Technical report
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Low Temperature Curable PI/PBO for Advanced Packaging

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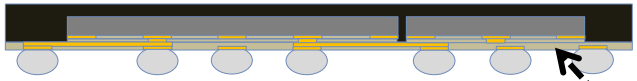
HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

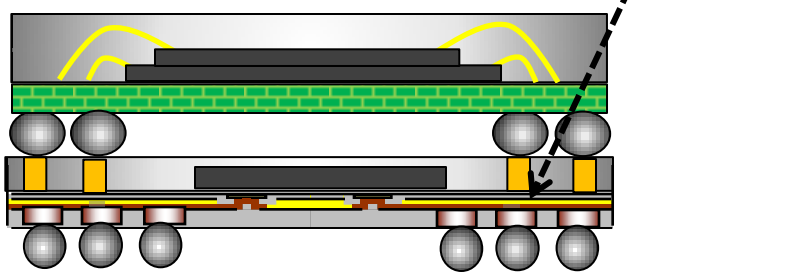
Requirements for Fan-out PKG and PI/PBO

<Requirements for Fan-out PKG>

Multi-Die



FO-POP

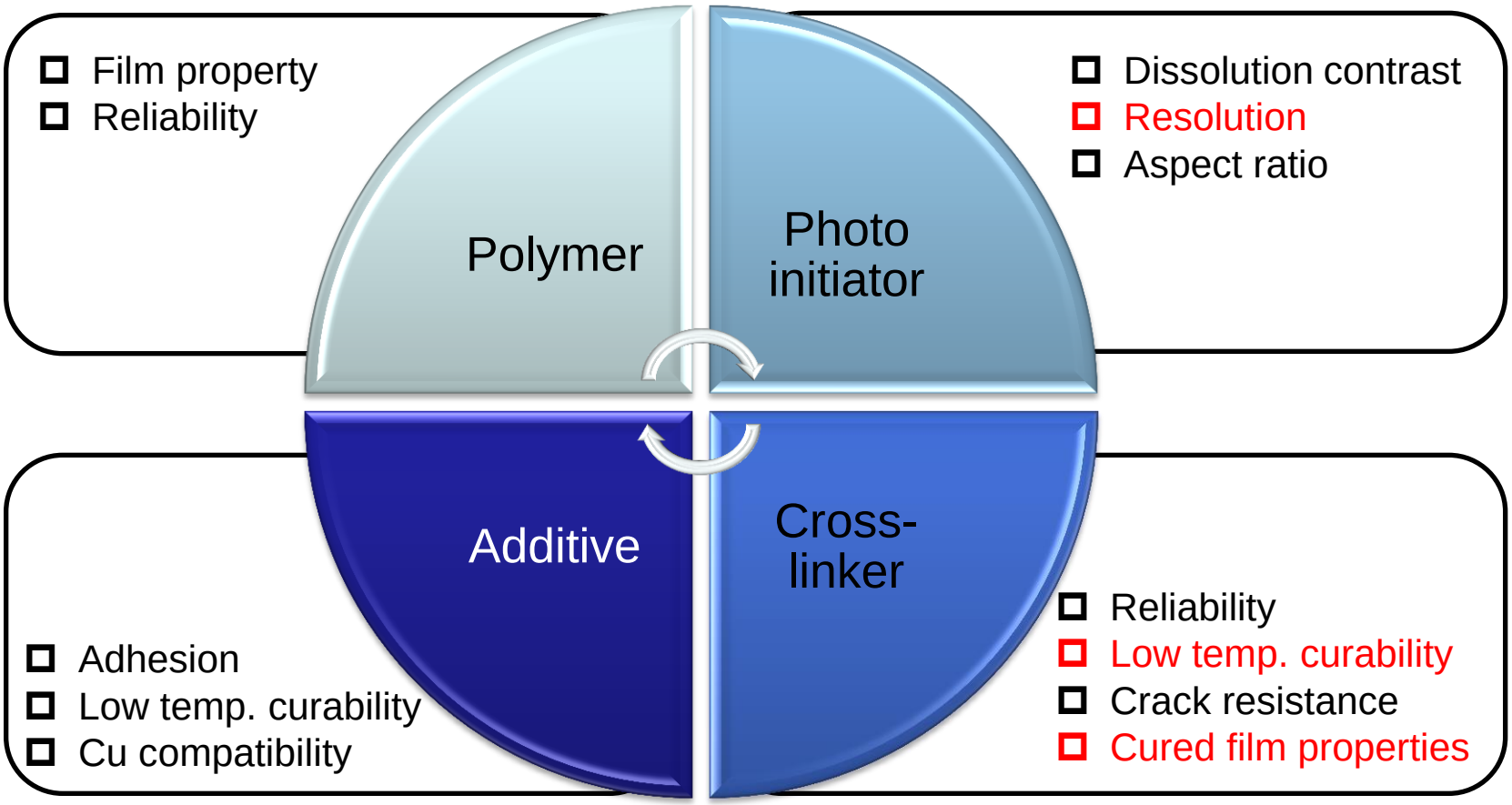


- Fine pitch and Complicated structure
- High Cu density
- Thicker RDL
- Multiple layer
- Large die size

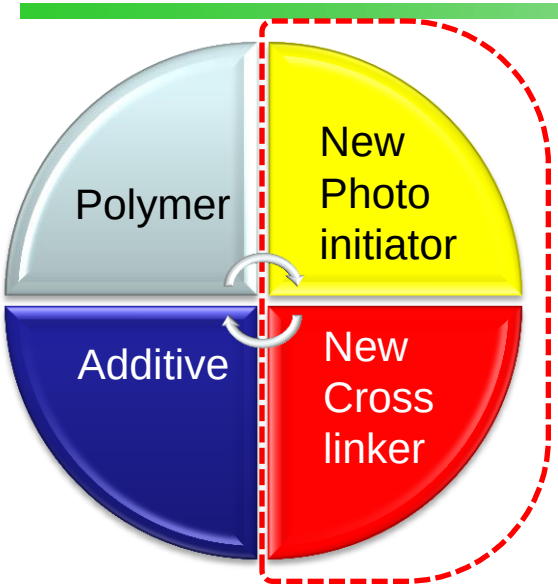
<Requirements for PI/PBO>

- High resolution
- Thicker film formability
- Good adhesion to Cu RDL
- PI/PI, PBO/PBO adhesion
- Good film properties
- Good crack resistance
- </=200 ^{o}C cure temp.
- High reliability

