International Microelectronics Assembly and Packaging Society

12th International Conference and Exhibition on *Device Packaging*

iMAPS Empire State Chapter

Emerging Flux Challenges for BGA Packages

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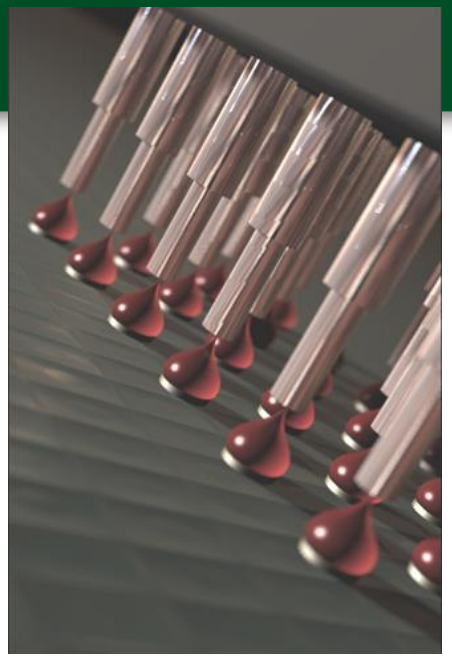
Challenges

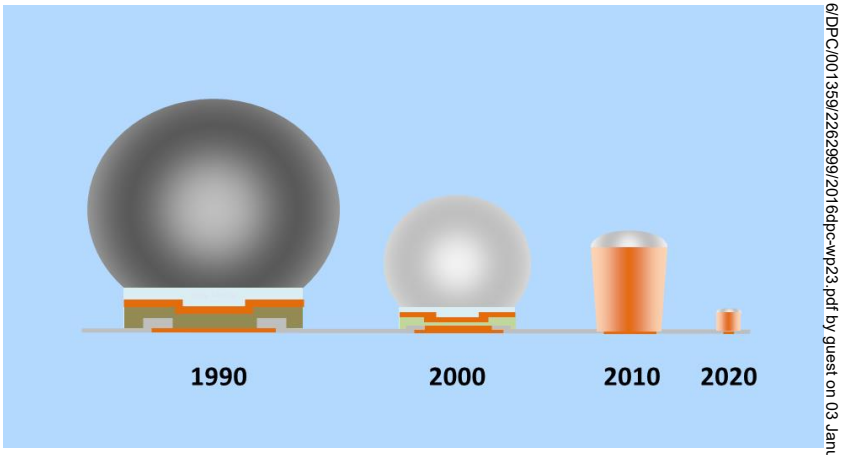


- **Halogen-free**
- **“One step” BGA reflow**
- **BGA flux key performance parameters**

