Formation Mechanisms of Various Solidification Defects in Lead-Free Soldering and Their Prevention

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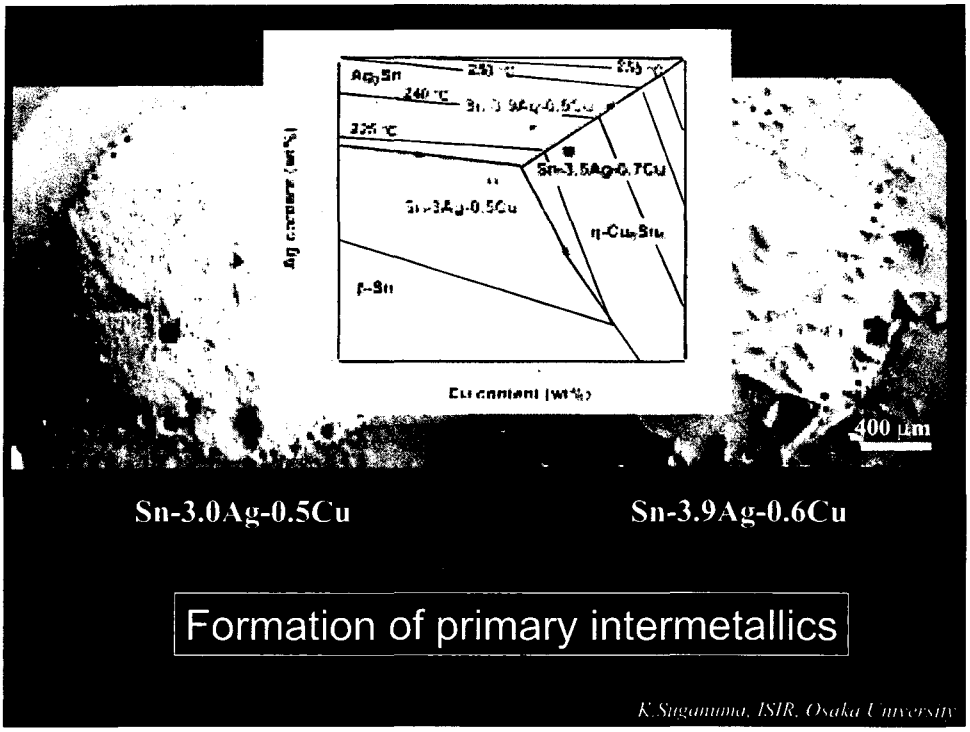
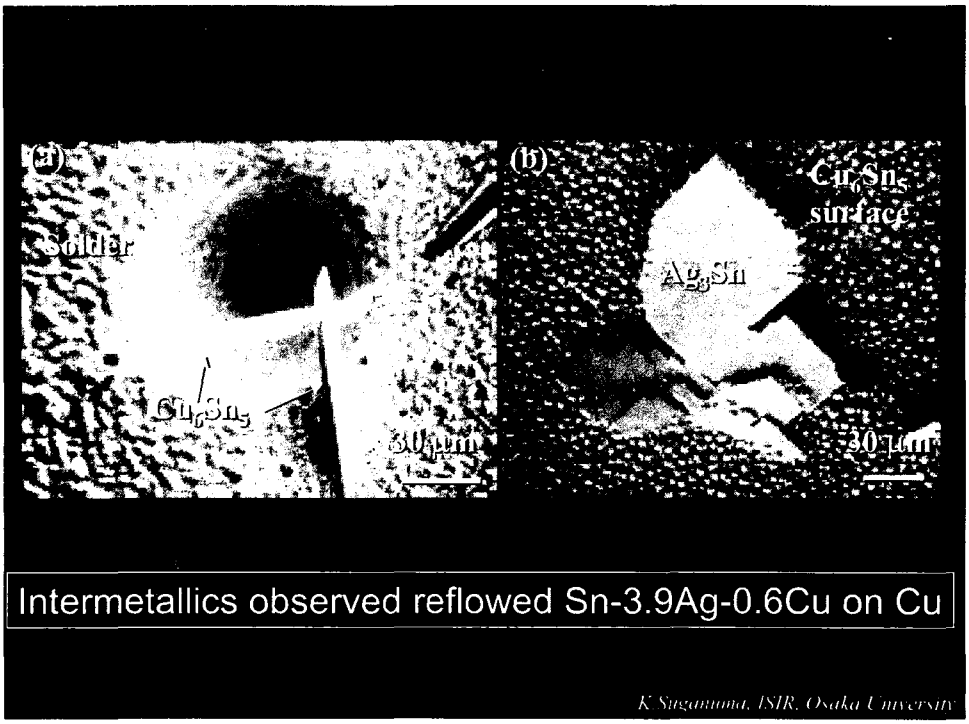
- ✓Defect formation on solidification and *in-situ* observation
- ✓Hot-cracking (Shrinkage cavity)
- ✓Lift-off
- ✓Solidification of solder ball

