Solder Flux Evolution for Heterogeneous Integration

Evan Griffith

Indium Corporation

IMAPS DPC

01058

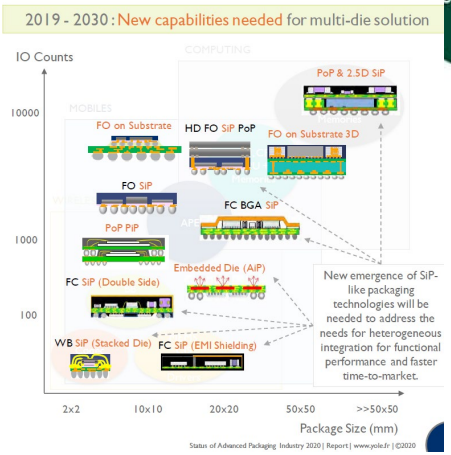
Outline

- Introduction
- Flip Chip Flux
- Ball-Attach Flux
- Flux-Free Processes and Materials
- Summary

Introduction

Advanced Packaging Needs

- Higher functional performance
- Smaller form factor / higher density
- Higher frequency



Challenges:

- Tighter pitch & smaller joints
- Thin/coreless substrate, thin/large die

- Flux residue cleaning effectiveness
- Warpage induced open joints

Characteristics of Flux

	NC Flux		WW Flux
	Regular NC Flux	NC-ULR Flux	
Cleaning Equipment	Typically Not Needed	Not Necessary	Required
Cleaning Solution	Typically Not Needed	Not Necessary	Required
Typical Residual Amount*	20~60%	0~10%	N/A
Compatibility with Underfill	Typically Low	Good	Good (After Clean)
Wetting Power	Strong	Good	Strong
Formulation Aspect	Hydrophobic Ingredients	Hydrophobic and Minimum of High Molecular Weight Ingredients	Hydrophilic Ingredients
Post Heat Treatment (TCB/LCB)		150°C (or 180°C) for an hour for TCB	

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Flip-Chip Challenges

- Package Design Changes
  - < 100um pitch
  - < 60um die clearance
  - Thin substrates (<20um) suspect to warpage
- Resulting Cleaning Challenges
  - Pitch reduction limits ability to completely remove water soluble flux residues:
    - Corrosive residues left behind
    - Block flow of CUF and MUF leading to underfill voiding
    - Interfere with CUF and MUF adhesion causing delamination
  - Cleaning process:
    - Increases substrate warpage after reflow and before underfill
      - Die damage
      - Cracked solder joints
    - Adds costs

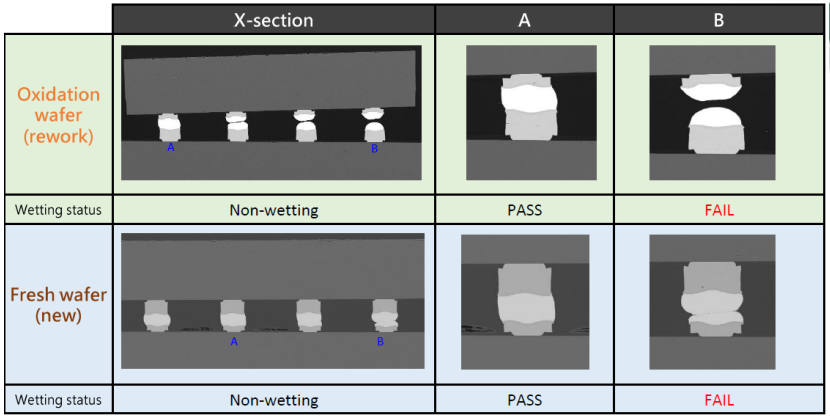
Flip Chip Die Attach Challenges

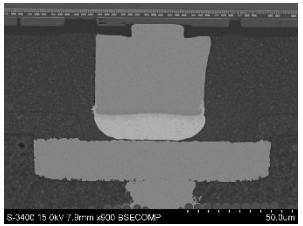
Warpage

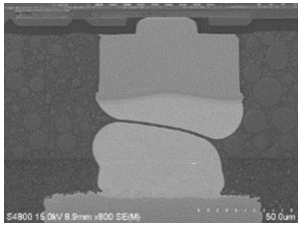
- Thinner Substrates
- Larger and thinner die
- Asymmetrical bump design

→ **Open joints**

CoW







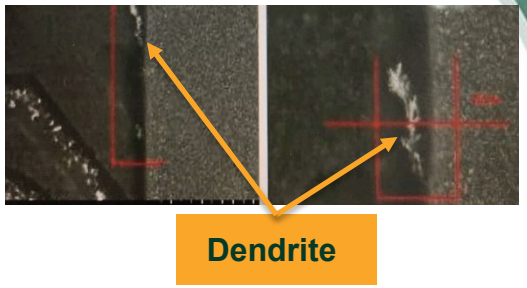
Possible solutions

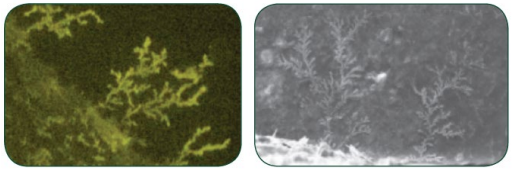
- Flux with better wetting or higher tack to hold die in place - even with warpage
- Mass reflow → TCB/LAB

Flip Chip Die Attach Challenges
Mass reflow + Water Washable Flux

- Shrinking pitch, tighter die-substrate clearance
- Flux residue cleaning challenges