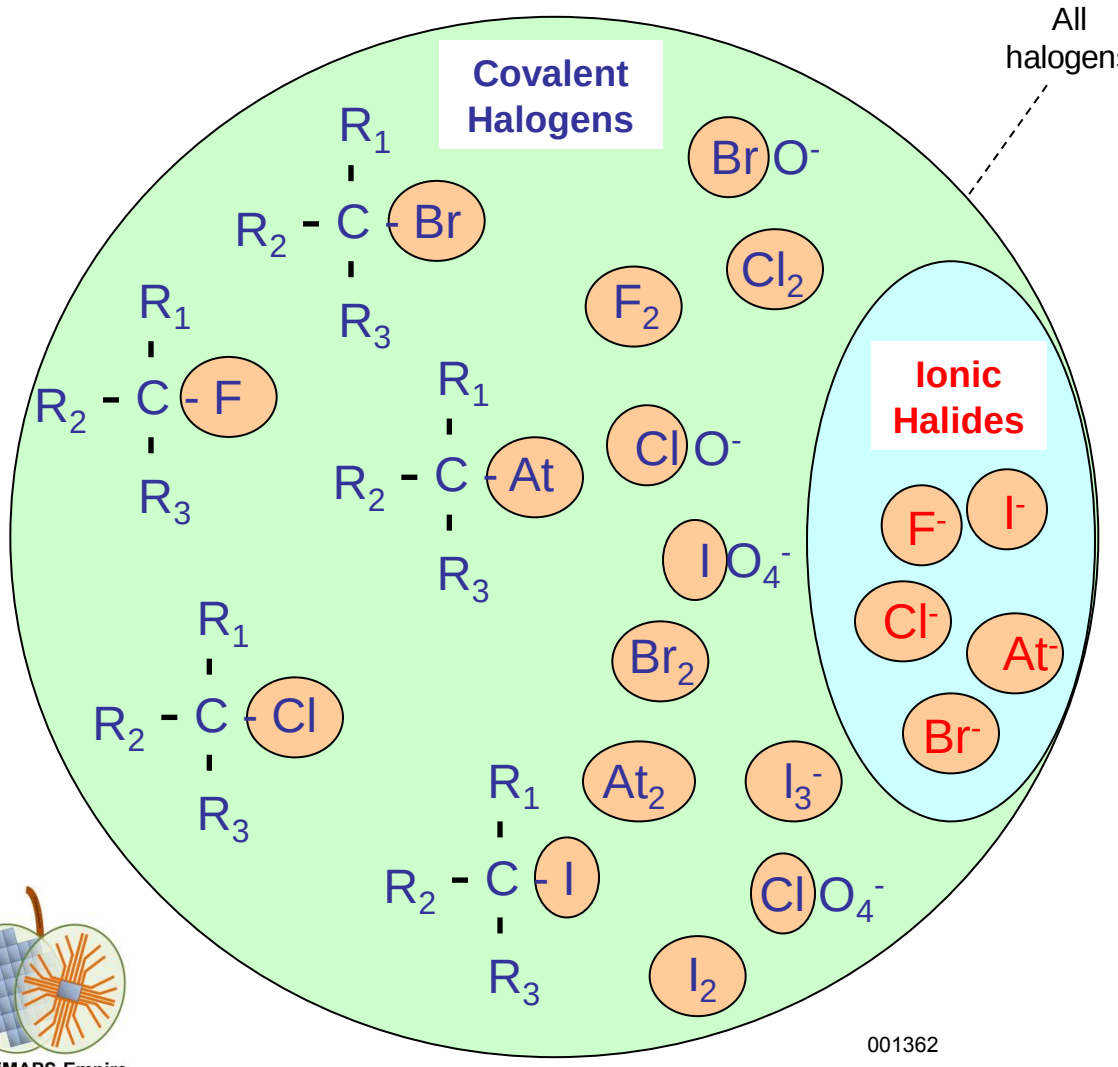
Halogen-free Drivers

- **Environmental Legislation and Industry Standards:**
  - RoHS
  - IEC 61249-2-21
    - Specific halogenated compounds
- **Reliability**
  - IPC J-STD-005
    - Halides

Are IPC standards relevant to semiconductor packaging and SiP?

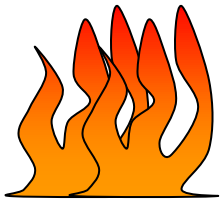


Why Halogen-free, not Halide-free?



All halogens

Oxygen Bomb



F = fluorine

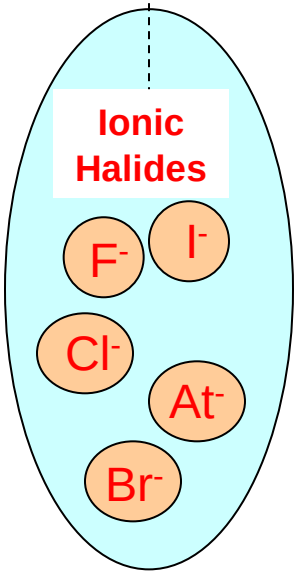
Cl = Chlorine

Br = Bromine

I = Iodine

At = Astatine (radioactive)

All halogens converted to ionic halides



Ion Chromatography (IC)

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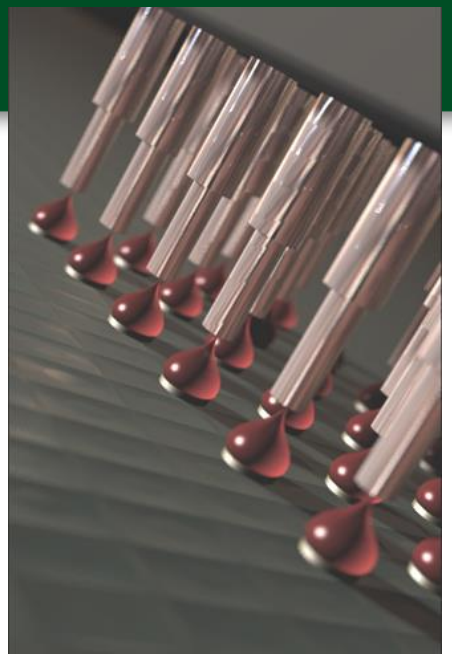
Halogen-Free: Three Level Approach

