A Study of Solder Optimization Development for Portable Electronic Device

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With increasing use of portable appliances such as PDA and cellular phone, changing environment of application requires higher solder joint reliability. The Cu-OSP process has been widely used for portable devices due to its benefits including good surface planarity, cheapest finish and higher drop reliability than others.

This study is about reliability according to solder materials on package with OSP finished, and is evaluated the various Ag, Cu contents and adding few special dopants.

The Inter-Metallic Compound between pad and solder material after reflow has the scallop type and is composed Cu_6Sn_5 by using EDS.

Investigated the 3 types fracture mode after drop strength: The first is the crack propagating along IMC layer which composed of Cu6Sn5 (interfacial fracture mode), the second is the crack propagating along solder side (bulk fracture mode); the final is the crack propagating along the above IMC layer between IMC and solder.

The unstable interface exists through IMC, pad material and solder bulk by the lattice mismatch, so that the thermal and physical stress due to the continuous exterior impact is transferred to the IMC interface. Therefore, it is strongly requested to control solder morphology, IMC shape and thickness to improve the solder reliability.

In case of increasing the Cu contents, IMC shape changed scallop type to spike type, and IMC had larger toughness by using nano-indenter.

Accelerated stress propagated along the weaken surface between solder and IMC, this phenomenon is caused to increasing drop performance.

Moreover, as the special dopants were added, the relatively weak thermal shock strength could be improved.

A Study of Optimizing Solder Development for Portable Electronic Device

DIV. R&D

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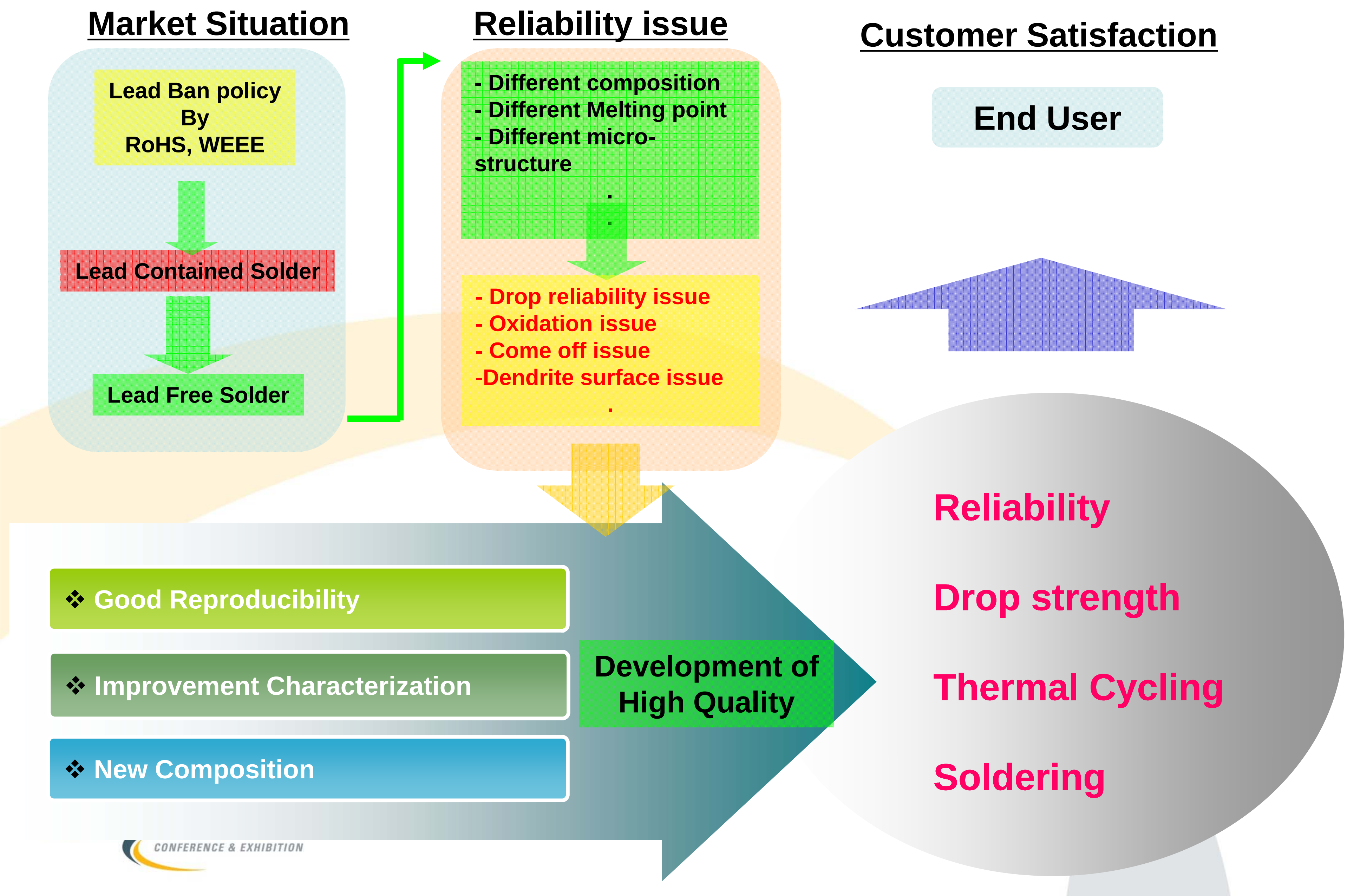
Market Situation
Lead Ban policy By RoHS, WEEE
Lead Contained Solder
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Reliability
Drop strength
Thermal Cycling
Soldering
CONFERENCE & EXHIBITION

Background

Summary for the properties of various solder alloys

Composition	Shear strength	Pull strength	Hardness	Wet-ability	Mush Zone	Drop strength	Thermal cycling	Extrude Ag_3Sn	Remarks
SAC105	Weak	Weak	Weak	Worse	Wide	Good	Worse	Weak	Good for Ni/Au pad
SAC1205-0.05Ni				Worse	Wide	Good	Worse		Good for Cu-osp pad
SAC2505				Good	Narrow	Good	Good		
SAC305				Good	Narrow	Worse	Good		
SAC3505				Good	Narrow	Worse	Good		
SAC405	Strong	Strong	Strong	Good	Narrow	worse	Good	Extrude	

Background

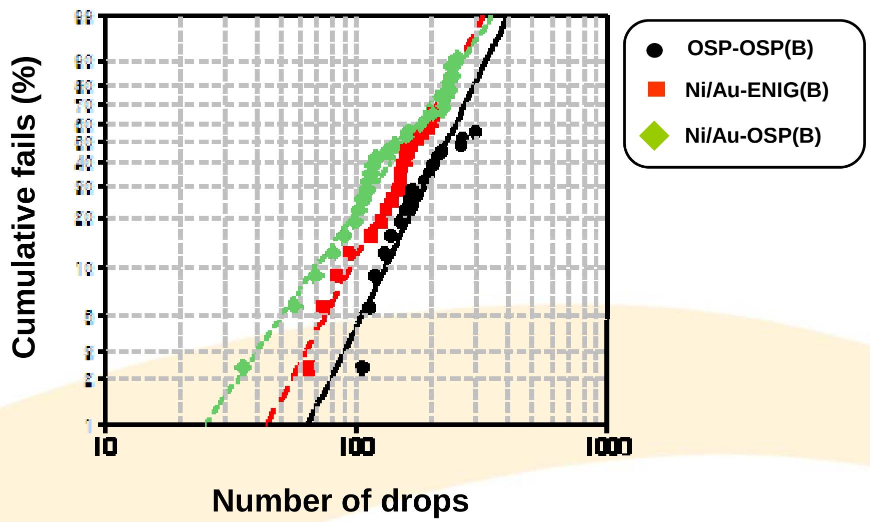
PCB trend

Finish	Advantage	Dis-advantage
Electro-lytic Ni/Au	-. Installed capacity, legacy process; excellent WB capability and solderability. -. Growth kinetics of Sn-Ni IMC is slower than Cu-Sn IMC. -. Better stability of the pad prior to soldering.	-. Au embrittlement when Au>3 wt% - Not an issue for flash packages
ENIG	-. Widely & generally used -. Good shelf life(-months) -. Handling tolerance	-. Industry variations due to different process chemistries. -. The most challenging PCB process requiring sophisticated controls. -. Requires disciplined process control or optimization
ENEPIG	-. Excellent solder-ability. -. Good shelf life (~12 months). -. Ni & Pd are oxidation barriers; E-less Pd is not corrosive to Ni. -. Excellent solder-ability.	-. Solder joint strength is dependent highly Upon Pd thickness. -. Much more complex Manufacturing process than that of ENIG.
OSP	-. Good surface planarity. -. Strongest solder joint through Cu-Sn inter-matallic. -. Cheapest finish -. Higher drop reliability than others	-. Short shelf life (~6 months) -. Very narrow time process window for multiple assembly-hours. -. Cannot detect the cause of quality issues -. solder joint issues due to interaction with assembly process by thermal damage.