Material design of photosensitive PI/PBO



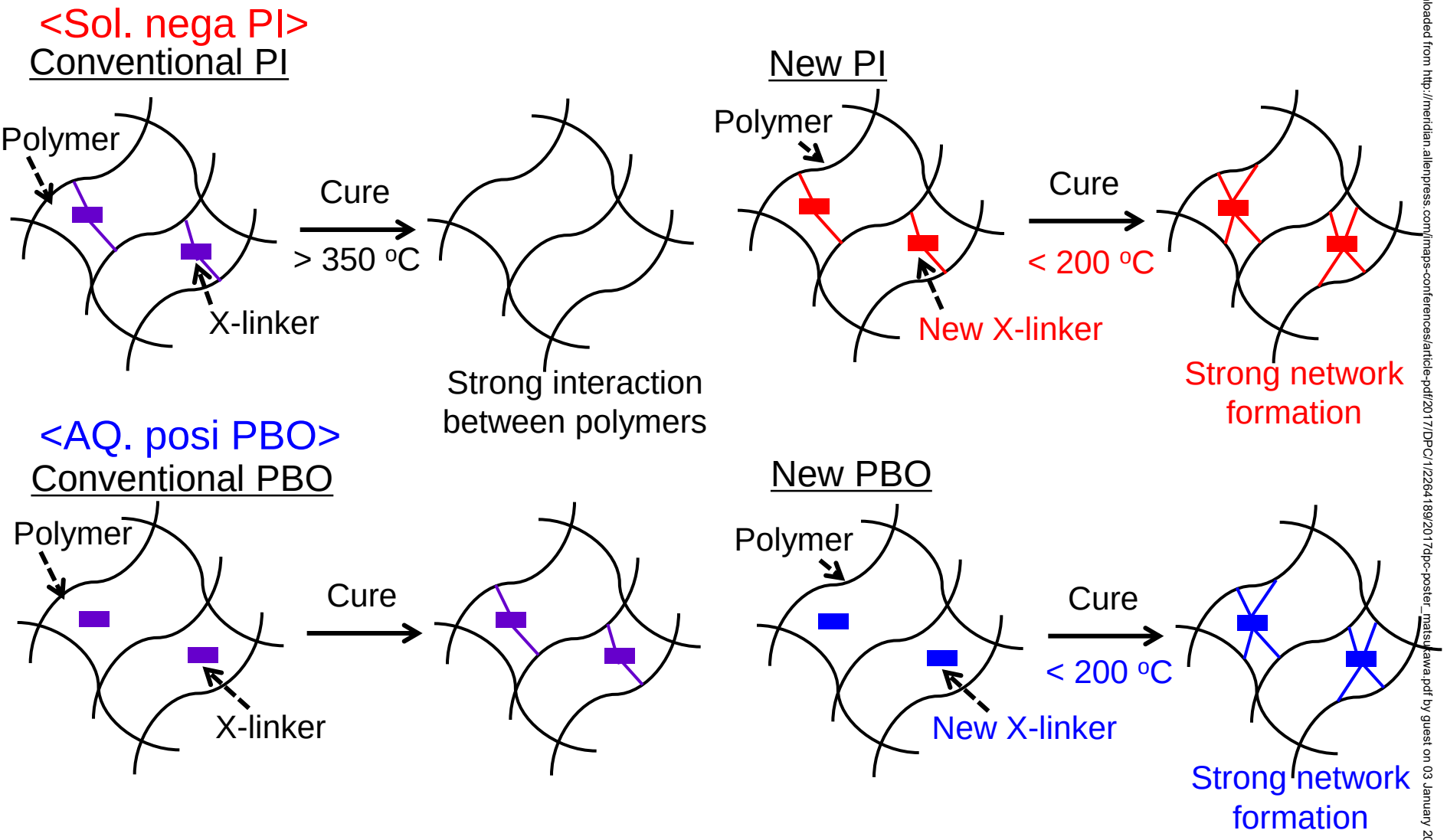
Our approach for new PI/PBO



Combination of new photo initiator and new cross linker to improve resolution and cured film properties.

Sample name	Photo initiator	Cross-linker
Conventional PI	A-1 (low resolution)	B-1 (high film property at high temp.)
New PI	A-2 (high resolution)	B-2 (high film property at low temp.)
Conventional PBO	C-1 (dissolution contrast: low)	D-1 (reaction temp.: middle)
