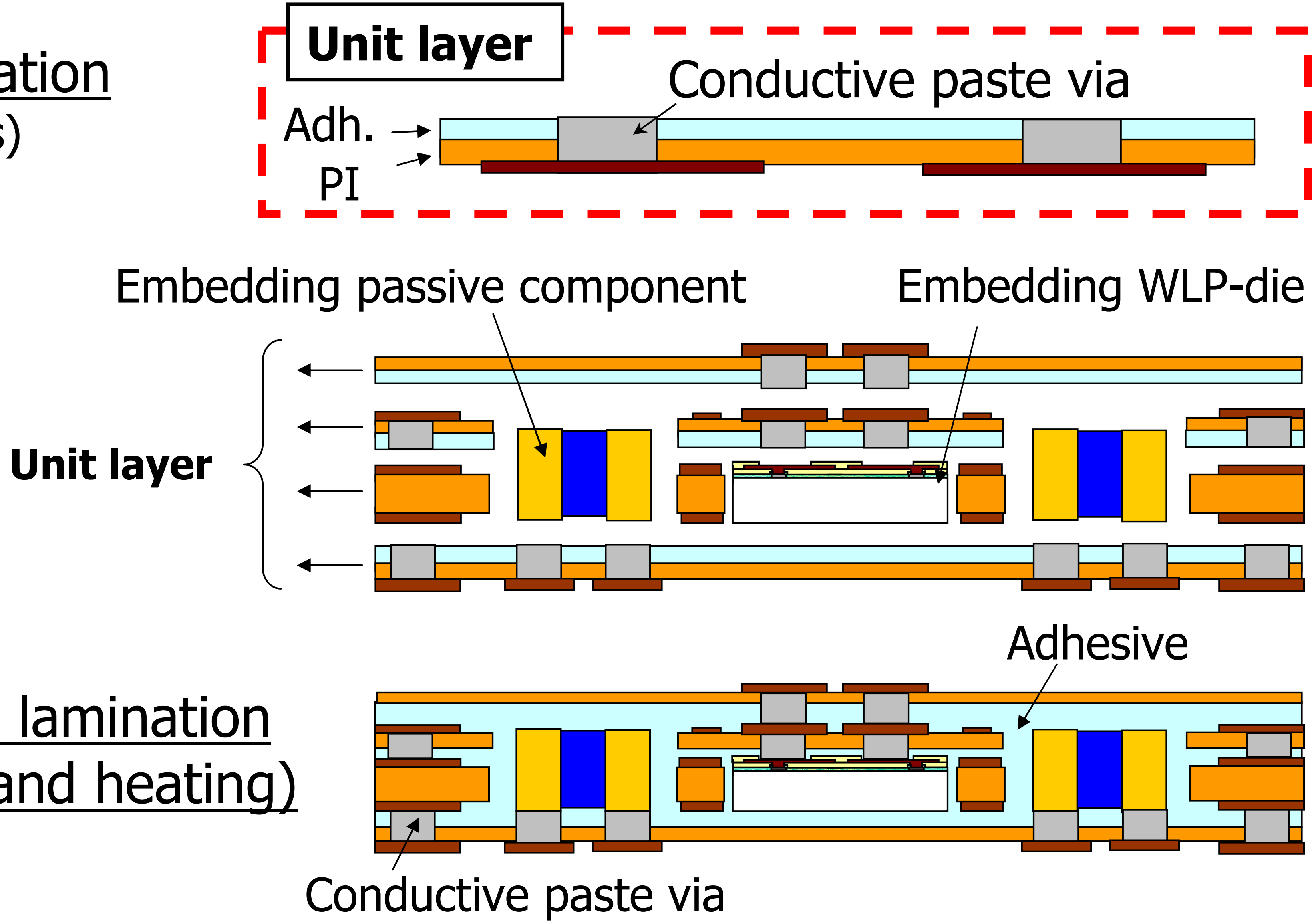
- RDL bridge design rule gap between IC / flex printed circuit
- Relax die placement, laser via and lamination tolerance
- Provide corrosion barrier for embedded integrated circuits

Fabrication process

FPC fabrication
(R-R process)