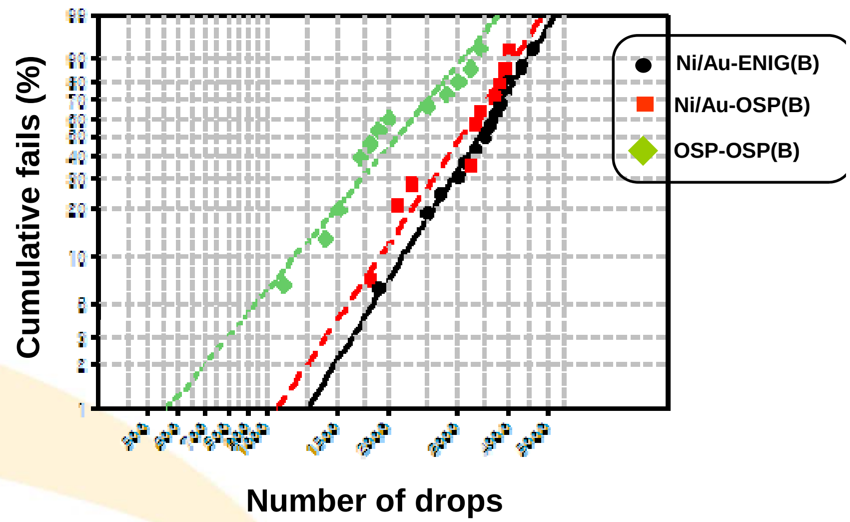
Aim of this study

- **Drop and TC results of SAC305 according to the combination.**

<Drop strength>



<TC strength>



- **Aim of this study**

-. It normally used the OSP-OSP(B) combination for portable electronic device.

-. This combination has high drop performance but very poor TC performance.

We need to develop solder ball which has high drop and TC performance.

Method for developing

Solder ball	Test items	Test machine		Test condition
		Type	Model (maker)	
Various Ag, Cu contents solder ball	Solder ball Image	Optical spectrometer	(OLYMPUS)	X500, X1,000
	Discoloring test	Reflow oven	1707EXL (HELLER)	Peak temp. : 240℃
	DSC test	DSC	DSC200F3 (NETZSCH)	Heating rate : 10℃/min
	Wetting test	Wet-ability test	SP-2 (MALCOM)	Bath temp. : 240℃
	Hardness test	Micro hardness	FM-700 (FUTURE-TECH)	100g X 30 sec.
	Ball shear test	BST	DAGE 4000series (DAGE)	Speed : 700um/sec Height : 20um
	Drop strength	Drop tester	SD10 (LAB)	Acceleration : 1,500G
	Thermal cycling test	TC test	JYT-S-100 (JINYOUNG)	-40℃ ~ 125℃
	IMC observation	FE-SEM	JEOL 6500F	X3,000

Test leg

Test Item		Surface finish	Solder ball	Size	Type
Board level	Drop, TC	OSP	-. Various Ag, Cu contents	0.30 mm 0.45 mm	1. OSP(P) - OSP(B)
	F/M				

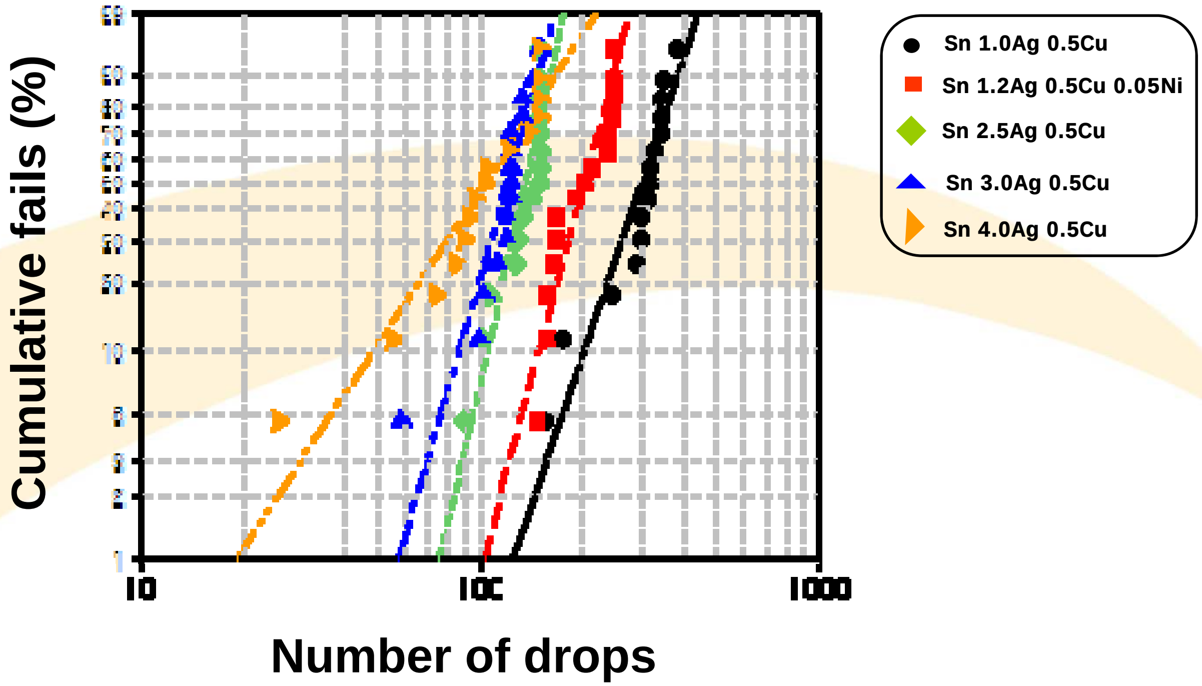
P* : Package (Pad), B* : Board

Basic properties with various Ag contents

Drop strength

-. The acceleration reaches about 900G (±50) upon impact. (activated time : about 0.7msec)

-. Drop shock failure result is analyzed by Weibull method.



-. Drop height : 300mm

-. Acceleration : 900G

-. Count : 400 drops

-. Package : ENIG

-. Board : Cu-OSP

-. Flux : WS type

-. Ball size : 0.45mm

-. Low Ag contents solder has better drop performance than high Ag contents solder.

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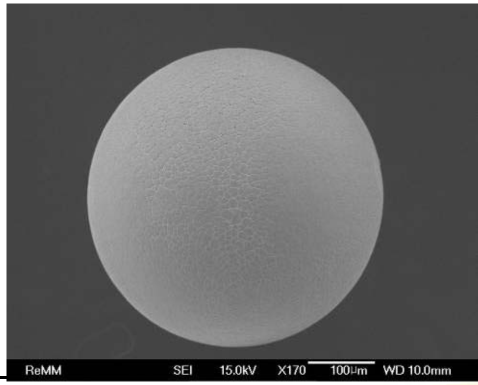
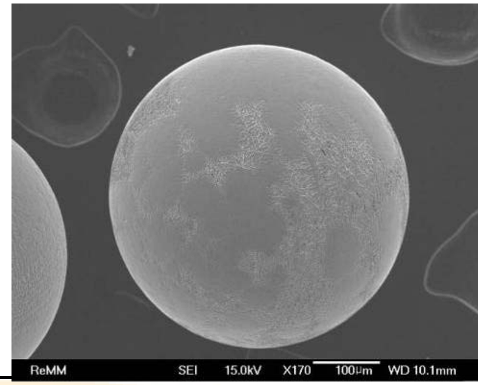
We focused on low Ag contents solder on drop strength.

