

Examining Formic Acid Reflow in Power Device Packaging For Flux- Free Soldering

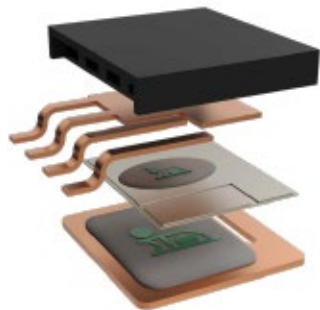


**APPE/CICMT/HiTEC
2025**

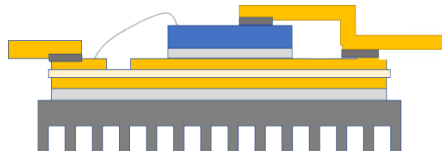
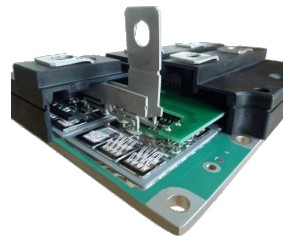
Dean Payne
Product Manager -
Semiconductor
Indium Corporation

Common Package Types

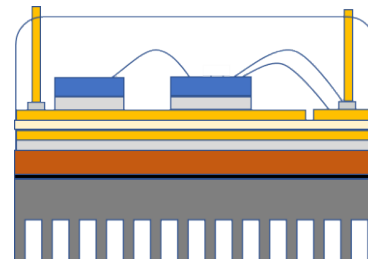
DISCRETE



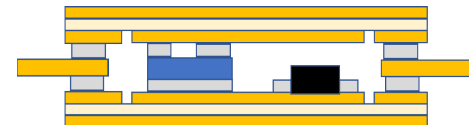
MODULES



MOLDED



BASEPLATE



DSC

Dual-side cooled

Flux + “Traditional” Reflow

Flux primary functions

- Oxide removal
- Oxidation prevention
- Surface tension control
- Promote wetting

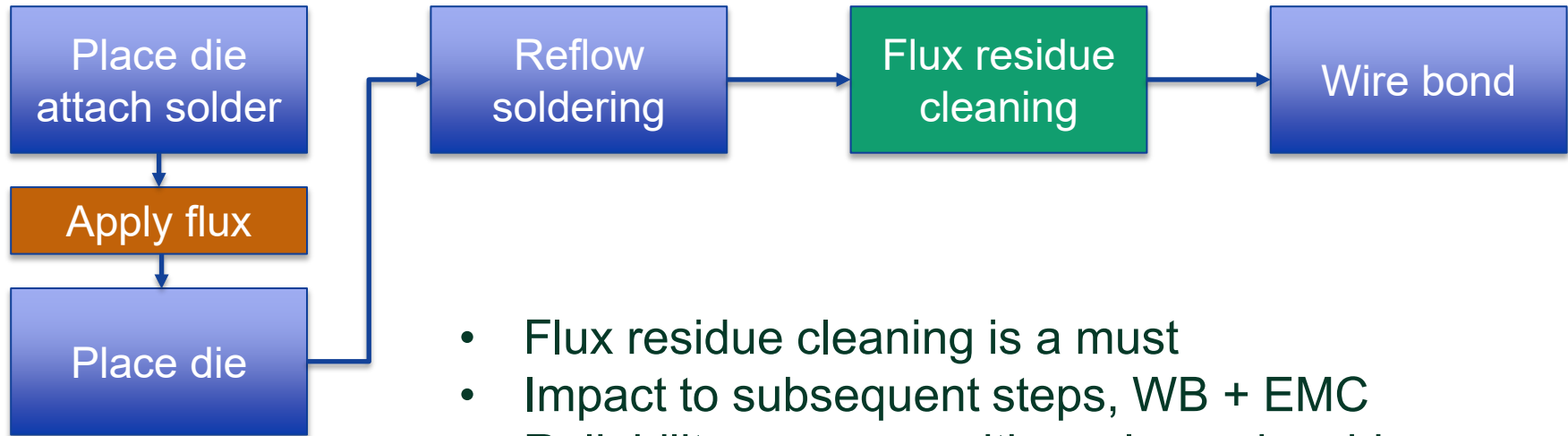
Flux mediums

- In solder paste
 - Mixed with solder alloy
- Preform coating or core
- Separate liquid or gel



