

Improving Reliability of Fan-Out Wafer Level Package Through Doping of Lead-Free Solder Balls

IMAPS DPC 2022

WP2: FOWLP: TECHNOLOGY & DESIGN

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Solder ball characterization

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TCOB lifetime for Bi-doping, solder pad and RF laminate variation

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Drop test results

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Drop test results

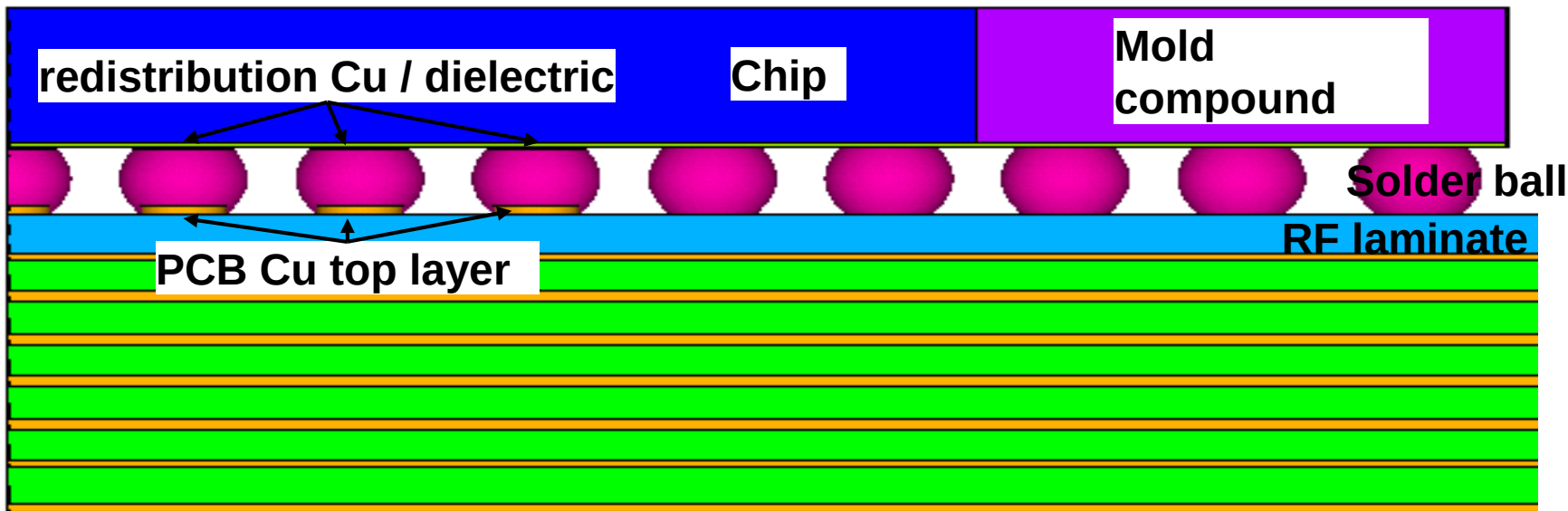
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Summary

Reliability improvement for Fan-Out Package through solder ball doping

Introduction

Chip/mold compound and FR4 layers below RF laminate are fixed
→ Vary solder balls, Cu layers and RF laminate