New PBO	C-2 (dissolution contrast: high)	D-2 (reaction temp.: low)

Design concept for low temp. curability

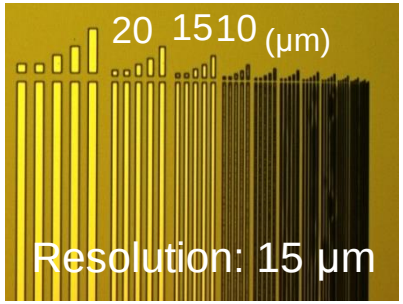


✓ **New PI/PBO formed strong network even cured at low temp..**

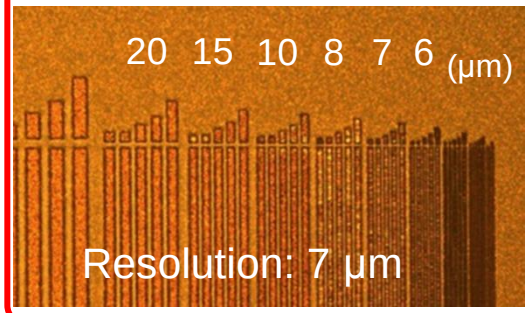
Lithographic properties of PIs

<Top view>

Conventional PI



New PI



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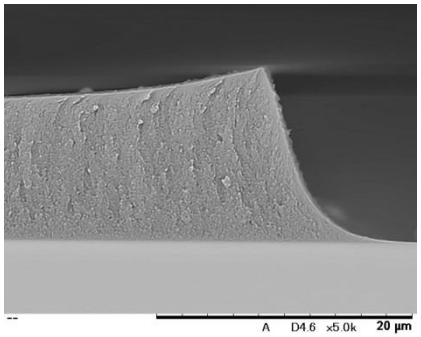
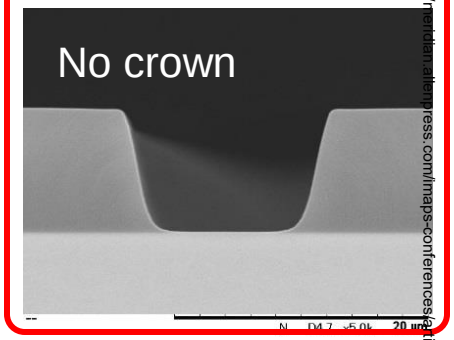
Conventional PI



