

**BLR(Board Level Reliability) study
for CuOSP solder joint in fine
pitch BGA**

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BLR (Board Level Reliability) study for OSP solder joint in fine pitch BGA

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

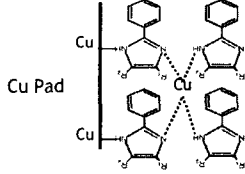
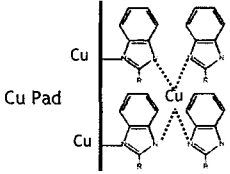
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• Substrate Pad finish

| Interconnection Area | Pad finish | Plating method | Applied Product |
|----------------------|------------|----------------|--------------------------|
| Wire bonding pad | Ni/Au | E-less (ENIG) | SIP |
| | | E-lytic | All wire bonding product |
| Solder ball pad | Ni/Au | E-less (ENIG) | - |
| | | E-lytic | Almost W/B Product |
| | OSP | Wet coating | Partial W/B Product |

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• OSP Materials

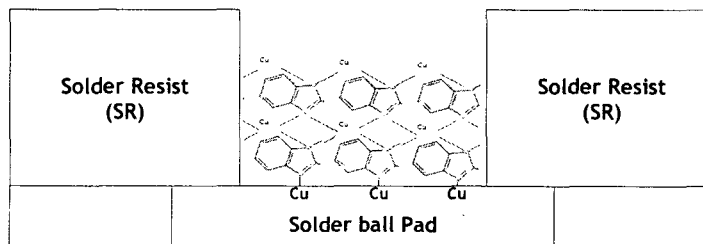
| OSP Material | F type | W type |
|---------------------|---|---|
| Base ingredient | Phenyl imidazole | Alkyl benzimidazole |
| Recommend Thickness | 0.15 - 0.35um | 0.20 - 0.50um |
| Base radical |  Phenyl-amine group |  Amine group |
| Bonding Formation |  |  |

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• OSP Coating



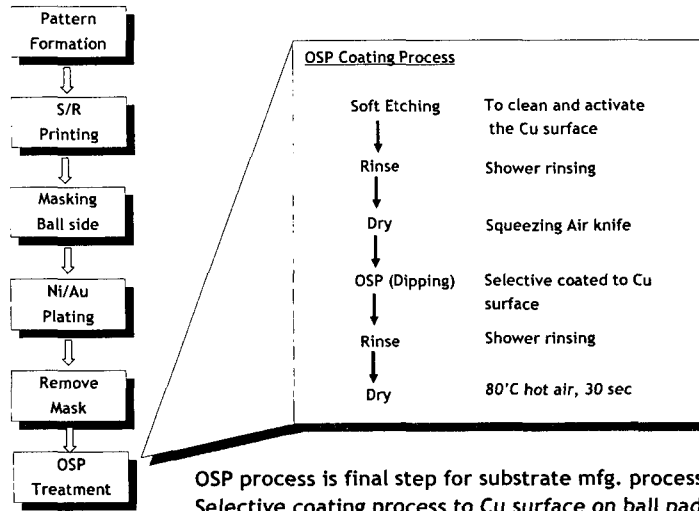
- > Bonding between unpaired electron of nitrogen of Imidazoles and Cu ions
- > Discoloration : - Loosen between Imidazole group and Cu ion under high temperature (High Temp. Process - baking, curing, wire bonding, Mold, etc.)
- Rearrangement of Imidazoles and Formation of Cu oxide
- > Remove : Reaction between Flux & Imidazole, and degradation of OSP

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Substrate Mfg. Process BLR study for OSP solder joint in fine pitch BGA

• OSP Substrate Mfg. Process



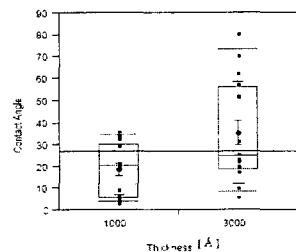
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• OSP thickness