Benefits of Flux-less Soldering

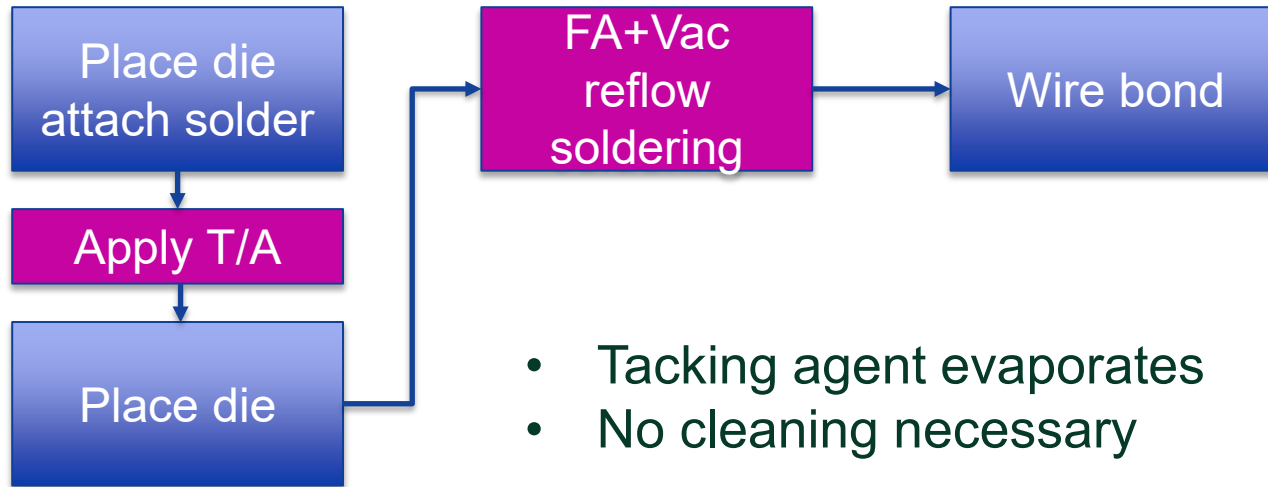
Traditional power module die-attach example



- Flux residue cleaning is a must
- Impact to subsequent steps, WB + EMC
- Reliability concerns with uncleaned residue

Benefits of Flux-less Soldering

Traditional power module die-attach example



Benefits:

- Throughput
- Lower cost
- Sustainability

- Tacking agent evaporates
- No cleaning necessary

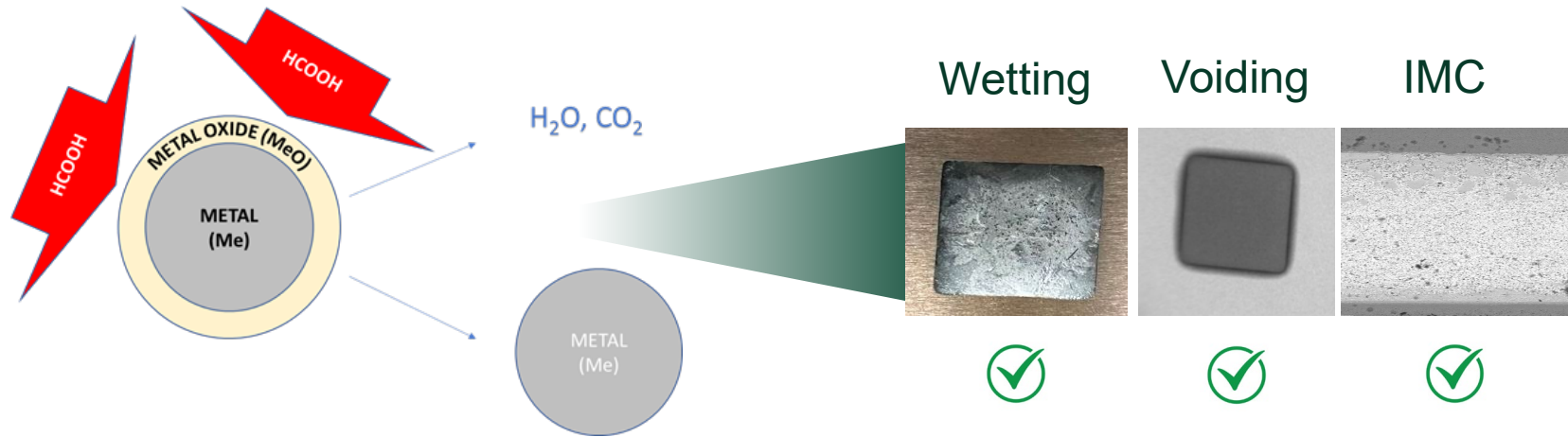
Flux-less Soldering

- Reducing gas atmospheres do the work of a flux
- Effectiveness varies based on process temperatures and oxide type