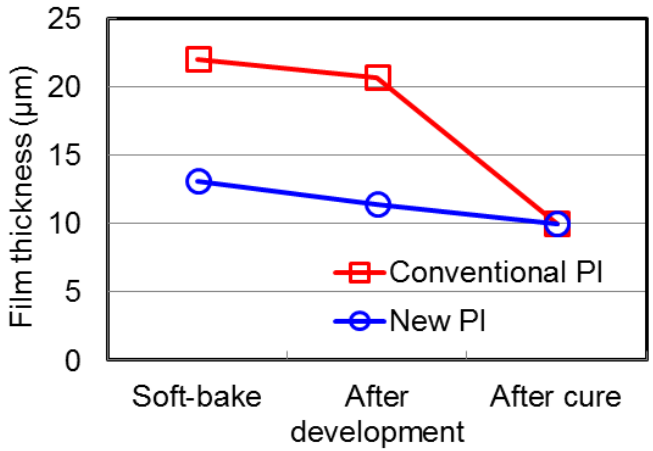
New PI



cured film thickness: 10 μm.

✓ **New PI showed high resolution (7 μm L/S) with smooth pattern profile.**

<Film thickness change at each steps>



✓ **New PI showed lower shrinkage than conventional PI.**

Cured film properties of PIs

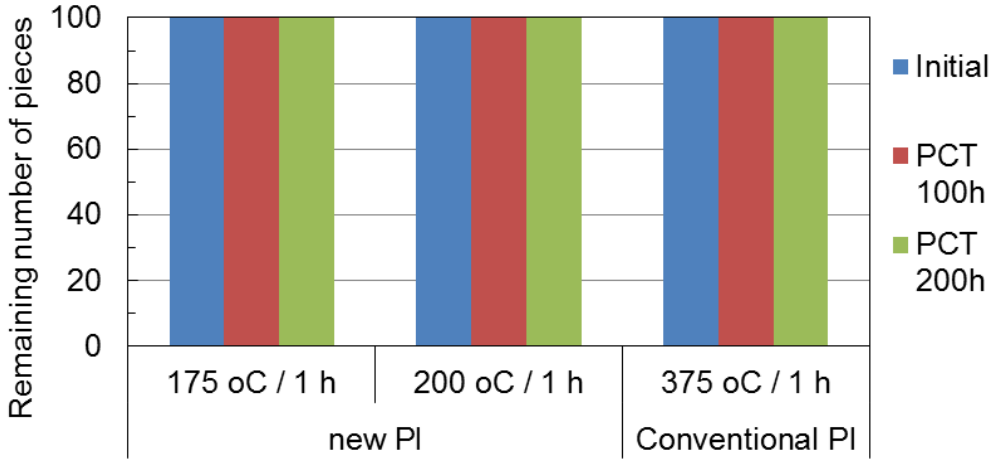
Item	Unit	New PI				Conventional PI
Cure temp.[a)]	°C	175	200	225	250	375
Tensile strength	MPa	200	200	210	190	200
Elongation	%	52	55	58	48	45
Young's Modulus	GPa	3.0	2.9	2.8	2.9	4.0
Tg value (TMA)	°C	211	217	234	253	325
CTE	ppm	68	68	58	57	35
Weight loss temp.(5%)	°C	314	320	336	342	480

[a)] Cure time: 1 h.