Analytical target				
Below :	150ppm	900ppm	1500ppm	
Above :	-	150ppm	900ppm	1500ppm
For individual Cl or Br :	Halogen-free (No intentionally Added: NIA)	Halogen-compliant	Halogen-compliant	Halogen-containing
For (Cl + Br) :	Halogen-free (No intentionally Added: NIA)	Halogen-compliant	Halogen-containing	Halogen-containing

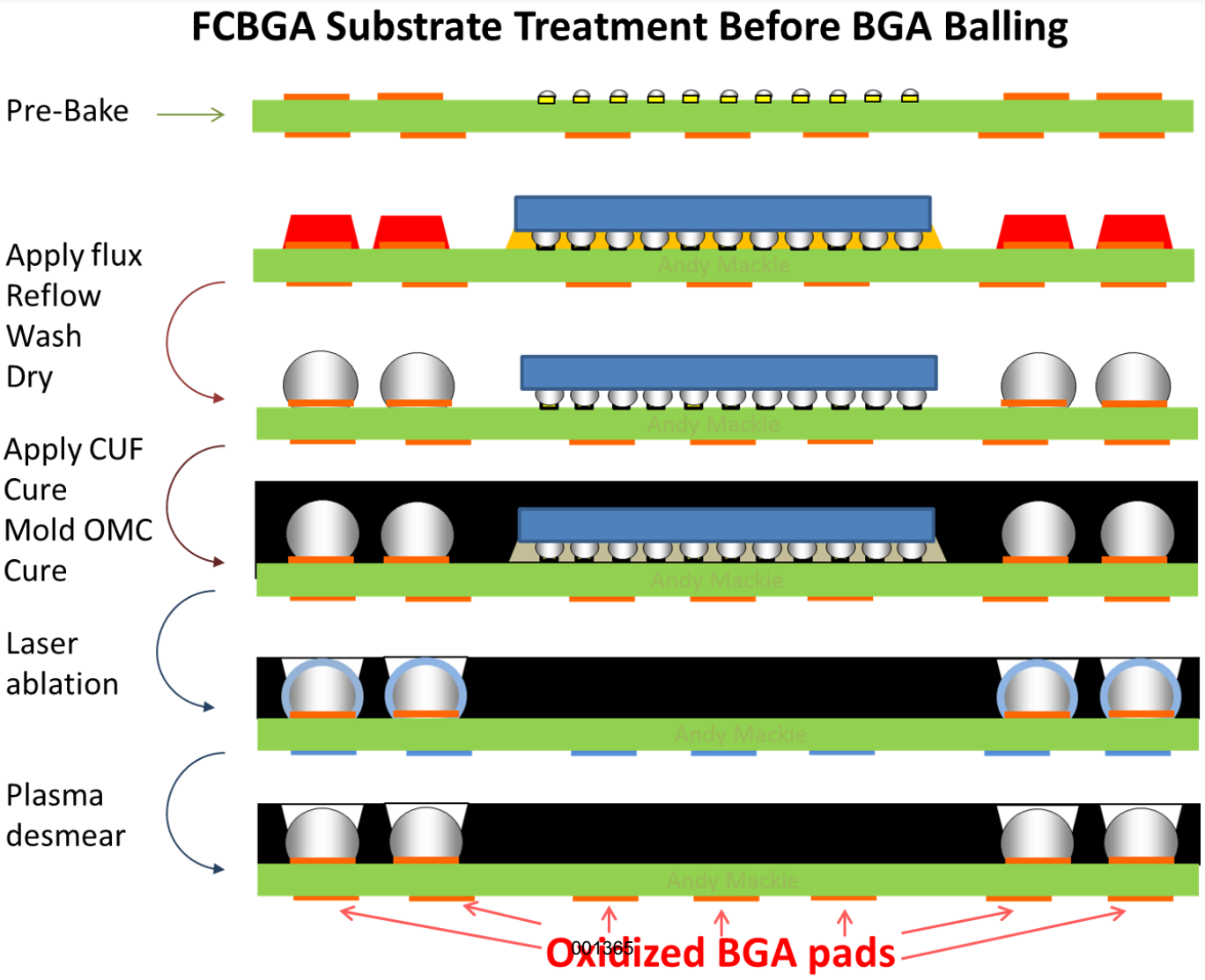
"How do you quantify 'Intent'"?