Inhomogeneity in solidification

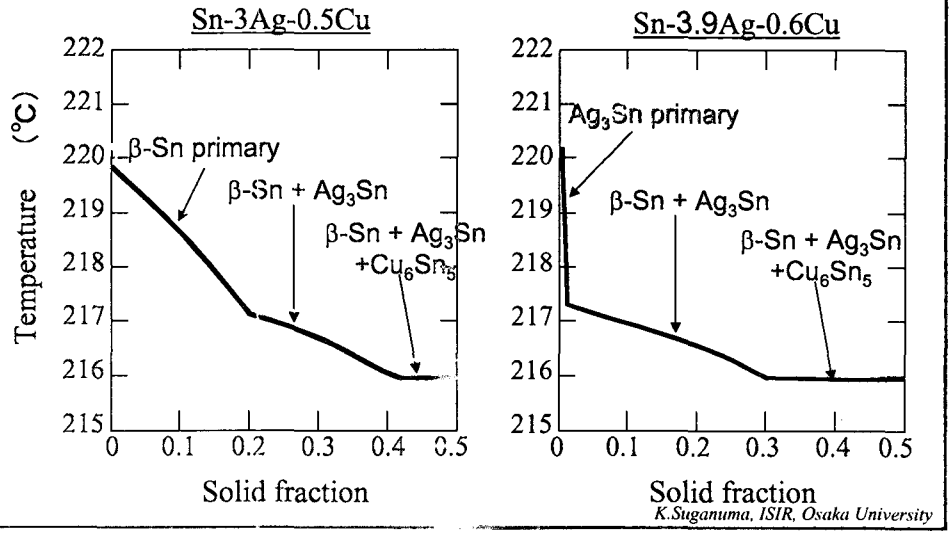

Ag3Sn
240 °C
220 °C
Sn-3.5Ag-0.7Cu
Sn-3Ag-0.5Cu
η-Cu6Sn5
β-Sn
400 μm
Sn-3.0Ag-0.5Cu
Sn-3.9Ag-0.6Cu
Formation of primary intermetallics
K.Suganuma, ISIR, Osaka University


(a)
Solder
Cu6Sn5
30 μm
(b)
Cu6Sn5
surface
Ag3Sn
30 μm
Intermetallics observed reflowed Sn-3.9Ag-0.6Cu on Cu
K.Suganuma, ISIR, Osaka University

Solidification process

$$f_s = 1 - \left(\frac{T_f - T}{T_f - T_L}\right)^{1/(k_0 - 1)}$$

f_s : solid fraction
T_f : melting temperature of Sn
T_L : liquidus temperature
k_0 : equilibrium distribution coefficient



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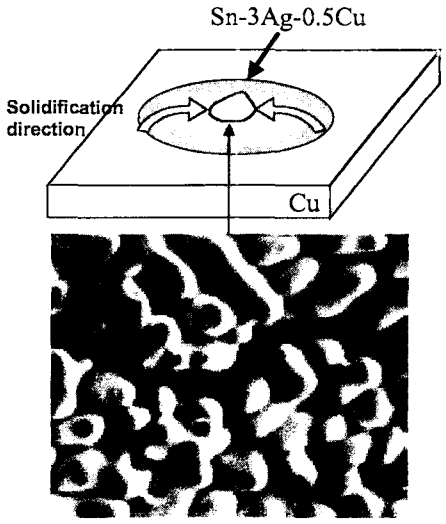
Solidification defects of Sn-3Ag-0.5Cu solder on Cu plate



Solder surface after solidification

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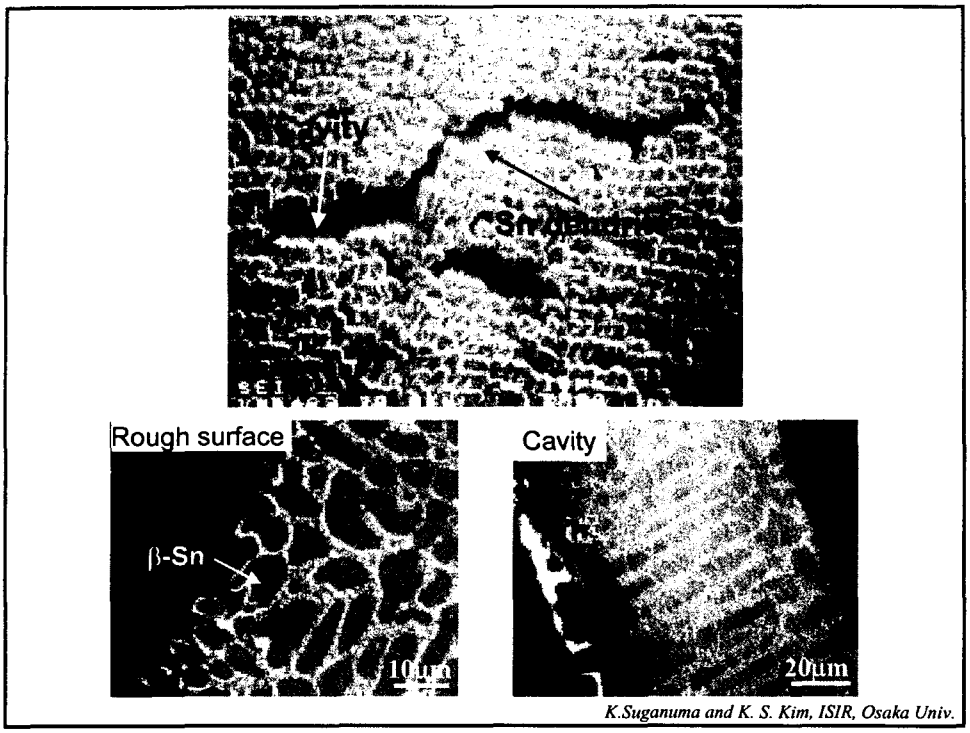

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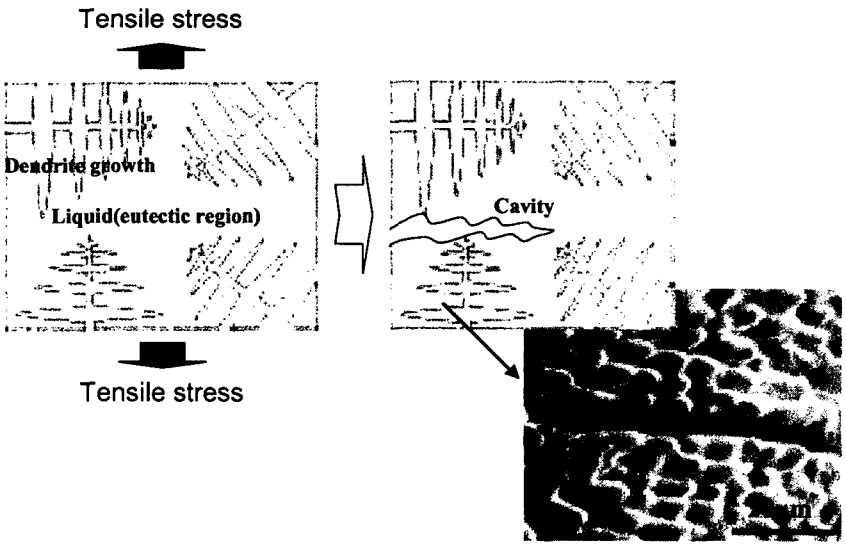
Mechanism of cavity formation