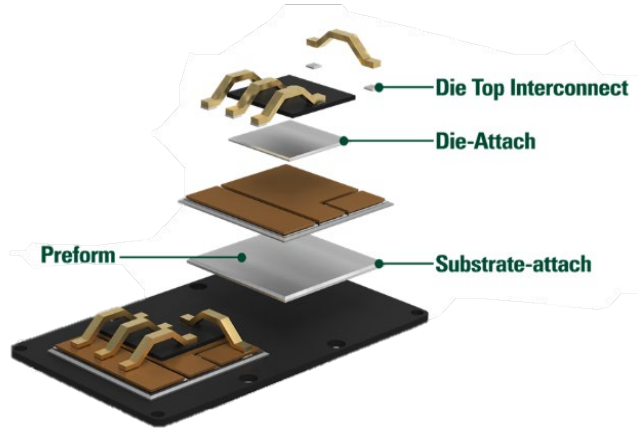
REDUCING AGENT	EFFECTIVE T RANGE	OXIDE SUITABILITY
Formic Acid HCOOH	180 to 250°C	CuO, Sn ₂ O ₃ , NiO, Sb ₂ O ₃
Forming Gas 5% H ₂ in N ₂	>300°C	CuO, Sn ₂ O ₃ , NiO
Hydrogen 100% H ₂	>250°C	CuO, Sn ₂ O ₃ , NiO, Sb ₂ O ₃

Formic Acid (FA) Soldering

- Utilization of FA (HCOOH) as reducing agent
 - $2\text{HCOOH} + \text{Metal Oxide (MeO)} \rightarrow \text{Me(HCOO)}_2 + \text{H}_2$
 - $\text{Me(HCOO)}_2 \rightarrow \text{“Clean” Metal} + 2\text{CO}_2 + \text{H}_2\text{O}$



Formic Acid Soldering + Preforms

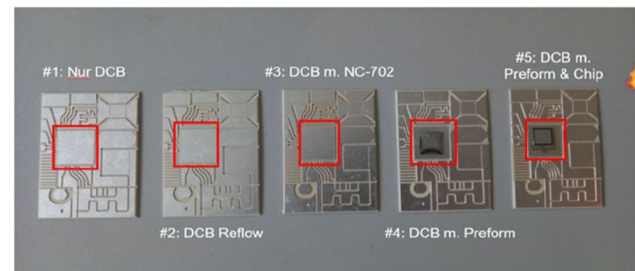


- Formic acid reflow is commonplace in power module assembly
- Can be utilized on multiple assembly steps
- A tacking agent can eliminate the need for tooling or fixtures

Surface Analysis

Comparison of bare materials and reflowed assemblies with tacking material: Ion Chromatography

Contamination in $\mu\text{g} / \text{cm}^2$						
Anions	#1	#2	#3	#4	#5	Reference values
Bromide	ND	ND	ND	ND	ND	1.55
Chloride	0.07	0.03	0.07	0.02	ND	0.93
Fluoride	ND	ND	ND	ND	ND	0.47
Nitrate	0.05	0.01	0.03	0.01	ND	0.47
Nitrite	ND	ND	ND	0.01	ND	0.47
Phosphate	0.01	ND	ND	ND	ND	1.09
Sulfate	ND	0.01	0.03	0.02	0.02	0.47
Weak org. acids						
Acetate	0.03	0.02	0.04	0.03	0.02	
Adipate	ND	ND	ND	ND	ND	
Formate	0.06	0.02	0.05	ND	ND	
Glutarate	ND	ND	ND	ND	ND	
Malate	0.01	ND	ND	ND	ND	
Methanesulfonate	ND	ND	ND	ND	ND	
Succinate	ND	ND	ND	ND	ND	
Total	0.10	0.04	0.09	0.03	0.02	≤ 3.88
Cations						
Ammonium	0.01	0.01	0.01	0.01	0.01	0.47
Calcium	0.05	ND	ND	ND	ND	0.16
Potassium	0.09	ND	0.02	ND	ND	0.47
Lithium	ND	ND	ND	ND	ND	0.47
Magnesium	0.02	ND	0.02	ND	ND	0.16
Sodium	0.03	ND	0.02	ND	ND	0.47