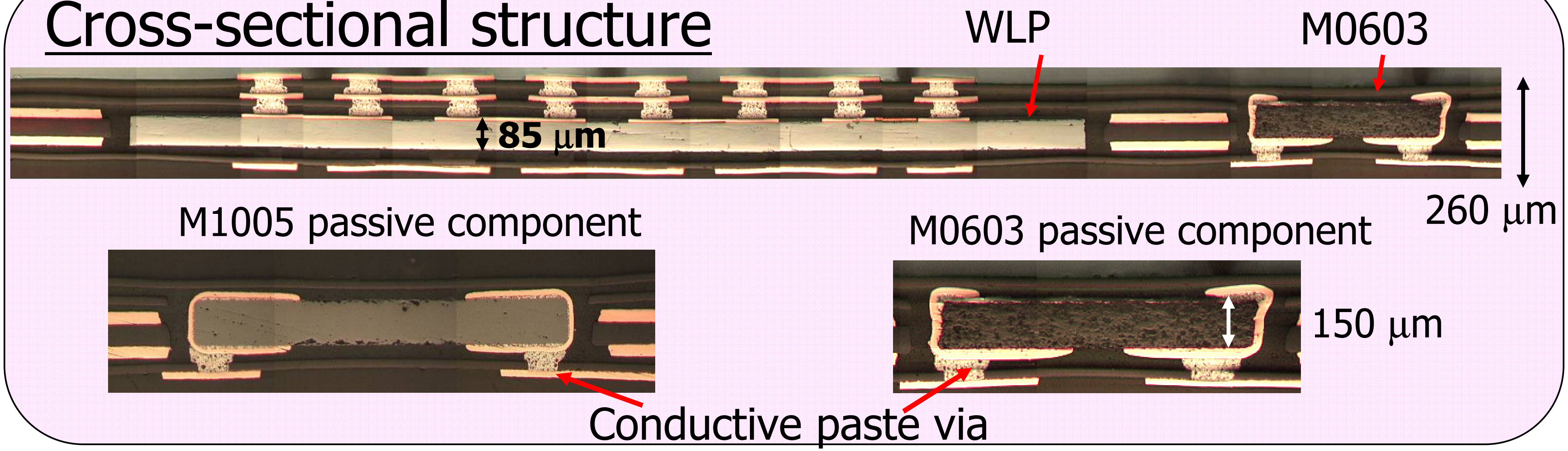
Alignment

Lamp-sum lamination
(Pressing and heating)