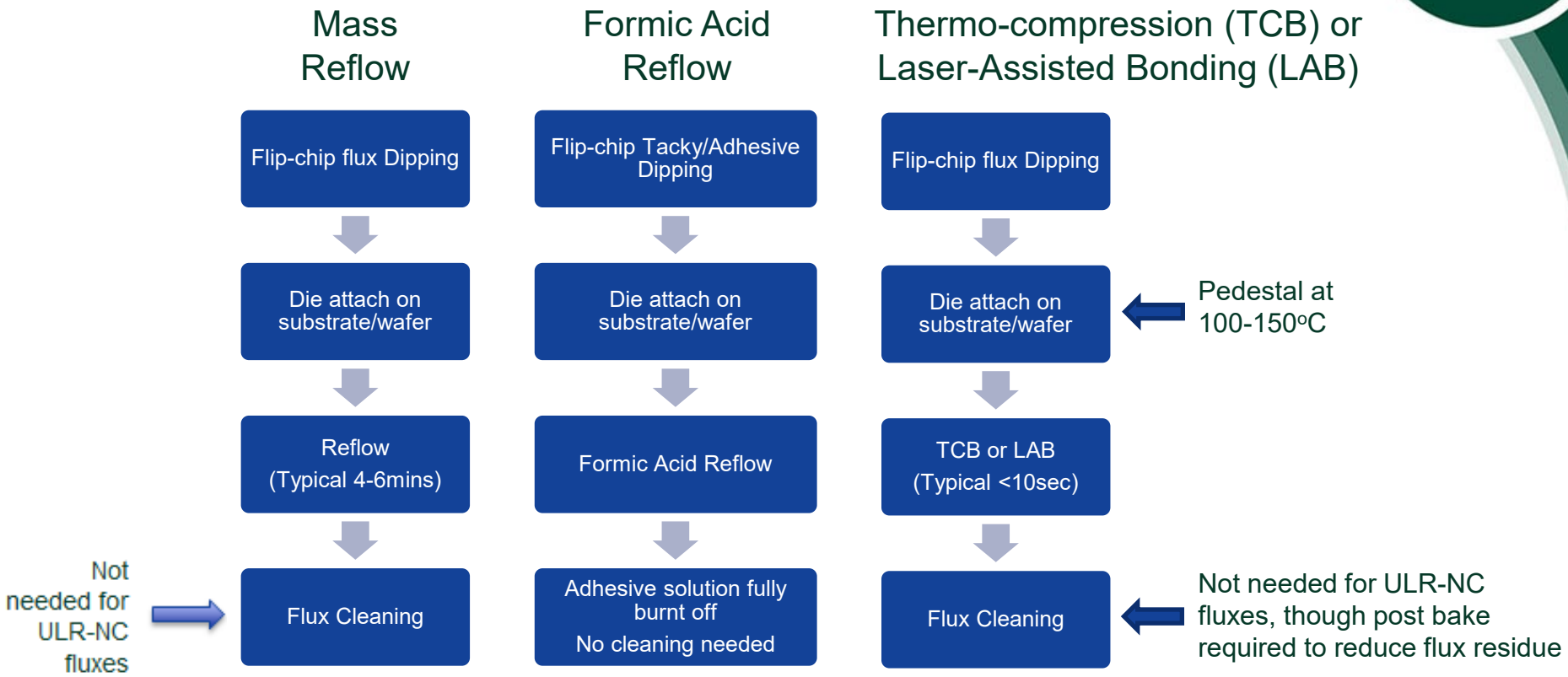
Dendrite
Conductive residue
Underfill void & delamination





- **Possible solutions**
  - No clean process using ultra-low residue (ULR) flux
  - Fluxless process

Assembly Process Flow



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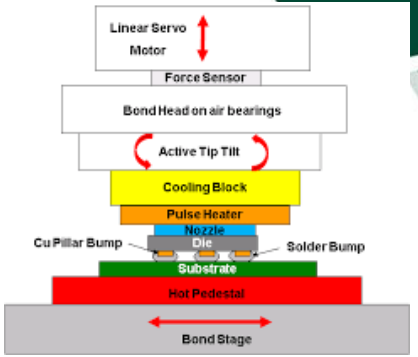
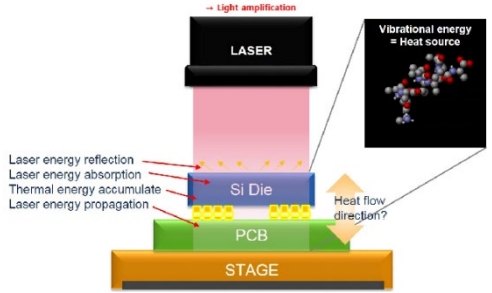
TCB / LAB Reflow

Less and shorter heat exposure reduces warpage

	Mass Reflow	TCB	LAB
Thermal Stress on ELK	5x	1x	2x
Warpage	High	Low	Low
UPH / Productivity	Fast	Slow/Moderate	Fast
Selective soldering	No	Die only	Yes
Multidie & components	Yes	No	Yes
Selfalignment	Yes	No	Yes
Fine pitchcapability	Challenging	Yes	Yes