- #1 – Bare DBC, before reflow
- #2 – Bare DBC, formic acid/vacuum reflow only, no solder
- #3 – DBC with tacking material, no solder
- #4 – DBC with tacking material, soldered (formic acid/vacuum)
- #5 – DBC and die with tacking material, soldered (formic acid/vacuum)

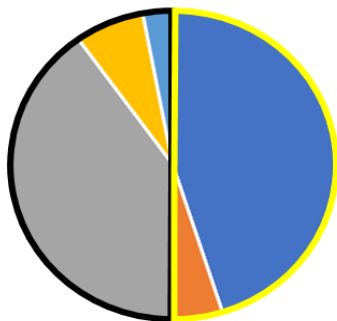
Assemblies subjected to formic acid/vacuum reflow have less contamination than items out of the package!

No significant residual components evident after reflow compared to bare assembly materials

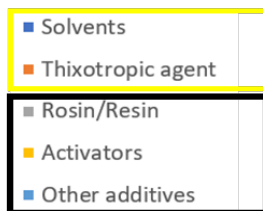
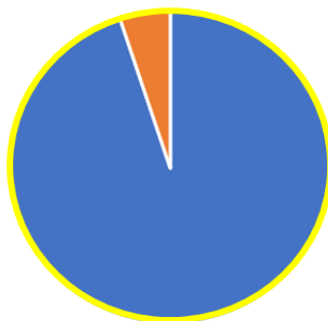
Source: Zestron Ingolstadt

FAST – Flux-less Solder Paste

TRADITIONAL FLUX VEHICLE



FLUXLESS FAST PASTE

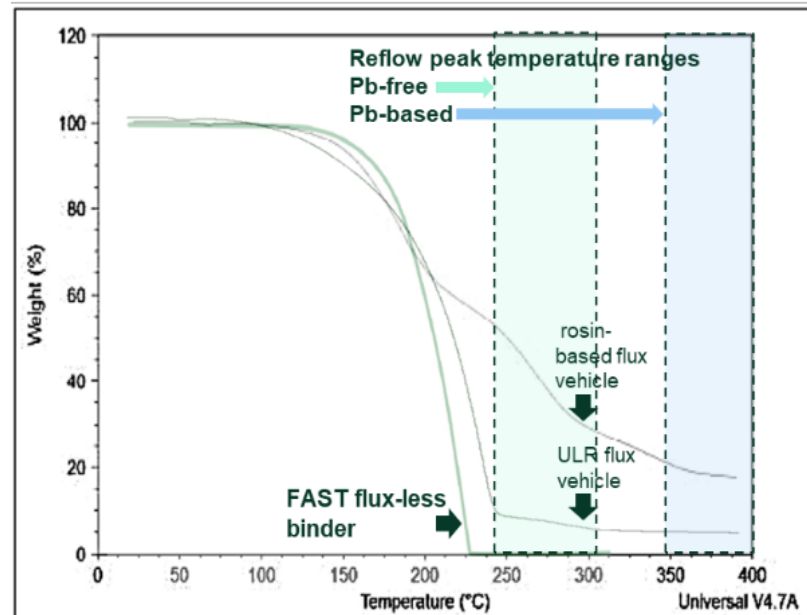


Decompose/evaporate
during thermal profile



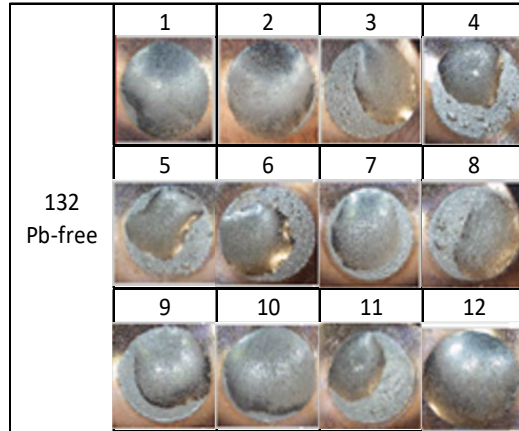
Residues remain after
reflow

TGA of flux vehicles

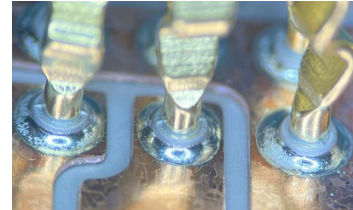


Flux-less, Pb-free Paste

Formulation screening – open wetting



Pin attach



NTC attach



Die attach

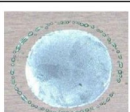
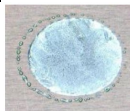
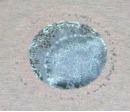


