

Reliability Study of A New Lead-Free SnAgBiIn Solder For Precision Motor Application

유 충 식 수석연구원
(삼성전기)

Reliability Study of A New Lead-Free SnAgBiIn Solder For Precision Motor Application

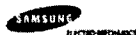
April 26, 2005

Sean Yoo*, Chang-Bae Lee, Jung-Yeol Yu



Outline

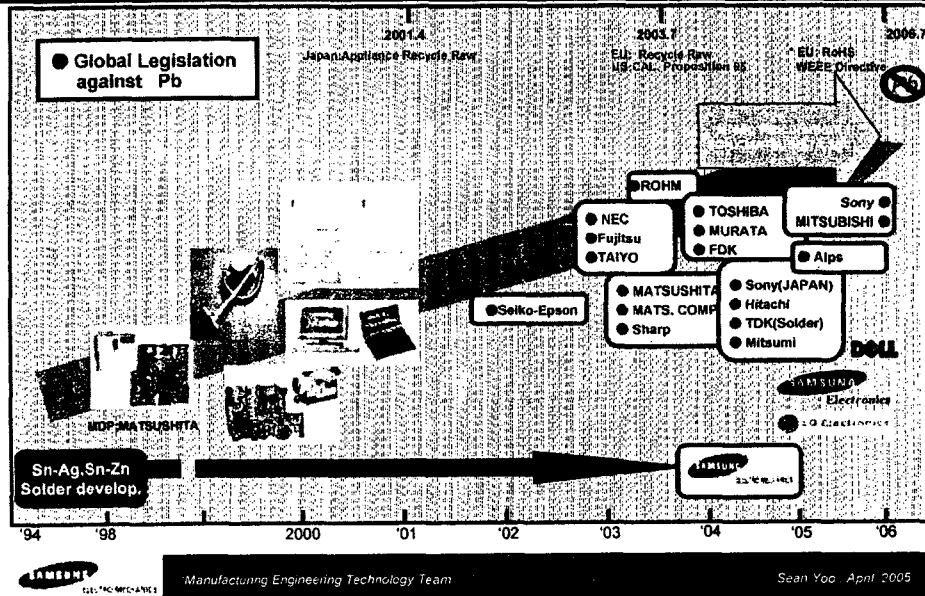
- Background
- Current Low Melting Temp. Pb-Free Solder Alloys
- New Sn-Ag-Bi-In Solder(SY362)
- Solder Alloy Design & Solder Paste Development
- Application of Sn3Ag6Bi2In for Capstan Motor
- Solder Joint Reliability of Sn3Ag6Bi2In
- Summary



Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Driving Force



Needs for Drop-In Replacement Process

● Sn3~4Ag0.5~1Cu Alloys

- Relatively good wetting, Mechanical property and Solder Joint Reliability.
- High Melting Temperature(221°C)/High Soldering Temperature.
 - Can not be applied for Drop-In Replacement Process(Sn-Pb).
- Thermal Damage:
 - 1) Circuit Boards(Blister esp. FR-1, Warping, Poor Wetting, Discoloring)
 - 2) Certain Passive Components(Low Solder Heat Resistance)
 - 3) Connecting Pins(Discoloring, Poor Wetting)

Current Low Melting temperature -Free Solder Alloys

- **Typical Pb-Free Solders having Mid-range Melting temperature Between 196°C and 213°C**
 - Sn-Ag-Bi-In and Sn-Zn-Bi alloys
- **Sn3~4Ag0.5~3Bi3~8In Alloys(Sn3.5Ag0.5Bi8In)**
 - Good Wetting and Solder Joint Reliability.
 - Provide Compatibility for Sn-Pb/Pb-free coated Components
- **However,**
Indium(In) Price has sharply risen.



Manufacturing Engineering Technology Team

Sean Yoo April 2005

Another Solution Exists?