- **Range of OSP film thickness**
 - Suggested thickness: 0.15 ~ 0.5 μm
- **Influence of OSP coating thickness on the solderability**
 - Too thin of a coating does not provide the appropriate protection of Cu pad from oxidation
 - Too thick of a coating actually makes the removal of the OSP more difficult
- **Effect of OSP layer thickness on wetting angle using SnAg alloy**



- Thinner OSP layer (0.1 μm) provides better wetting than the thicker layer (0.3 μm) using same OSP material and flux having mid activity

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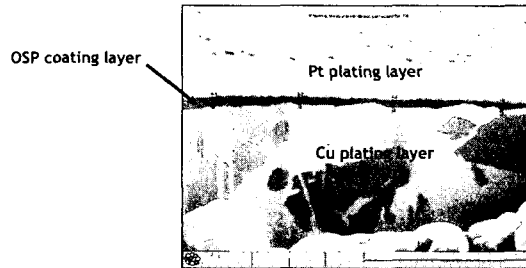
• OSP Thickness Measurement Methods

> UV Spectrometry

- Most popular method
- Indirect method using dummy board
- Thickness range : 0.15 ~ 0.5um

> FIB (Focused Ion Beam) Photo

- Destruction method using actual product
- To measure the photo image after FIB treatment



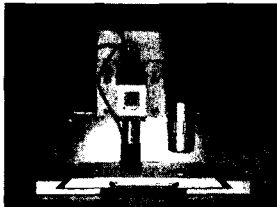
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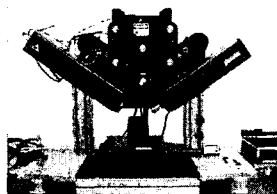
> Nano-indentation



- Measurement Procedure

- 1) Recording of load/displacement
- 2) Observe the discontinuity in stiffness of sample
- 3) Estimate OSP thickness at the discontinuity point

> Ellipsometer



- Ellipsometer uses polarized light to determine OSP layer thickness.

- Reflected light coefficients were used to measure OSP layer thickness.

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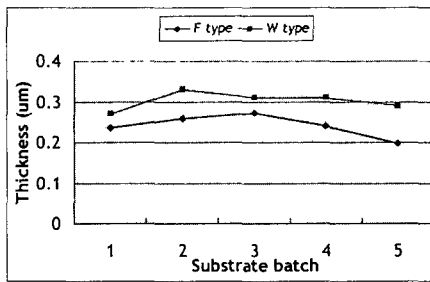
• OSP Layer Thickness data

> UV Spectrometry

- OSP thickness Spec. of each suppliers

| Suppliers | OSP Type | Thickness Spec. | Remark |
|-----------|----------|-----------------|--------|
| A | F type | 0.15 - 0.35um | - |
| B | W type | 0.20 - 0.50um | - |
| C | | | |
| D | | | |

- Actual thickness



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> FIB photo

Unit : um

| OSP type | F type | W type | | | |
|---------------|-----------|--------|-------|-------|-------|
| Supplier | A | B | C | D | |
| UV-S | 0.235 | 0.27 | 0.33 | 0.31 | |
| OSP thickness | FIB photo | | | | |
| | | 0.592 | 0.253 | 0.134 | 0.192 |

- The root cause of difference thickness

1. Soft etching variance before OSP coating process
2. FIB photo showed at very small area

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> Nano-indentation

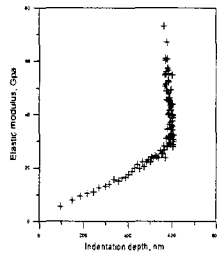
- **Basic information of Nano-indentation for OSP thickness measurement:**

- OSP thickness was determined by the indentation depth at which the elastic modulus changed suddenly.