TCB



LAB: no z-axis compressive forces

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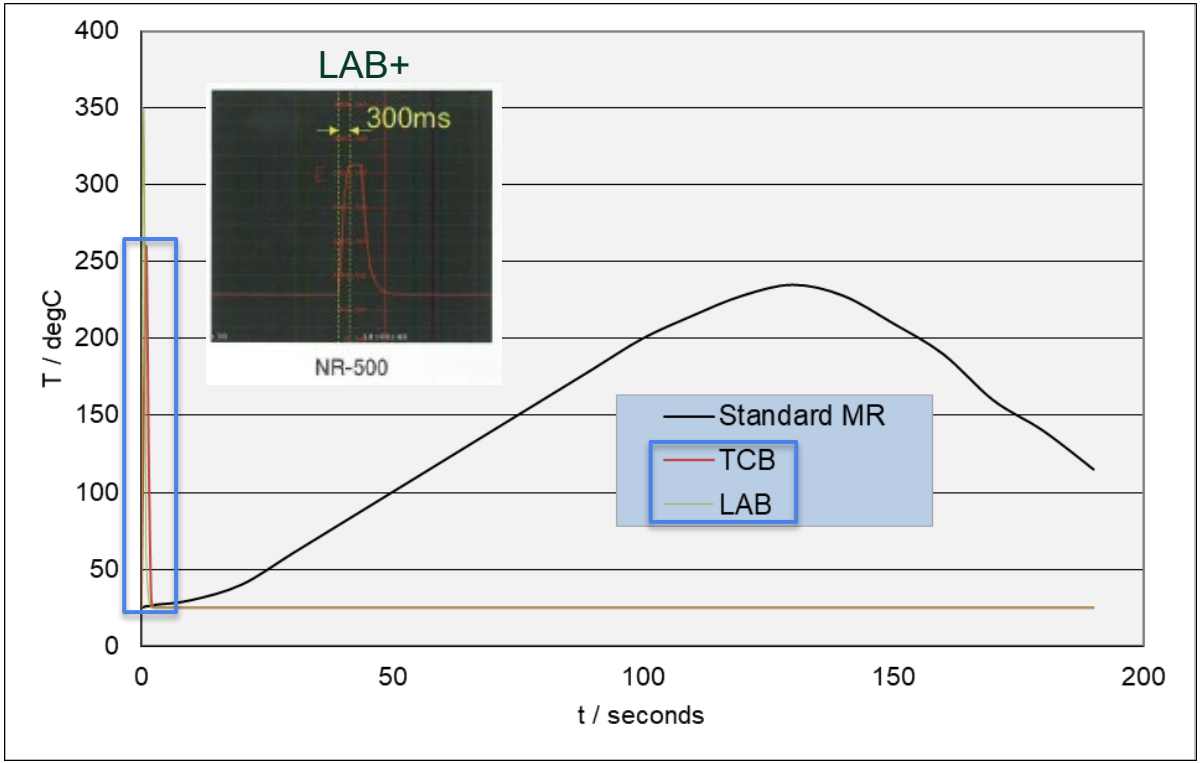
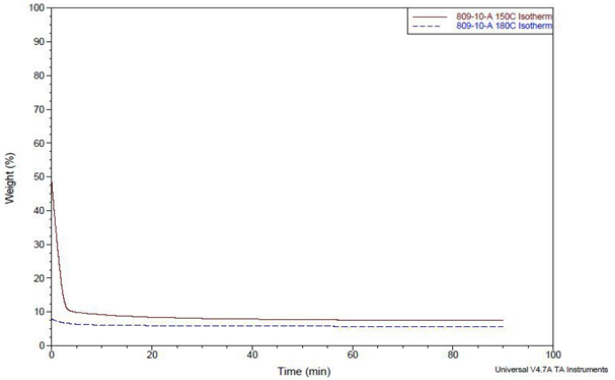
TCB / LAB Reflow



Short “pulse” profiles for TCB and LAB necessitate post-reflow heat treatment for ULR Fluxes



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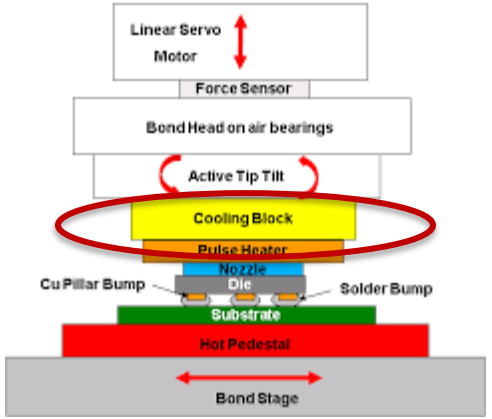
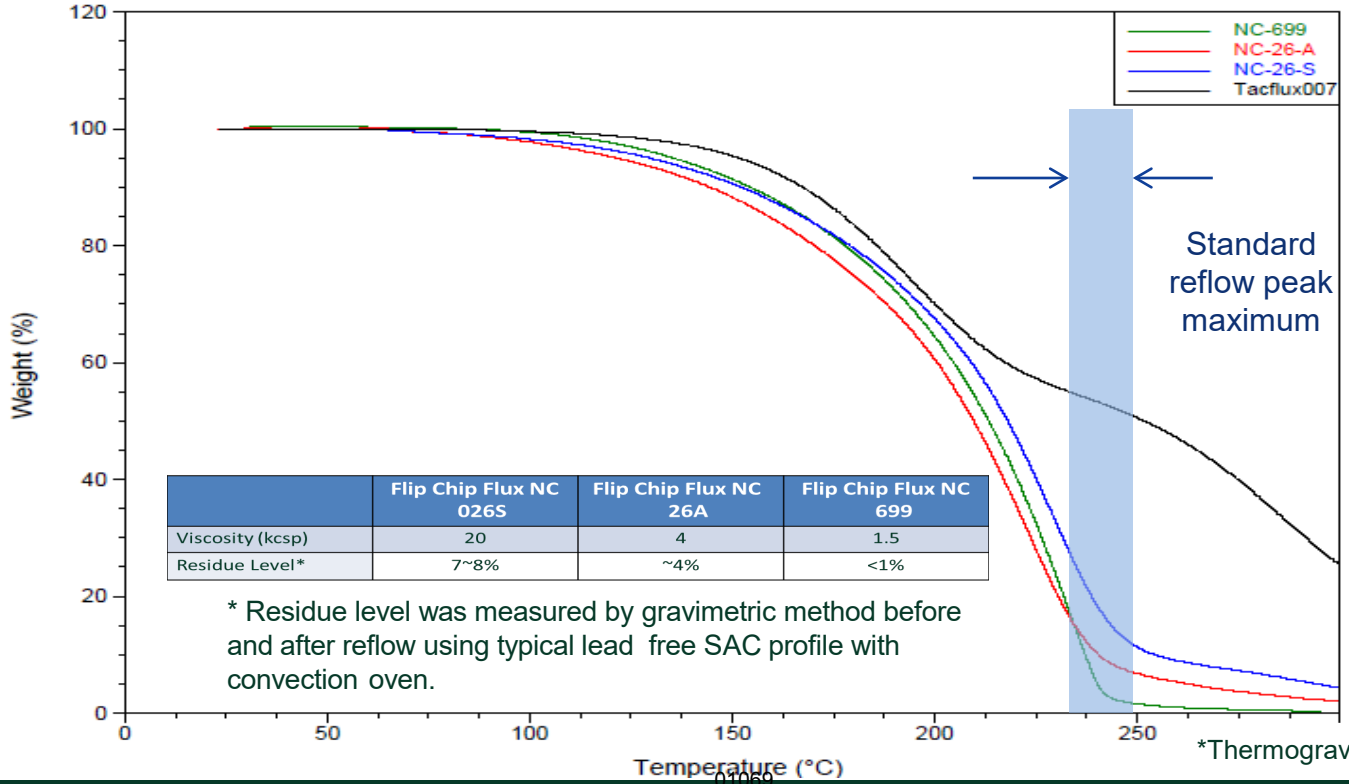
TCB / LAB Reflow