- **Sn-Ag-Bi Alloy? ► Sn-Ag-Bi can't be a solution**
 - Bi content possessing optimum M.T. should be 7.5 to 10wt%.
 - Failure mechanism of Solder Joint Interface was known as a Brittle Mode with high Bismuth containing Alloy.
 - Bi Segregation usually happens with higher Bi containing SnAgBi.
 - Bi Segregation leads to Low M.P. Phase Formation
 - Low M.P phase leads to Cracking and Solder joint strength decrease during thermal cycling.



Manufacturing Engineering Technology Team

Sean Yoo April 2005

New Sn-Ag-Bi-In Solder(SY362)

Suggestion

Alloy having Sn-Ag-Bi-In Composition, Good Wetting and Solder Joint Reliability.
Moreover, Low Price.

Sn-3Ag-6Bi-2In(SY362)

- Low Indium containing Sn-Ag-Bi-In Solder Alloy

: Patented in US, Japan, China, Singapore, Korea

1) Solution Providing for Price Problems and Solder Joint Reliability

2) Bi segregation can be controlled by minimum Indium addition.

3) Compatibility Problems between 6% Bi and Sn/Pb coated Components,

But this should be solved by Global Pb-Free Policy.



Manufacturing Engineering Technology Team

Sean Yoo April 2005

Solder Alloy Design

Alloy Design

- Sn-Ag-Bi-In Alloy designed by Thermodynamic Simulation

- Sn-3Ag-6Bi-2In Alloy selected

1) 6 wt% Bi: Lower M.P.

Good Wetting

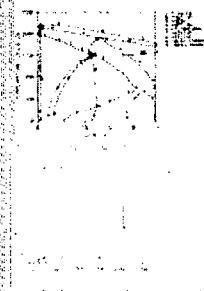
Increase Joint Strength

Minimize Bi segregation

2) 2 wt% In: Lower M.P.

Control Microstructure of Solder Alloy

Restraint from Bi Segregation



Manufacturing Engineering Technology Team

Sean Yoo April 2005

Solder Paste Development

● Developed Solder Paste Properties and Material Cost

Alloy Composition(wt%)	Sn3Ag6Bi2In (SY362)	Sn3.5Ag0.5Bi8In	Sn37Pb
Melting point(°C)	191~213	196~206	183~184
Flux content(%)	11	11	11
Viscosity(Pa.s)	170	170	200
Spreadability(%)	86	83	89
Solder ball	Class 2	Class 2	Class 2
Powder size(micron)	22~45	22~45	22~45
Tensile strength(Mpa)	98	77	49
Elongation(%)	9.2	12.4	35
Materials cost	513	1327	100

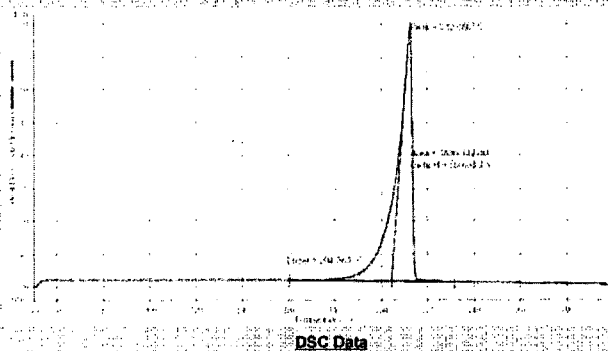


Manufacturing Engineering Technology Team

Sean Yoo April 2005

Melting Temperature of Sn3Ag6Bi2In(SY362)

- Solidus/Liquidus Temperature : 191/213 °C
- Low M.T. Phase Formation was not found.