- ✓ **New PI showed high elongation regardless of curing temperature.**
- ✓ **Especially, New PI showed > 50 % elongation even cured at 175 °C.**

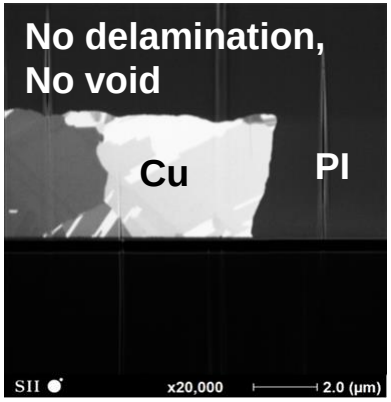
Adhesion properties of PIs

<Results of tape test>



✓ **New PI showed high adhesion to Cu wafer even cured at 175 °C.**

<X-section>



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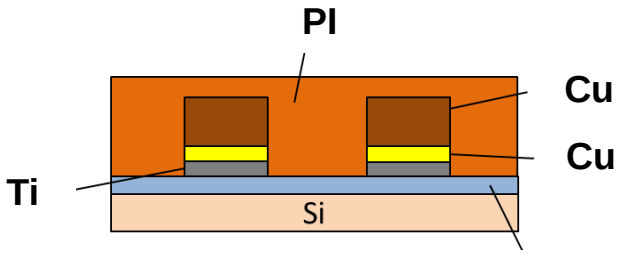


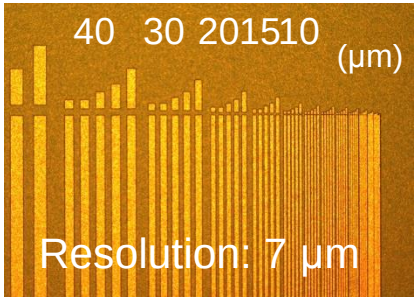
Cure cond. : 175 °C/1h
PCT condition : 121 °C / 100 %RH / 2 atm
PCT time: 168 h.

✓ **No delamination was observed with New PI cured at 175 °C.**

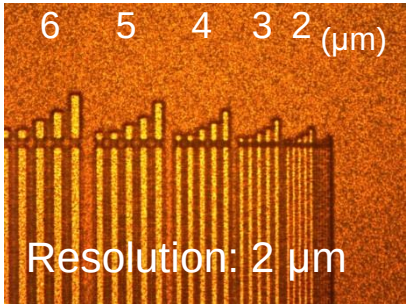
Lithographic properties of PBOs

<Top view>

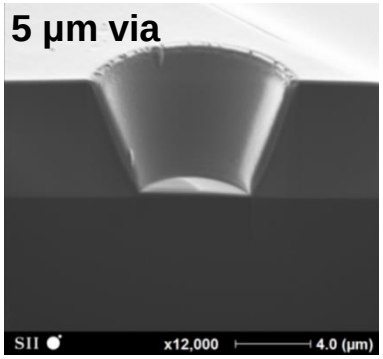
Conventional PBO

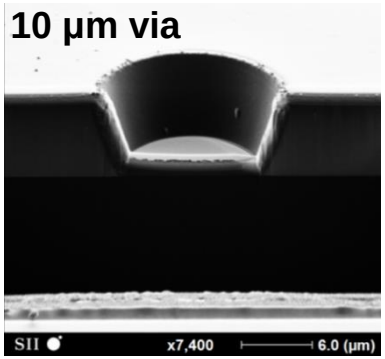


New PBO



<X-section of New PBO>





Exposure dose : 220 mJ/cm^2 (i line)
Cure condition : 200 ^{o}C / 1 h

- ✓ **High resolution and 2 μm opening is available!!**
- ✓ **Smooth pattern profile, high sputtering compatibility**

<Thick film formability>

Sample	Thickness after softbake (μm)	Exposure dose (mJ/cm^2)	Thickness after development (μm)	Thickness after cure (μm)	Resolution (μm)
New PBO	11.4	180	8.5	7.2	**2**
	27.4	640	19.9	15.6	**3**
Conventional PBO	11.2	230	8.5	7.3	**7**
	19.8	**1040**	15.2	12.2	**15**

