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# Lead-free Technical Documentation

Misconceptions regarding the use of  
Tin-Bismuth Plating  
in Component Packages

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# Introduction

Renesas Technology uses Tin-Bismuth (Sn-Bi) as a major lead-free plating material particularly for surface mount packages because of its high resistance against whisker growth.

However, within the market place there are a number of common misconception regarding its use.

1. “Bi accumulates in the flow solder bath.”
2. “Lift-off (or fillet lifting or separation) will occur during flow soldering.”
3. “Using Sn-Bi with a eutectic Sn-Pb solder creates a ternary eutectic alloy of Sn-Pb-Bi (melting point: 96 deg C), which leads to surface separation and concerns for long term reliability.”
4. “Bi separates to the surface of the joint; weakening the joint.”
5. “Bi is not recyclable.”
6. “Bi has a negative effect on the environment.”

See following pages for reasons why none of the above are valid concerns.



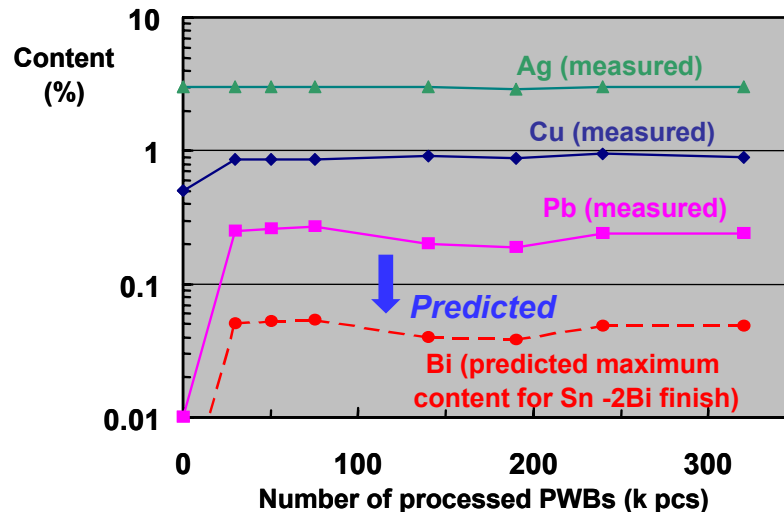
# Misconception 1

“Bi accumulates in the flow solder bath.”

Bi does accumulate in the flow bath, but the concentration only increases by about 0.05%; this causes no problems.

This value of Bi concentration is given from an estimation based on the measurement of Pb content in a solder bath after assembling Sn-Pb plated parts by flow soldering with Sn-3Ag-0.5Cu over 28 months.

- Solder composition: Sn-3Ag-0.5Cu
- Solder bath capacity: 350 kg
- Solder consumed: 3 to 5 kg/day
- Board size: 158 × 250 mm
- Major component plating: Sn-(10 to 40)Pb plating
- Evaluation term: 28 months



# Misconception 2

**“Lift-off (or fillet lifting or separation) will occur during flow soldering.”**

This has been considered a problem since the beginning of the trend towards lead-free products (around 1999). One report has said that a large enough proportion of Bi in the **solder** (e.g. 3%) will give this result when it is used in combination with Sn-10Pb plating. However, including Bi in the **plating** is not the problem here.

Flow solder evaluation of various plating materials was performed in JEITA\*. According to the result\*\*, lift-off occurred only with the Sn-Pb plated devices (3%, 10%, 37%(fusion) of Pb content). With Sn-Bi plating, lift-off and Bi segregation did not happen for contents of Bi (0.5%, 2%, 5%). Renesas Technology use Sn-2%Bi plating.

In addition, two companies involved in the assembly of parts, and well recognised in Japan, evaluated the lift-off and reached the same conclusion as above.

\* JEITA: Japan Electronics and Information Technology Industries Association

\*\* Hiroyuki Watanabe: "Relationship between Terminal Plating Composition and Incidence of Fillet Separation", Research Report on Practical Application of Lead-Free Solders 2002, pp.90-120, June, 2002, Japan Electronics and Information Technology Industries Association



# Misconception 3 (1)

**"Using Sn-Bi with a eutectic Sn-Pb solder creates a ternary eutectic alloy of Sn-Pb-Bi (melting point: 96 deg C), which leads to surface separation and concerns for long term reliability."**

No problems occur when plating including Bi is used in combination with Sn-Pb eutectic solder. We have checked this in joint-strength tests, and even if this ternary alloy is formed, it will have little effect on the strength, due to the small amount of Bi at the joint. Please refer to results in Appendix 1.