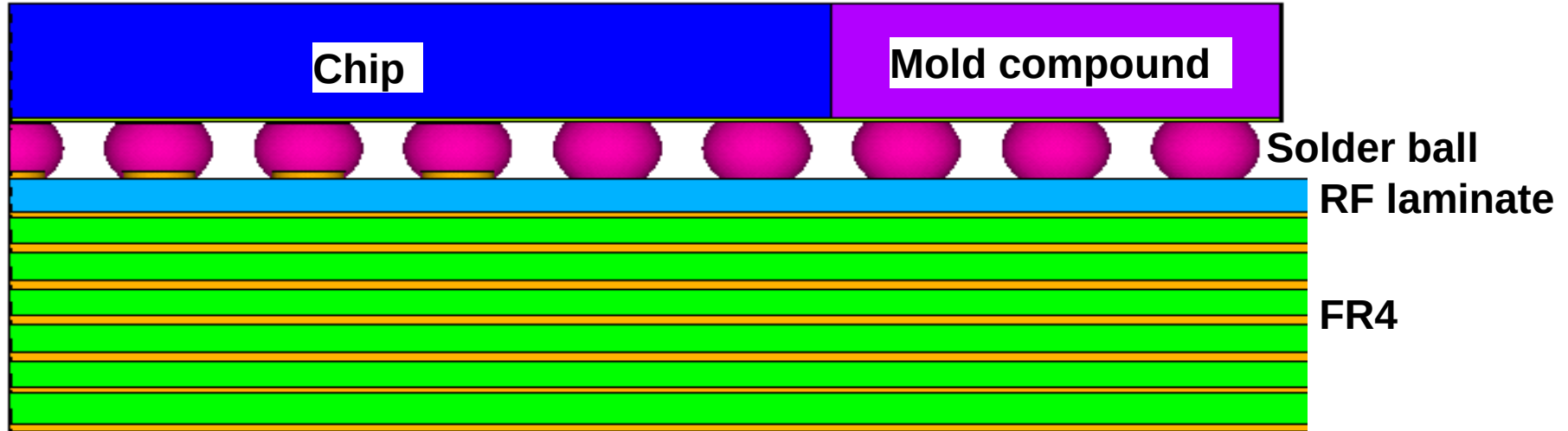


FR4 laminate with other Cu layers

Nice Video of breathing stack 😊

Reliability improvement for Fan-Out Package through solder ball doping

Introduction

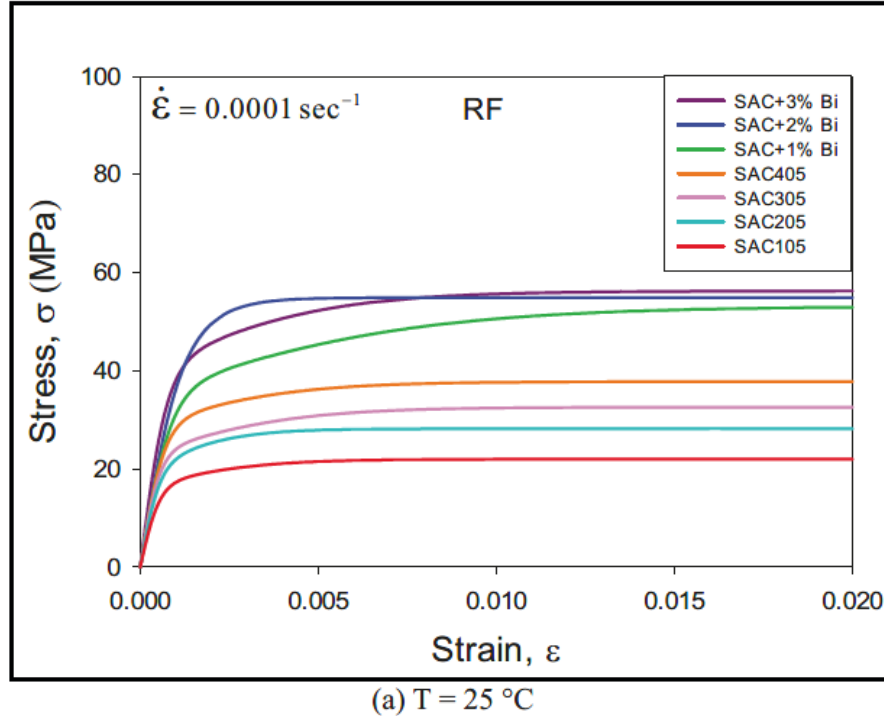


Reliability improvement for Fan-Out Package through solder ball doping

Introduction

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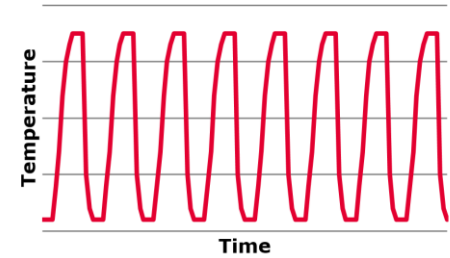


KM R. Hassan et al “Mechanical Behavior and Reliability of SAC+Bi Lead Free Solders with Various Levels of Bismuth”, Proc. 71st Electronic Components and Technology Conference (ECTC 2021), 2021

Reliability improvement for Fan-Out Package through solder ball doping

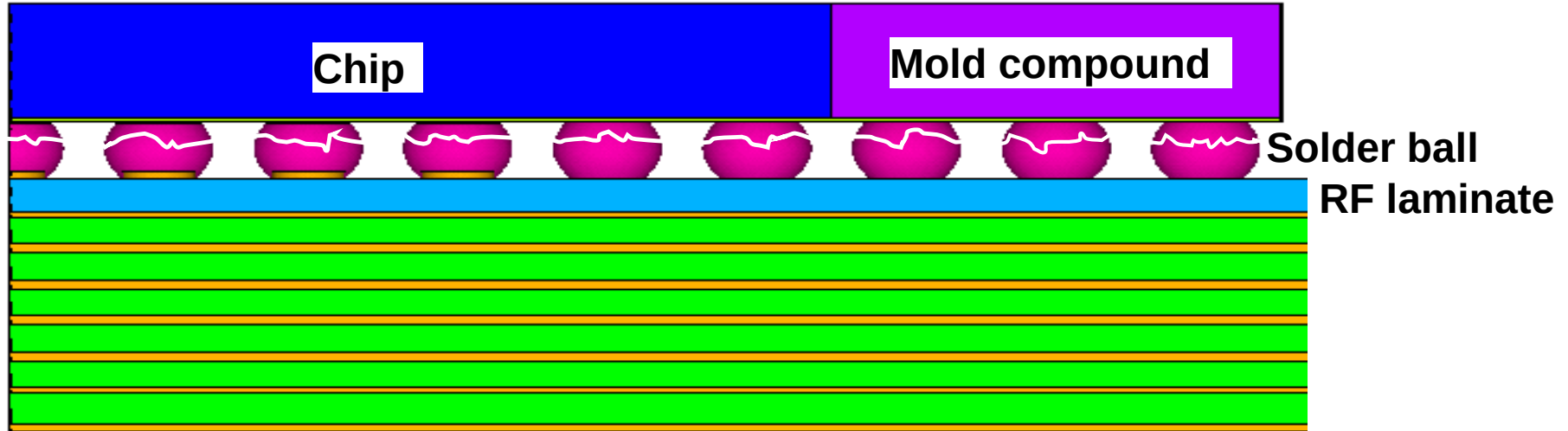
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Temperature Profile



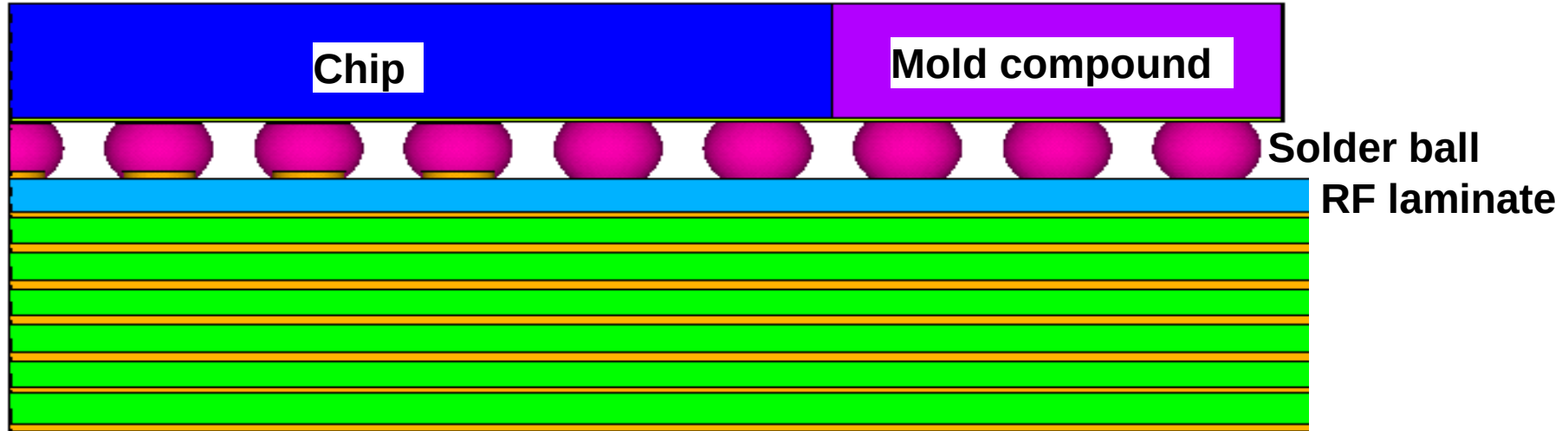
Reliability improvement for Fan-Out Package through solder ball doping

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Reliability improvement for Fan-Out Package through solder ball doping