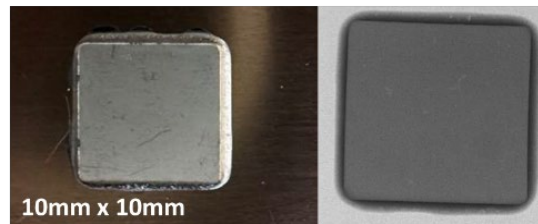
Voiding ~1%
Chip size 10 x 12mm

000370

Flux-less, High-Pb Paste

Formulation screening – open wetting

124 High Pb	1	2	3
			
	4	5	6
			
	7	8	9
			



Voiding 1 to 2%

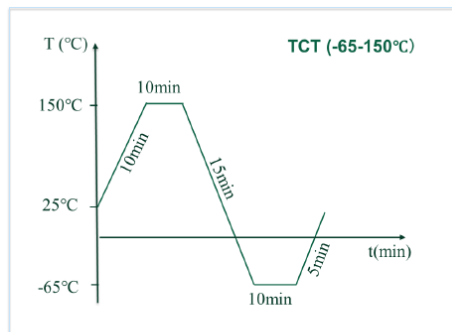
Die Shear Strength & TCT

Alloy: Pb92.5Sn5Ag2.5

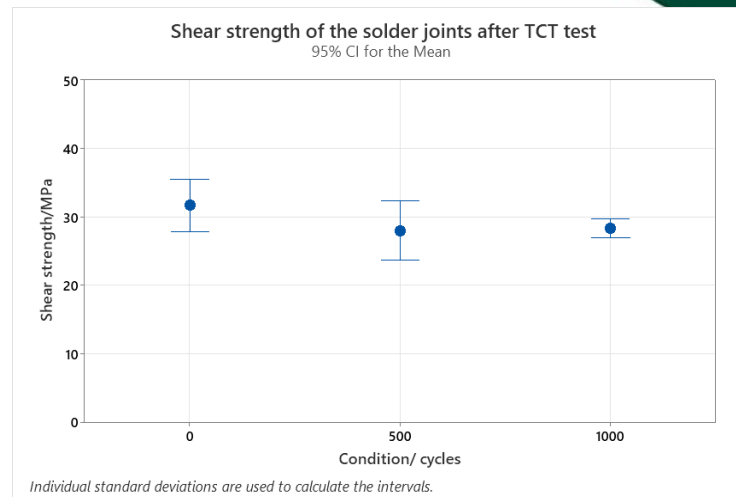
Die shear strength tested post reflow (T0),
after 500 cycles and after 1000 cycles of TCT
(-65 to 150°C)



5 x 5 mm



Conditions for TCT



Mean shear strength:

T0: 31.7MPa

TC500C: 28MPa

TC1000C: 28.3MPa

Typical for high-Pb solder: 25 to 32MPa

FA/Vacuum Systems (non-exhaustive list)

Chamber Heating Systems

- PINK GmbH Thermosysteme (VADU100*/200/300/400)
- Budatec (VS160/320/XL)
- HVTech (KD-V3/V300/V400L HVT)
- Invacu (VSU12/28/35/45)
- Palomar (SST) (Model 1200/5100)
- YES (VeroTherm FAR)
- Centrotherm (Vacunite 300A/300/180)
- ATV (SRO-700/716, i-LINE)