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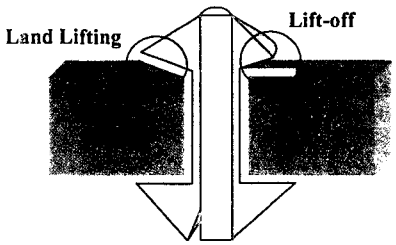
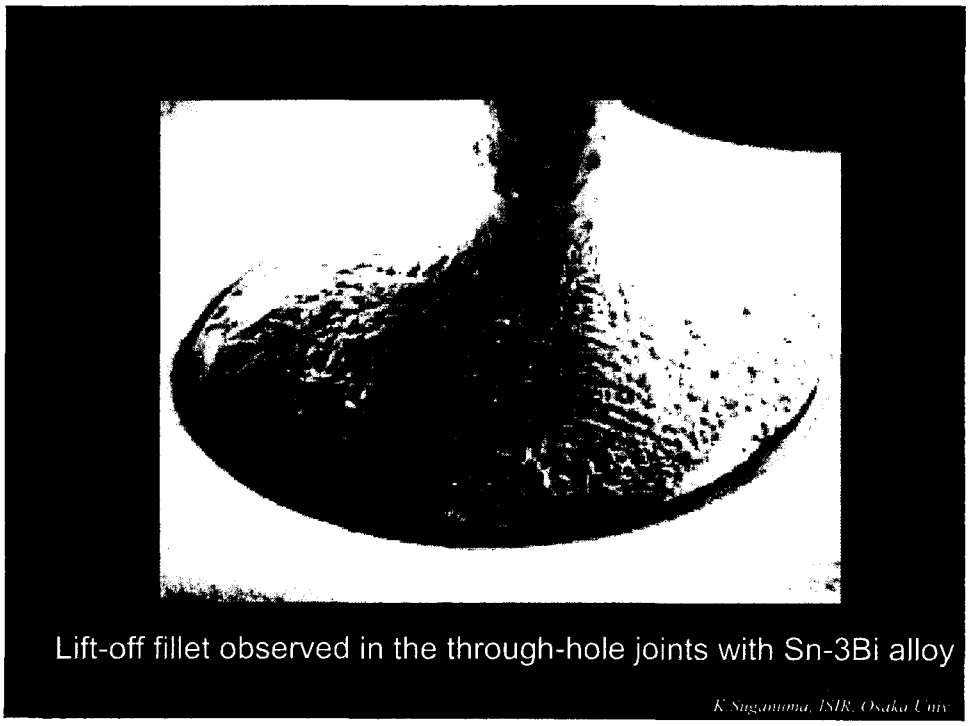
Lift-Off/Fillet Lifting