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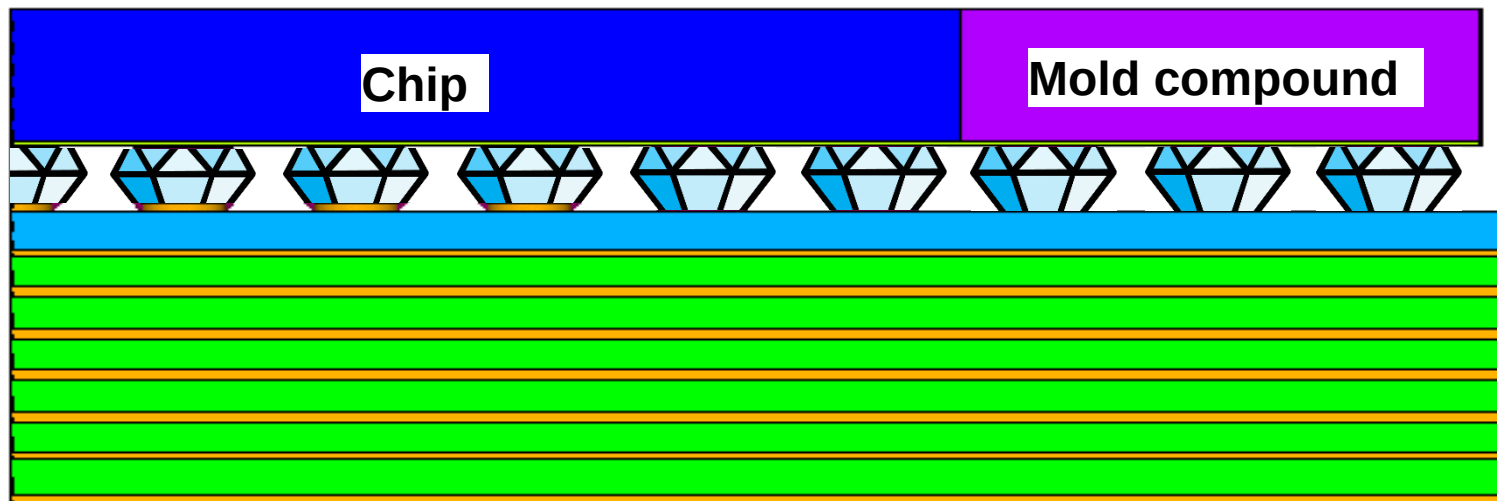
Reliability improvement for Fan-Out Package through solder ball doping

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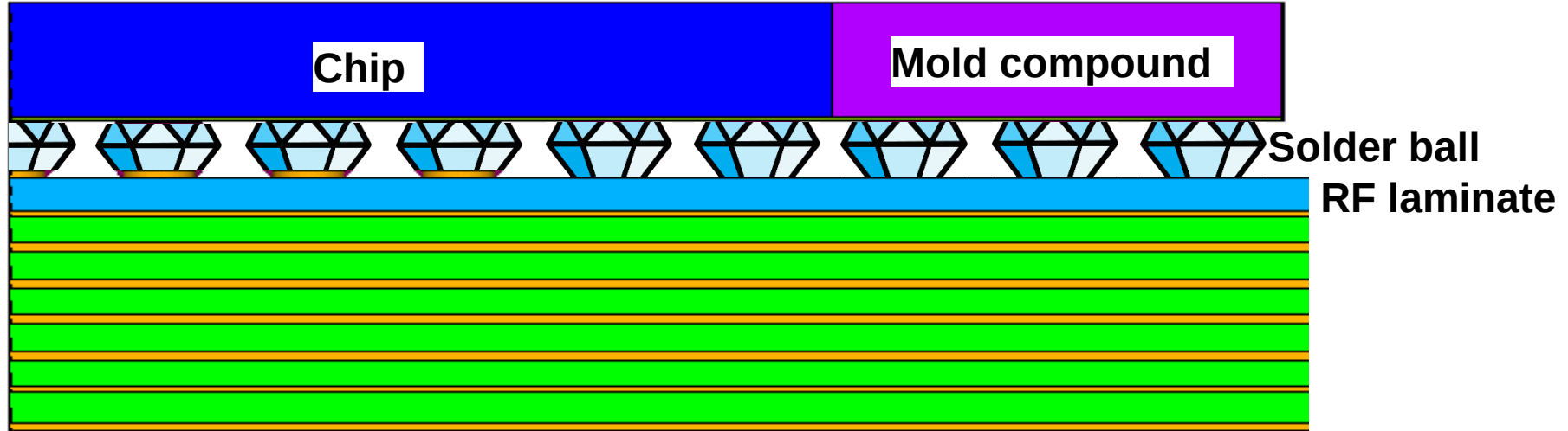
Reliability improvement for Fan-Out Package through solder ball doping

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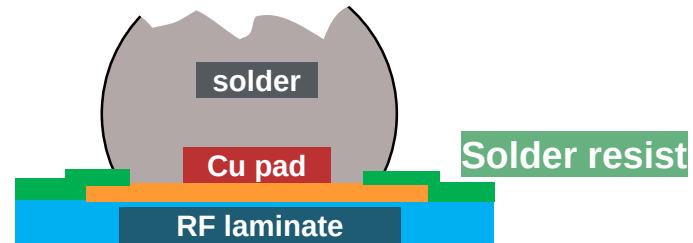
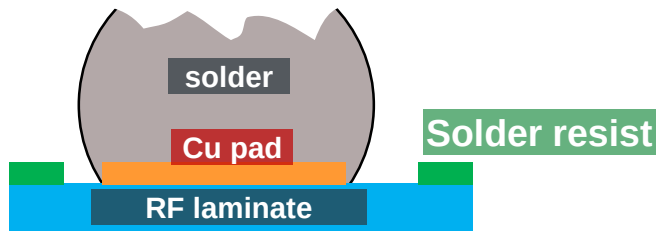
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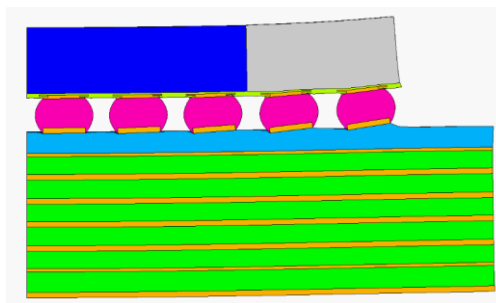
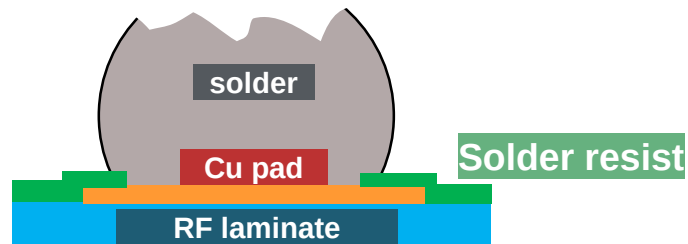
Introduction