Heated pedestal (typically around 100-150°C) holds the substrate or wafer for the whole duration of TCB process (1-2hrs or longer)

- If standard water washable or no-clean flux is used, excessive “baking” at 100-150°C may hardened flux residue further, making it difficult to be cleaned off
- For fine pitch micro bump/Cu pillar, flux induced corrosion may happen at such temperature for prolong hours



Flip Chip Flux Residue levels from TGA

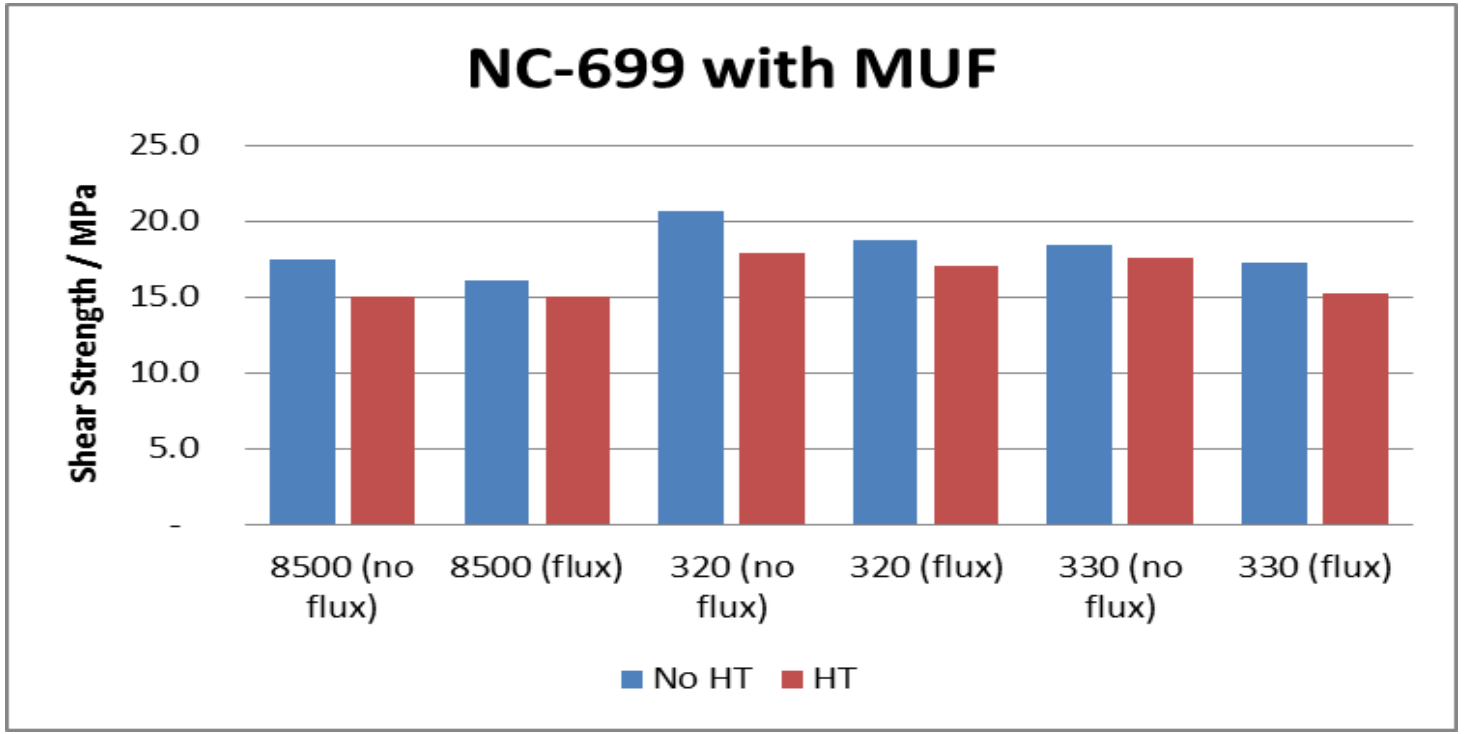


	Flip Chip Flux NC 026S	Flip Chip Flux NC 26A	Flip Chip Flux NC 699
Viscosity (kcsp)	20	4	1.5
Residue Level*	7~8%	~4%	<1%

* Residue level was measured by gravimetric method before and after reflow using typical lead free SAC profile with convection oven.