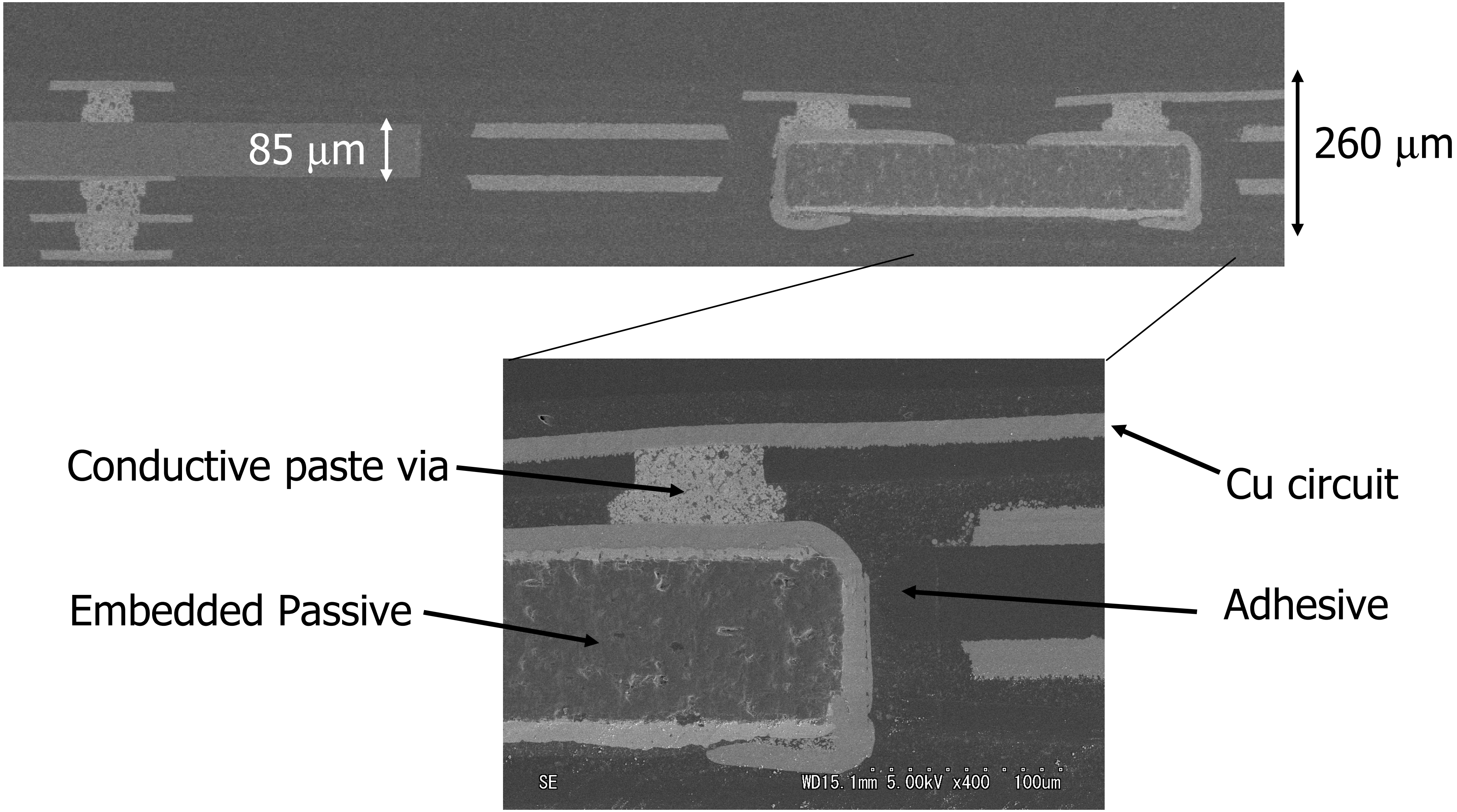
Fabrication results

Cross-sectional structure



Board size	20 x 20 mm
Total thickness	260 μm (4 polyimide, 5 wiring layer)
Embedded passive components dimensions	1.0 mm x 0.5 mm x 150 μm^t (M1005 size) 0.6 mm x 0.3 mm x 150 μm^t (M0603 size)
Type of passive components	Jumper type resistor (0 Ω)
Embedded Active dimensions	3 mm x 3 mm x 85 μm^t

Fabrication results



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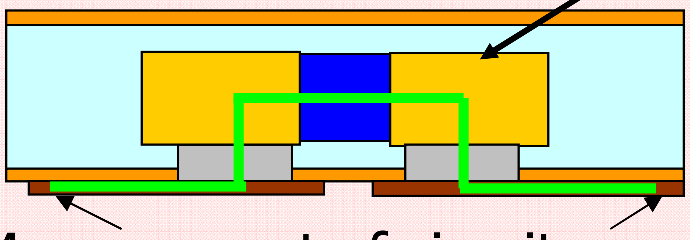
Environmental test



Circuit resistance = (Passive device + Conductive paste via + Copper circuit)

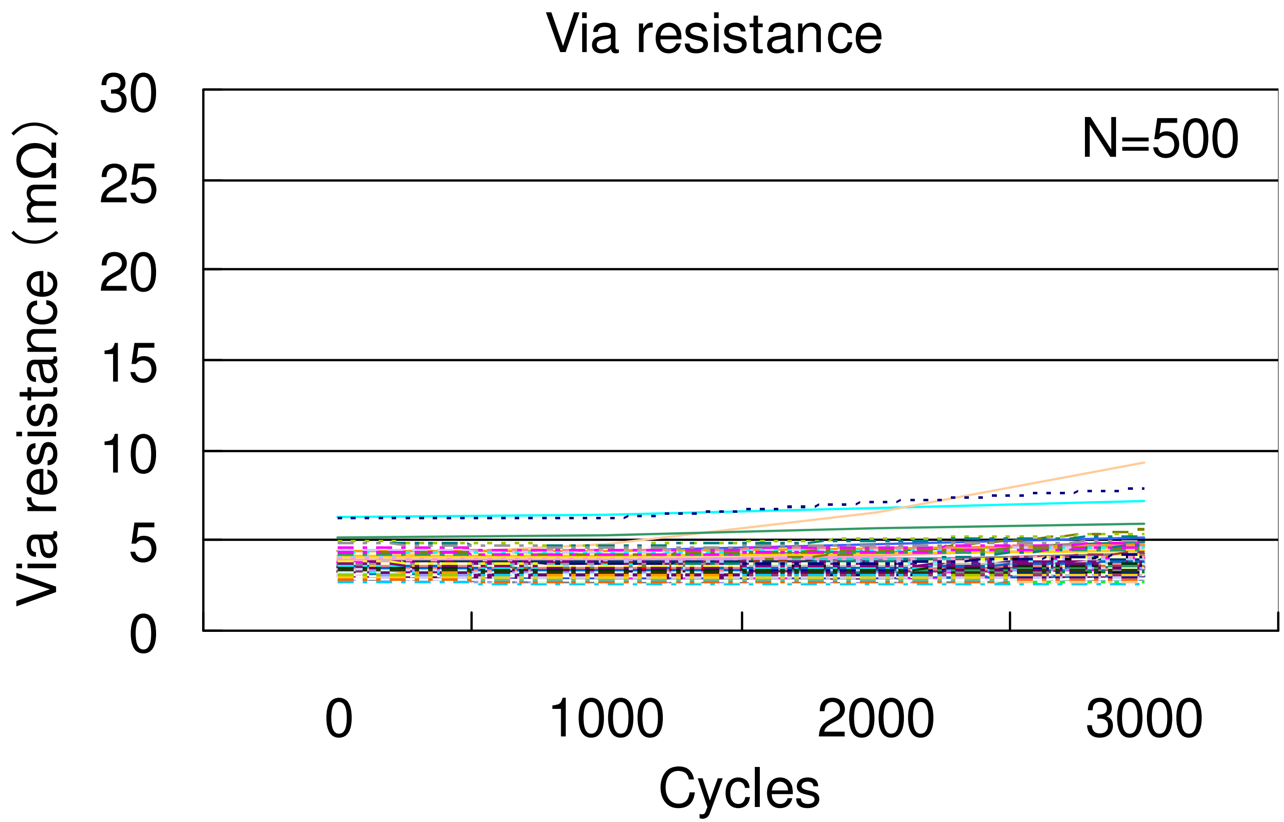
Criteria **:Appearance : no void, no delamination**
:Circuit resistance change : less than 20%