Non Solder-Mask Defined (NSMD) pad



Solder-Mask Defined (SMD) pad





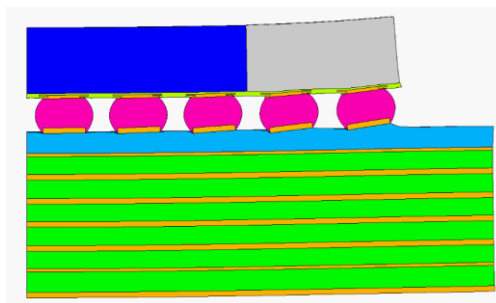
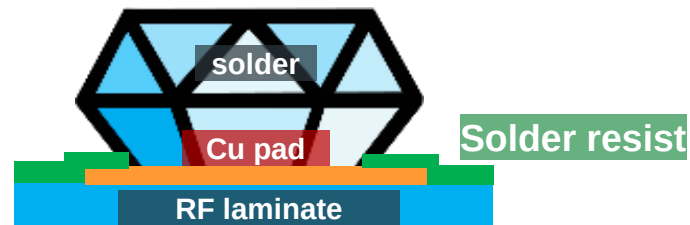
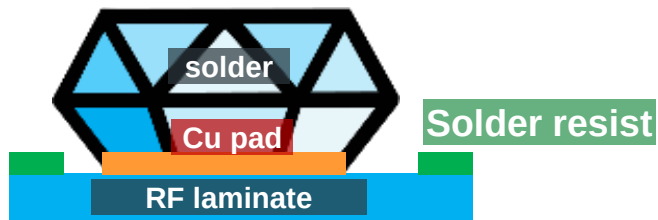
Reliability improvement for Fan-Out Package through solder ball doping

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**Non Solder-Mask Defined
(NSMD) pad**



**Solder-Mask Defined
(SMD) pad**



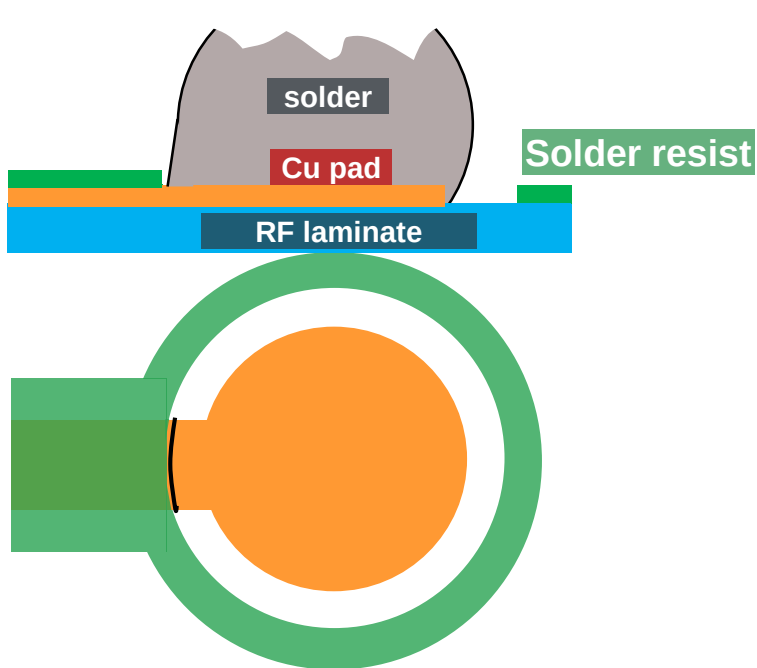
Reliability improvement for Fan-Out Package through solder ball doping

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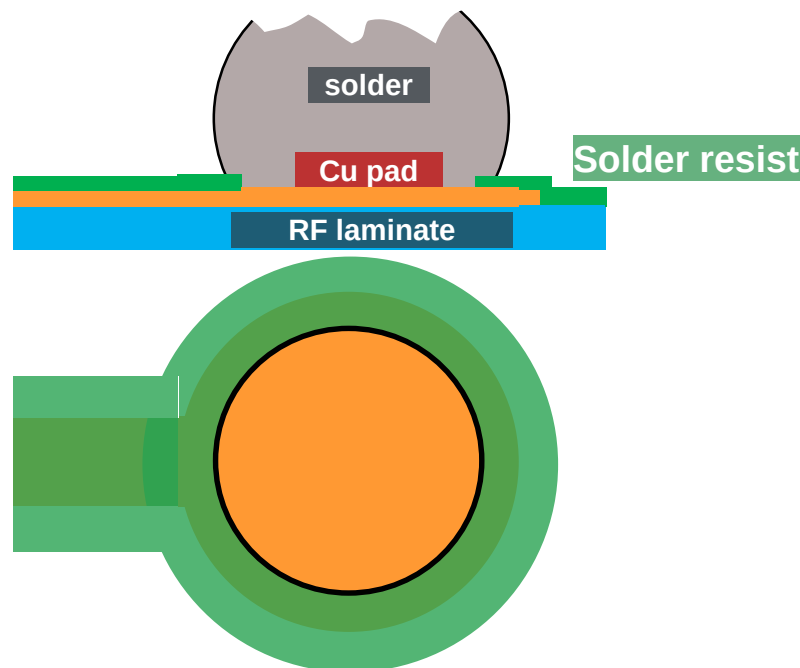
Non Solder-Mask Defined (NSMD) pad



Solder-Mask Defined (SMD) pad



NSMD: short crack causes fail



SMD: full circular crack causes fail

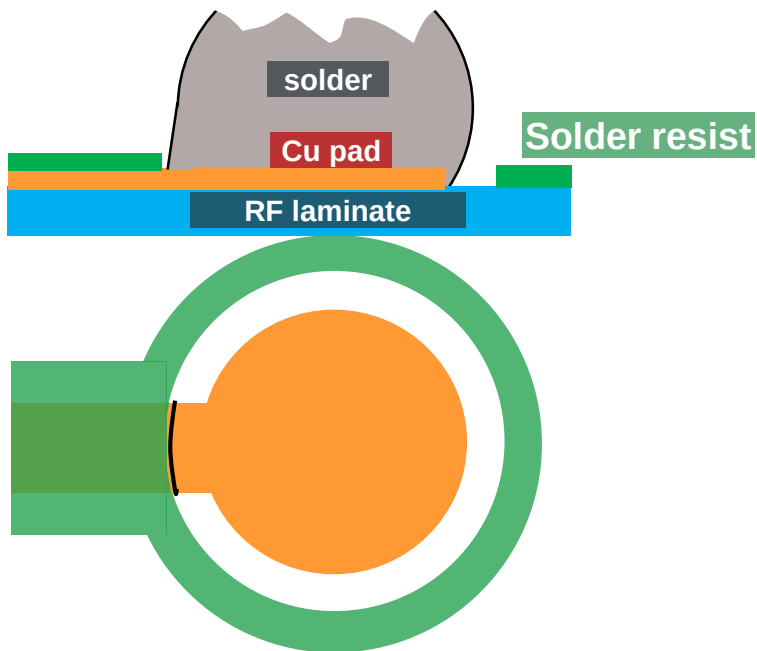
Reliability improvement for Fan-Out Package through solder ball doping