- ✓ **3 μm opening is available for thick film**

Cured film properties of PBOs

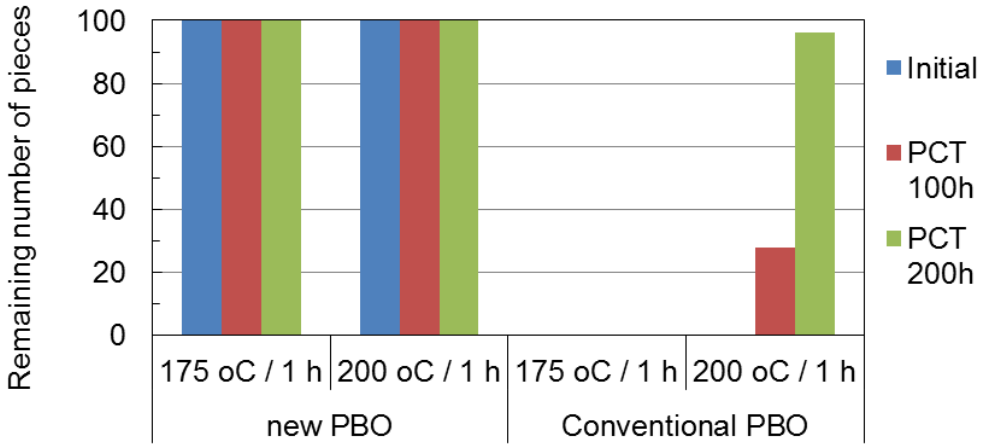
Item	Unit	New PBO				Conventional PBO		
Cure temp.[a)]	°C	175	200	225	250	200	225	250
Thickness	μm	3-10				7-10		
Sensitivity (i-line, 5 μm)	mJ/cm^2	180				210		
Tensile strength	MPa	160	150	120	120	170	170	170
Elongation (Max.)	%	65	60	50	50	80	80	80
Young's Modulus	GPa	2.1	2	1.7	1.8	1.8	1.8	1.7
Tg value (TMA)	°C	250	250	260	260	240	245	245
CTE	ppm	70	70	70	75	80	80	80
Weight loss temp.(5%)	°C	295	320	345	360	310	345	360

a) Cure time: 1 h.

✓ **New PBO showed high mechanical properties even cured at 175 °C.**

Adhesion properties of PBOs

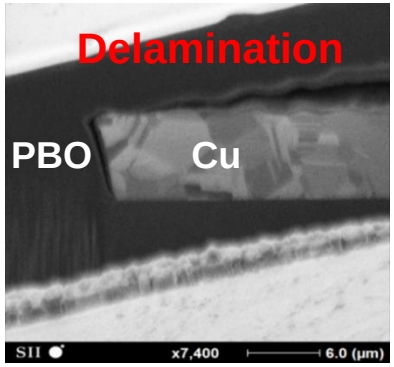
<Results of tape test>



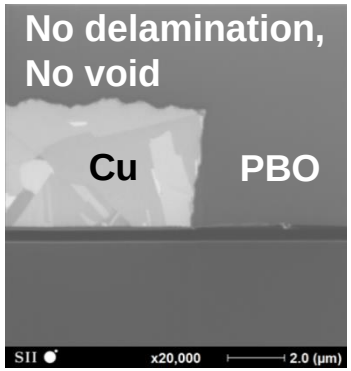
✓ **New PBO showed high adhesion to Cu wafer even cured at 175 ºC.**

<X-section>

Conventional PBO



New PBO



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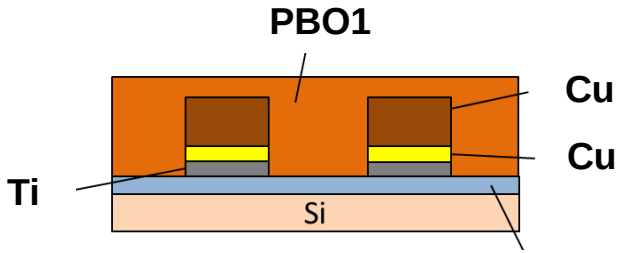


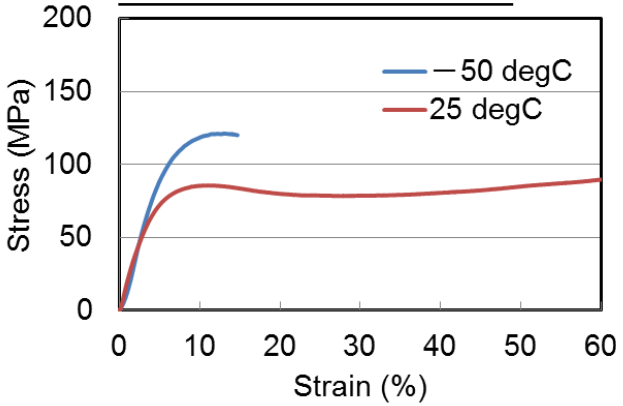
Cure cond. : 200 ºC/1h
PCT condition : 121 ºC / 100 %RH / 2 atm
PCT time: 168 h.