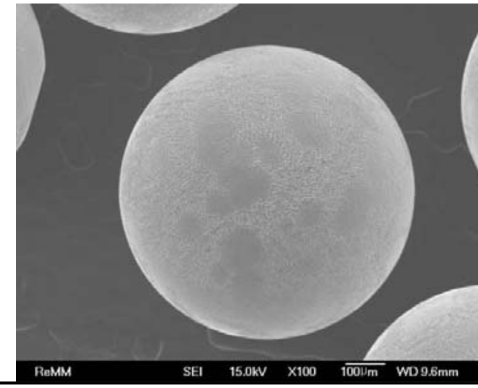
Surface image



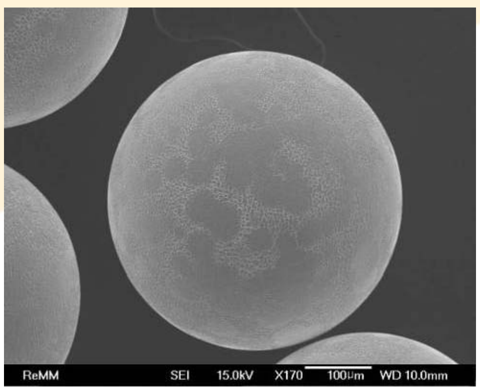
Sn 1.0Ag - 0.45mm



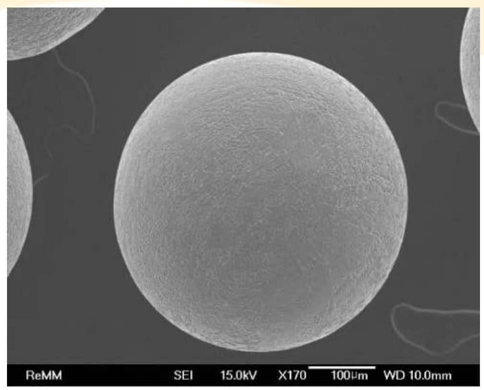
Sn 3.0Ag 0.5Cu – 0.45mm



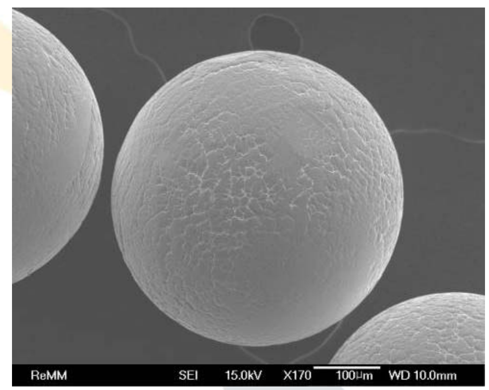
Sn 1.2Ag 0.5Cu 0.05Ni– 0.45mm



Sn 1.0Ag 0.5Cu – 0.45mm

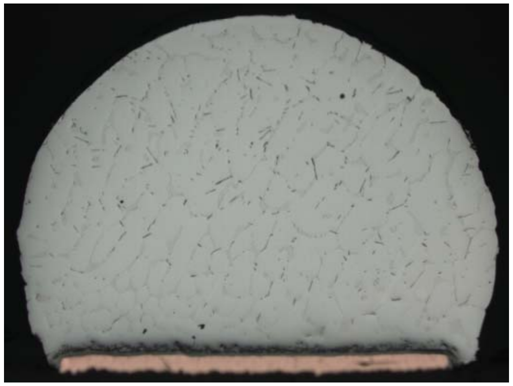


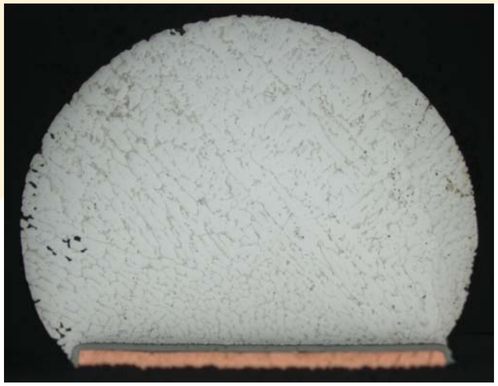
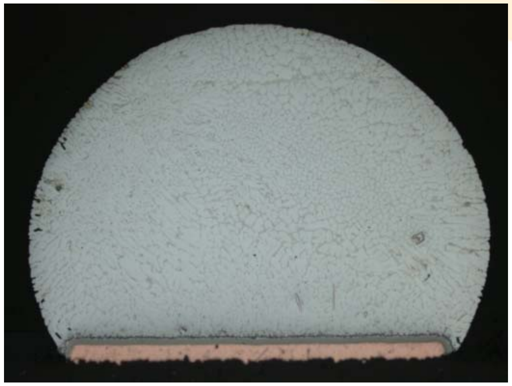
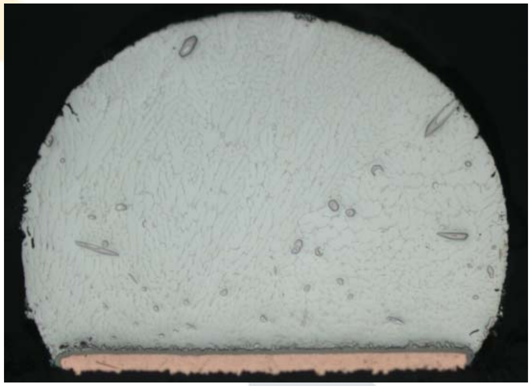
Sn 1.0Ag 1.0Cu – 0.45mm



Sn 1.0Ag 1.5Cu – 0.45mm

Solder bump morphology

	
Sn 1.0Ag – 0.45mm	**Sn 3.0Ag 0.5Cu – 0.45mm**

		
Sn 1.0Ag 0.5Cu – 0.45mm	**Sn 1.0Ag 1.0Cu – 0.45mm**	**Sn 1.0Ag 1.5Cu – 0.45mm**

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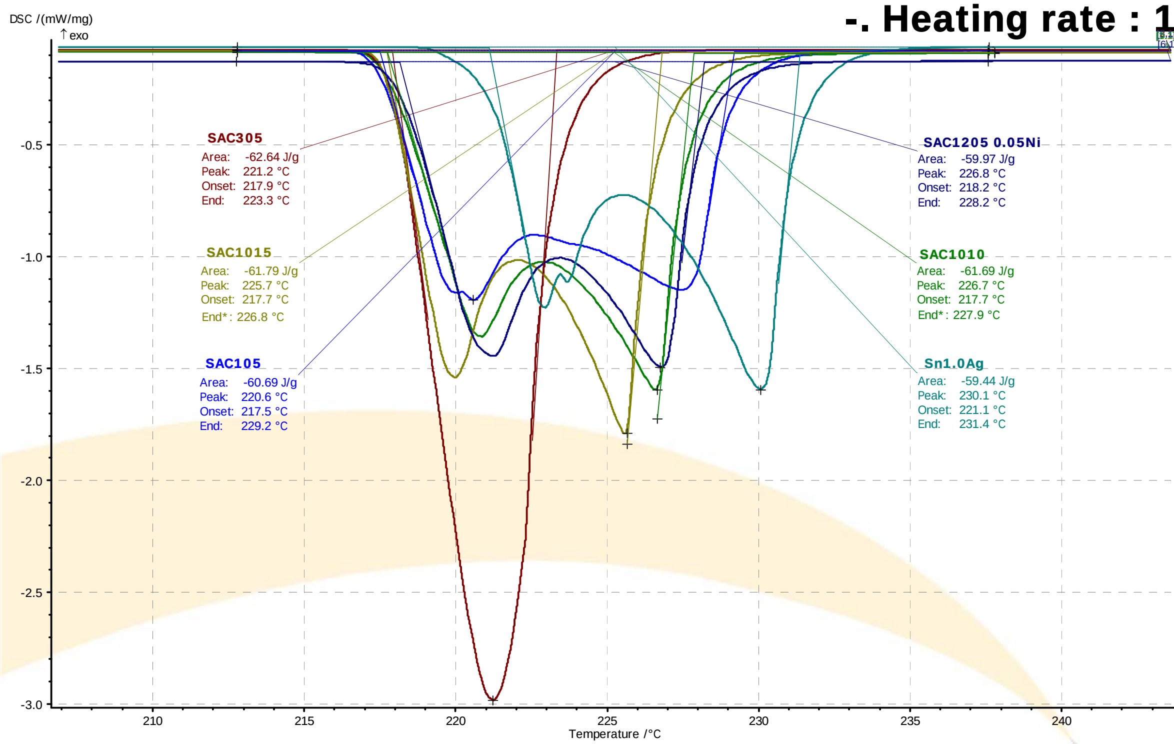
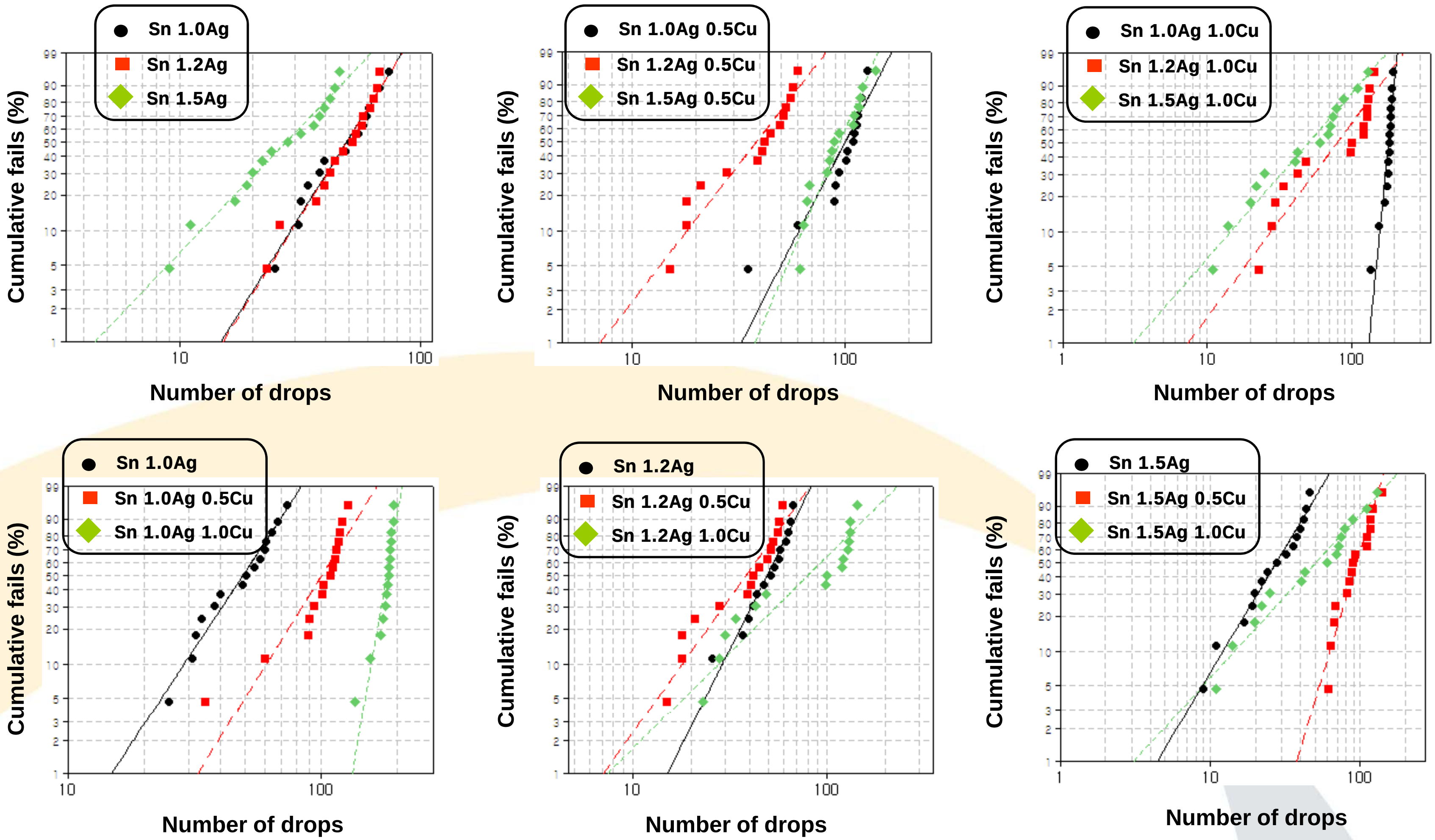
DSC curve

-. Heating rate : 10℃/min.