Test Item	Conditions	Appearance/Circuit resistance change
Moisture Reflow Test	85degC, 60%RH, 168 hrs 260degC peak reflow 3 times (compliant to M.S.L. JEDEC Level.2)	Passed/Less than 5%
Thermal Cycle	-55degC, 30 min / 125degC, 30 min, 1000 times	Passed/Less than 10%
High Temperature Storage Test	150degC, 1000 hrs	Passed/Less than 6%

Precondition : MSL JEDEC Level2

Via resistance and reliability

- WABE Technology → Conductive paste via for z-axis connection
- Thermal cycling test



Test condition
- -25 ←→ 125deg.C
- 500 vias

Maximum via resistance after 3000 cycles → 9.3mΩ

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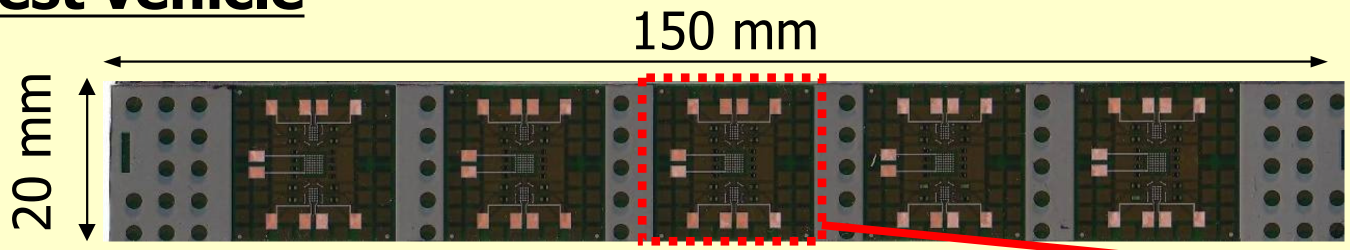
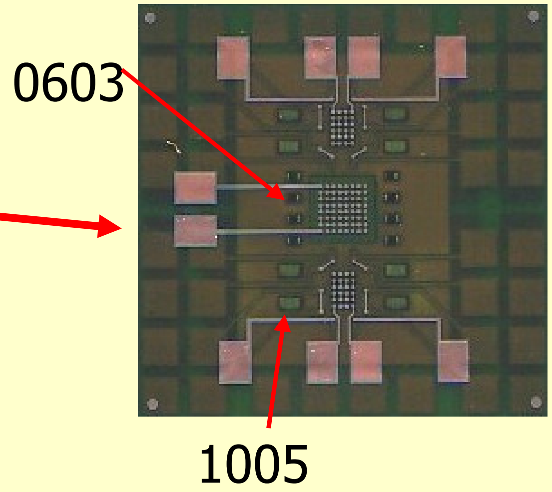
Conditions of bending test