Lift-off fillet observed in the through-hole joints with Sn-3Bi alloy

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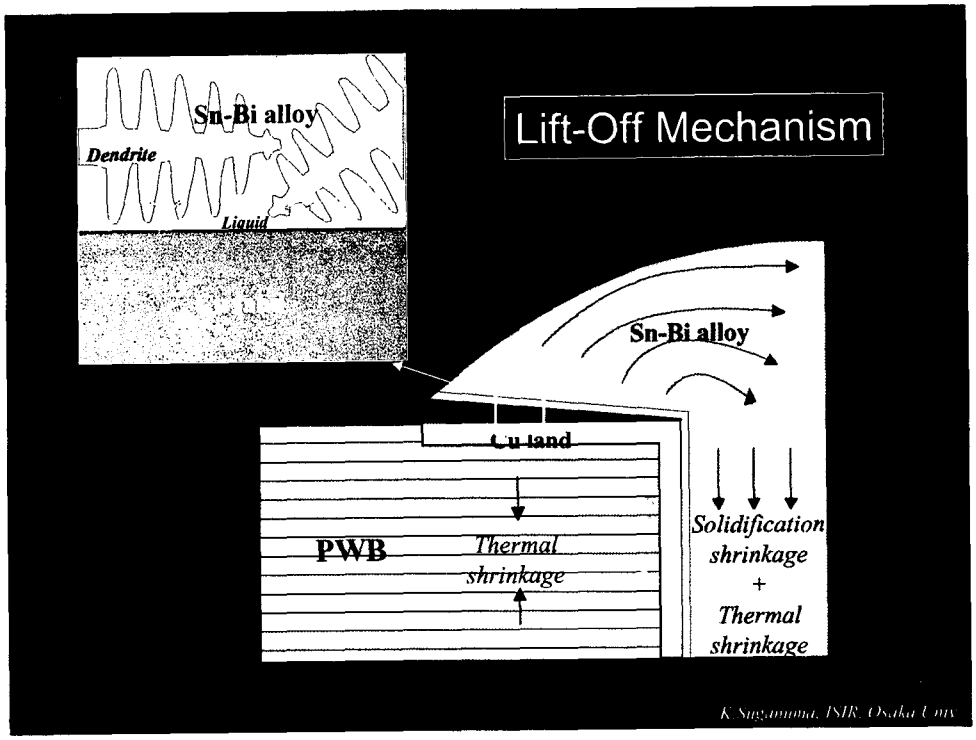
Lift-Off Mechanism
Sn-Bi alloy
Dendrite
Liquid
Sn-Bi alloy
Cu land
PWB
Thermal shrinkage
Solidification shrinkage + Thermal shrinkage
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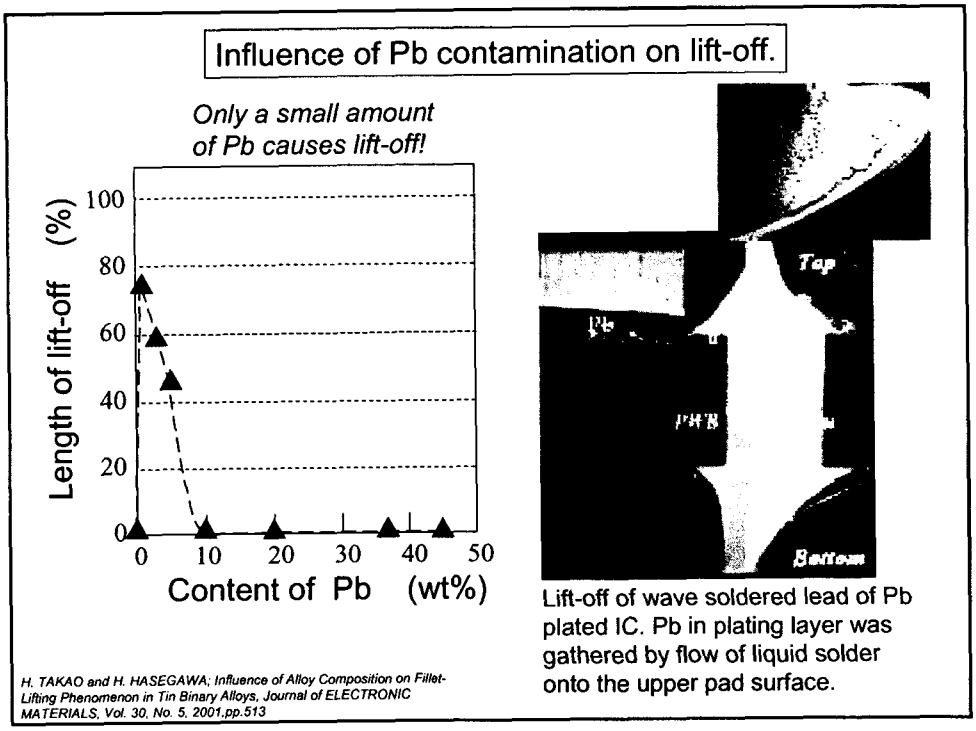
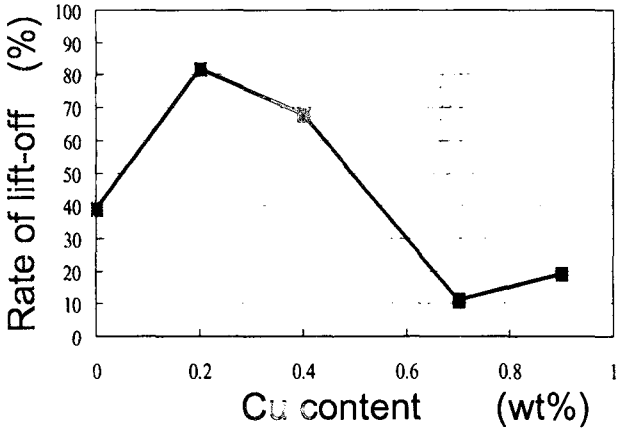

Influence of Pb contamination on lift-off.
Only a small amount of Pb causes lift-off!
Length of lift-off (%)
100
80
60
40
20
0
0
10
20
30
40
50
Content of Pb (wt%)
Top
Pb
PWB
Bottom
Lift-off of wave soldered lead of Pb plated IC. Pb in plating layer was gathered by flow of liquid solder onto the upper pad surface.
H. TAKAO and H. HASEGAWA; Influence of Alloy Composition on Fillet-Lifting Phenomenon in Tin Binary Alloys, Journal of ELECTRONIC MATERIALS, Vol. 30, No. 5, 2001,pp.513

Rate of lift-off for Sn-3.5Ag-xCu as a function of Cu content



T. Hibino, et. als :MES2000, (2000), 211.

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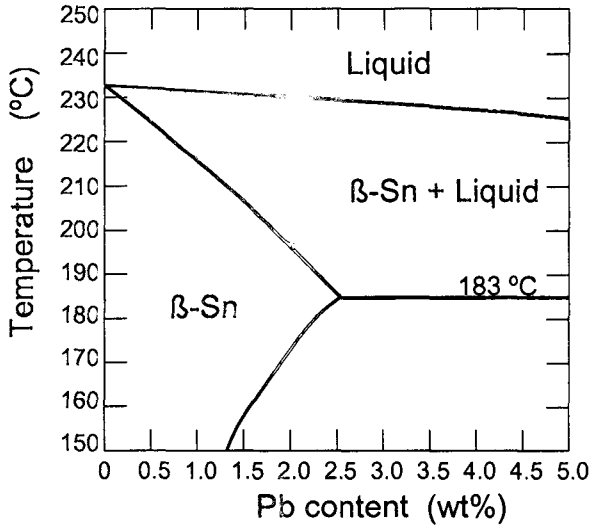
Phase diagram of Sn-Pb system near Sn corner



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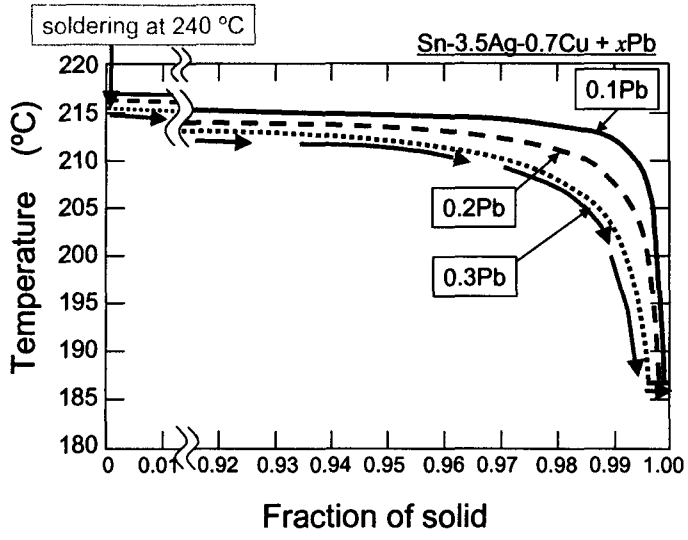