Manufacturing Engineering Technology Team

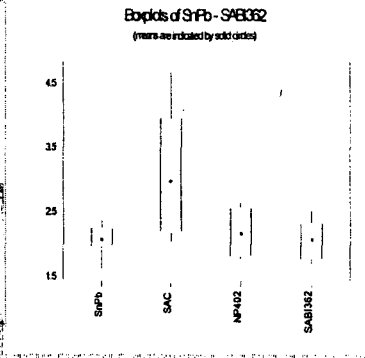
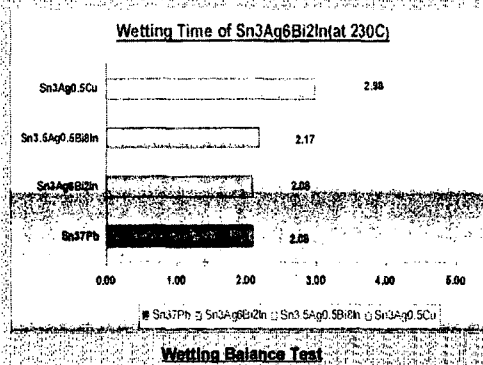
Sean Yoo April 2005

Wetting of Sn3Ag6Bi2In(SY362)

- **Wetting time: Wet Faster than Sn3.5Ag0.5Bi8In**

- ZCT(230 °C): Sn3Ag6Bi2In(SY362) ≈ Sn37Pb > Sn3.5Ag0.5Bi8In > Sn3Ag0.5Cu

- Process yield may have advantage for non-wetting defect.



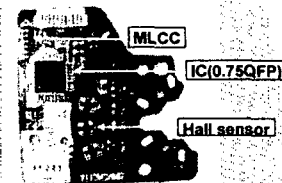
Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Application of Sn3Ag6Bi2In(SY362) for Capstan Motor

<ul style="list-style-type: none"> ● Materials ▶ Solder Paste : Sn3Ag6Bi2In(SY362), Sn3.5Ag0.5Bi8In ▶ PCB : FR-1(OSP) ▶ Components : All Pb-free finished
<ul style="list-style-type: none"> ● Process ▶ Reflow Temp. Profile: - Preheating(130°C~170°C): 105sec - Peak Temp.: 232°C - 210 °C over Time: 30sec
<ul style="list-style-type: none"> ● Analysis ▶ Phase Analysis by SEM/EPMA, XRD,X-ray Scan ▶ Solder Joint Strength
<ul style="list-style-type: none"> ● Reliability ▶ Motor Reliability Test - Low & High Motion Test ▶ Temperature Cycling: - 40 ~ + 85°C, 1000 cycles - 35 ~ + 125°C, 1000 cycles

Reflow Temp. Profile



Capstan Motor For VCR



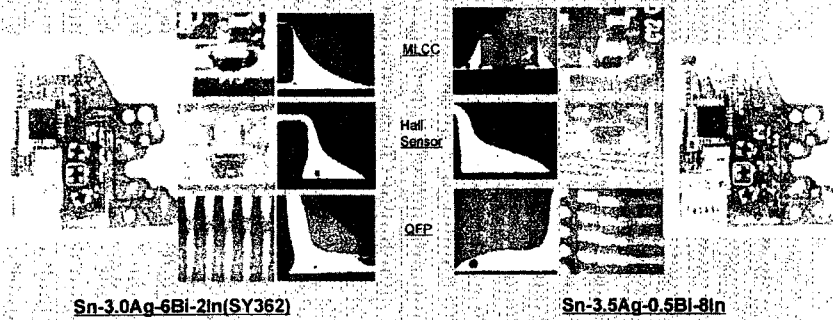
Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Solder Joints of Reflowed Capstan Motor