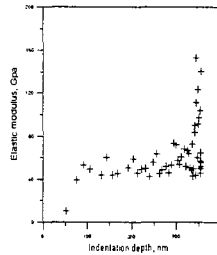
- **Ranges of OSP thickness measurements for F and W type**

- 1) Thickness of F type : AVG=0.55 μ m, STD=0.099 μ m
- 2) Thickness of W type : AVG=0.44 μ m, STD=0.08 μ m

F type OSP



W type OSP



* Number of samples = 3 on each OSP coupons

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> Ellipsometer

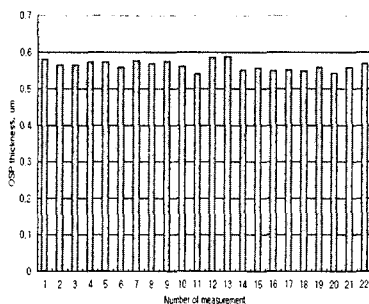
- **Basic information of Ellipsometer for OSP thickness measurement:**

- Ellipsometry uses polarized light to determine the OSP thickness

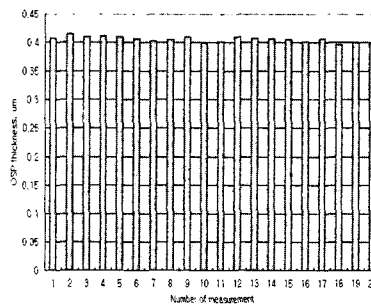
- **Ranges of OSP thickness measurements for WPF 207 and F2LX**

- 1) Thickness of F type : AVG= 0.56 μ m, STD=0.013 μ m
- 2) Thickness of W type : AVG = 0.41 μ m, STD=0.005 μ m

F type OSP



W type OSP



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> The results of OSP thickness measurement

Unit : um

| Measurement Method | F type | W type | Remark |
|--------------------|-----------|---------|-----------------------------|
| Supplier Recommend | 0.15-0.35 | 0.2-0.5 | - |
| UV-S | 0.235 | 0.27 | Indirect method |
| FIB photo | 0.592 | 0.253 | Direct & destruction method |
| Nano-indentation | 0.55 | 0.44 | Direct & destruction method |
| Ellipsometer | 0.56 | 0.41 | Direct method |

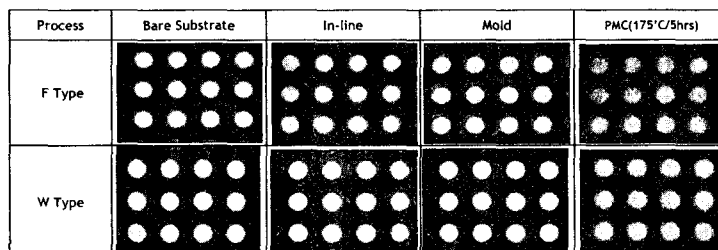
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FAI BLR study for OSP solder joint in fine pitch BGA

• OSP Discoloration under assembly process

- > Occurred discoloration by thermal exposure, specially PMC(175°C/5 hrs) process
- > Discoloration during assembly process
 - Temp & time ↑ : Discoloration ↑
 - OSP discoloration : the thermal behavior of OSP layer (Cu oxide ↑)



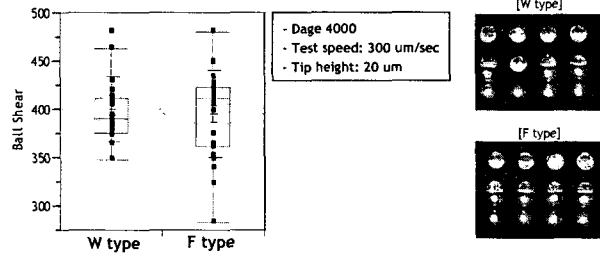
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• Assembly process-ability test with F & W type

- Substrate : 8×10, 44LD, 0.5 pitch
- OSP : F & W type
- Flux : Water soluble & High activation type
- Solder Ball : Sn1.205Ni, 0.3mm dia.
- Process flow : Bake → Mold → PMC(175°C, 5 hrs) → SBM → Quality Check
- Check Items : Visual inspection after BST, ZST
- BST results



- * All of the fracture modes are "Ductile Mode"
- * However, F type has a large standard deviation value and an abnormal small ball shear value.