✓ **New PBO showed no delamination after PCT.**

Reliability test results: elongation

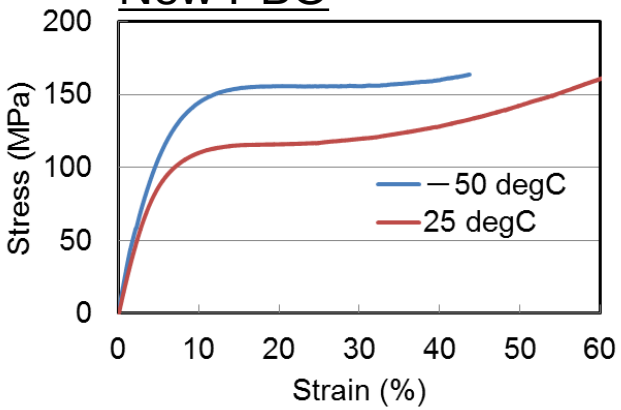
<Elongation at R.T. and - 50 °C>

Conventional PBO



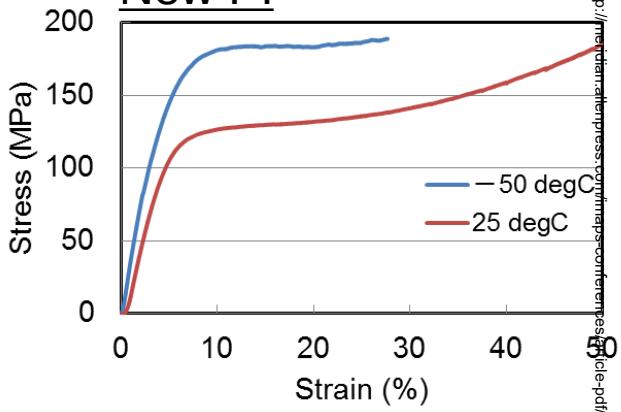
Cure temp.: 225 °C.

New PBO



Cure temp.: 200 °C.

New PI



Cure temp.: 200 °C.

✓ **HDM PI/PBO showed high elongation at both R.T. and - 50 °C.**

<Mechanical properties after TCT>

Sample	TCT cycle	Tensile strength (MPa)	Elongation (%)	Modulus (GPa)
New PBO	0	150	60	2.0
	200	130	60	2.0
New PI	0	200	55	2.9
	200	190	50	2.9

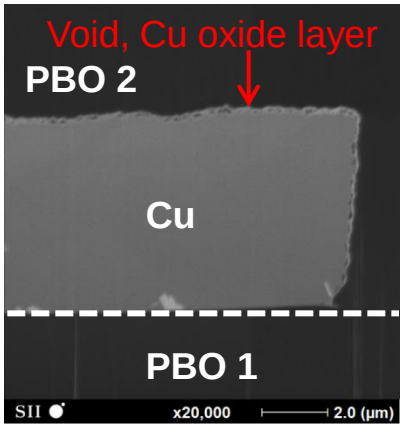
TCT condition: from -65°C to 150°C, each 30 min.

✓ **HDM PI/PBO showed high elongation after TCT.**

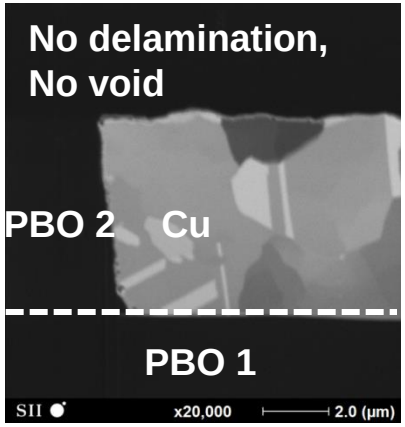
Reliability test results: adhesion

<X-section after TCT>

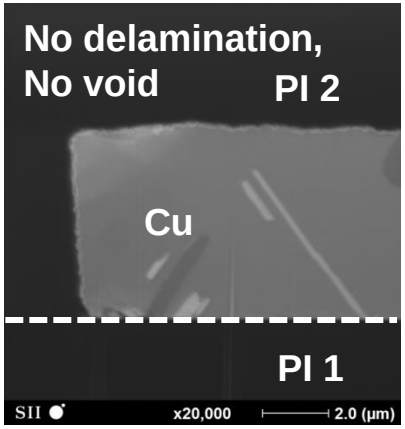
Conventional PBO



New PBO

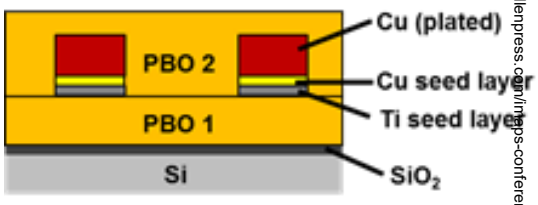


New PI



<Test condition>

TCT condition:
from -50ºC to 125ºC, each 15 min.