- Good Solder Joints for both Sn3Ag6Bi2In(SY362) and Sn3.5Ag0.5Bi8In

- Same level of Wetting ability, No fillet-lift, No Crack

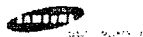
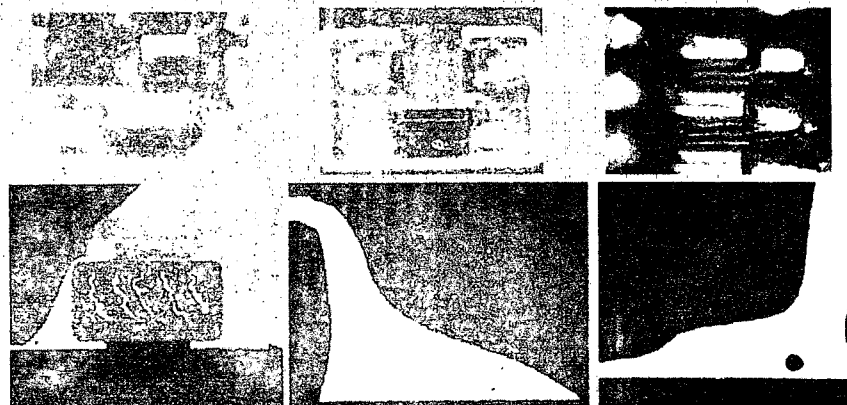


Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Temp. Cycled Solder Joints of SY362 for Capstan Motor

- After Temperature Cycling at 1,000 cycles(-40°C~85°C), Solder Joints of Sn3Ag6Bi2In(SY362) was sound without Internal Crack.

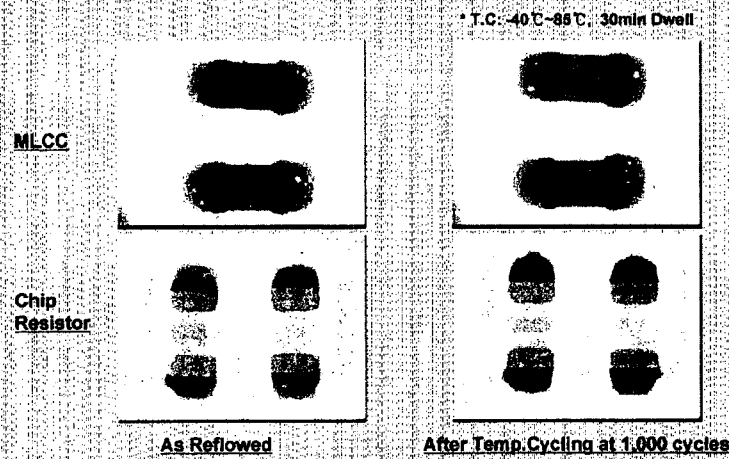


Manufacturing Engineering Technology Team

Sean Yoo, April 2005

X-ray Scan to detect Voids in Solder Joints of Passive Chips for Sn3Ag6Bi2In(SY362)

- No Excess Voids both reflowed and Temp.cycled of Solder Joints



TECHNOLOGY

Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Motor Reliability Test Results for Sn3Ag6Bi2In(SY362)

- Reliability Test including Electrical Properties, Low Temp.Motion Test,High Temp. Motion Test and Thermal Shock Test was Passed.



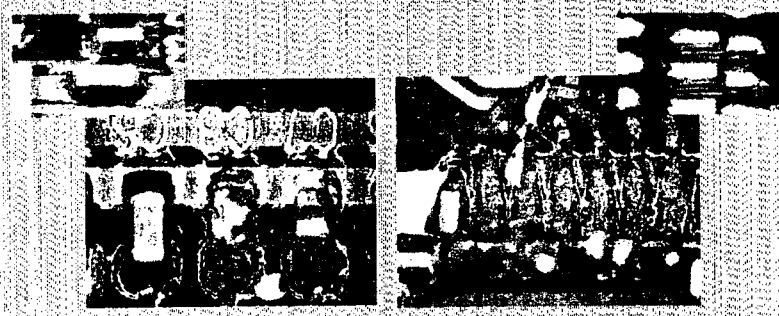
TECHNOLOGY

Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Solder Joint Strengths of Capstan Motor