Challenges

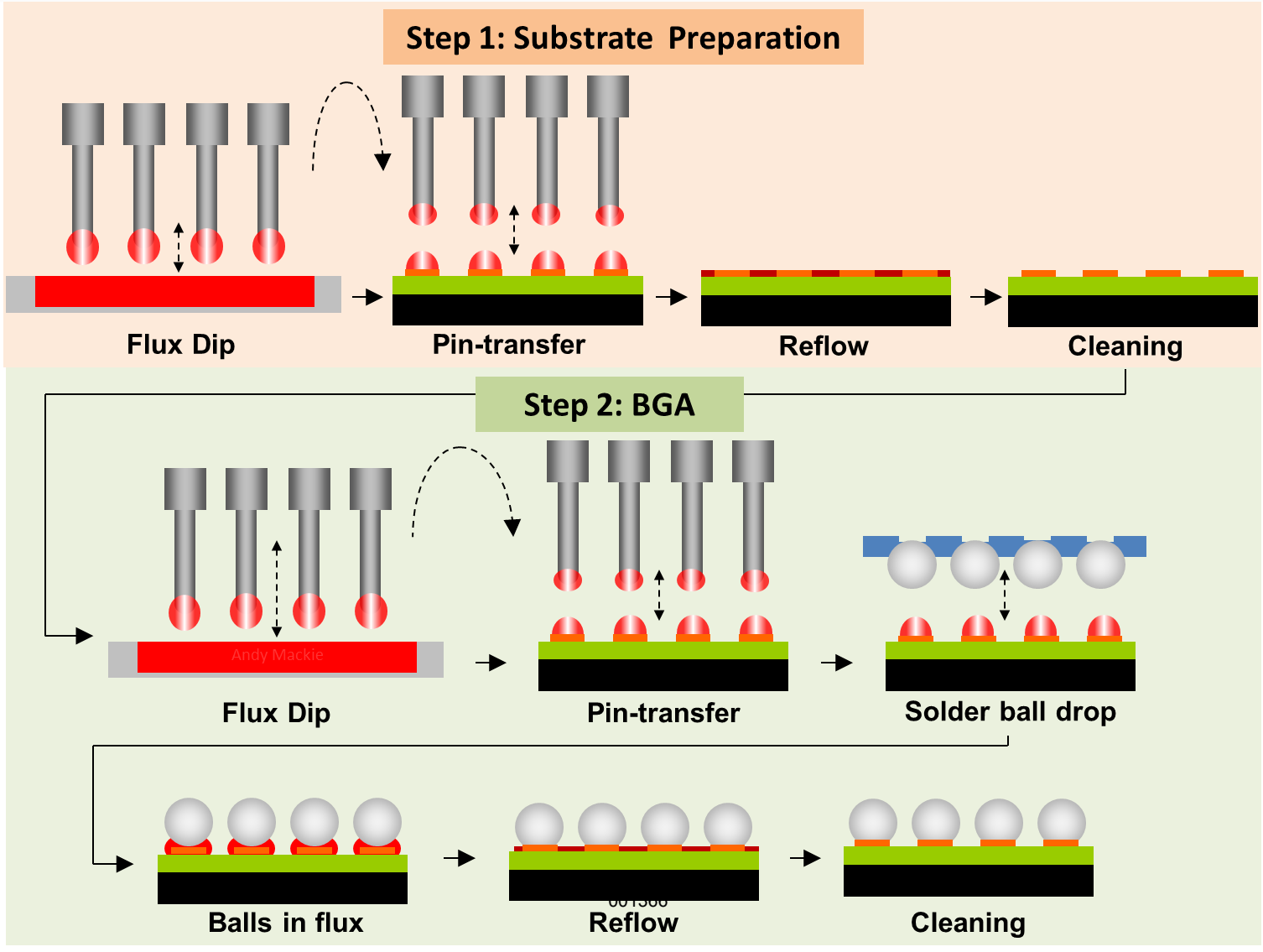


- Halogen-free
- **“One step” BGA reflow**
- BGA flux key performance parameters

Processes Leading to OSP Degradation



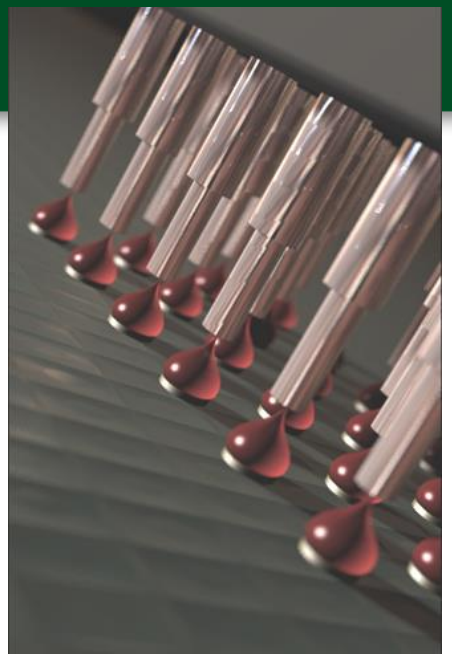
Typical Two-Step BGA Ball-attach Process



Goal:
Eliminate Substrate Prep (Step 1)

- Increase UPH
- Reduce costs
- Reduce warpage

Challenges



- Halogen-free
- "One step" BGA reflow
- **BGA flux key performance parameters**

Ideal Flux for "One Step"

- **Good solderability (Joint strength)**
  - Unaffected by extreme copper-OSP substrate pretreatment
- **No missing ball**
  - No movement during reflow (MDR)
- **Long consistent usage life**
- **Cleanability**
  - Room temperature DI water

Ideal BGA Flux

- **Good solderability / No missing ball**
- **Long consistent usage life**
- **Cleanability**

Simulated Preconditioning of Substrates

- **Solder Spheres**
  - SAC305, 28mil
- **Reflow**