Also related to this misconception, is a fear that if the Bi concentration becomes high, it brings about a fall in the melting point of the solder. However, in flow soldering:

**Reply to Misconception 1** shows that the concentration of Bi in the solder bath does not increase significantly.

**Reply to Misconception 2** shows that Bi is also reliable for reflow soldering.



# Misconception 3 (2)

## Further explanation

1. From ternary alloy phase diagram, the composition ratio of Sn, Pb, Bi is approximately 15%, 35%, 50% respectively. Concentration of Bi is as high as 50% at ternary eutectic point. Since Bi concentration of plating is at most 4%, such segregation does not happen.
2. According to NEMI Tin-Whisker user group's "Interim Recommendations on Lead-Free Finishes for Components Used in High-Reliability Products" it is not thermodynamically possible to form this ternary eutectic with small (1-5% by weight) additions of Bi.  
[ftp://nemi.org/webdownload/projects/ese/TW\\_User\\_Group\\_position0304.pdf](ftp://nemi.org/webdownload/projects/ese/TW_User_Group_position0304.pdf)
3. According to the paper "Influence of Alloy Composition on Sn-Pb-Bi Eutectic Crystallization" reported by Denso at the Symposium "Microjoining and Assembly Technology in Electronics" held in Feb. 2000 in Yokohama, low melting point phase appears at more than 10wt% in high Bi concentration plating in combination with Sn-37%Pb solder and only possible down to 6wt%Bi where the Bi density varies within the plating.

In conclusion, for Sn-Bi plating where Bi concentration is typically 2% and a maximum of 4%, ternary eutectic of Sn-Pb-Bi is not formed.



# Misconceptions 4, 5 and 6

## 4. “Bi separates to the surface of the joint; weakening the joint.”

Again, the small amount of Bi in the plating means that even if this occurs, the effect itself will be weak, and so will not lead to a dramatic loss of strength for the joint.

Please refer to results in Appendix 1.

## 5. “Bi is not recyclable.”

This reflects a concern that the Bi is not separately recycled when the Cu is recycled from the product, but rather remains as an impurity. In practice, however, refinery operators are able to recycle Bi separately, and there are no technical obstacles to doing so.

## 6. “Bi has a negative effect on the environment.”

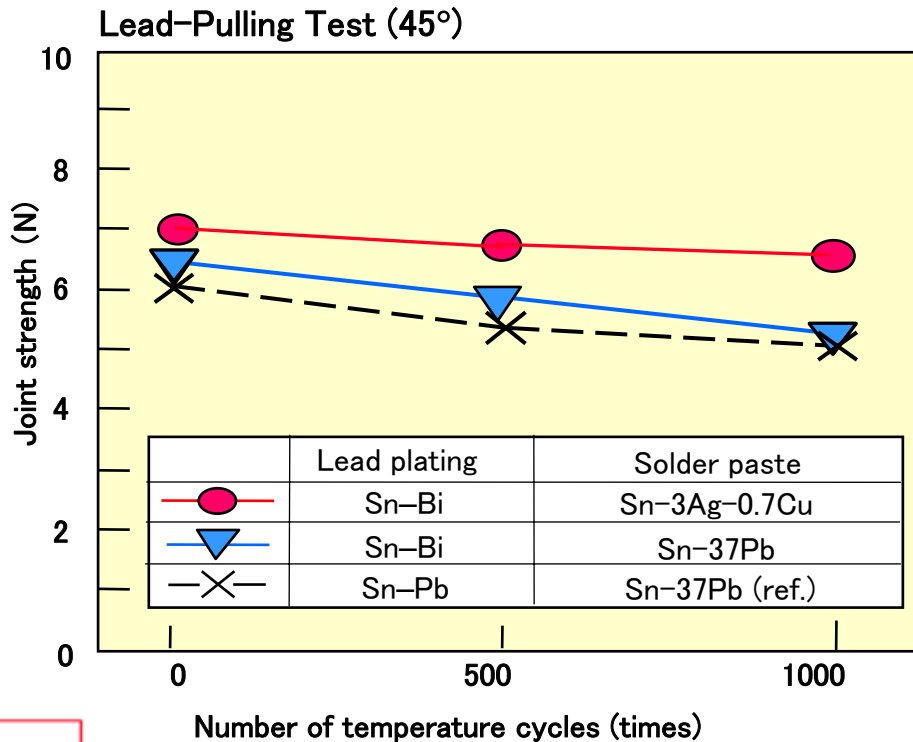
Solubility in natural rain fall is low. The effects of Bi on the germination and growth of plants, on carcinogenesis in animals, and on soil microbes have all been investigated. Although it is not completely free of toxicity, it is not considered to be a hazardous material. Please refer to Appendix 2.