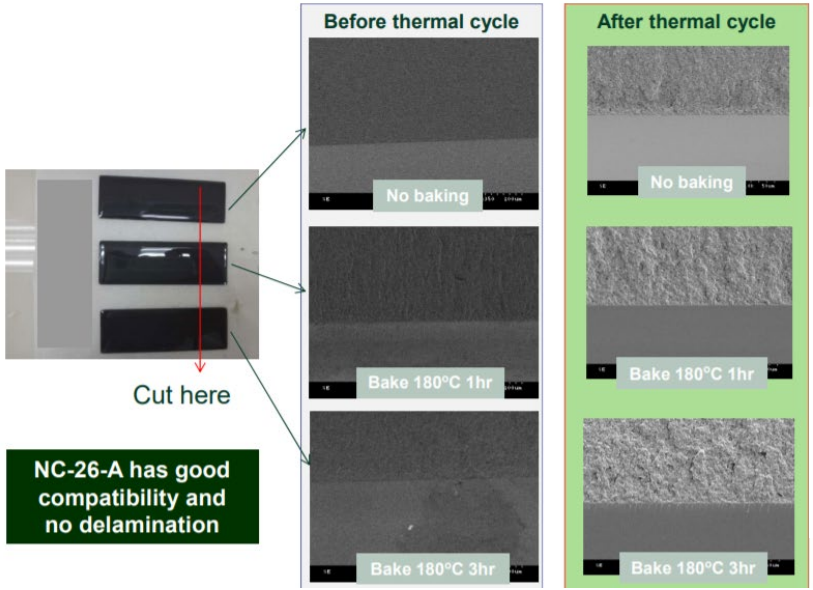
*Thermogravimetric analysis

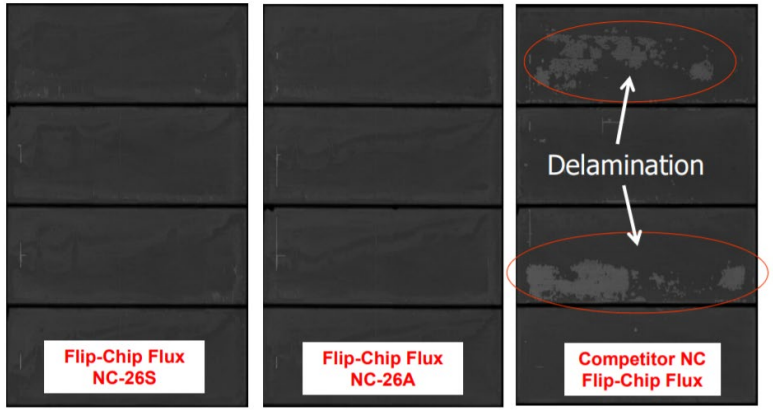
ULR Flux Compatibility with Molded Underfills



HT: steam autoclave treatment at 108.4 C / 135kPa steam pressure

Residue/CUF Compatibility

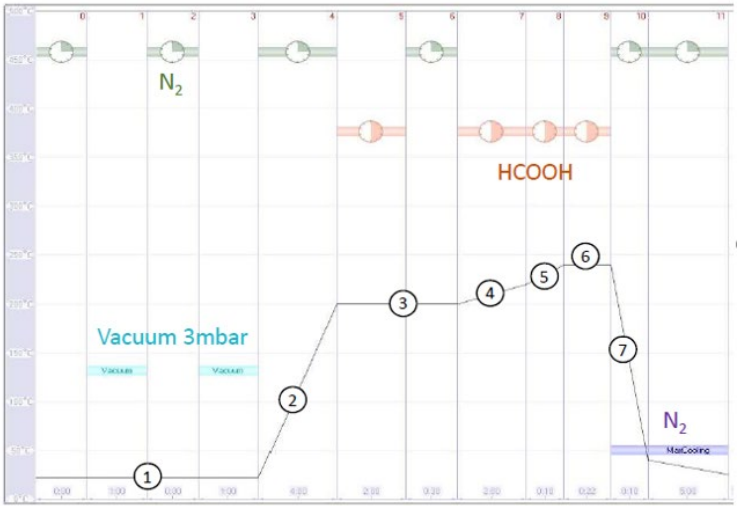




Formic Acid Reflow

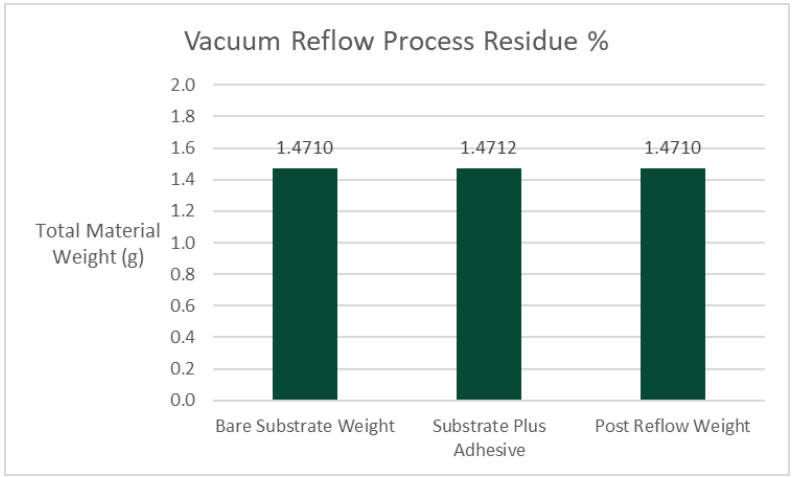
- Formic acid (HCOOH) vapor reacts with metal oxides
  - Resulting formates are further decomposed and removed through a vacuum system
- Eliminates need for pre-reflow fluxing and post-reflow flux removal
- Need a tacky adhesive solution to be compatible with this reflow process