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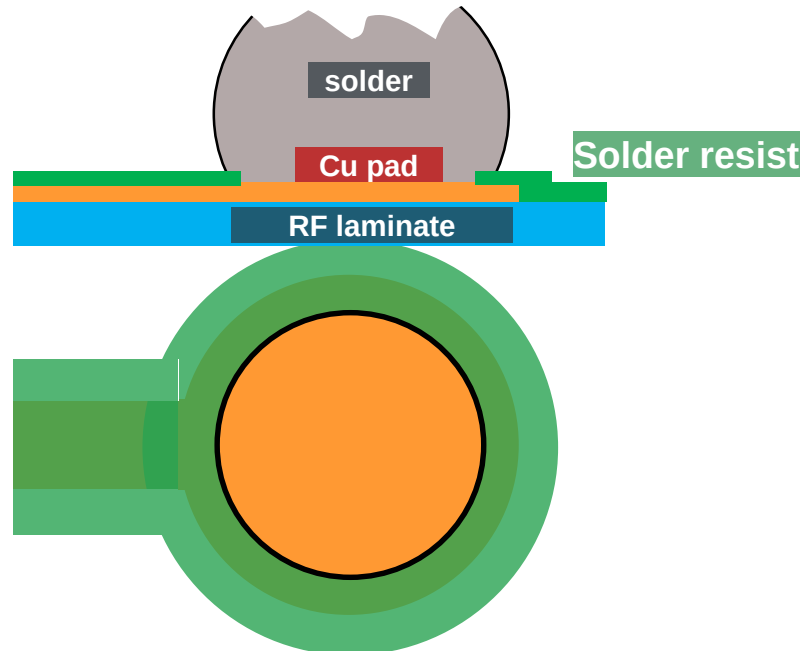
Non Solder-Mask Defined (NSMD) pad



Solder-Mask Defined (SMD) pad



NSMD: short crack causes fail

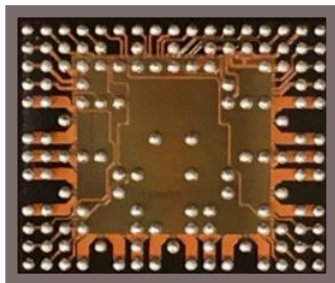


SMD: full circular crack causes fail

Reliability improvement for Fan-Out Package through solder ball doping

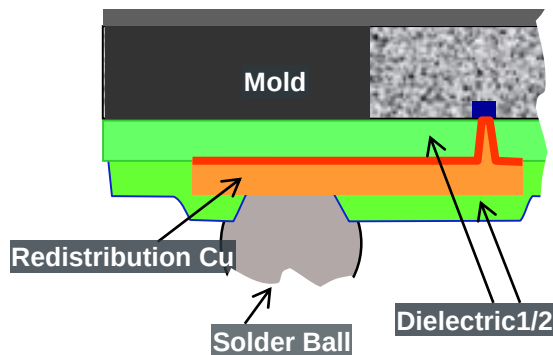
Test vehicle and test matrix

eWLB test vehicle



7mmx8,5mm

Schematic cross section



Test matrix

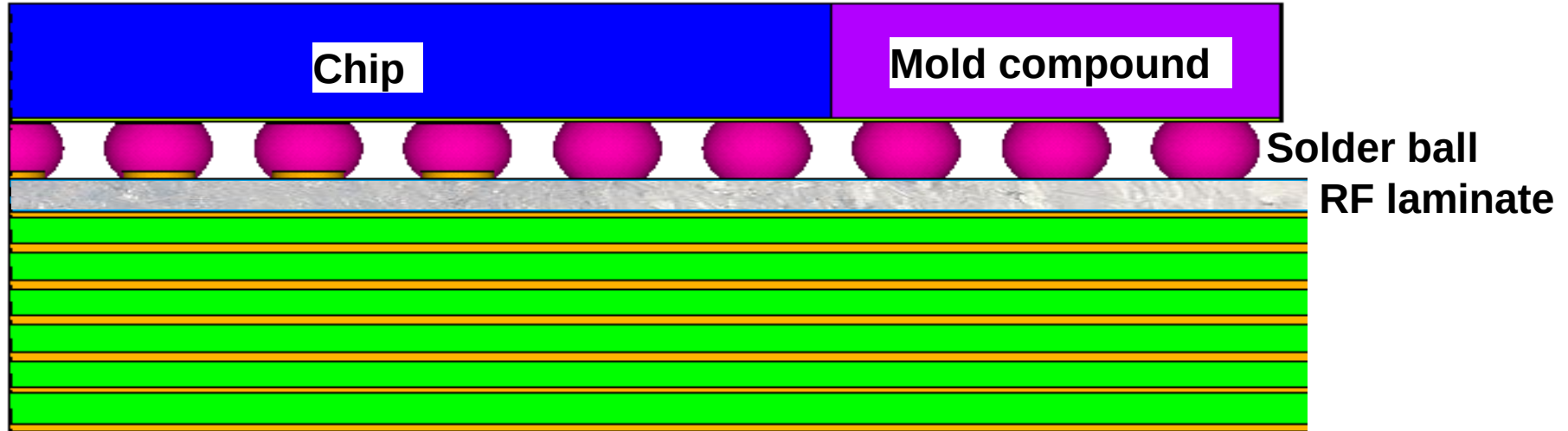
Property	variation
A) Bi doping	0% – 2.5%
B) Cu Pad design	SMD/NSMD
C) RF laminate	soft/med/FR4

Solder ball stiffness, PCB Cu layers and PCB stiffness variation

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Reliability improvement for Fan-Out Package through solder ball doping