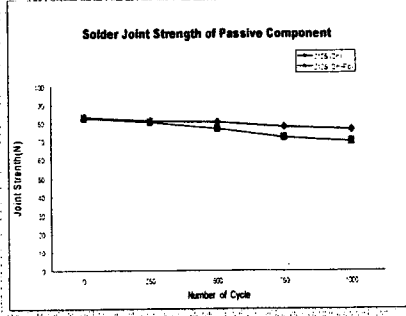
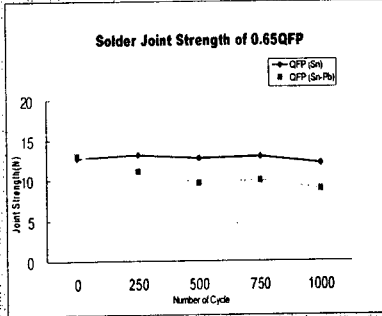
● Solder joint strengths of capstan motor for SY362 and Sn3.5Ag0.5Bi8In could not be evaluated correctly due to Land-lift.(Joint strength>Bonding force of FR-1 PCB)



Solder Joint Strength of QFP and 2125 Chip Resistor

● Solder joint strengths of SnPb and Pb-Free coated 0.65mmQFP and 2125Chip Resistor for SY362

- Pb-Free Sn Coated Components have good Solder Joint Reliability
- Solder Joint Strength of SnPb Coated Components was decreased slightly.

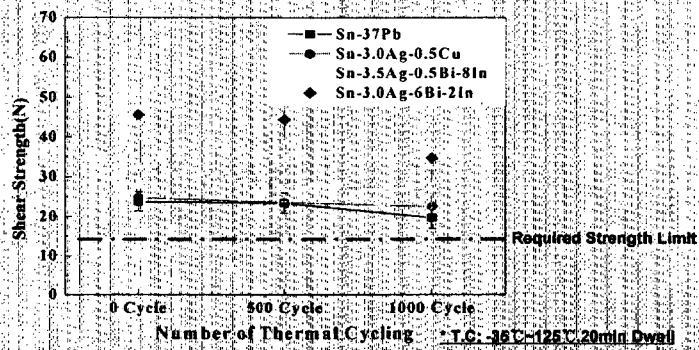


* T.C: -40°C-85°C, 30min Dwell

Solder Joints Strength of 1608MLCC with various Pb-Free Solder Alloys

● Solder joint strength of Sn coated 1608MLCC for SY362

- Sn3Ag6Bi2In(SY362) > Sn3.5Ag0.5Bi8In > Sn3Ag0.5Cu > Sn37Pb
- After Temperature Cycling at 1000 cycles, No Internal Crack at Solder Joints of SY362 was found.



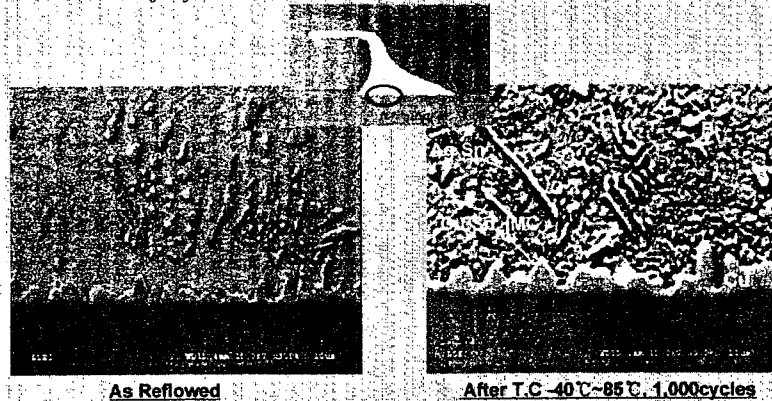
Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Microstructures of As-reflowed and Temp. cycled Solder Joints of Sn3Ag6Bi2In(SY362)

● Solder Joint between SY362 and Cu

- Solder : Sn matrix, SnAg intermetallics(Ag₃Sn) with finely dispersed Bi
- Cu : Cu₆Sn₅ Intermetallics