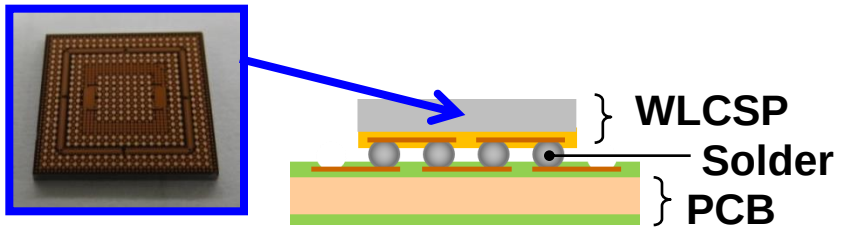
<Adhesion results after TCT>

Sample	Cure temp. (ºC)	Cu adhesion		
		TCT cycle:0	TCT cycle: 1000	TCT cycle: 2000
Conventional PBO	200	Passed	Delaminated	Delaminated
	225	Passed	Delaminated	Delaminated
New PBO	175	Passed	Passed	Passed
	200	Passed	Passed	Passed
New PI	200	Passed	Passed	Passed
	225	Passed	Passed	Passed

✓ **HDM PI/PBO showed high adhesion after TCT.**

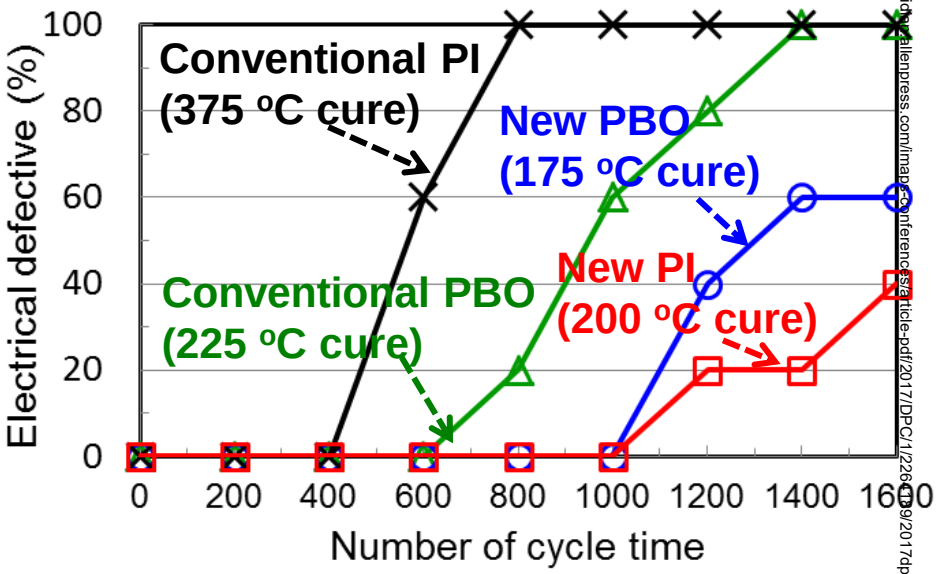
Reliability test results: electrical defective

<Test vehicle>



WLCSP: 1 Cu RDL, 2 PBO layers
Ball mount area: 3.5 x 3.5 mm
Chip size: 10 x 10 mm

<Result>



TCT condition: from -50ºC to 125ºC, each 15 min

- ✓ **New PI and New PBO showed excellent reliability result.**
- ✓ **HDM PI/PBO showed high TCT resistance.**

Summary

Our new photodefinable PI/PBO has following features.

- High resolution (1) 7 μm L/S is available for new PI
  (2) 2 μm L/S is available for new PBO
- Low temperature (175 °C) curable
- High reliability after TCT