Influence of Pb content on fraction of solid in solidification of Sn-3.5Ag-0.7Cu

Scheil's simulation by TC/NIST database

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Solidification of lead-frame solder fillet

Solidification of SOP joints (Cu and 42 alloy lead frame)

In situ observation
Solidification simulation

- To clarify the formation mechanism of solidification defects
- Effect of various lead frame materials for Sn-Ag-Cu soldering

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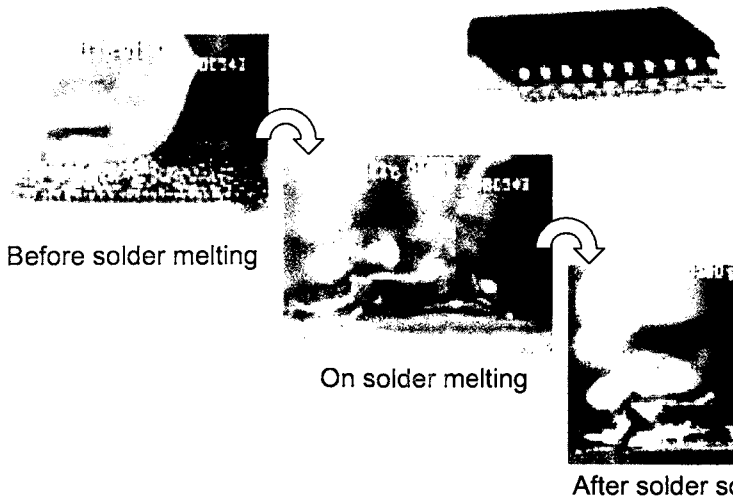
In-situ solidification observation of IC lead frame joint



Before solder melting

On solder melting

After solder solidification

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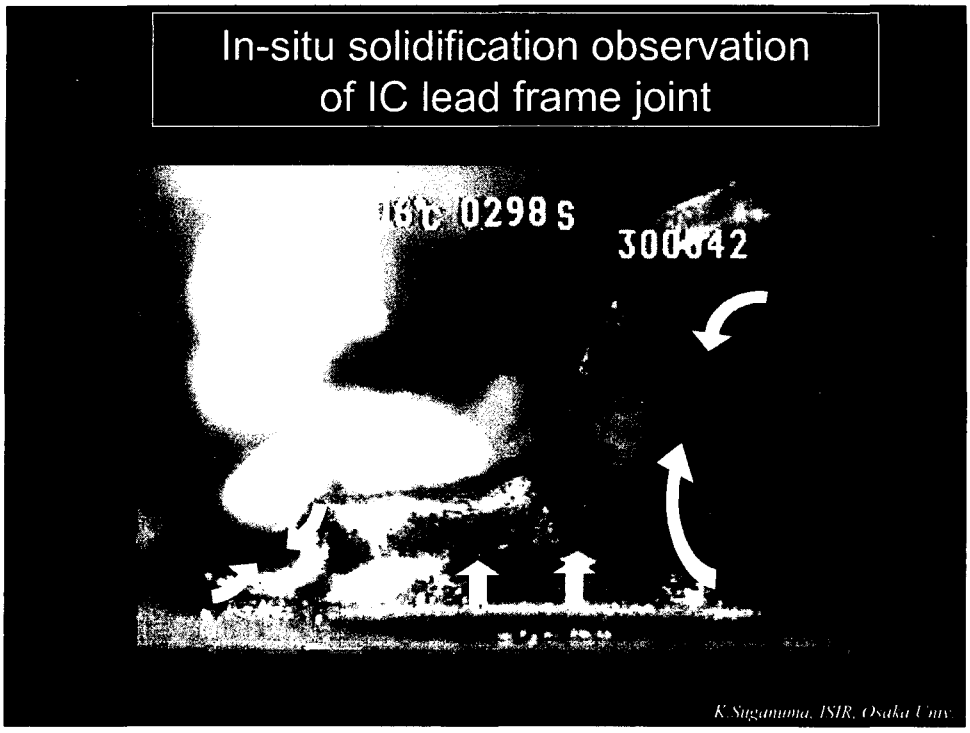
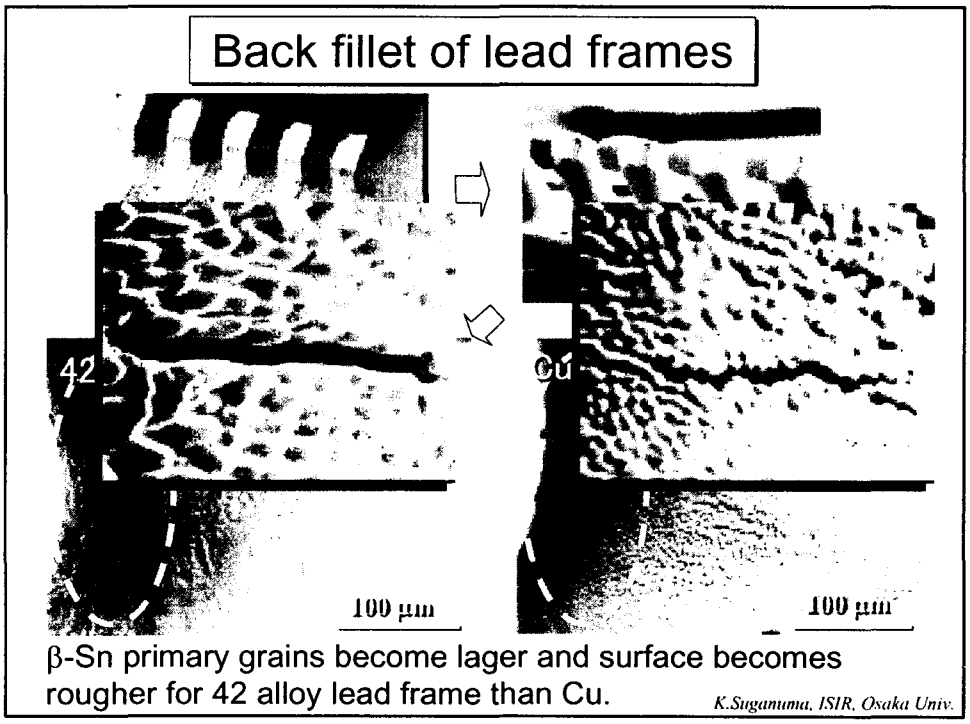
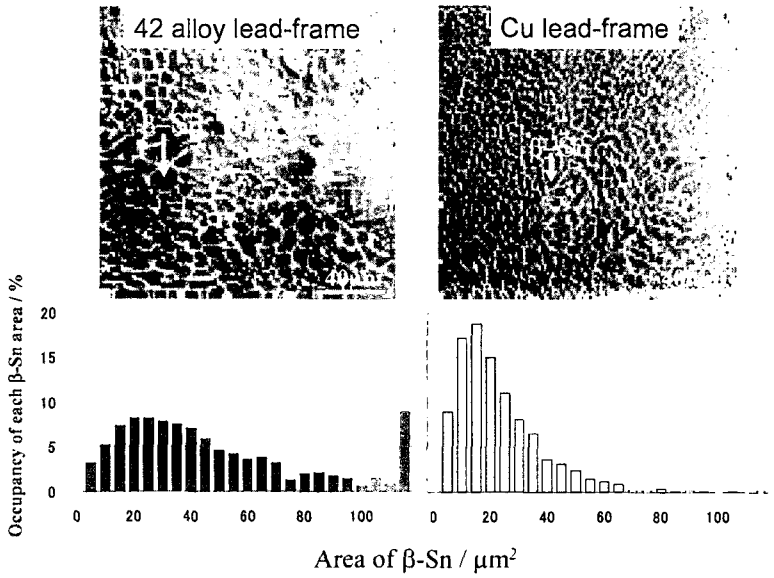