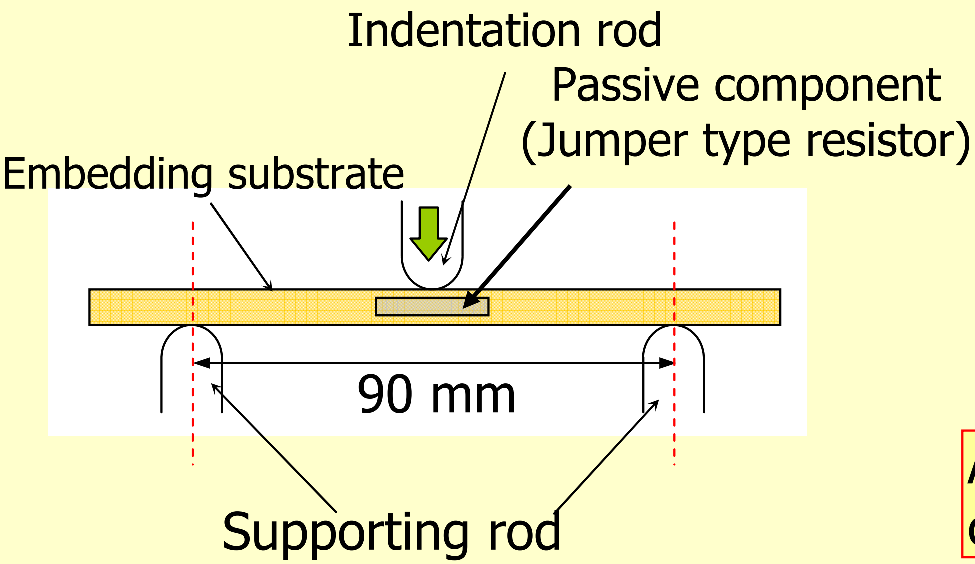
Test vehicle

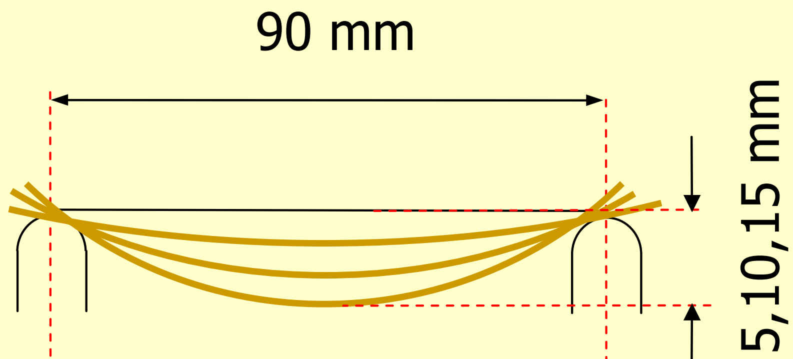




Conditions of three-point bending method

Supporting span	Bending speed	Radius of supporter
90 mm	10 mm/min	5.0 mm





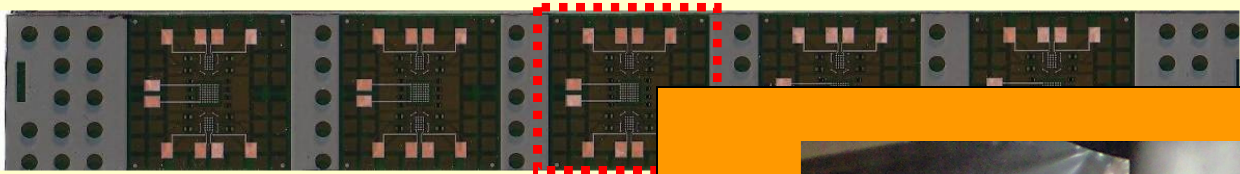
After bending, the circuit resistance change was measured.