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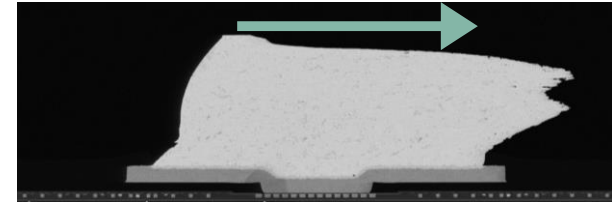
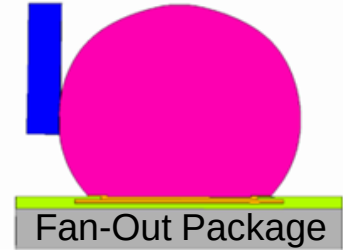
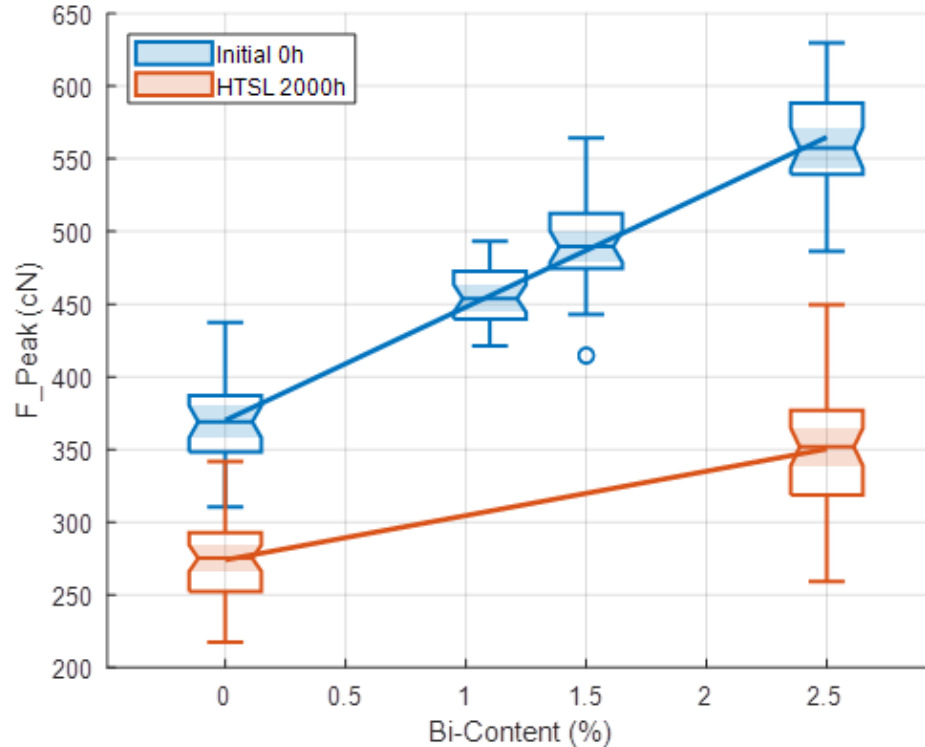
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Reliability improvement for Fan-Out Package through solder ball doping

Solder ball characterization

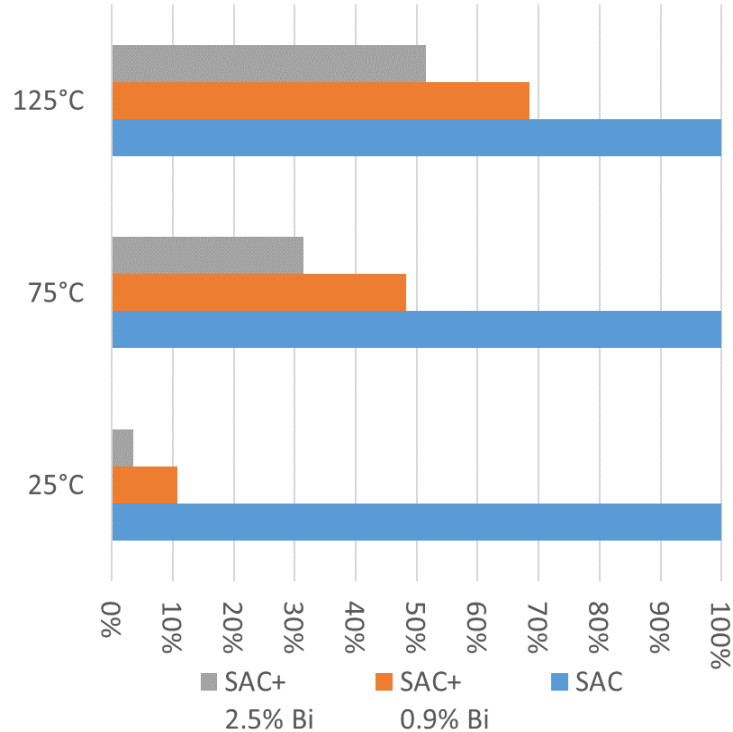
Solder ball peak shear force F_{Peak}



Reliability improvement for Fan-Out Package through solder ball doping

Solder ball characterization

measured solder secondary creep rates



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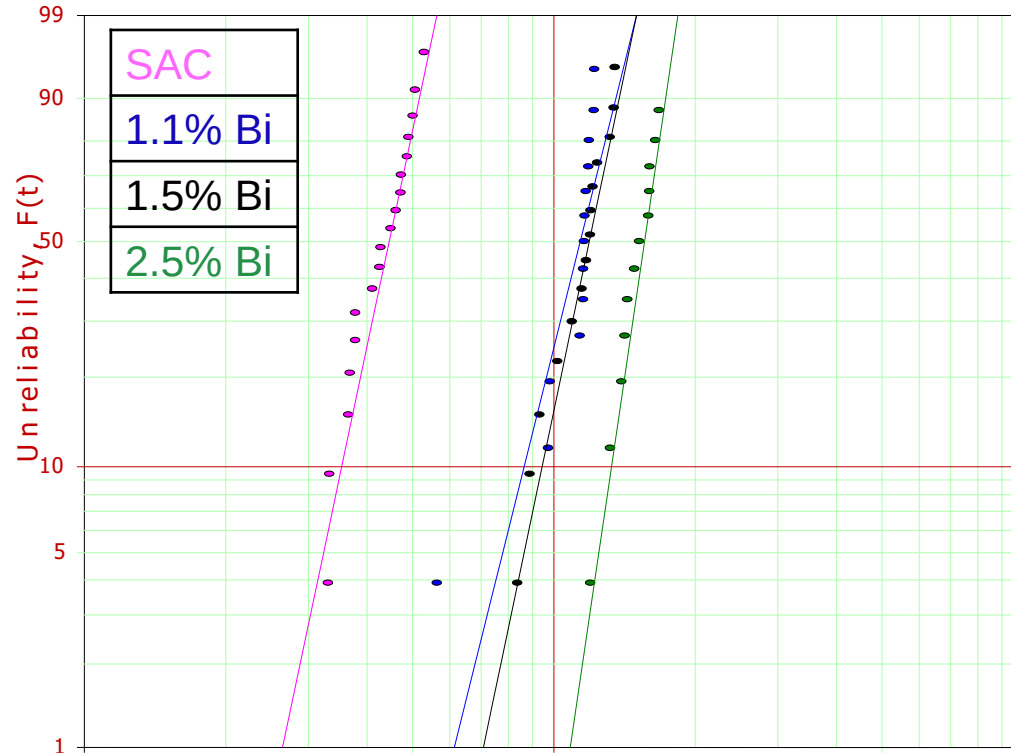
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Reliability improvement for Fan-Out Package through solder ball doping