In-situu solidification observation
of IC lead frame joint
K.Suganuma, ISIR, Osaka Univ.


Back fillet of lead frames
42
Cu
100 μm
100 μm
β-Sn primary grains become lager and surface becomes rougher for 42 alloy lead frame than Cu.
K.Suganuma, ISIR, Osaka Univ.



The difference in thermal conductivity of lead-frame materials is attributed to the apparent β-Sn growth for the 42 alloy lead frame joint

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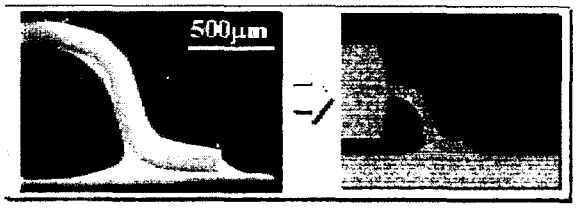
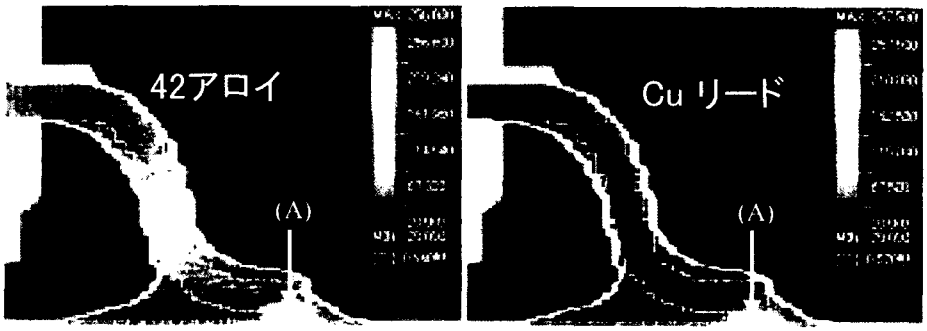
Solidification simulation

JS-CAST(R)
Sn-3Ag-0.5Cu





Cooling is much faster for Cu lead frame than 42 alloy

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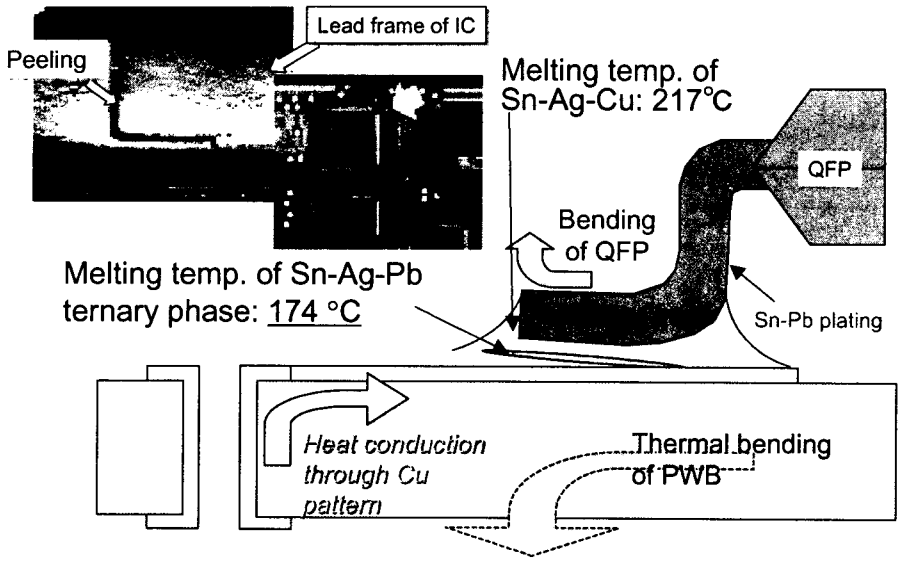