Metal Oxide + HCOOH -> Metal + CO_2 +H_2O



Typical formic acid reflow profile

Adhesive Solution Near-Zero Residue & Tacky

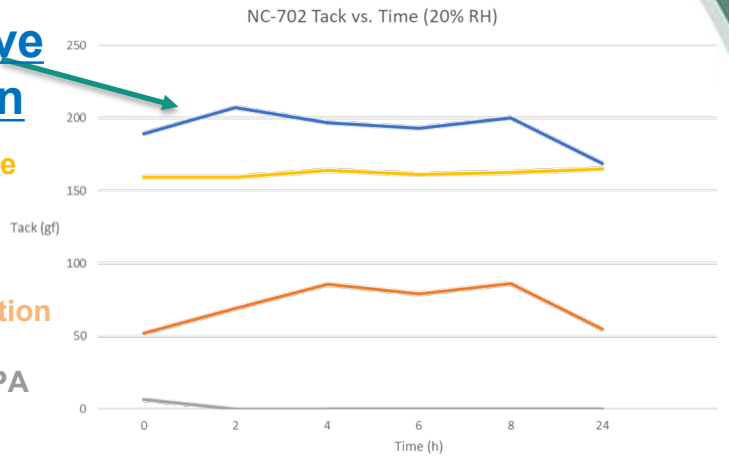


Adhesive Solution

Solder Paste *(Reference)*

68% IPA Solution

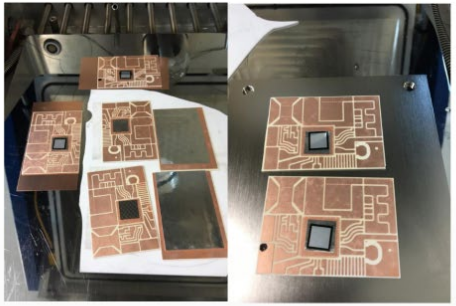
Pure IPA



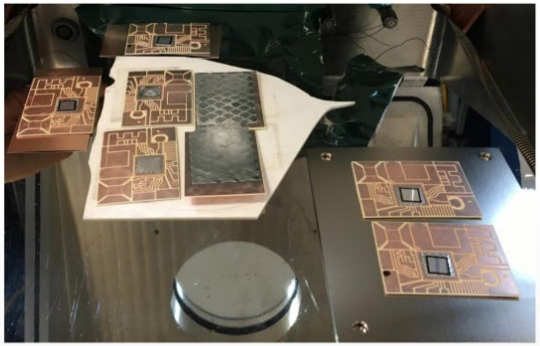
No measurable adhesive residues present post reflow

Maintains high tack strength over time to hold chip in place

Soldering Performance



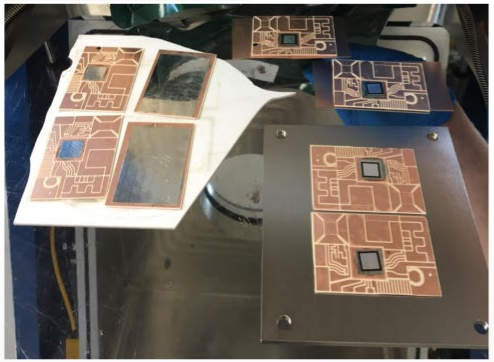
Before reflow



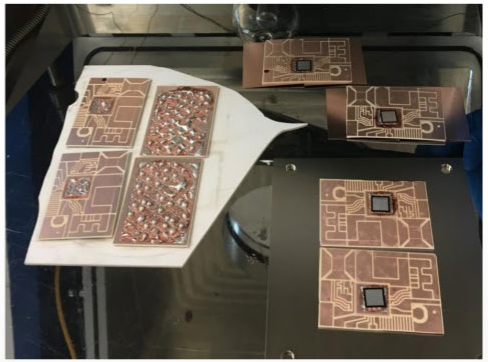
After reflow

Adhesive

Typical Product



Before reflow



After reflow

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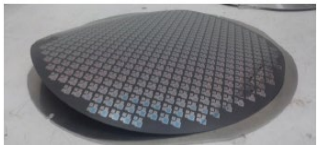
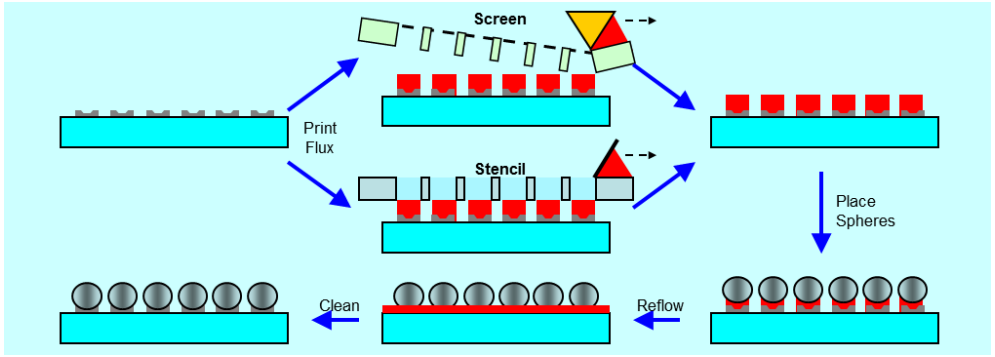
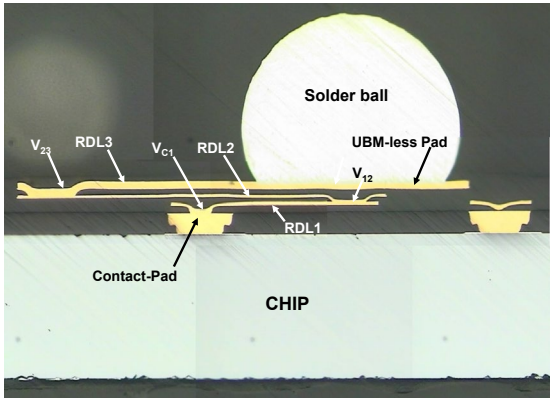
Challenges of ball attach process