As Reflowed

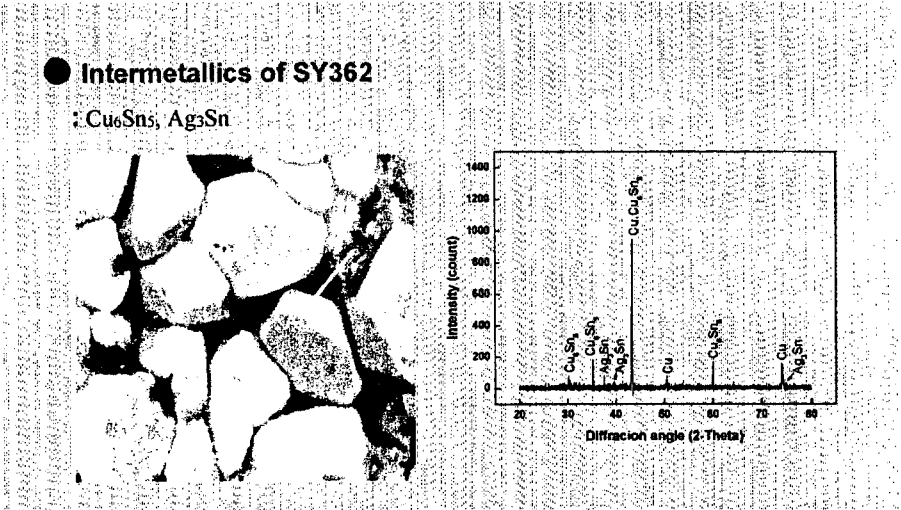
After T.C -40°C ~ 85°C, 1,000cycles



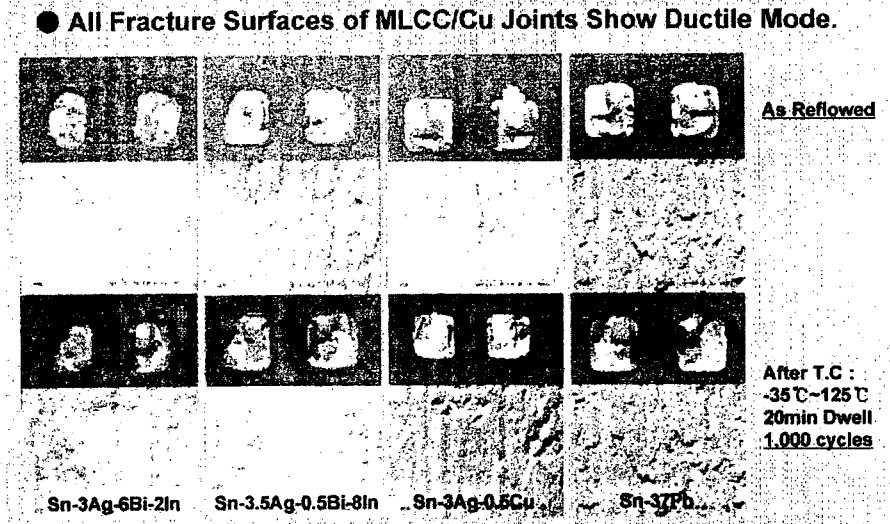
Manufacturing Engineering Technology Team