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> Zone Shear Test

| OSP type | Conforming Part | | Non-Conforming Part | | | TOTAL | Remark |
|----------|-----------------|------------|---------------------|-----------|----------------|---------------|--------|
| | Bulk solder | Void < 20% | Void > 20% | IMC > 25% | Any exposed Cu | | |
| F type | 440 | 0 | 0 | 0 | 0 | 440 (10 unit) | Pass |
| W type | 440 | 0 | 0 | 0 | 254 | 440 (10 unit) | Fail |

- W type meets ZST criteria in SCK , but F type is not good

- Note) 1. Measuring equipment → Dage 4000HS
2. Shear speed : 5mm/sec
3. Shear height : 20um



- * All of the fracture modes are "Ductile Mode"

- * 34 of 44 balls are "Non-wetting"
- * The rests are "Ductile Mode"

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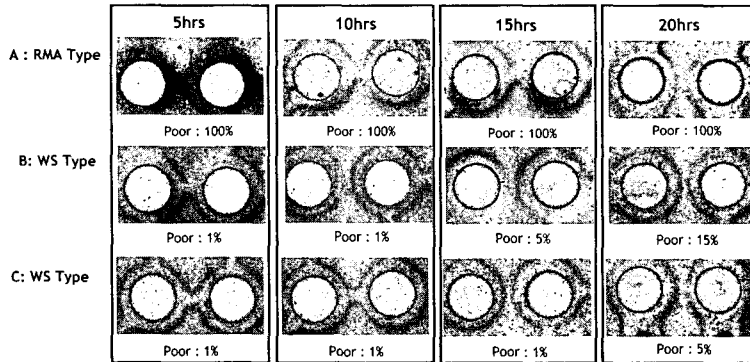
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• Oxide layer removal performance

- OSP Type : W Type

- Evaluation procedure

Bare substrate -> Thermal aging(175°C, 5hrs) -> Flux apply -> Lead free reflow -> Deflux -> Visual inspection



Poor % : Oxide remain rate on ball pad

"C" flux showed the best performance to remove OSP layer & oxide

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• Solder ball Alloy Evaluation

- Purpose : To select best solder ball alloy for CuOSP finish

- Package : TFBGA, 341L, 0.5pitch

- Substrate : W type OSP

- Solder ball : Different Ag content & Ni dopant alloy, 0.3mm ball

- Evaluation Matrix

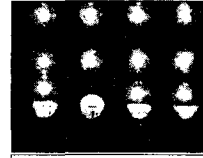
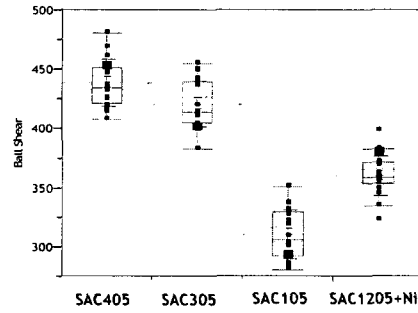
| Leg# | Solder ball alloy | Description | Remarks |
|------|-------------------|-----------------------------|-------------------|
| 1 | SAC405 | Different Ag content | Ag content effect |
| 2 | SAC305 | | |
| 3 | SAC105 | | |
| 4 | SAC1205Ni | Reduce Ag + Ni dopant alloy | Dopant effect |