TCOB lifetime for Bi-doping, solder pad and RF laminate variation

Bi doping variation on SMD pad

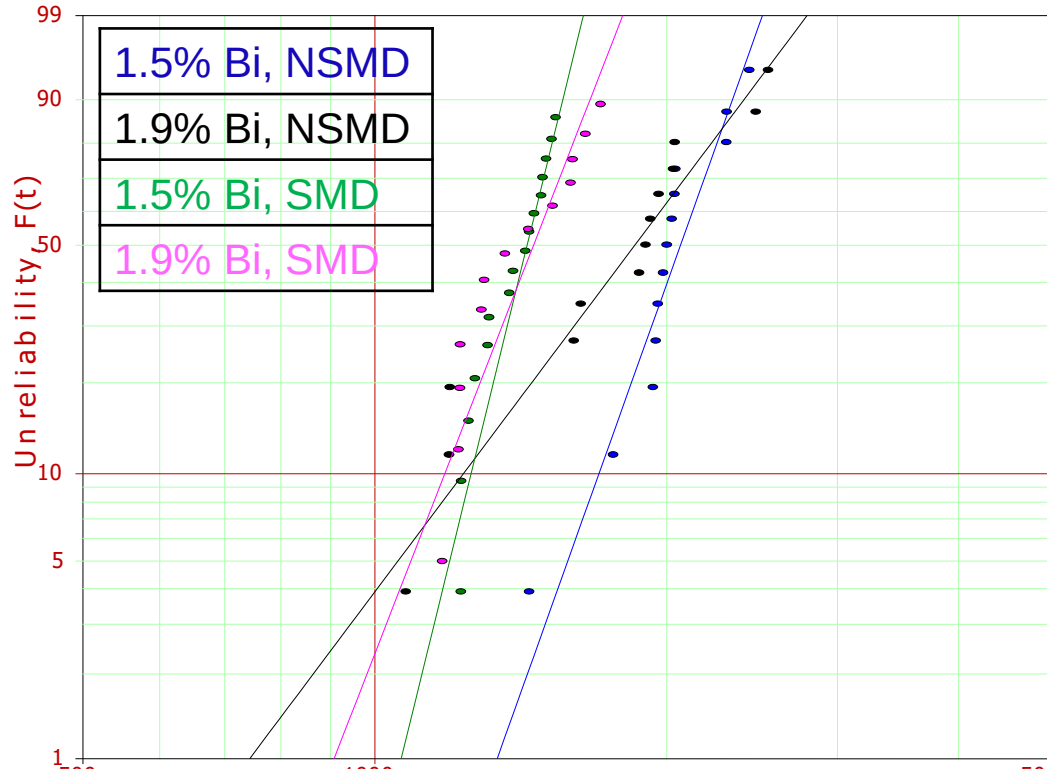


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Reliability improvement for Fan-Out Package through solder ball doping