	On set (℃)	End (℃)	Peak temp. (℃)	Melting range (℃)
Sn 1.0Ag	221.1	231.1	230.1	**221.1 ~ 231.1**
Sn 1.0Ag 0.5Cu	217.5	229.2	220.6	**217.5 ~ 229.2**
Sn 1.0Ag 1.0Cu	217.7	227.9	226.7	**217.7 ~ 227.9**
Sn 1.0Ag 1.5Cu	217.7	226.8	225.7	**217.7 ~ 226.8**
Sn 1.2Ag 0.5Cu 0.05Ni	218.2	228.2	226.8	**218.2 ~ 228.2**
Sn 3.0Ag 0.5Cu	217.9	223.3	221.2	**217.9 ~ 223.3**

Drop strength according to various Ag, Cu contents



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-. Sn 1.0Ag 1.0Cu solder ball has the best drop performance among all samples.

TC strength according to various dopants

Thermal Cycle Tester

Test Machine	Thermal Cycle Tester
Model	JYT-S-500
Maker	JIN YOUNG (in Korea)
Temp. Range	-70℃ ~ 180℃
Reference	JESD22-A104-B

Test condition : JEDEC C condition

-65℃ ~ 150℃

	1% failure	5% failure	10% failure
Sn 1.0Ag 1.0Cu 0.03Pd	819	958	1113
Sn 1.0Ag 1.0Cu 0.03Co	330	600	1064
Sn 1.0Ag 1.0Cu 0.03Sb	424	593	816
Sn 1.0Ag 1.0Cu	632	812	1033

* 1% failure means that there are 1% fail units after 819 cycles.

* There is a different TC strength according to various dopants.

* Solder ball added Pd is the best TC performance among all samples.

Summary

1. Low Ag solder had better drop performance than high Ag solder.

2. Sn 1.0Ag 1.0Cu had the best drop performance among all samples.

3. Sn 1.0Ag 1.0Cu of adding Pd had better TC performance than that of nothing.

4. There was a difference reliability kinds of adding materials.

<Further work>

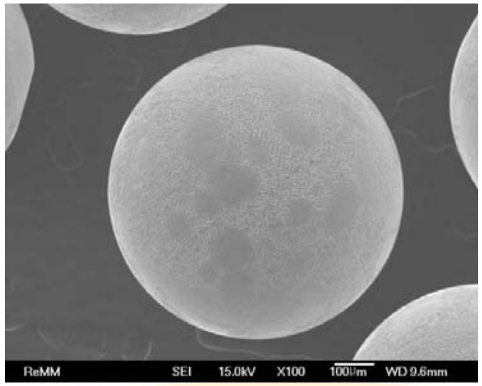
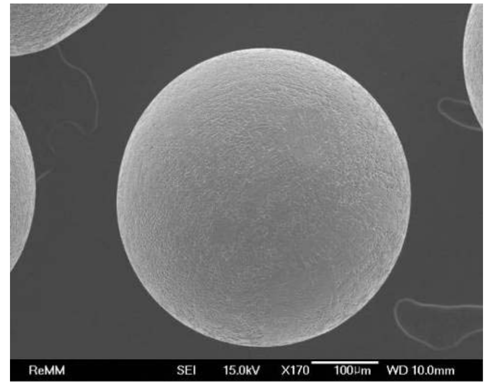
1. Reliability test comparing

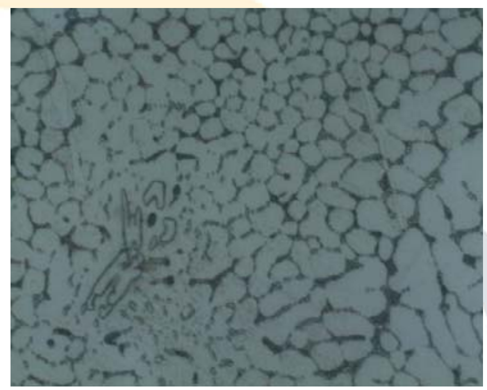
Sn 1.0Ag 1.0Cu 0.03Pd with Sn 1.2Ag 0.5Cu 0.05Ni on OSP-OSP system.

-. SAC1010Pd stands for Sn 1.0Ag 1.0Cu 0.03Pd.

-. SAC1205Ni stands for Sn 1.2Ag 0.5Cu 0.05Ni.

Solder ball image

	
Sn 1.2Ag 0.5Cu 0.05Ni	**Sn 1.0Ag 1.0Cu 0.03Pd**

	
Sn 1.2Ag 0.5Cu 0.05Ni	**Sn 1.0Ag 1.0Cu 0.03Pd**

-. SAC1010Pd had fine grains comparing SAC1205Ni.

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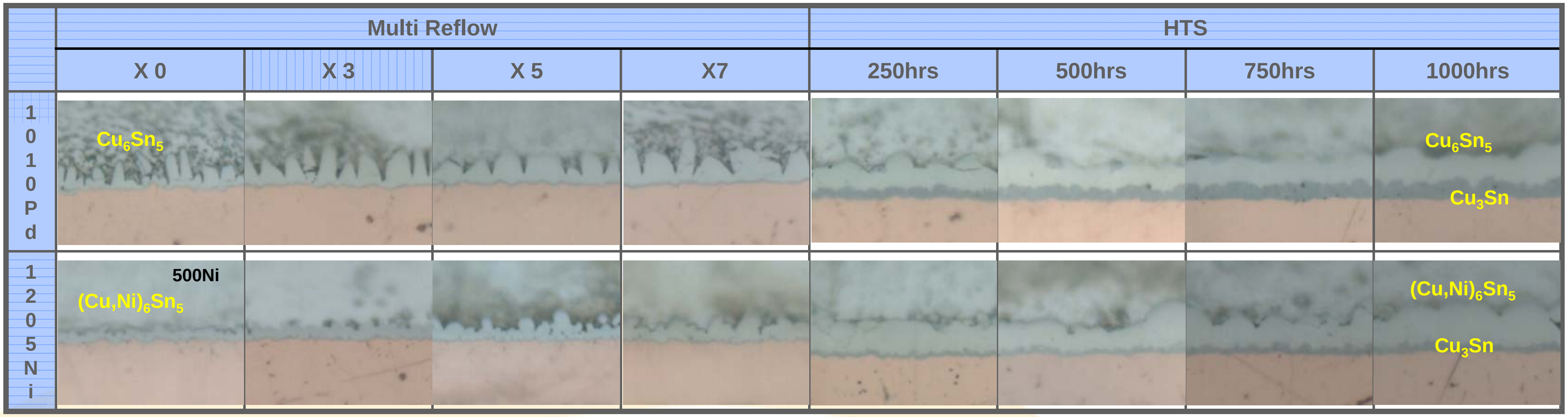
Inter-metallic compound on OSP finished



1. SAC1010Pd had a needle type IMC and SAC1205Ni had a scallop type IMC.

2. The thickness of SAC1205Ni IMC has smaller than that of SAC1010Pd.

⇨ It seems that Ni controlled the IMC growth.

3. The 2nd IMC was observed all samples after heat treatment.

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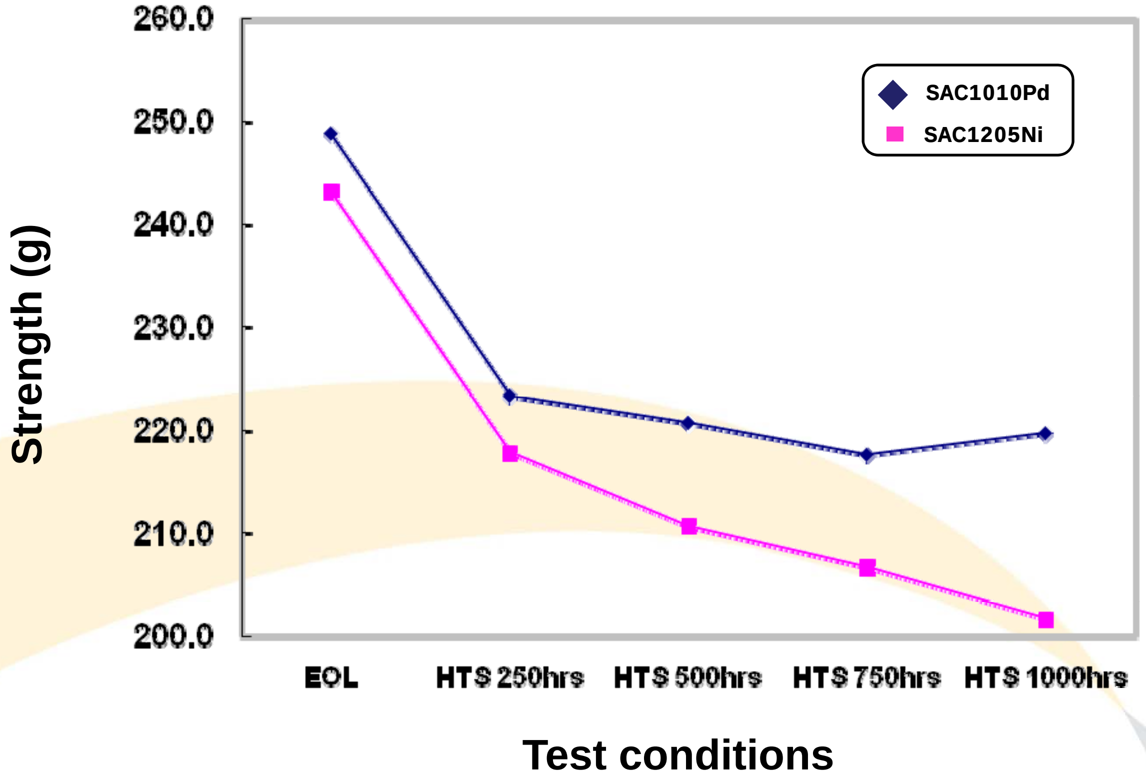
BST strength