Conditions of bending test

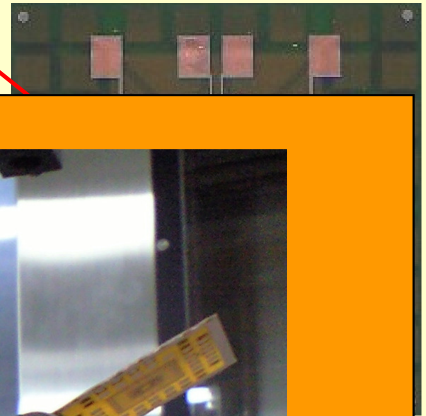
Test vehicle

150 mm

20 mm

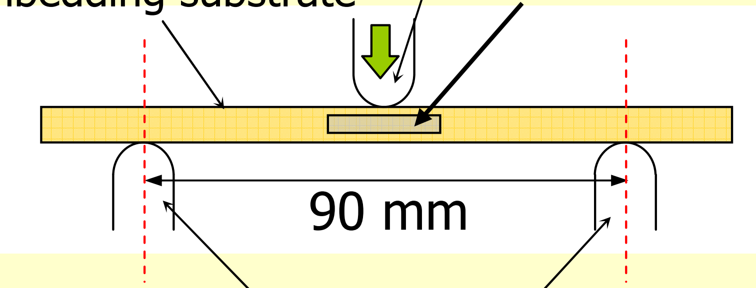


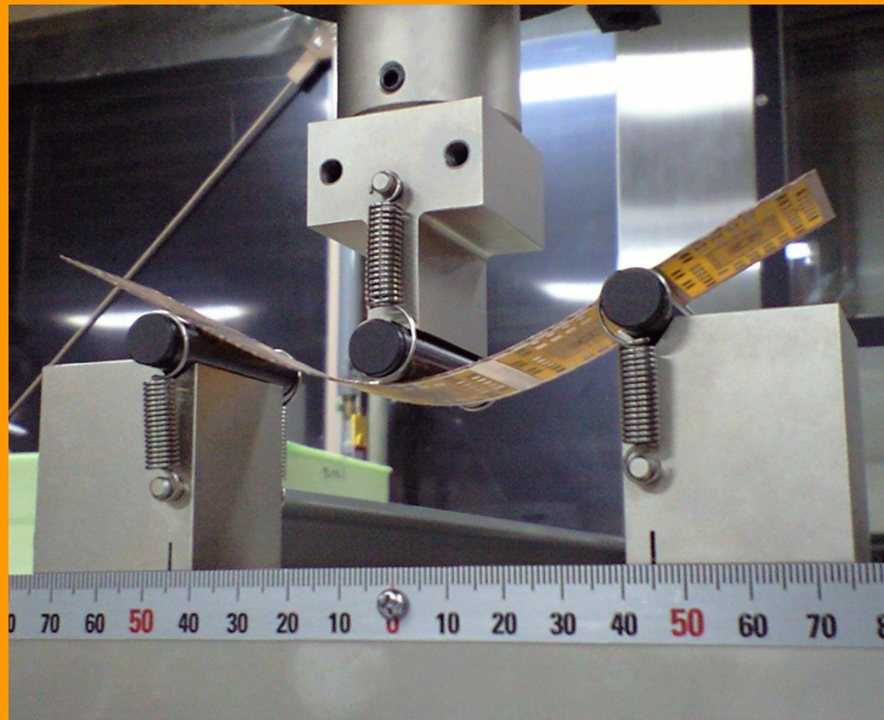
0603



Conditions of three-point be

Supporting span	Bending spe
90 mm	10 mm/mi



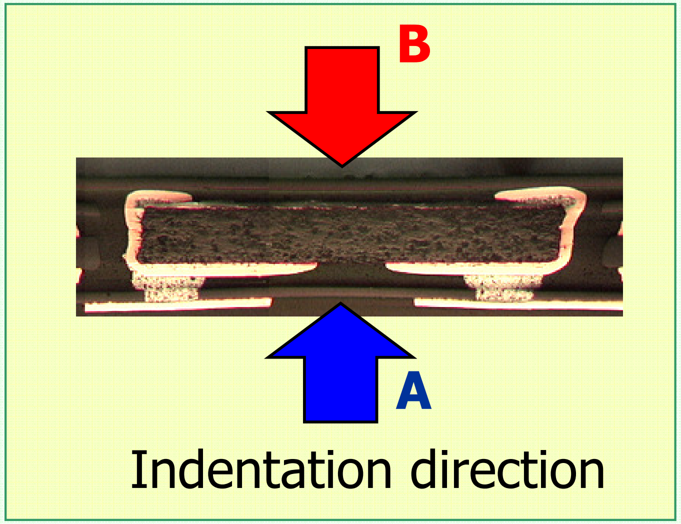


(Autograph/ SHIMADZU)

After bending, the circuit resistance change was measured.

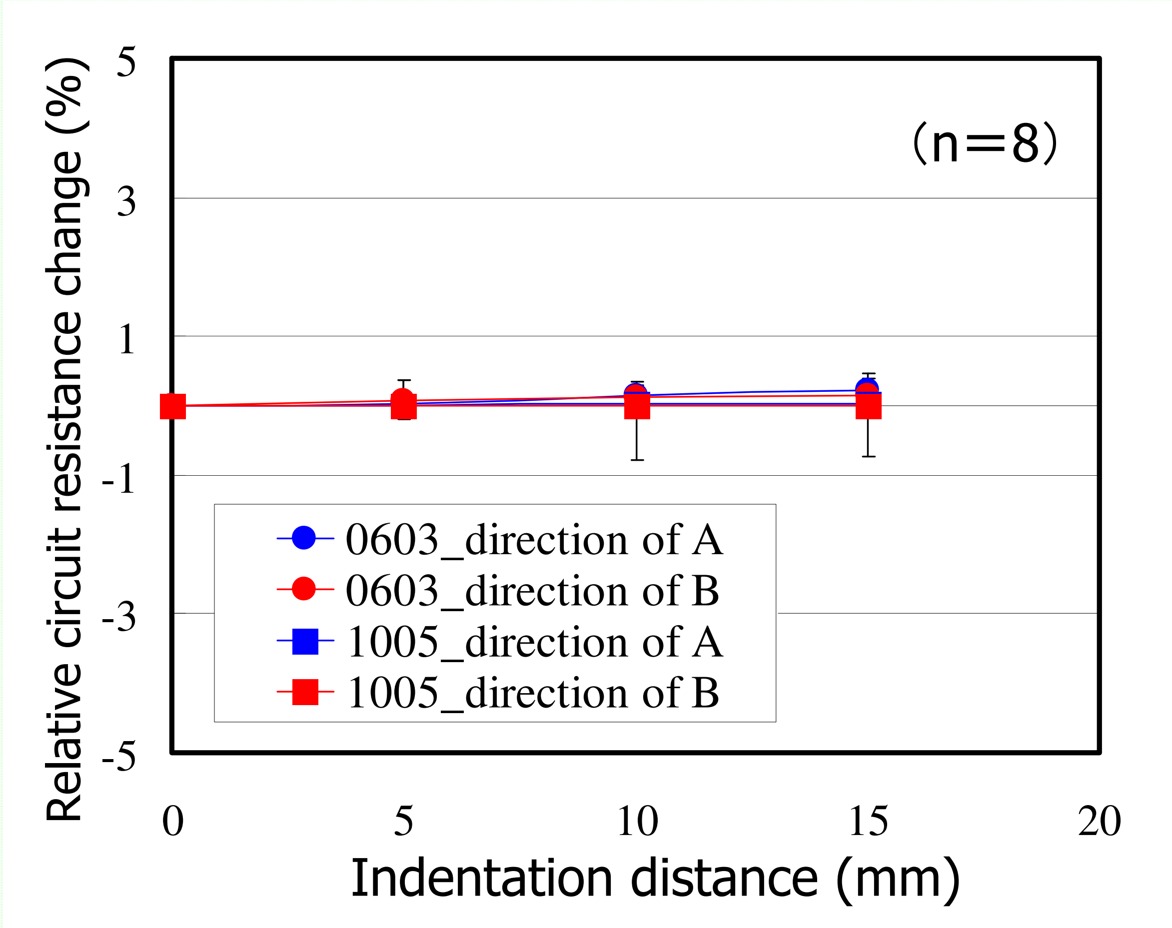
Results of the bending test

Relative circuit resistance change before and after the bending



A : Compressive to electrode

B : Tensile to electrode



- Breaking of the embedded passive components : **Not occurred**
- Max. circuit resistance change : **Less than 1%**