TCOB lifetime for Bi-doping, solder pad and RF laminate variation

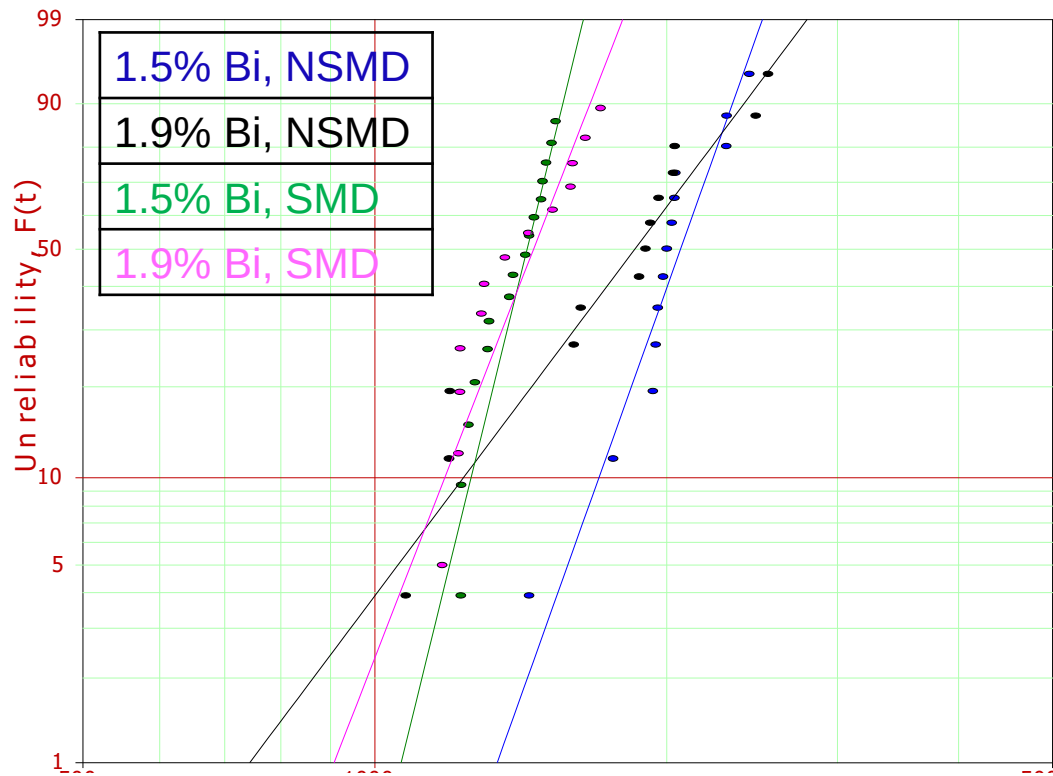
SMD vs NSMD pad



Reliability improvement for Fan-Out Package through solder ball doping

TCOB lifetime for Bi-doping, solder pad and RF laminate variation

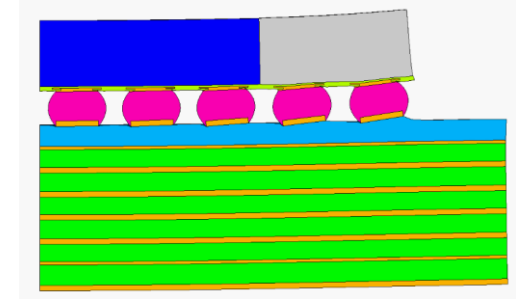
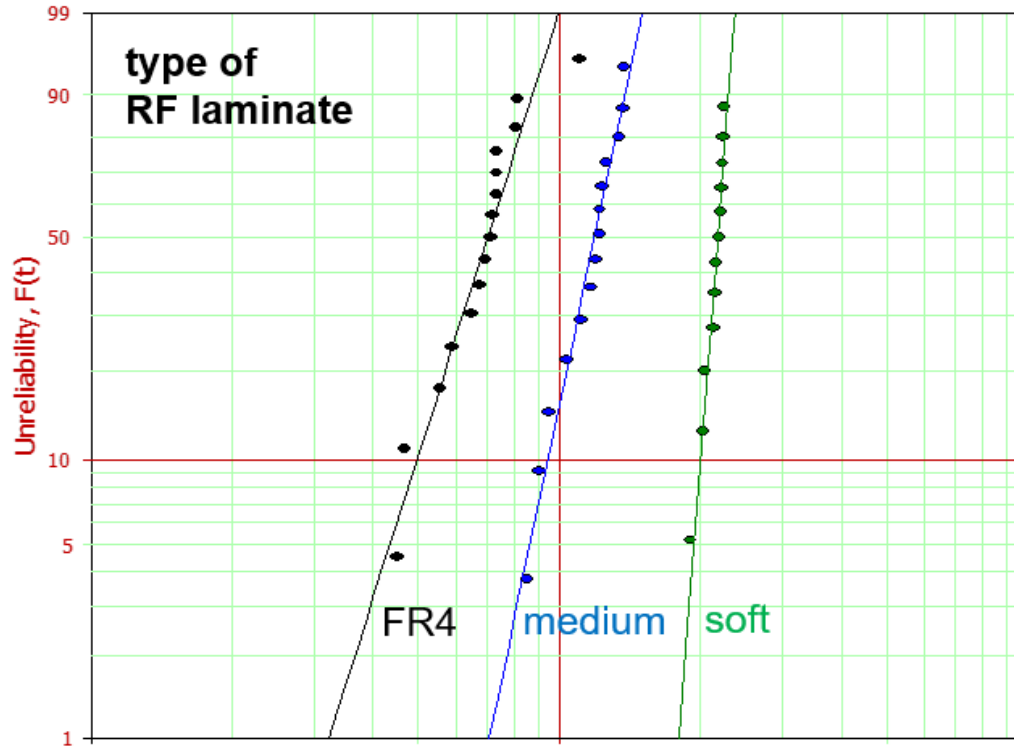
SMD vs NSMD pad



First fail 1.9% Bi, NSMD

Reliability improvement for Fan-Out Package through solder ball doping

TCOB lifetime for Bi-doping, solder pad and RF laminate variation



Soft RF laminate buffers stress

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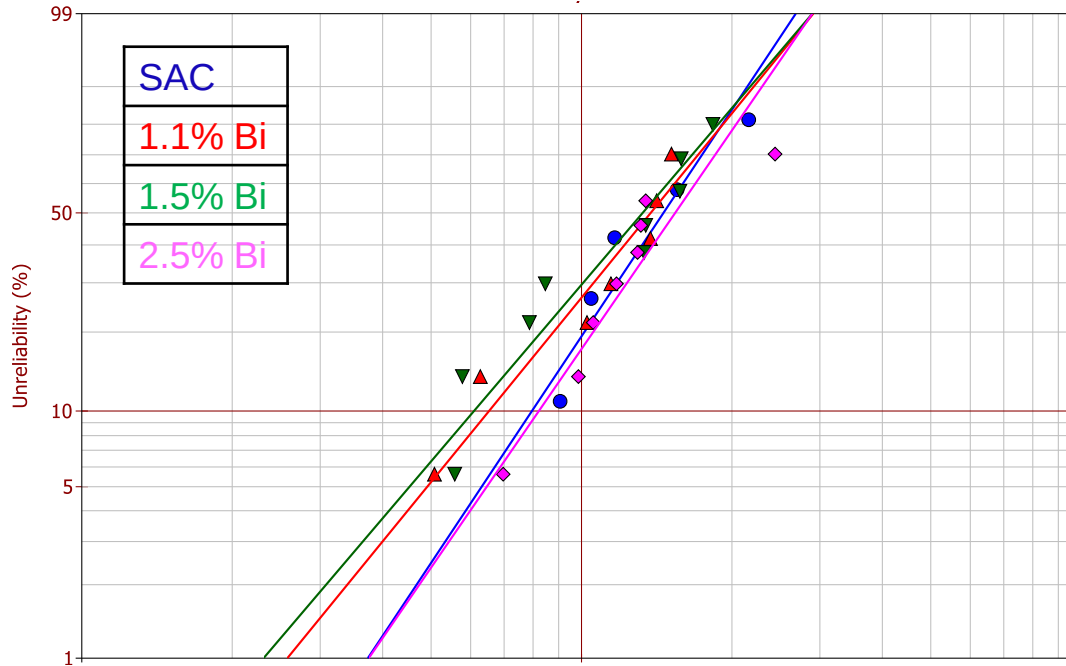
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Summary

1. Bi-doping of the solder balls improves the TCOB performance of fan-out wafer level packages
2. BUT: Care needs to be taken to avoid unwanted extrinsic failures
3. Other performance parameters like droptest are not negatively influenced

Reliability improvement for Fan-Out Package through solder ball doping

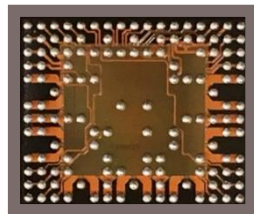
Good Bye!



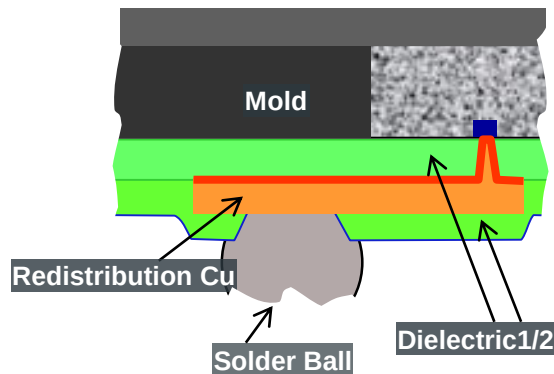
TCOB improvement for eWLB via Bi-doping

Test vehicle and test matrix

eWLB vehicle

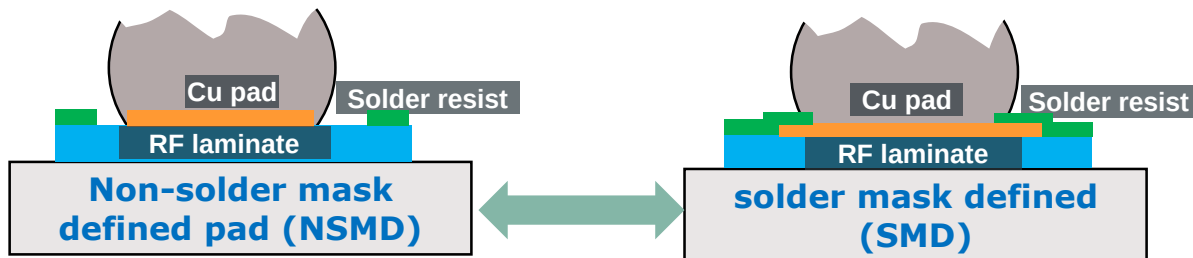


7mmx8,5mm



Test matrix

Property	variation
A) Bi doping	0% – 2.5%
B) Cu Pad design	SMD/NSMD
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Solder ball doping, PCB Cu layers setup, and PCB stiffness relevant