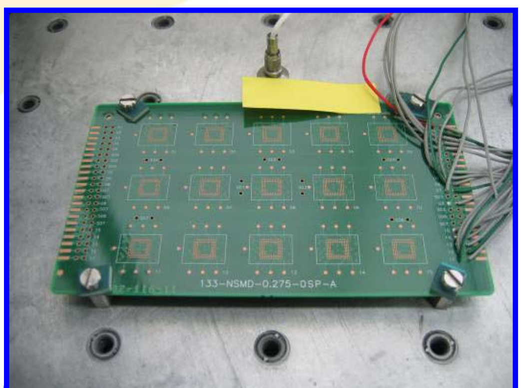


1. The shear strength of SAC1010Pd had a stronger than that of SAC1205Ni.

2. The strength decreased regardless samples after heat treatment.

High drop performance

Test machine



Drop Test Board

Test condition

	Conditions			
Test Conditions	Machine	SD-10 (LAB)		
	Accelera tion	1500 G		
	Count	600 times		
	Ball size	0.30mm		
Packages	Package	Board	Unit No	15 units / Leg X 7
	OSP	OSP	105 units	
Solder Alloys	SAC1010Pd (Sn 1.0Ag 1.0Cu 0.03Pd)			
	SAC1205Ni (Sn 1.2Ag 0.5Cu 0.05Ni)			

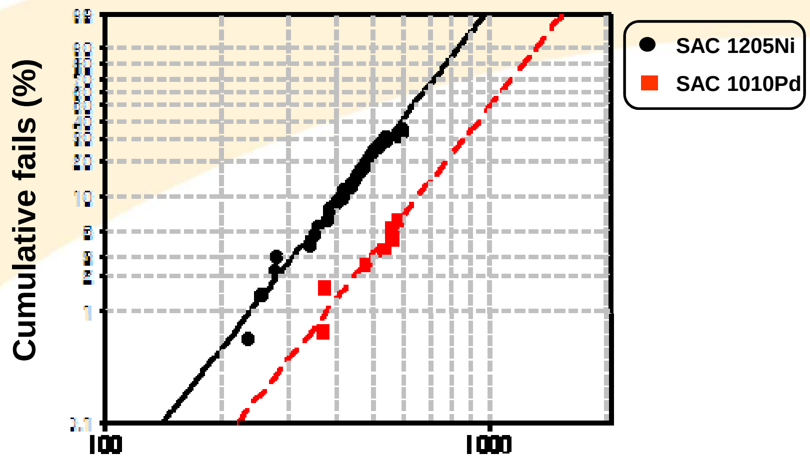
*** All samples have been assembled by assembly house**

Drop strength

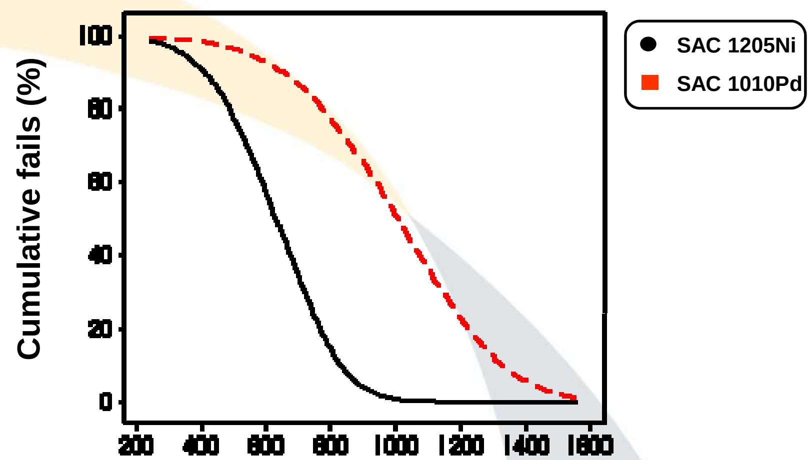
➢ Drop test result of *OSP – OSP (board)* system & 0.30mm S/B

	1% failure	5% failure	10% failure	63.2% failure
SAC 1205Ni	239	348	411	689
SAC 1010Pd	379	553	653	1099

Weibull distribution



Survival probably



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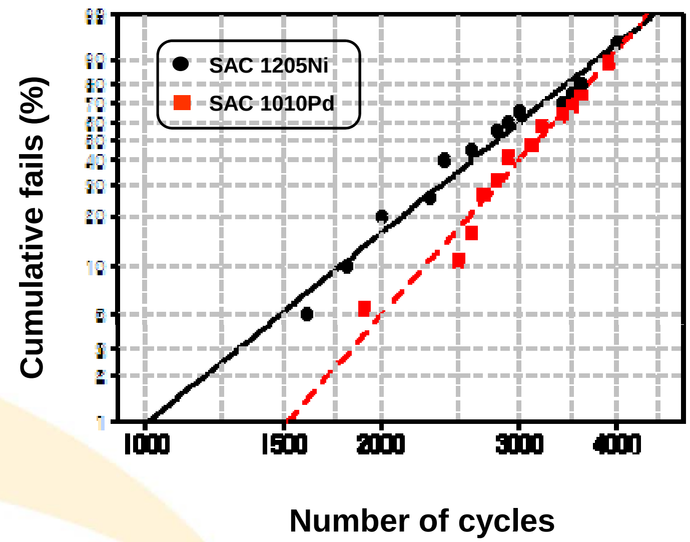
TC strength

•TC Performance:

SAC1010Pd > SAC1205Ni

Weibull distribution



-. TC test : -40℃ / + 125℃, 10min hold / 5min ramp

(JEDEC G condition)

-. Continuous electrical test : measurement of resistivity

of each ball during TC test until 100% failure.

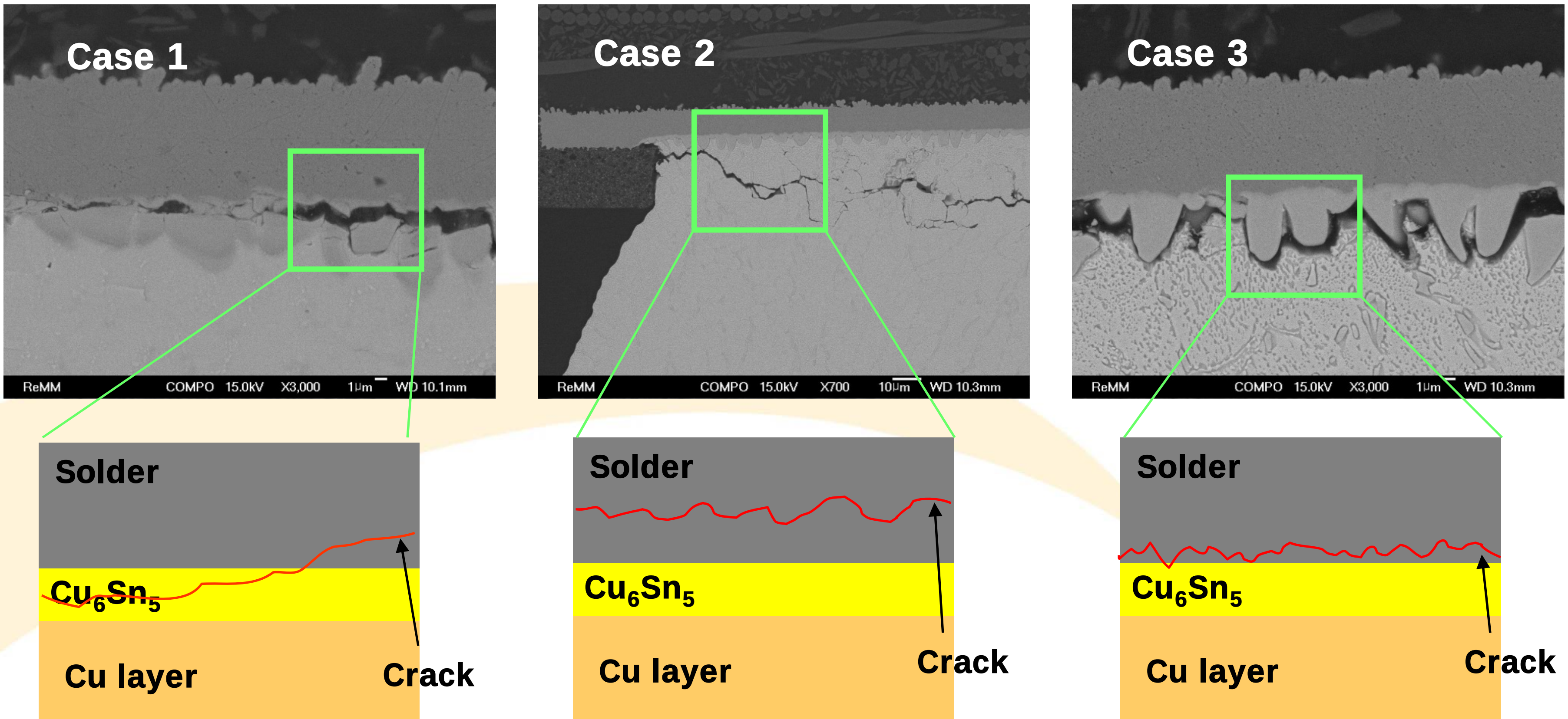
-. Definition of failure of 1 unit :

10% increase in solder joint resistance

Sample	1% failure	10% failure	50%fail	62.3%fail
SAC1010Pd	1512	2009	2277	3369
SAC1205Ni	1003	1490	1775	3067

Fracture mode after drop strength

- **OSP-OSP system**



-. Crack propagate along IMC layer which composed of Cu_6Sn_5 (Interfacial Fracture Mode)

-. Crack propagate along solder side (Bulk Fracture Mode)

-. Crack propagate along the above IMC layer solder between IMC and solder.