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> SBM Quality – BST / BPT



Typical Ductile Mode
Test speed : 300um/sec
Tip height : 20um

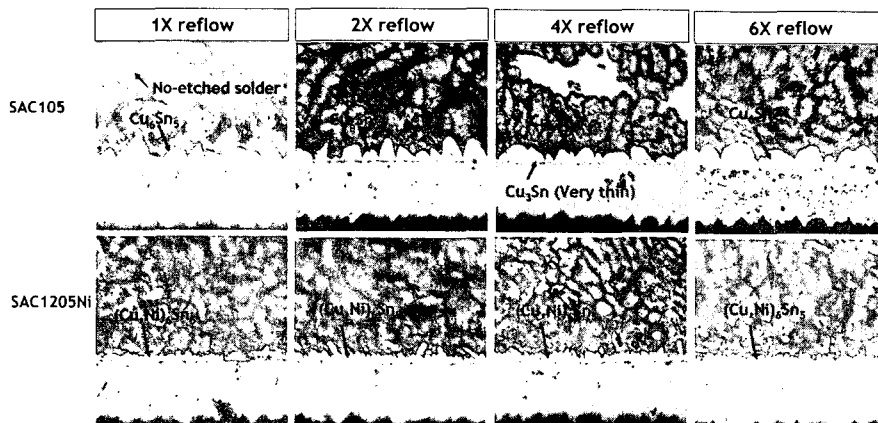
- BST value trend
- Ag content : High Ag > Low Ag
- Ni dopant : With Ni > without Ni

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> IMC Analysis – Multi Reflow



- SAC405, 305, 105 showed very similar interface IMC morphology under multi reflow
- All of legs was little IMC growth under multi reflow.
- IMC morphologies of SAC405, 305, 105 were changed according to reflow time.

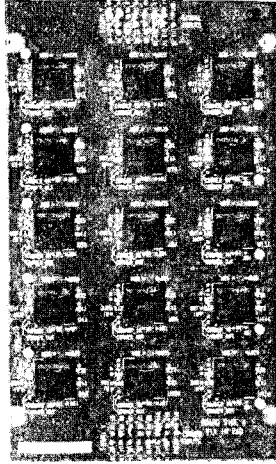
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> Drop Test

• Drop Test Board



- Test Condition
 - JESD22-B104-B Condition B
 - Impact - 1500G +/- 20%,
 - Duration - 0.5ms +/- 30%
- Samples size
 - 4 boards/15 units = 60 units/leg
- # of Drops
 - 1000 drops
- Package pad design : SMD
- Drop board design : NSMD



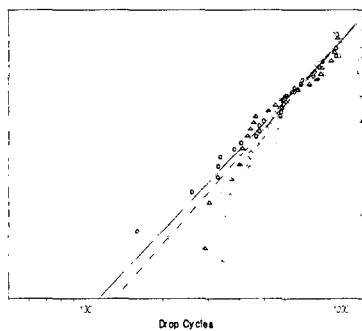
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> Drop Test Result

| Leg# | Solder Ball Alloy | Drop Result (JESD22-B111) | | | |
|------|-------------------|---------------------------|-----------------------|------------------------|------------------------|
| | | 30 drops #of fail | 250 drops #of fail | 1000 drops #of fail | 1st fail # of drops |
| 1 | SAC405 | 0/60 | 0/60 | 22/60 | 294 |
| 2 | SAC305 | 0/60 | 0/60 | 32/60 | 212 |
| 3 | SAC105 | 0/60 | 2/60 | 29/60 | 160 |
| 4 | SAC1205+0.05Ni | 0/60 | 0/60 | 30/60 | 342 |



- SAC1205NI showed good drop performance

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> Conclusion

- It seems that UV-S is not good method to measure actual OSP thickness. Ellipsometer is good because it is non-destructive & easy measurable method using actual substrate.
- The discoloration of OSP substrate occurs by thermal exposure during assembly process, especially after post mold cure, and high activating flux is needed to remove OSP later of thermal attacked substrate to attach solder ball on the pad.
- BST value trend
 - Ag content : High Ag > Low Ag
 - Ni dopant : With Ni > without Ni
- Multi Reflow
 - SAC405, 305, 105 showed very similar interface IMC morphology
 - All of legs was little IMC growth.
 - IMC morphology of SAC405. 305, 105 were changed from small swelling to large, but Ni dopant alloy was not remarkable.
- Low Ag & dopant solder alloy(SAC1205Ni) with OSP showed the best performance in drop test