- Warpage
- Compatibility of flux with passivation material
- Cleanability of flux after ball attach process





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Ball-Attach Process

Substrate Treatment

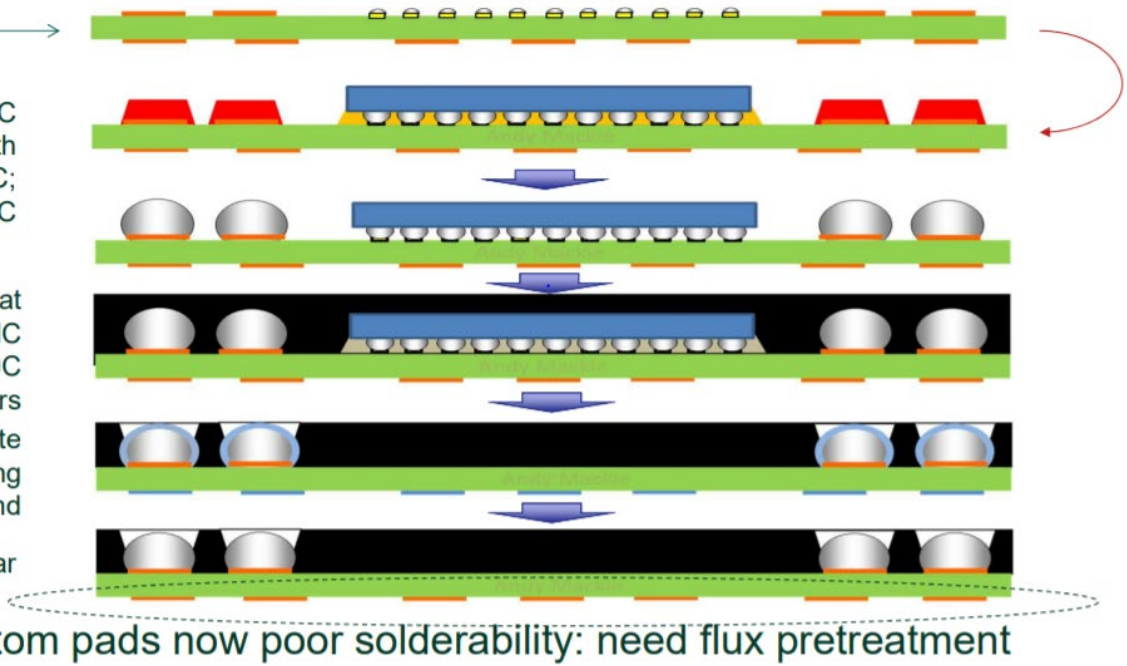
Pre-bake at 170C for 2 hours

Apply flux; Reflow at 240C for 90 seconds ; wash with cleaning chemistry at 96C; dry for 2 hours at 130C

CUF: cure CUF for 2 hours at 130C. Transfer mold EMC and post-mold cure at 130C for 2 hours

Laser ablate overmolding compound

Plasma desmear



Bottom pads now poor solderability: need flux pretreatment

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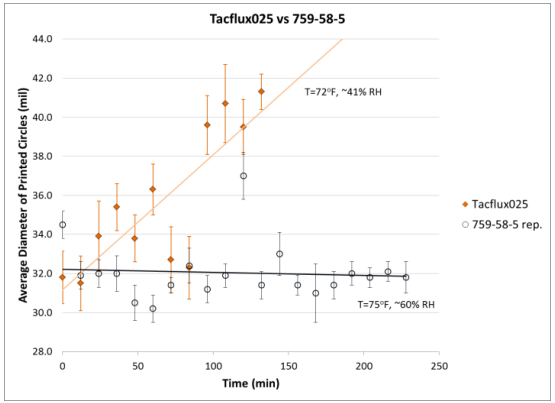
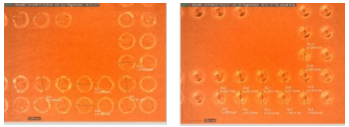
Challenges of ball attach process

Flux requirements

Printing

No (or low) flux smear with long stencil life





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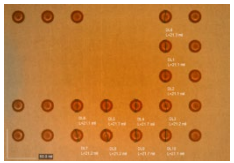
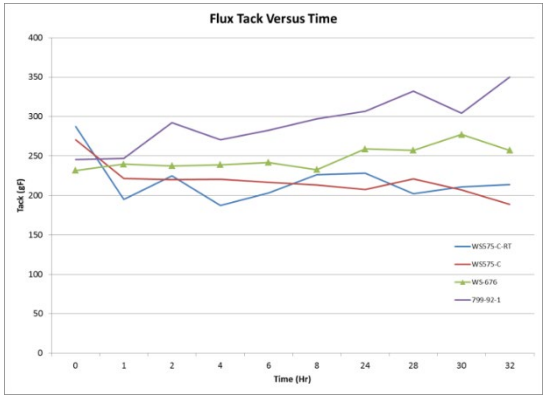
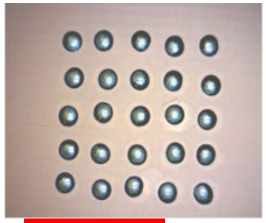