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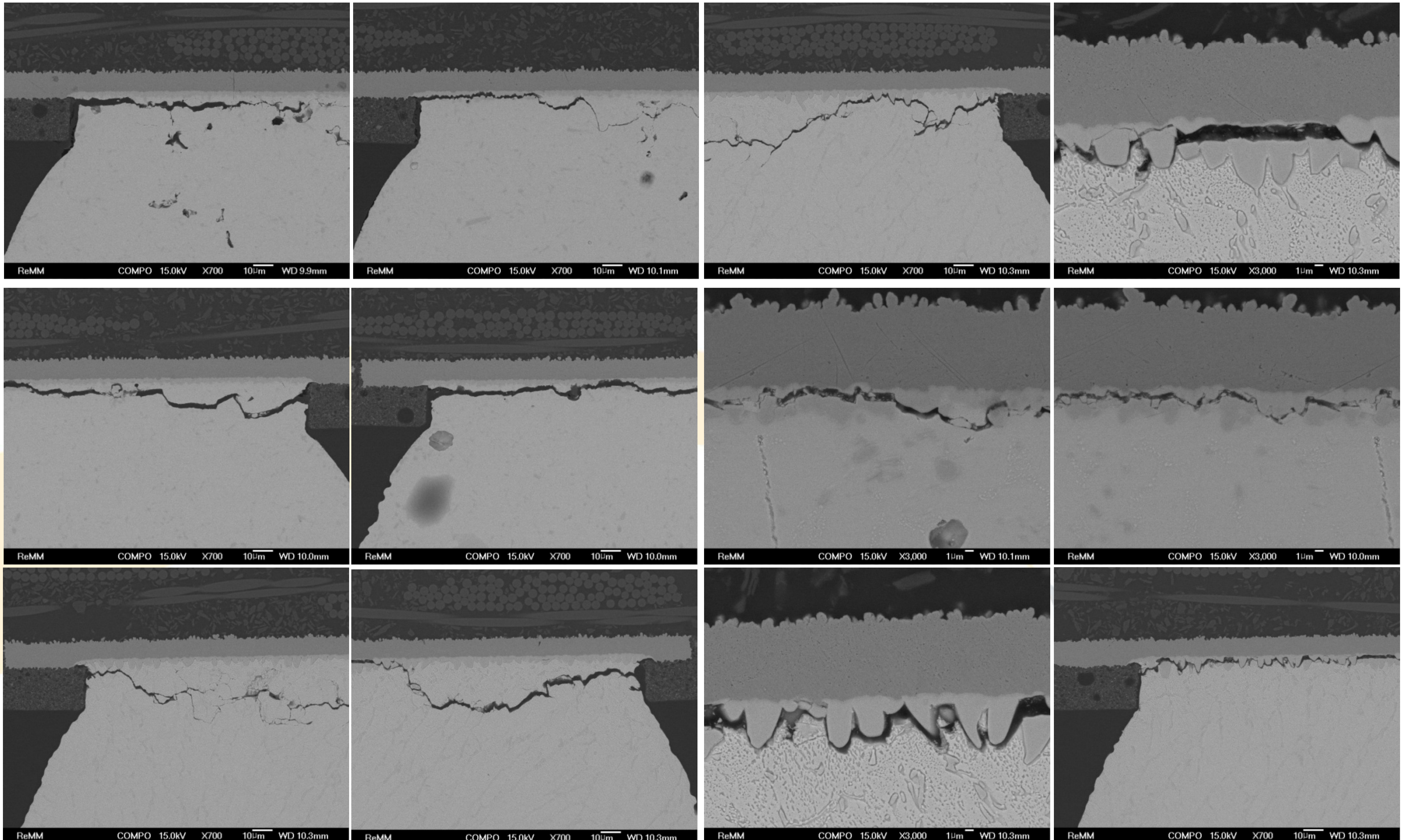
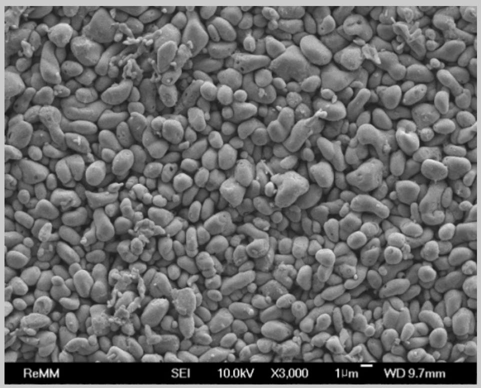
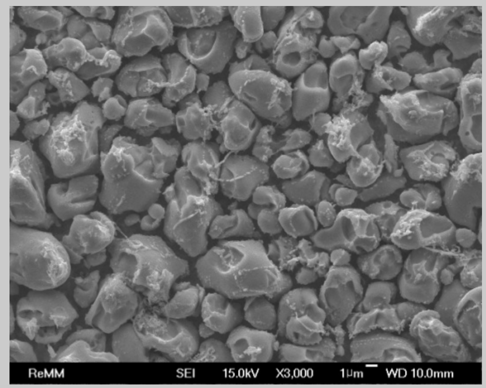
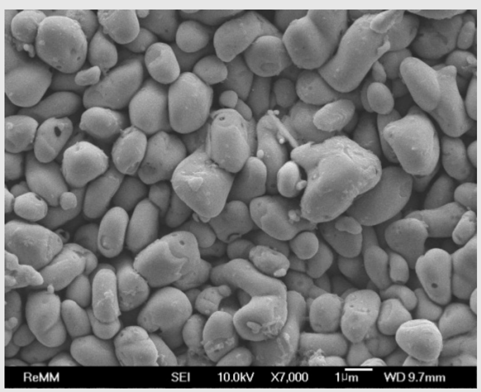
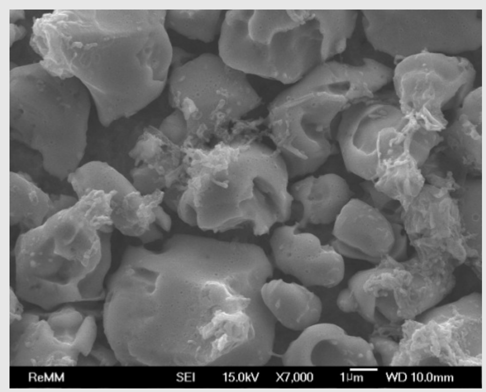
Fracture mode after drop strength



MIDWEST CONFERENCE & EXHIBITION

Analysis of mechanism drop strength

- **The reason why SAC1010Pd shows high drop performance than SAC1205Ni**

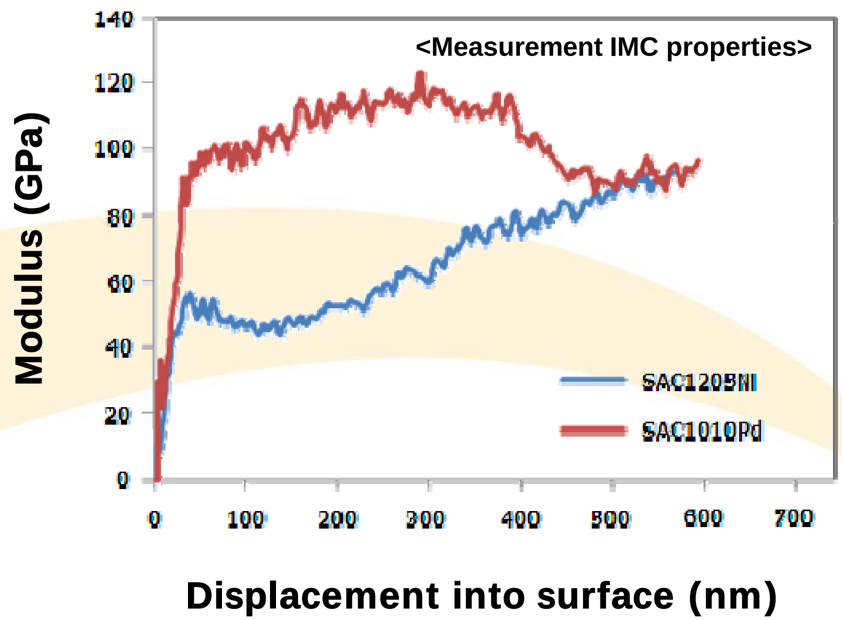
SAC1205Ni	SAC1010Pd
	
	

-. IMC size of SAC1205Ni has smaller than that of SAC1010Pd.

Analysis of mechanism : drop strength

The reason why SAC1010Pd shows high drop performance than SAC1205Ni

<Equipment : Nano Indenter XP >



-. Toughness of SAC1010Pd shows bigger value than that of SAC1205Ni does.

→ The fracture occurred along the soft surface between solder and IMC surface,

and SAC1010Pd had higher durability than SAC1205Ni does.