In-line Heating Systems

- Heller (1936MK5-F, 2043MK5-F)
- SMT Thermal Discoveries
- 3S Silicon Tech

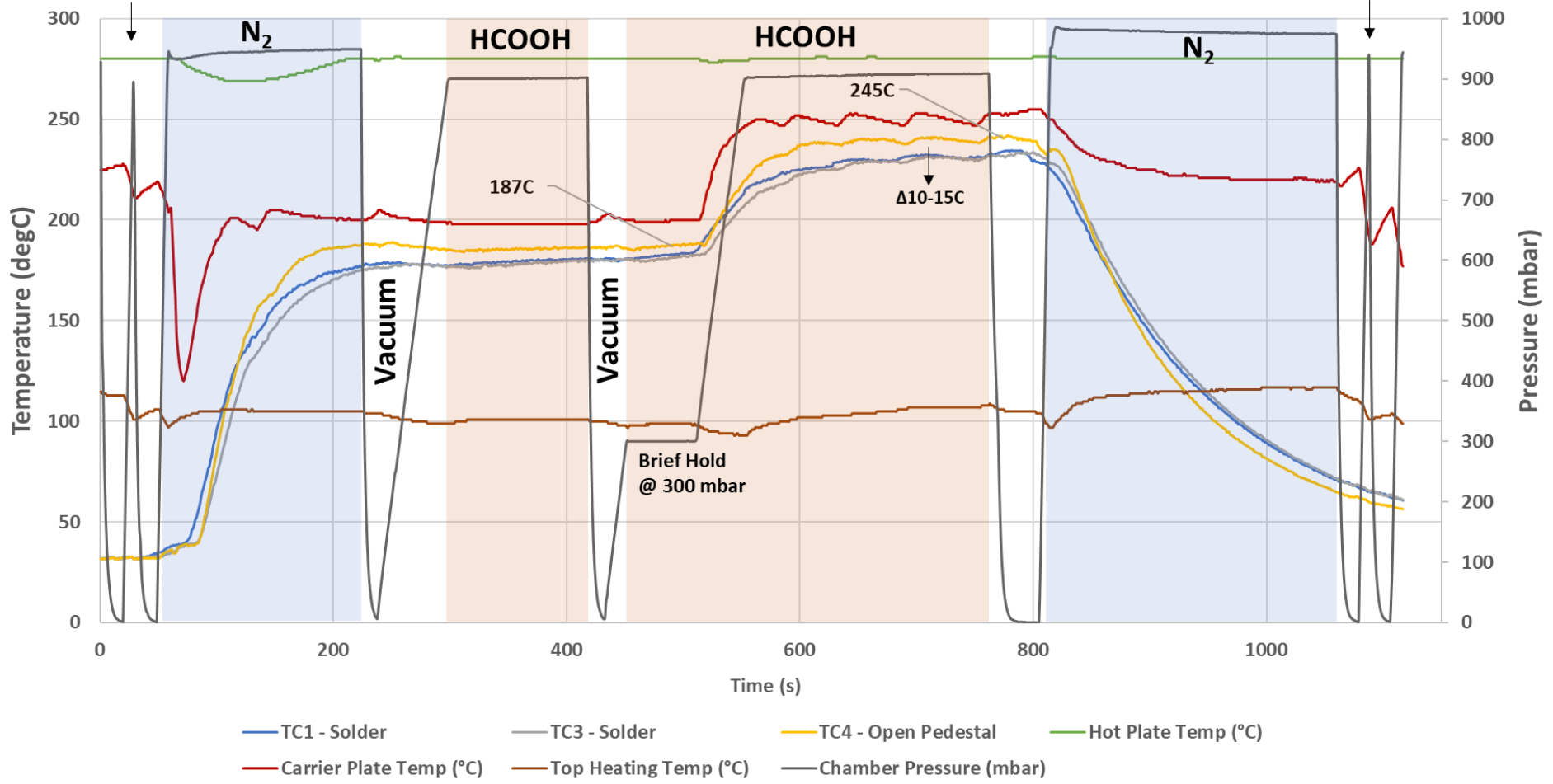
Profiles and processes vary depending on the equipment type