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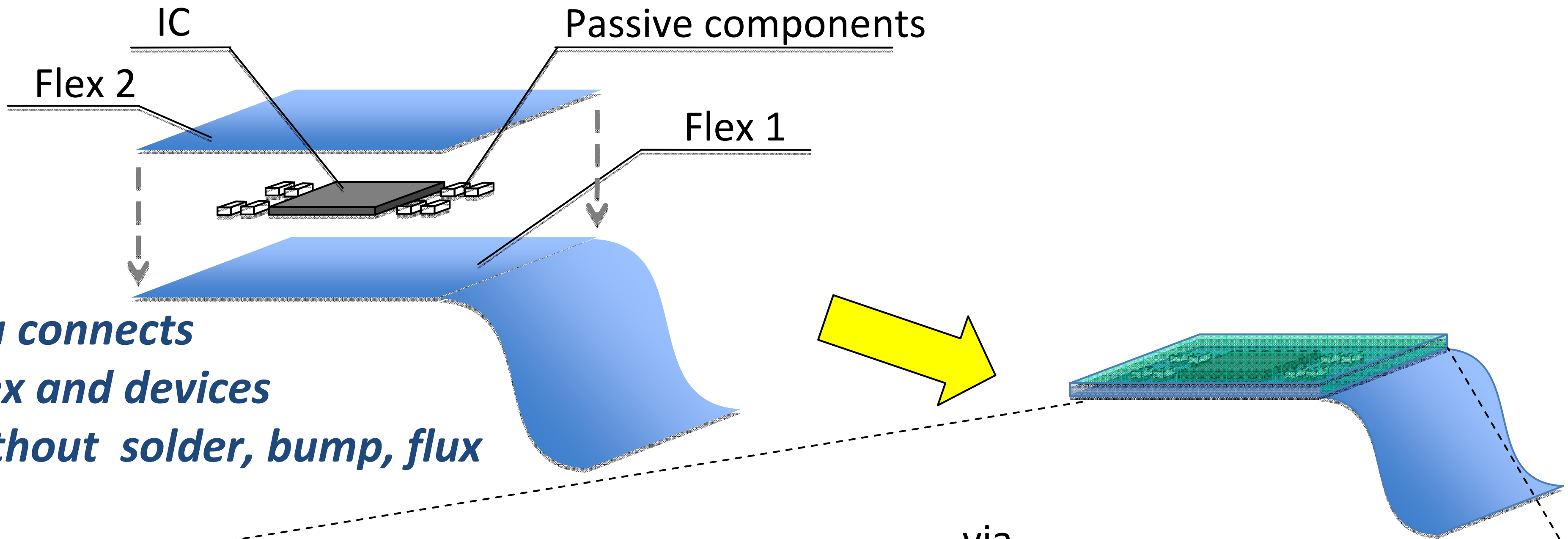
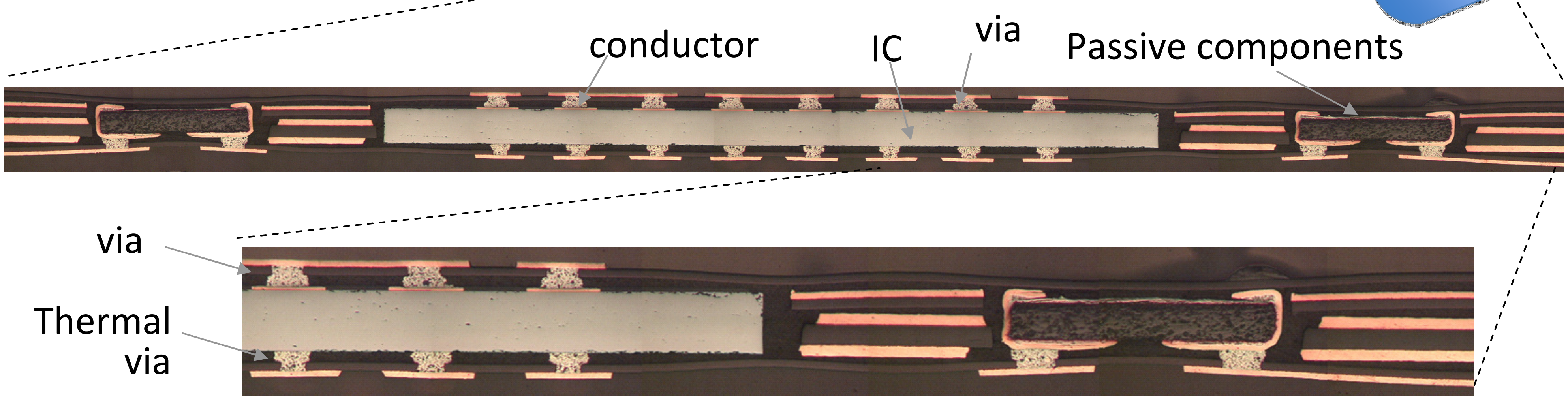
Thermal via option