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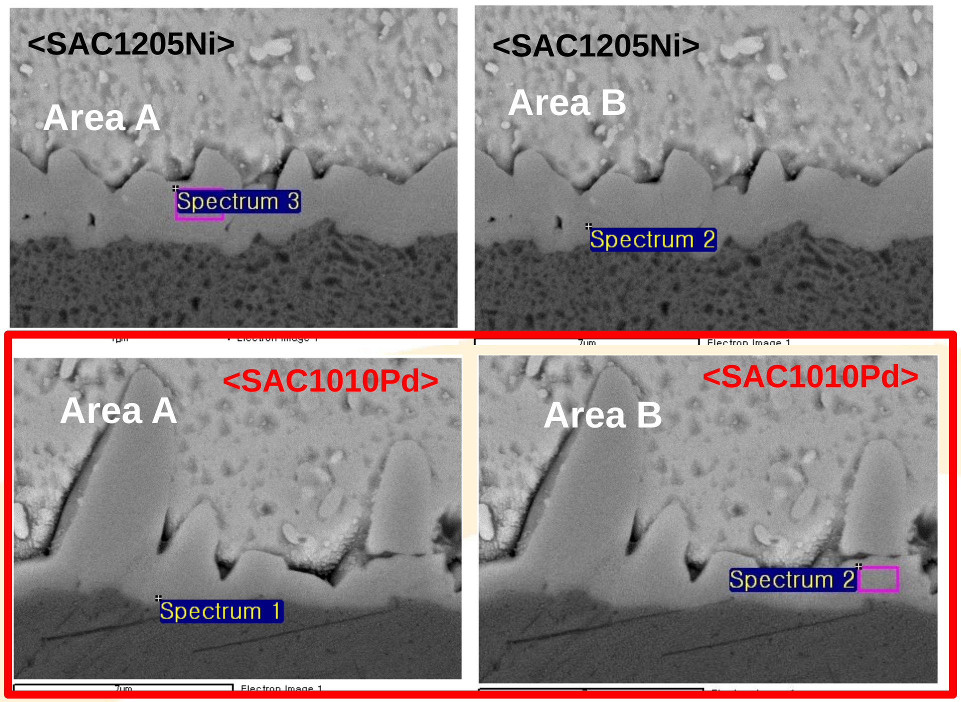
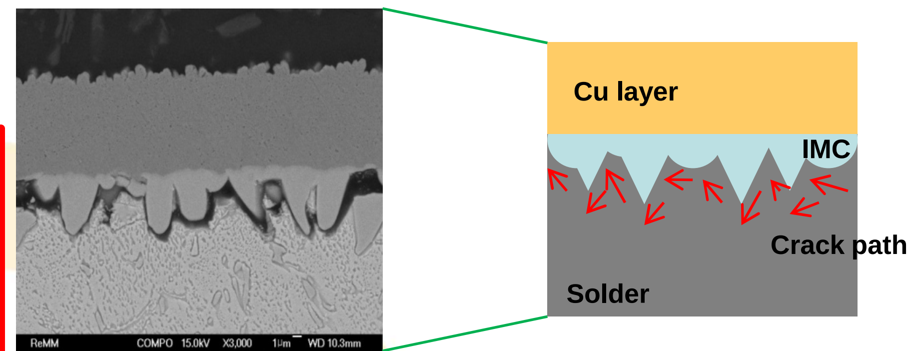
Analysis of mechanism : drop strength

The reason why SAC1010Pd shows high drop performance than SAC1205Ni



<Schematic for the crack path of SAC1010Pd after drop strength>



		% of weight				
		N	O	Ni	Cu	Sn
SAC1205Ni	Area A	7.17	4.29	1.18	30.36	59.99
	Area B	6.18	6.89	1.14	35.98	49.81
SAC1010Pd	Area A	2.64	5.69	-	44.05	47.62
	Area B	2.91	7.06	-	34.12	55.91

-. IMC layer of SAC1010Pd is spike type and might be tough (not brittle).

-. IMC shape, size, composition of SAC1010Pd are all different comparing SAC1205Ni.

→ Different IMC properties can cause high drop resistance.

Long crack path → High drop resist

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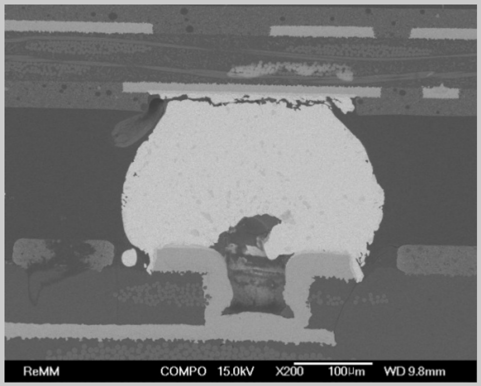
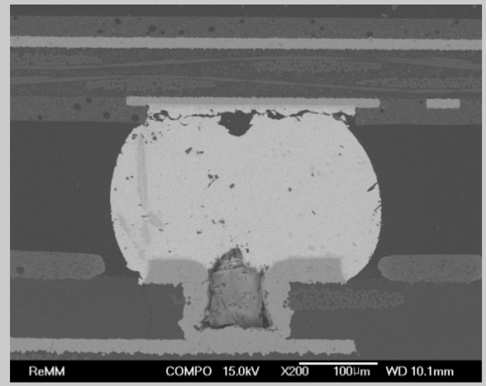
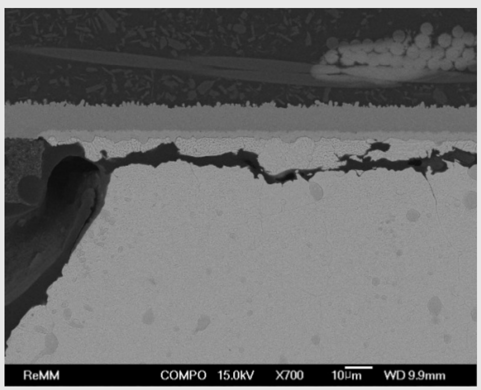
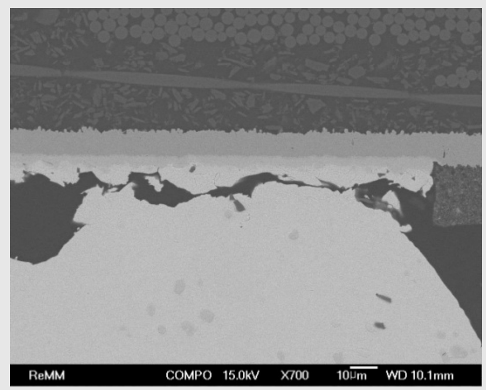
Analysis of mechanism : TC strength

SAC1205Ni	SAC1010Pd
	
	

-. The crack propagated through the grain boundary.

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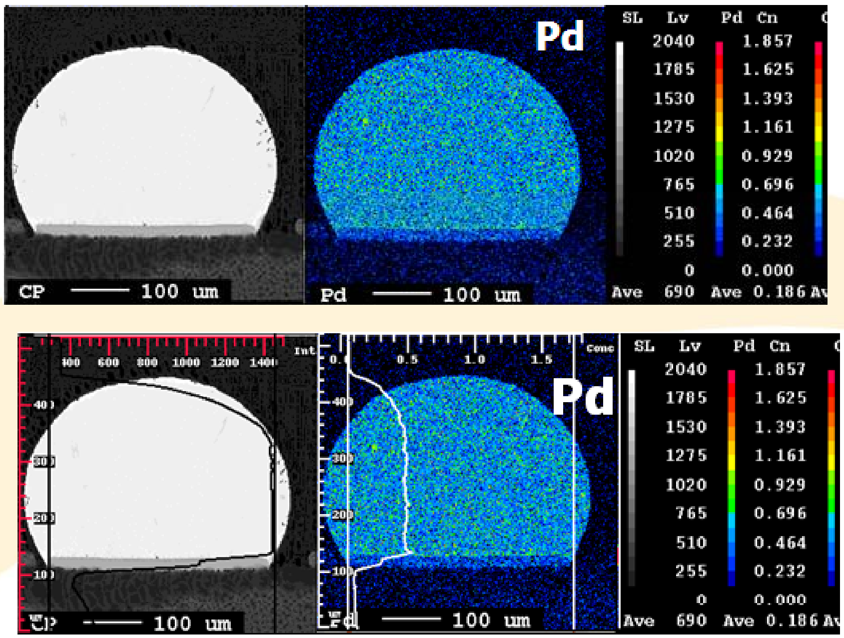
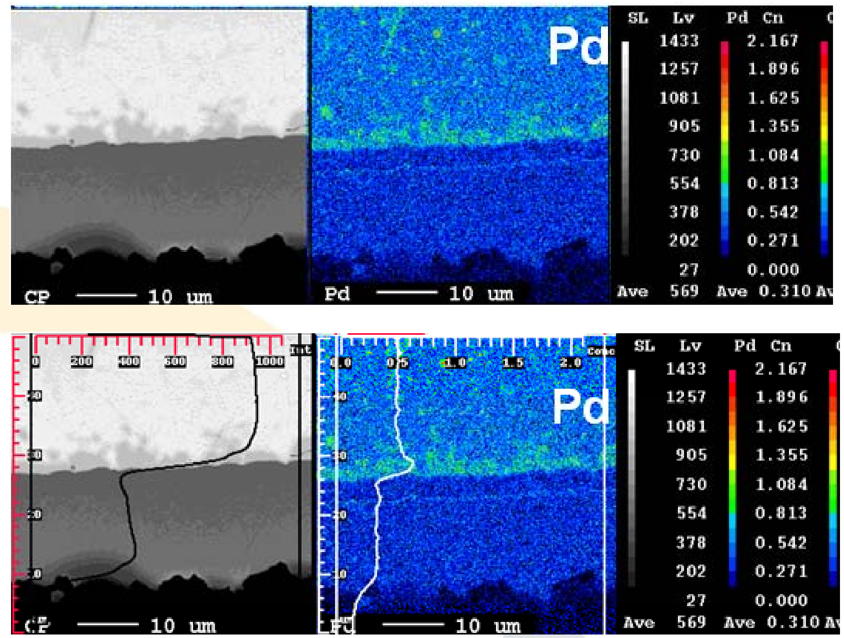
Analysis of mechanism : TC strength