  - Soak (preheat) reflow profile
  - Air reflow
- **Substrates**
  - OSP substrates

- **Preconditioning**
  - None
  - Bake
    - 2hr bake @ 170C
    - 7hr bake @ 130C
  - Bake and Cleaner
    - 2hr bake @ 170C
    - Cleaned with aggressive aqueous flux cleaner @ 96C
    - 7hr bake @ 130C
  - Double Bake and Cleaner
    - 2hr bake @ 170C
    - Cleaned with aggressive aqueous flux cleaner @ 96C
    - 7hr bake @ 130C
    - 2hr bake @ 170C
    - Cleaned with aggressive aqueous flux cleaner @ 96C
    - 7hr bake @ 130C

Wetting and MDR* test method

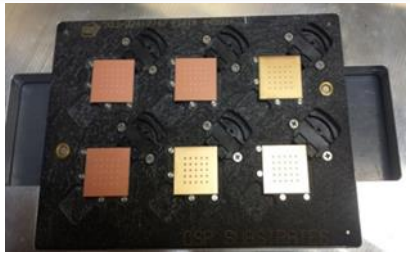
1. **Print flux onto metallized surface**
2. **Place spheres onto flux deposit**
3. **Reflow**

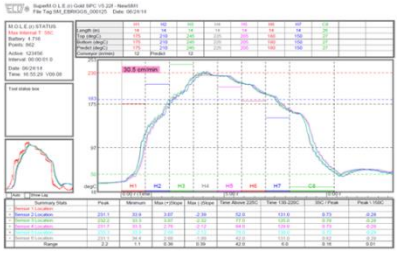
Wetting:

Calculate percent spread (wetting)

MDR:

Calculate mean sphere center movement





$$S_R = \frac{D-H}{D} \times 100 \quad \text{(16)}$$

where, S_R : spreading ratio (%)

H : height of the spread solder (mm)