Sean Yoo, April 2005

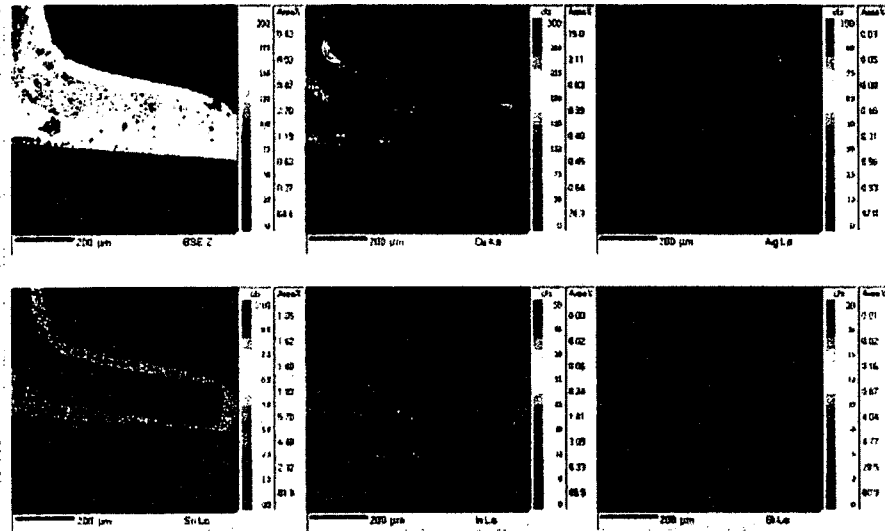
Intermetallics of Sn3Ag6Bi2In(SY362)



Fractography of Sn3Ag6Bi2In(SY362)



EPMA Analysis of As-reflowed Solder Joint between QFP and Cu for Sn3Ag6Bi2In(SY362)

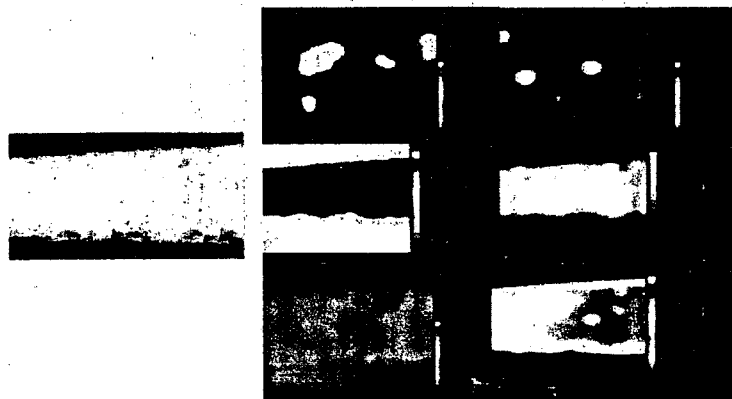


Manufacturing Engineering Technology Team

Sean Yoo, April 2005

EPMA Analysis of Temp.cycled Solder Joint between QFP and Cu for Sn3Ag6Bi2In(SY362)

- After Temperature Cycling at 1,000 cycles(-40°C~85°C), Bi was partly segregated. But Joint Strength was not affected by Bi segregation not due to formation of low M.T.phase.



Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Summary

- A strong Pb-free candidate of new Sn-Ag-Bi-In system with relatively low cost and reliable for electronics products was proposed in this study.
- Sn-3Ag-6Bi-2In Microstructure : Sn + Ag₃Sn + Bi + finely dispersed Indium
- Wettability: Sn-3Ag-6Bi-2In > Sn-3.5Ag-0.5Bi-8In.
- Solder joint strength:
Sn-3Ag-6Bi-2In > Sn-3.5Ag-0.5Bi-8In > Sn-3.0Ag-0.5Cu > Sn-37Pb.
- Failure mode of Sn-3Ag-6Bi-2In was observed as ductile mode.
- Future Plan
 - Solder joint reliability for 42 Alloy will be investigated.
 - Drop and vibration test will be investigated.



Manufacturing Engineering Technology Team

Sean Yoo, April 2005

Manufacturing Engineering R&D Institute

Thank You All !!

劉忠植 首席研究員
生產技術Team 實裝技術
生產技術研究所
三星電機 株式會社
syoo1@samsung.com
Tel: 82-31-210-3401
Mobile: 82-19-9769-3401



Manufacturing Engineering Technology Team

Sean Yoo, April 2005