# Appendix 1: Mechanical strength of joints

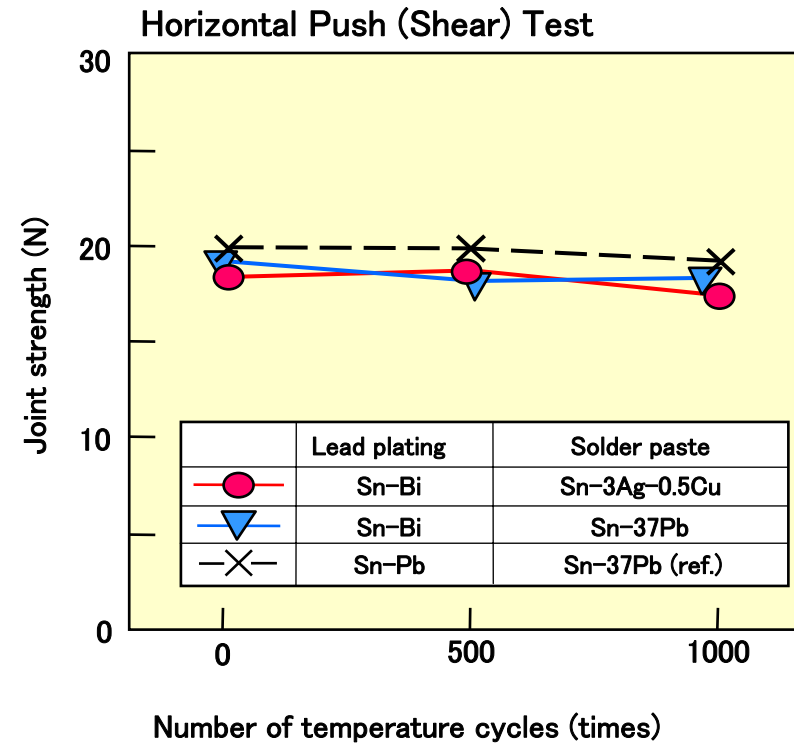
## Data 1

Package: QFP2828-208-0.5 (Fe-Ni)  
 Condition of temperature-cycling: -55/125 deg C  
 10 min./10 min.  
 Temperature for joint formation:  
 Sn-3 Ag-0.5Cu: 245 deg C, Sn-37Pb: 210 deg C



## Data 2

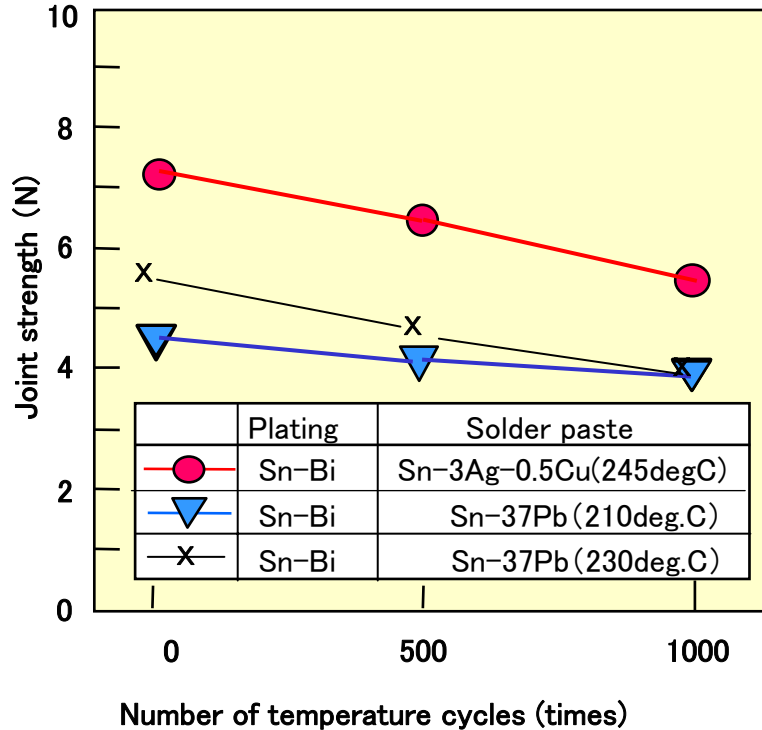
Package: CMPAK-4 (Cu leads)  
 Condition of temperature cycling: -55°C/125 deg C  
 Temperature for joint formation:  
 Sn-3 Ag-0.5Cu: 245 deg C, Sn-37Pb: 210 deg C



### Data 3

Package: QFP1414-100-0.5 (Fe-Ni leads)  
 Condition of temperature cycling:  
 -55 deg C /125 deg C 10 min./10 min.