Initial Gas Exchange
(Vacuum / N₂) - 2x

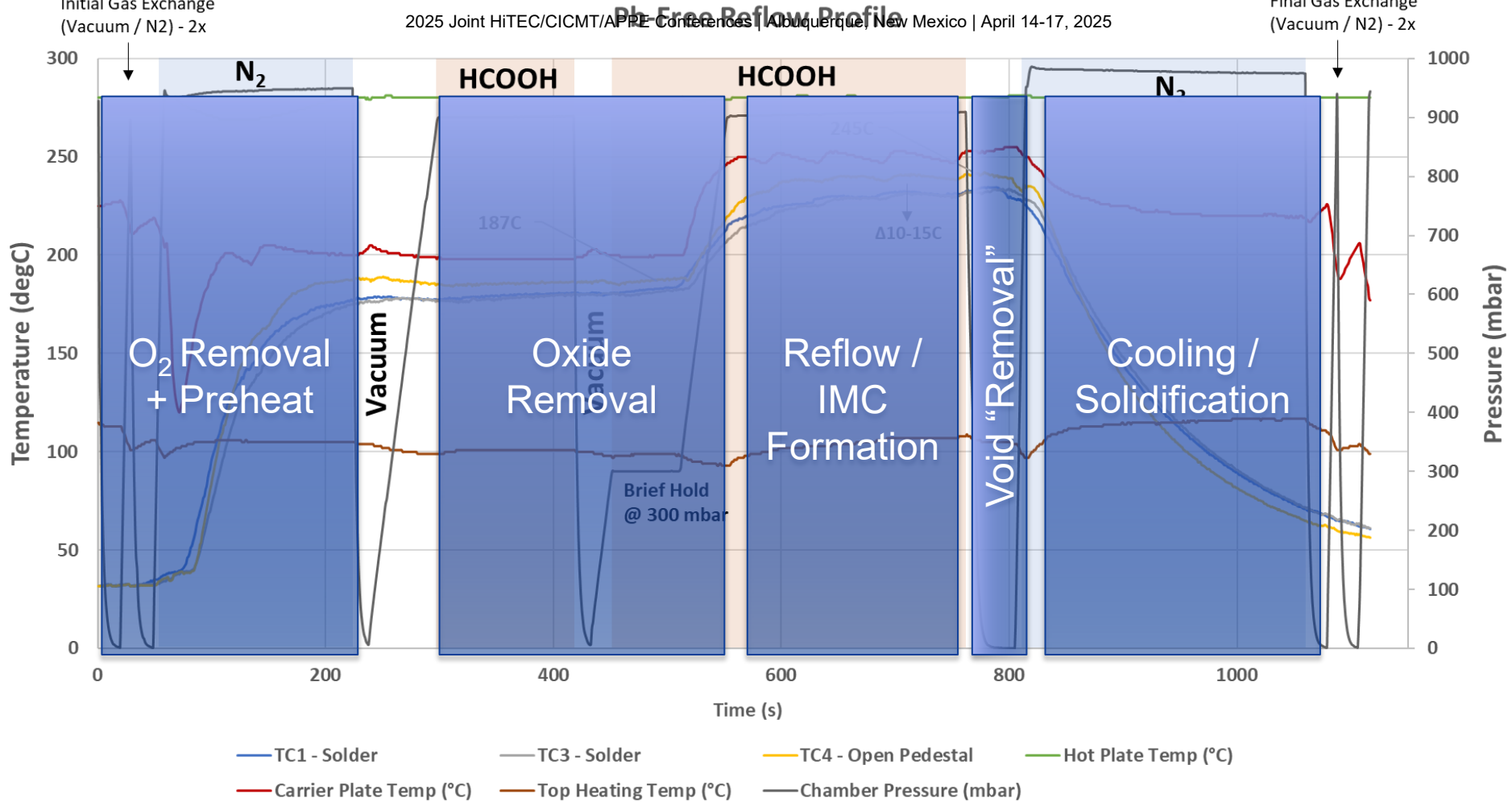
2025 Joint HiTEC/CICMT/APPE Conferences | Albuquerque, New Mexico | April 14-17, 2025

Pb-Free Reflow Profile

Final Gas Exchange
(Vacuum / N₂) - 2x



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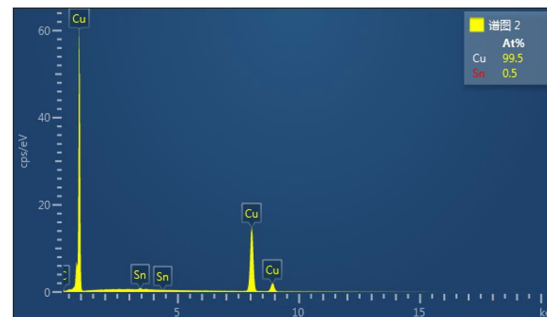
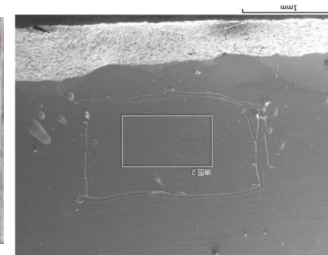
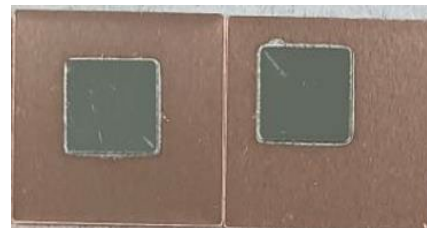
New Challenges

Tin steaming

- A phenomenon affecting Sn based solders. After formic acid reflow substrate surfaces become “contaminated” around the solder area

Causes of tin steaming

- Excessive H₂ generation from HCOOH reacting with surface oxides
- Quick release can cause solder splash, interfacial voids, blistered solder
- Excessive formic acid exposure time or too high concentration
- Heavily oxidized surfaces have greater impact