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• Solder ball & Pad Finished Evaluation for 0.4 Pitch

> Test Vehicle

Package : VFBGA 0.4mm pitch
 Substrate : Ni/Au, OSP
 Solder Ball : 0.25mm dia.
 SR Opening : 0.23mm

> Leg Information

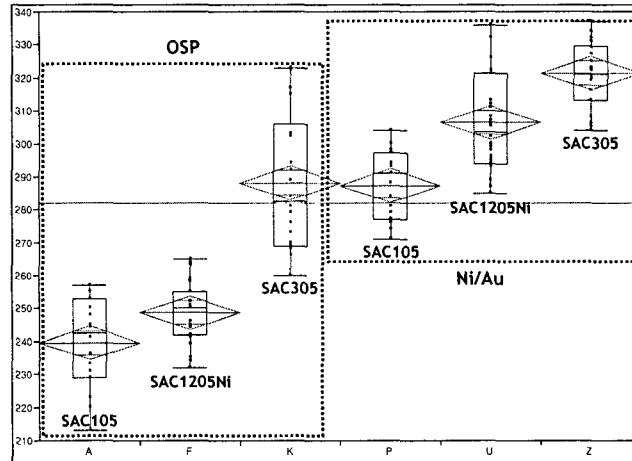
| Leg # | Substrate | Solder Ball | Flux |
|-------|-----------|-------------|--------------------------------------|
| 1 | OSP | SAC105 | - Water soluble - High Activation |
| 2 | | SAC1205Ni | |
| 3 | | SAC305 | |
| 4 | Ni/Au | SAC105 | |
| 5 | | SAC1205Ni | |
| 6 | | SAC305 | |

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> Solder ball shear Data at EOL

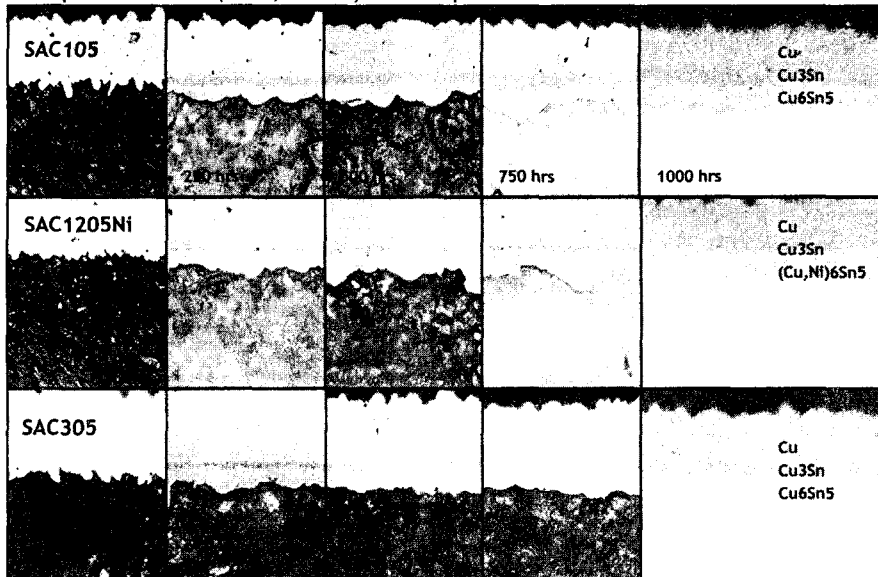


- BST value trend
 - Pad finish : Ni/Au >> OSP
 - Ag content : High Ag > Low Ag
 - Ni dopant : With Ni > without Ni
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> IMC photo after HTST (150°C, 1000hrs) with OSP pad finish