- **Analysis of SAC1010Pd solder**

<EPMA : mapping>



<EPMA : two line scanning>

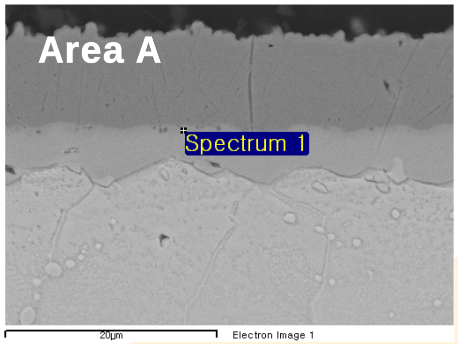


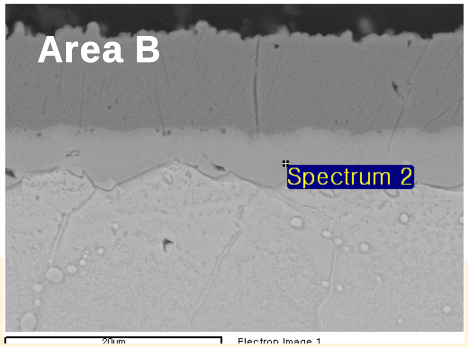
-. Donpants (Pd) : well dispersed

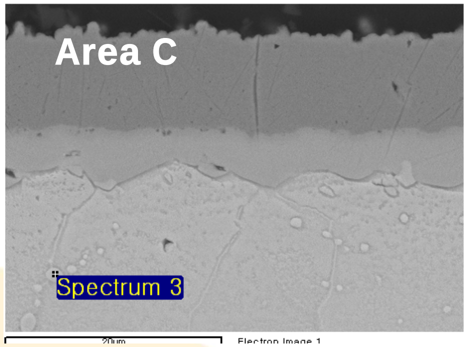
-. Concentration of Pd : higher in IMC

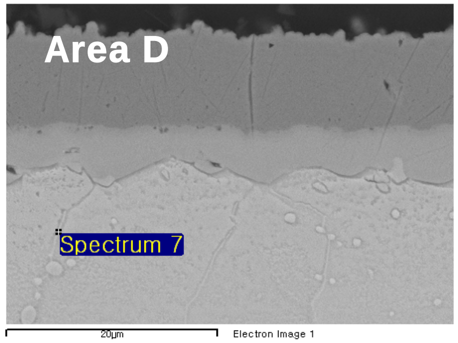
Analysis of mechanism : TC strength

EDS analysis of SAC1010Pd after TC strength

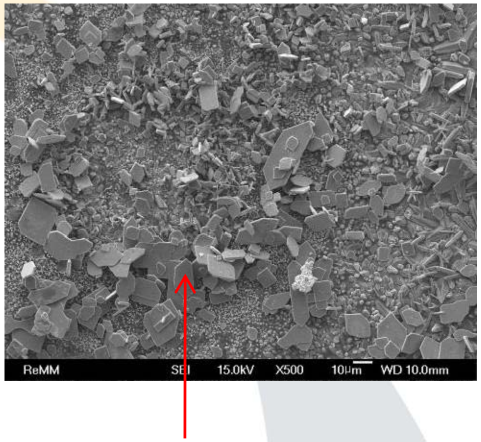








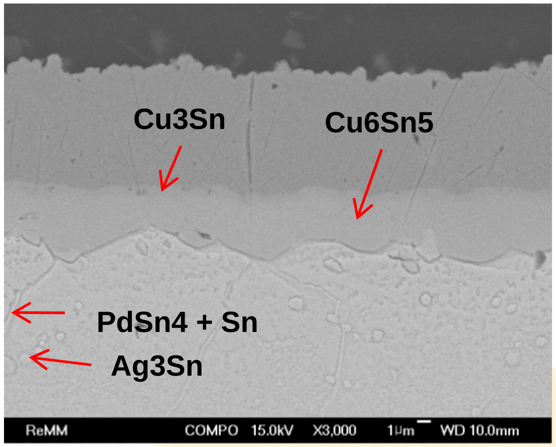
	% of weight					
	N	O	Cu	Ag	Sn	Pd
Area A		1.46	59.53	0.75	38.26	
Area B	3.41	2.77	35.68		58.14	
Area C	8.79	1.43	0.75	52.77	36.26	
Area D	6.96	6.06	1.44		85.07	0.47

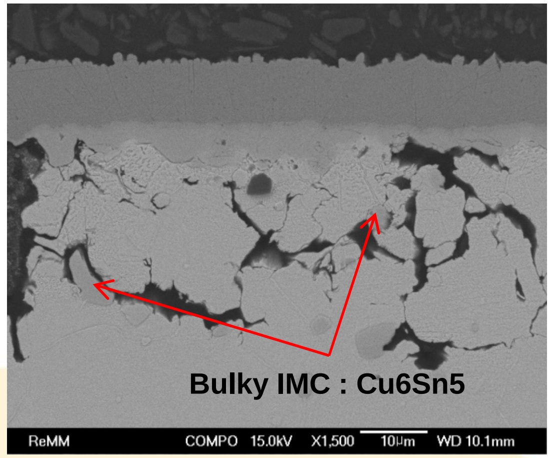


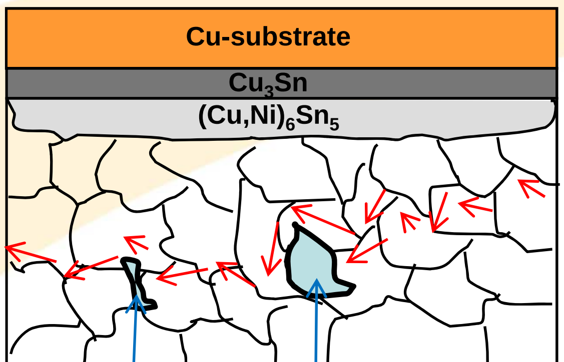
<Pd-Sn inter-metallic compound>

Analysis of mechanism : TC strength

SAC1010Pd

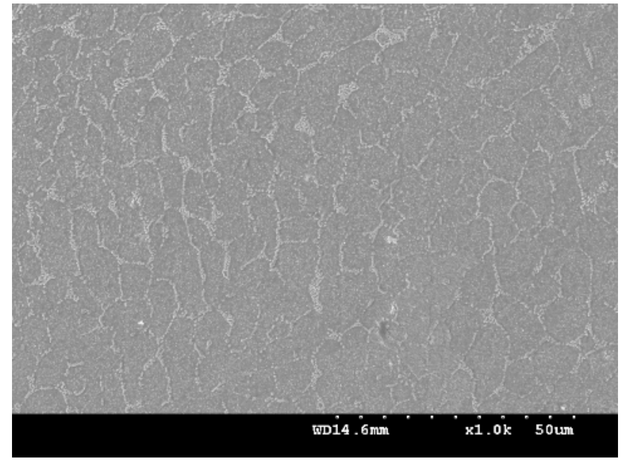






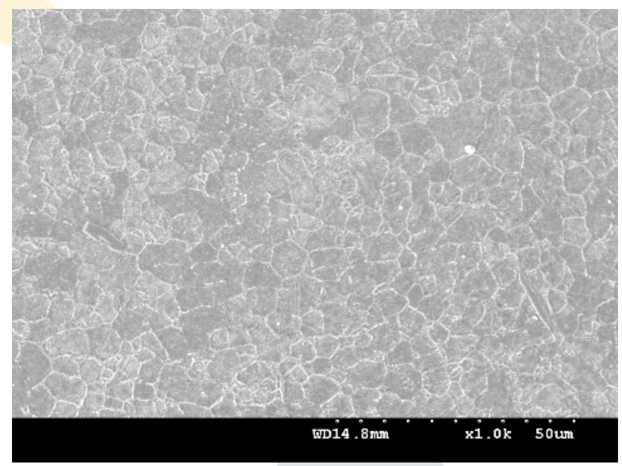
-. Fine grain and dispersed bulky IMCs interrupted the crack propagation.

Long crack path → High TC resist



SAC1205Ni

Grain size : about 33.13 μm^2



SAC1010Pd

Grain size : about 19.95 μm^2

Conclusion

SAC1010Pd solder has better drop and TC performance than SAC1205Ni.

<The reason why SAC1010Pd shows high drop performance than SAC1205Ni>

-. **IMC layer of SAC1010Pd is spike type and might be tough (not brittle).**

-. **IMC shape, size, composition are all different comparing SAC1205Ni.**

→ **Different IMC properties can cause high drop resistance.**

→ **The fracture occurred along the soft surface between solder and IMC surface,**

and SAC1010Pd has higher durability than SAC1205Ni does.

⇨ **Long crack path** ⇨ **High drop resist**

Conclusion

- **SAC1010Pd solder has better drop and TC performance than SAC1205Ni.**

<The reason why SAC1010Pd shows high TC performance than SAC1205Ni>

-. The crack propagated through the grain boundary.

-. Adding materials are well dispersed in all solder area and

especially concentrated around inter-metallic compound.

-. Grain size of SAC1010Pd is smaller than that of SAC1205Ni.

-. Fine grain and dispersed bulky IMCs interrupted the crack propagation.

➡ **Long crack path** ➡ **High TC resist**

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