Via connects flex and devices without solder, bump, flux



Thermal Capability Enhancement

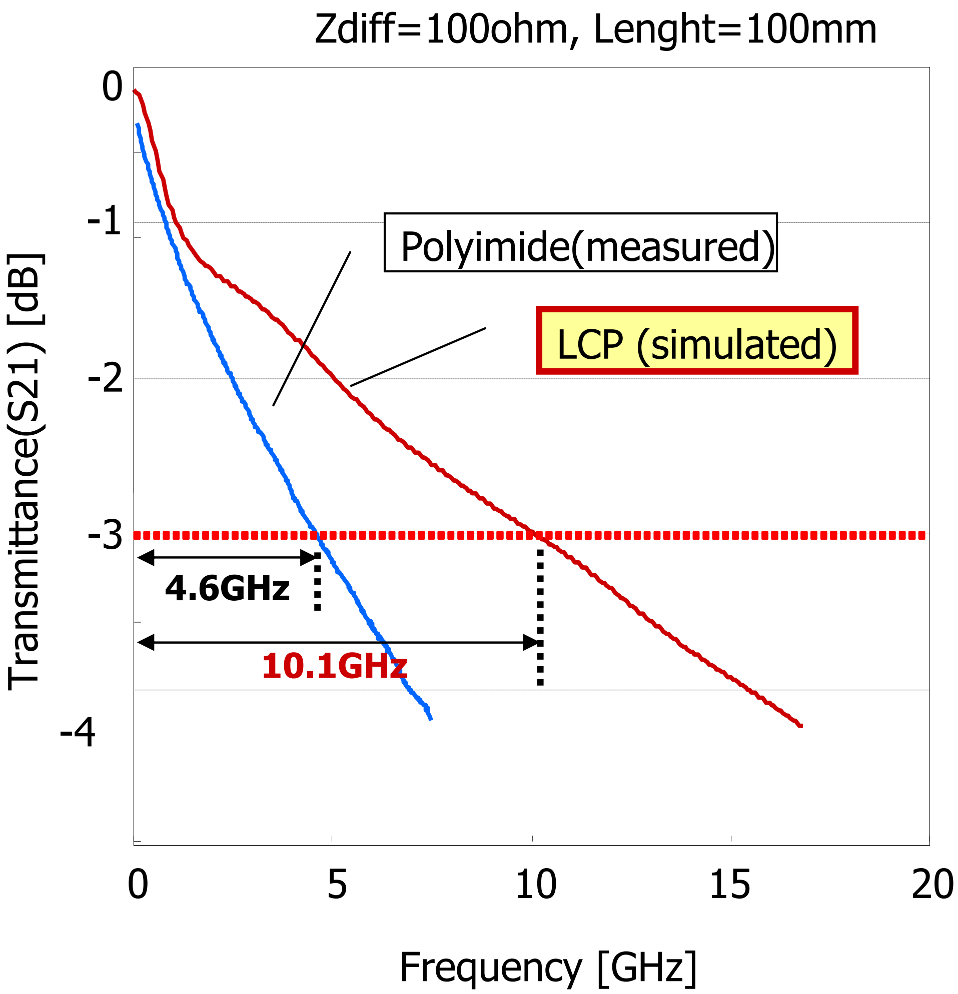
RF Option

LCP Based multilayer flex board (LCP : Liquid Crystal Polymer)

●Material parameters

	Polyimide	LCP
εr	3.0～3.2	3.0
tanδ	0.006	0.0008
Water absorption	0.8%	0.04%

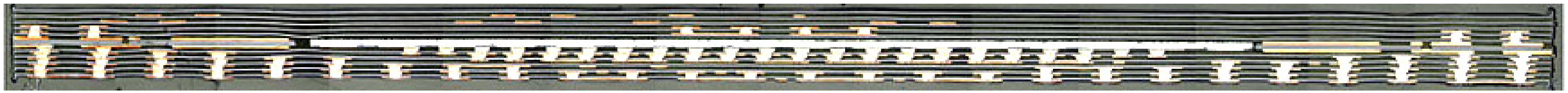
●High freq. transmission performance



Conclusions

WLP die and passive components embedded multilayer polyimide wiring boards have been developed based on our WABE Technology™.

1. Thin passive components having 150 μm thickness with its electrodes being copper are employed.
2. The fabricated embedded boards have thickness about 260 μm for 5 wiring layers (4 Polyimide layers).
3. The reliability of the fabricated embedded boards have been confirmed.
   - Environmental test
   - Bending test



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