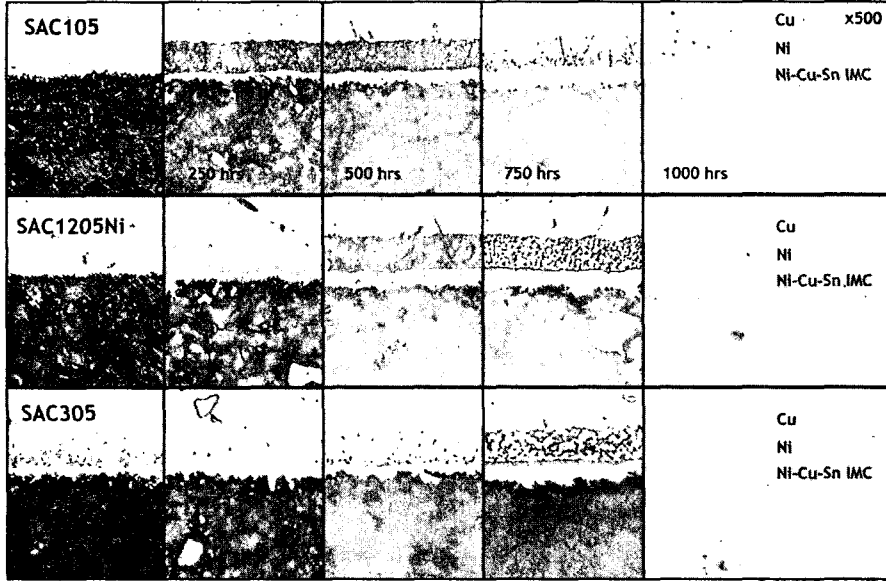


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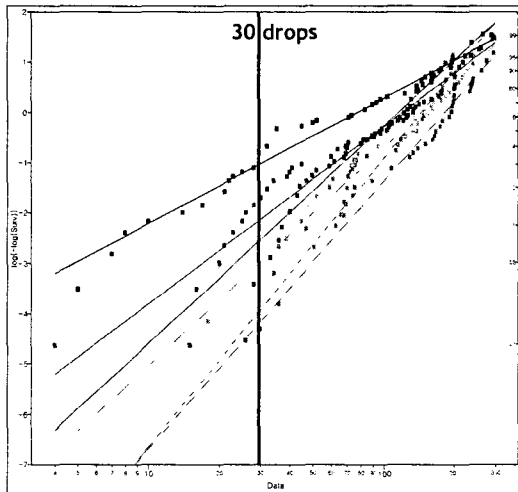
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> IMC photo after HTST (150°C, 1000hrs) with Ni/Au pad finish



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> Drop Test Results with 0.4mm pitch



| | | |
|------|-------|-----------|
| Leg1 | OSP | SAC105 |
| Leg2 | OSP | SAC1205Ni |
| Leg3 | OSP | SAC305 |
| Leg4 | Ni/Au | SAC105 |
| Leg5 | Ni/Au | SAC1205Ni |
| Leg6 | Ni/Au | SAC305 |

- # of drop : 300 drops
- SAC105 with Ni/Au & SAC1205Ni with OSP showed the best Performance

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BLR study for OSP solder joint in fine pitch BGA

> Conclusion

1. BST value trend
 - Pad finish : Ni/Au >> OSP
 - Ag content : High Ag > Low Ag
 - Ni dopant : With Ni > without Ni
2. IMC after HTST (150°C, 1000hrs)
 - With OSP
 - . The effect of Ag content : No difference of IMC growth
 - . The effect of Ni dopant : the growth of brittle IMC as Cu₃Sn on OSP pad
 - With Ni/Au
 - . The effect of Ag & Ni : No difference of IMC growth regardless alloy composition
3. Drop Test
 - OSP with SAC1205Ni & Ni/Au with SAC105 shows good drop performance.