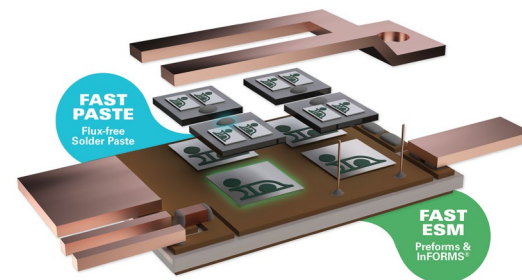
To Summarize:

- Flux-free soldering offers many benefits over traditional reflow soldering
- Formic acid as a reducing agent is suitable for Pb-free and Pb-based solders
- Preform soldering with formic acid is already established. A tacking agent replaces liquid flux and can eliminate the need for tooling
- Flux-free paste is emerging and offers more material options and increased flexibility
- New processes bring new defects types to be understood

Any Questions?

- Thank you for your attention!

FAST



Fluxless
Solder
Paste



Specialized
Solder
Preforms



320+
Indalloy®
Options

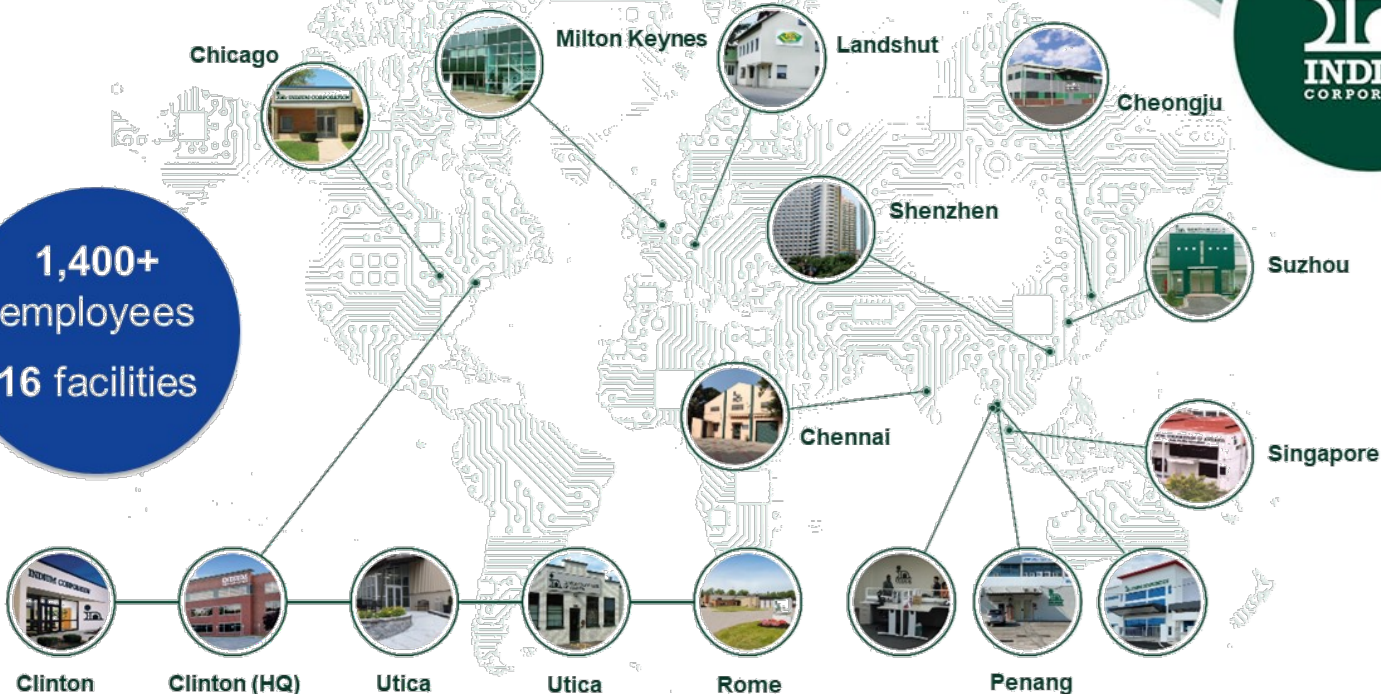


Expert
Application
Knowledge

Complete portfolio of Soldering Materials
designed specifically for
Fluxless Manufacturing Processes

We Believe that
MATERIALS
SCIENCE
Changes the World

1,400+
employees
16 facilities



Dean Payne

Product Manager

Semiconductor Advanced Assembly Materials

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