Good

Tackiness sufficient to hold sphere in place during reflow, even with slight warpage





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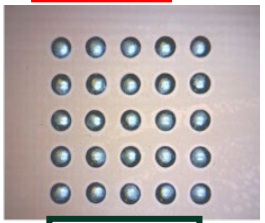
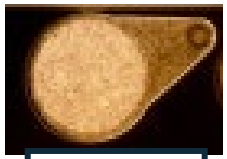


Good

Challenges of FOWLP ball attach process

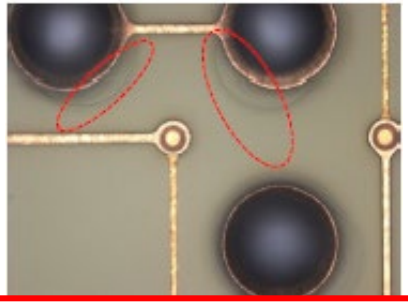
Flux requirements

- Compatible with passivation material
- No reaction (swelling) with various polymers; does not cause “volcano” effect
- No reaction with RDL/copper, does not cause delamination
- No residue after cleaning



Good

Delamination and discoloration observed after reflow



“halo” ring of stain around the solder bump after cleaning

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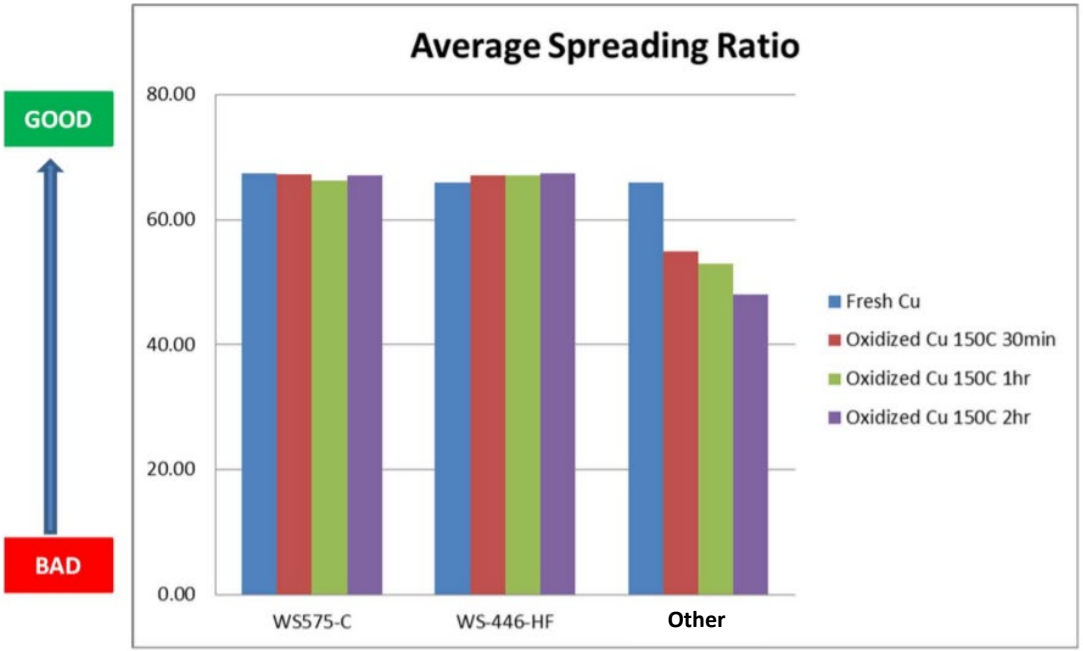
Wetting Comparison: One-Step Process



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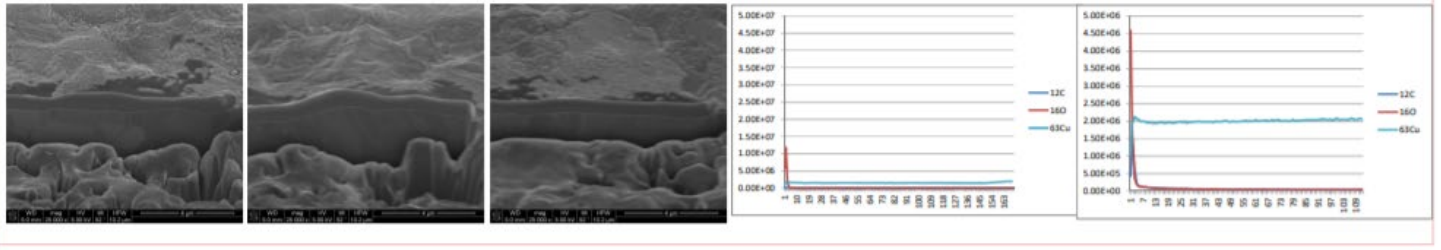
Cleaning Efficiency: One-Step Process

One-Step Flux



Non-One Step

OSP residue

Summary

- Proper selection and application of interconnect materials for the various assembly processes is crucial to ensuring high production yield for the assembly process for reliable packages.
  - ULR flux for TCB/LAB
  - Adhesives for Formic Acid Reflow (fluxless)
  - Flux for ball attach

- Indium Corporation is directly engaged with customers and equipment partners to bring innovations into advance packaging

Acknowledgement

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Thank You!

egriffith@indium.com