Solder fillet peeling caused by Pb plating of lead-frame in wave soldering after reflow soldering.

from NEC

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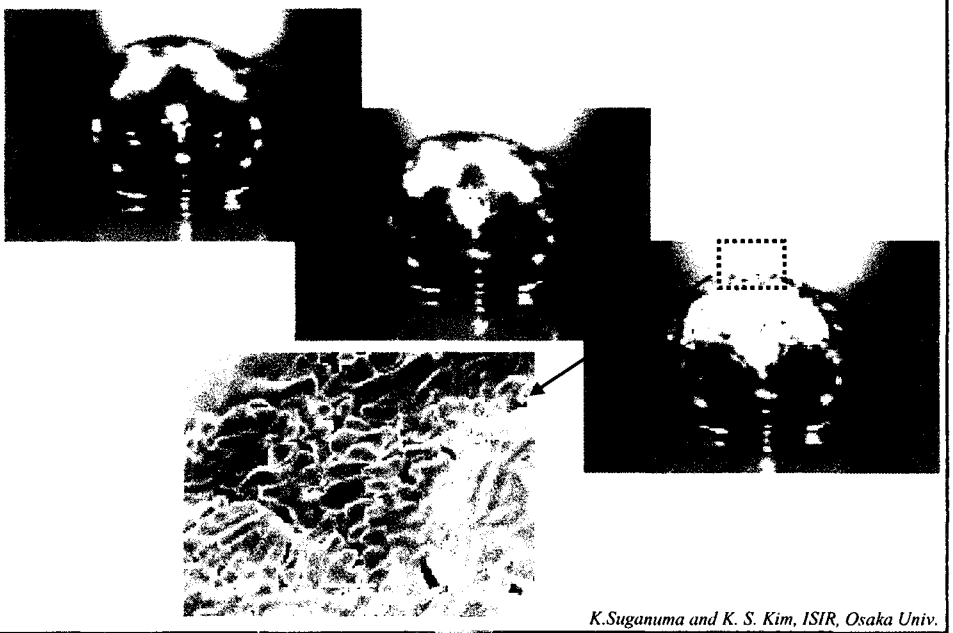
Solidification of solder ball

In-situ observation of a Sn-3Ag-0.5Cu solder ball on a PCB



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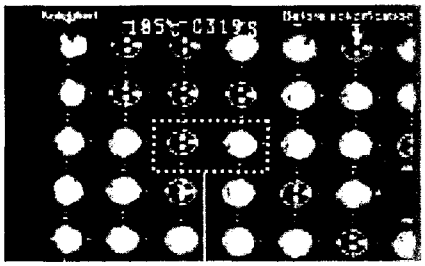
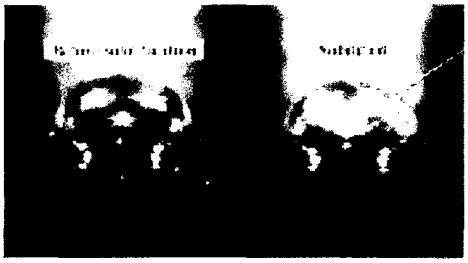
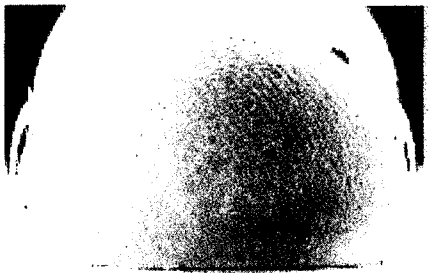
Solidification aspect of Sn-3Ag-0.5Cu solder balls on CSP







Solidification directions of solder ball on a CSP

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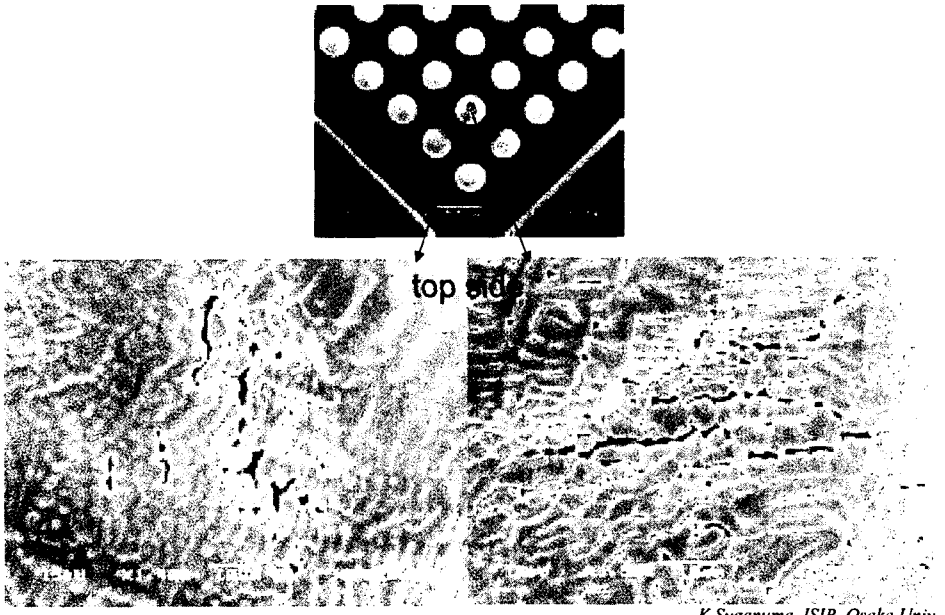
Solder ball surface after solidification