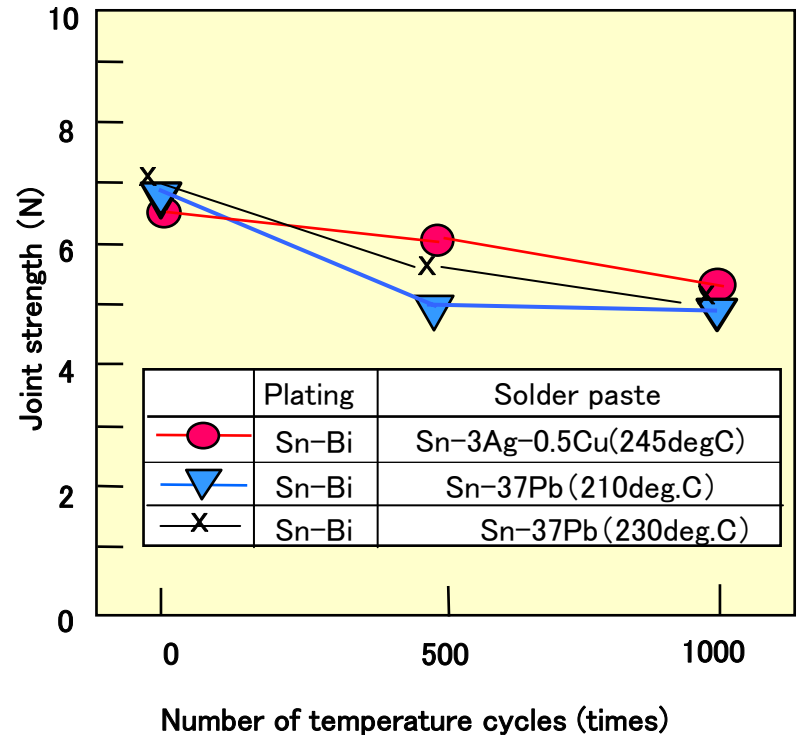
#### Lead-Pulling Test (45°)



### Data 4

Package: QFP1414-100-0.5 (Cu leads)  
 Condition of temperature cycling:  
 -55 deg C /125 deg C 10 min./10 min.

#### Lead-Pulling Test (45°)



Note: Temperature in the diagrams means one for joint formation .



## Data 5

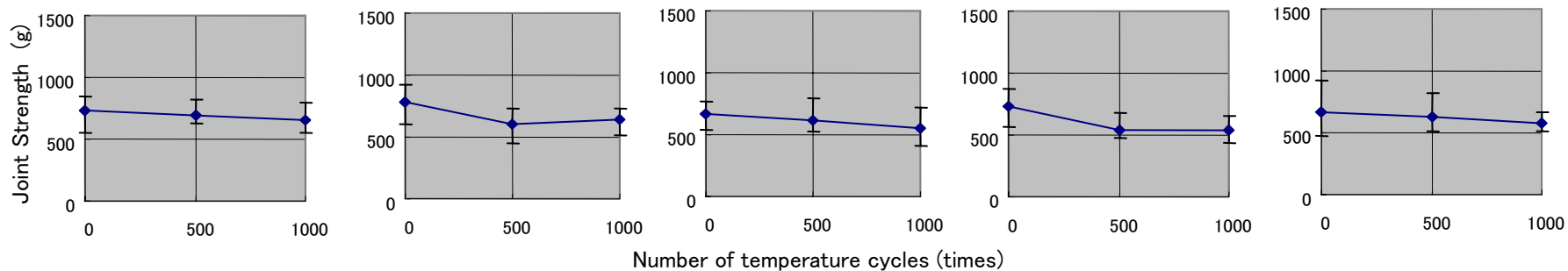
Package: QFP1414-100-0.5 (Cu leads)

Condition of temperature cycling: -55 deg C /125 deg C 10 min./10 min.

Joint formation temperature: 245 deg C

Solder paste: Sn-3Ag-0.5Cu

### Lead-Pulling Test (45°)



Sn-0.5%Bi

Sn-1%Bi

Sn-2%Bi

Sn-3%Bi

Sn-4%Bi



# Appendix 2: Biological Impact of Metals in Lead-Free Solders

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## Abstract

The toxicity of the constituent metals of lead-free solder was investigated by animal (rat) experiments. Tests on oral toxicity (acute and chronic) and intratracheal toxicity (acute and chronic) were performed, and two kinds of preliminary tests for carcinogenicity were conducted. These tests covered those necessary for checking the safety of lead-free solder. It was found that the oral toxicity of bismuth, silver and indium were very low compared with that of lead, and their carcinogenicity was negative. Moreover, bismuth showed a little intratracheal toxicity. On the other hand, antimony showed the same level of chronic oral toxicity as lead and also tested positive for carcinogenicity; i.e., it exhibited a higher level of toxicity than that of lead. In addition, the dose of antimony had a comparatively small negative effect on intratracheal toxicity, though the toxicity of antimony was relatively high compared with that of bismuth. It is summarized that the toxicity of bismuth, silver and indium were very low and that of antimony was high compared with that of lead.