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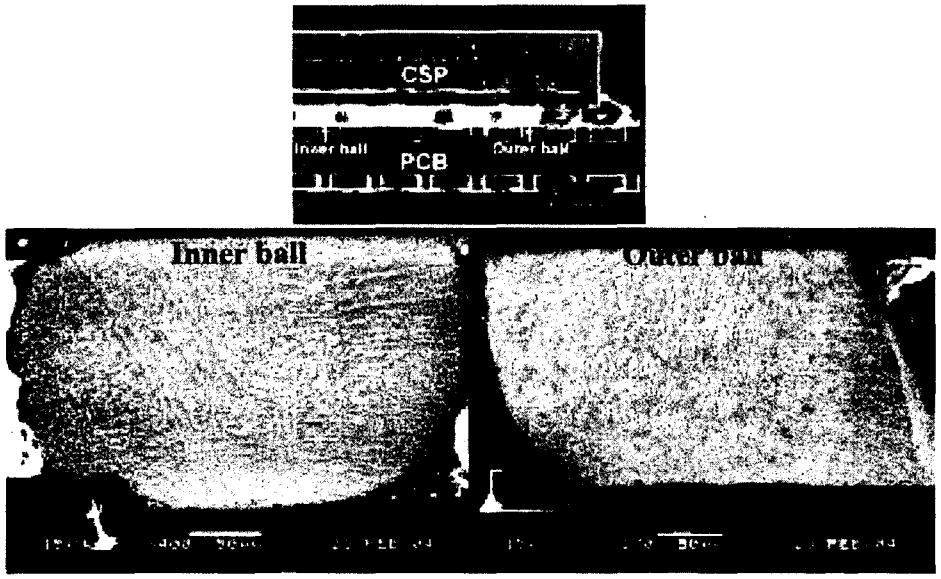
Solder balls in CSP-on-PCB assembly



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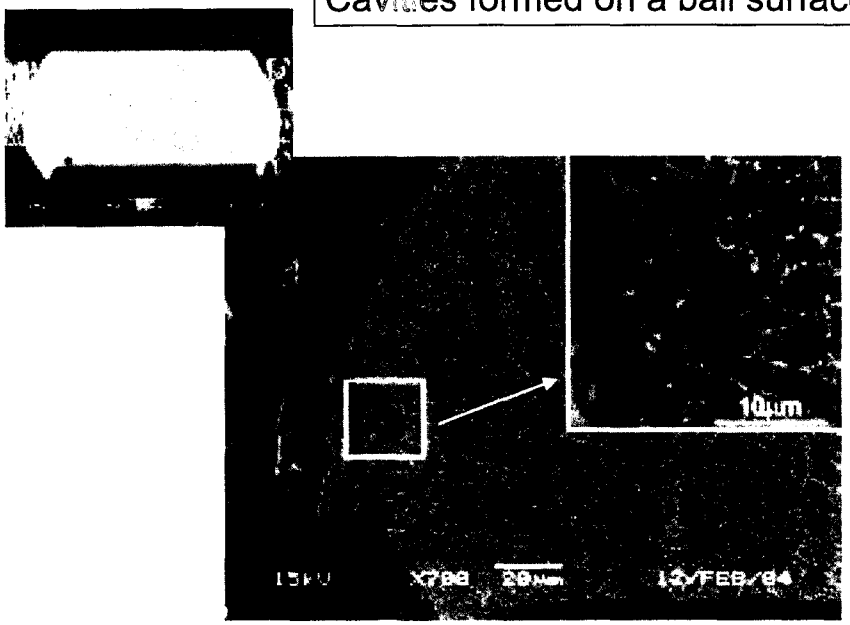
Cavities formed on a ball surface



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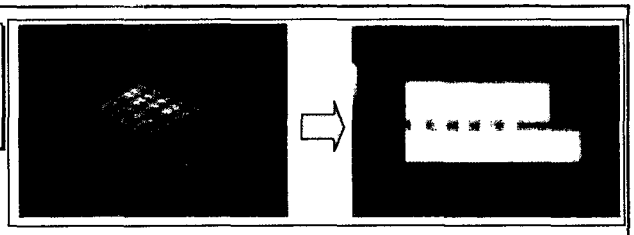
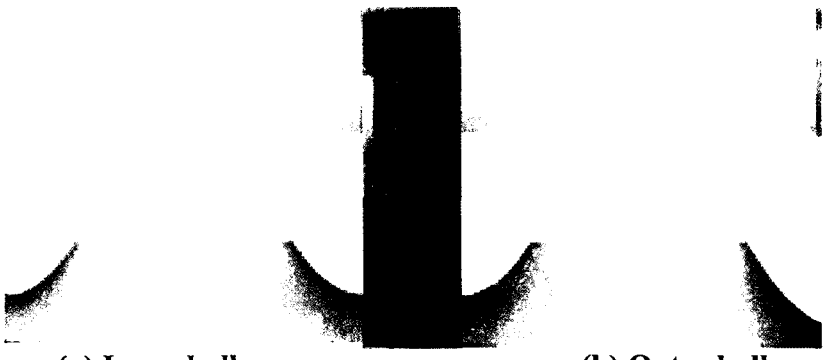
Solidification simulation





(a) Inner ball **(b) Outer ball**

The cooling speed of inner solder ball was slower than that of outer solder ball.

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Effects of Pb contamination in soldering

Enhancing defect formation by expanding pasty range.

➡ *Lift-off, Solidification cracking, Segregation*

Formation of low temperature phase, e.g., Sn-Bi-Pb....

➡ *Undesirable reaction proceeds rapidly*

Weakening interfaces, grain boundaries?

➡ *Boundary cracking*

Enhancing diffusion?

➡ *Undesirable reaction proceeds rapidly*

..... etc.

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