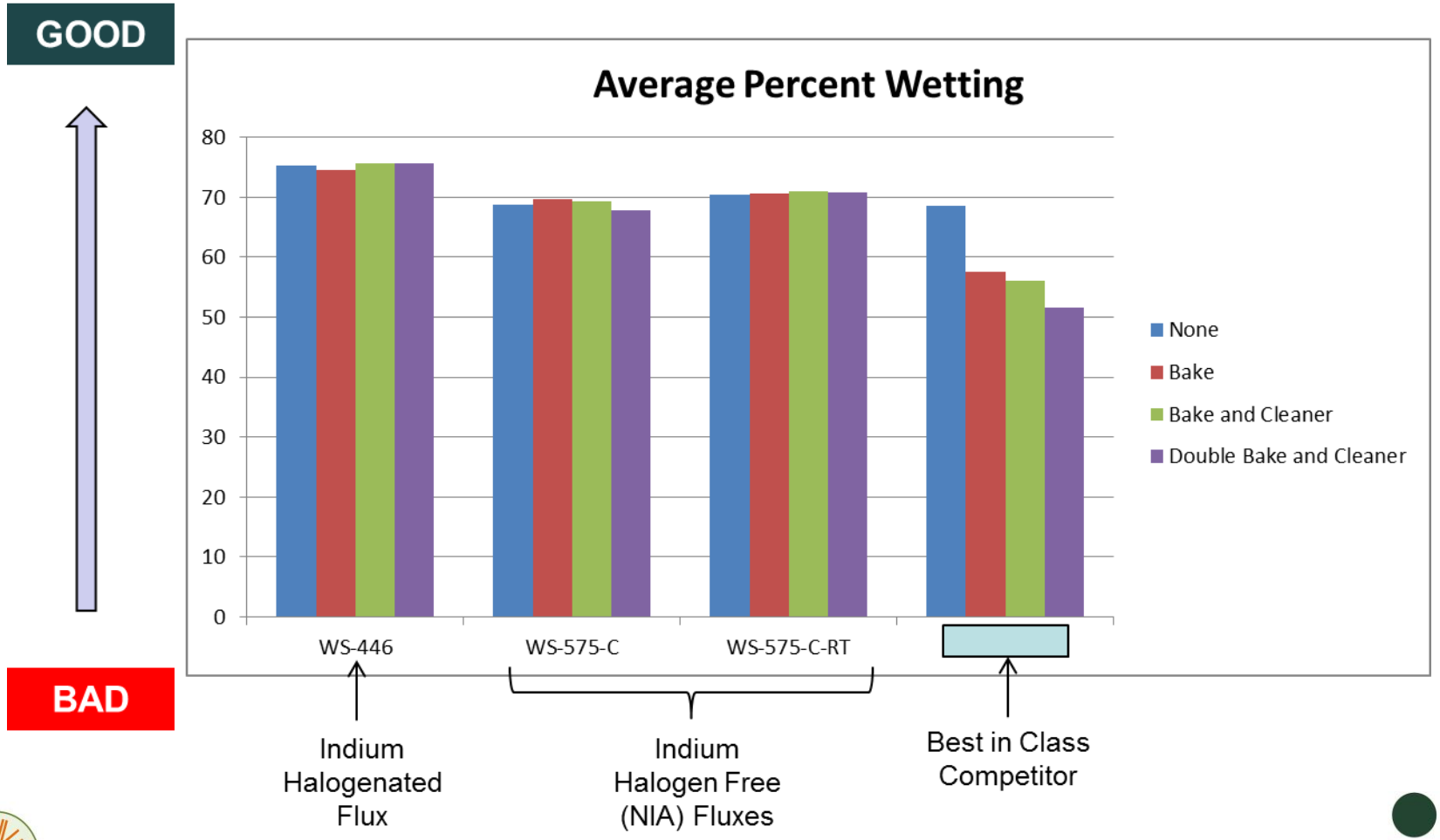
D : diameter of the solder, when it is assumed to be a sphere (mm)

$D = 1.24V^{1/3}$

V : mass[12]/density of tested solder

*Movement during reflow

Wetting Comparison



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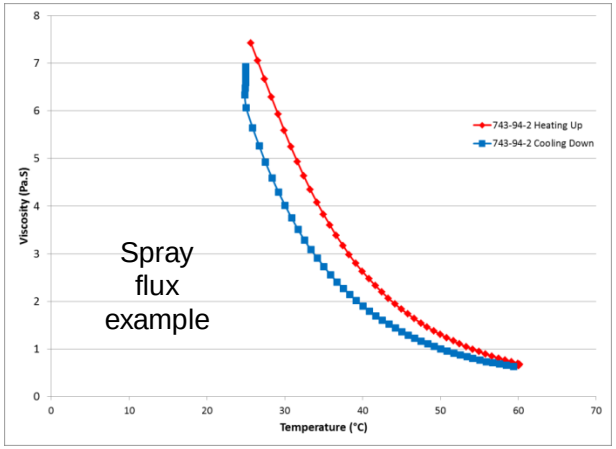
Movement During Reflow

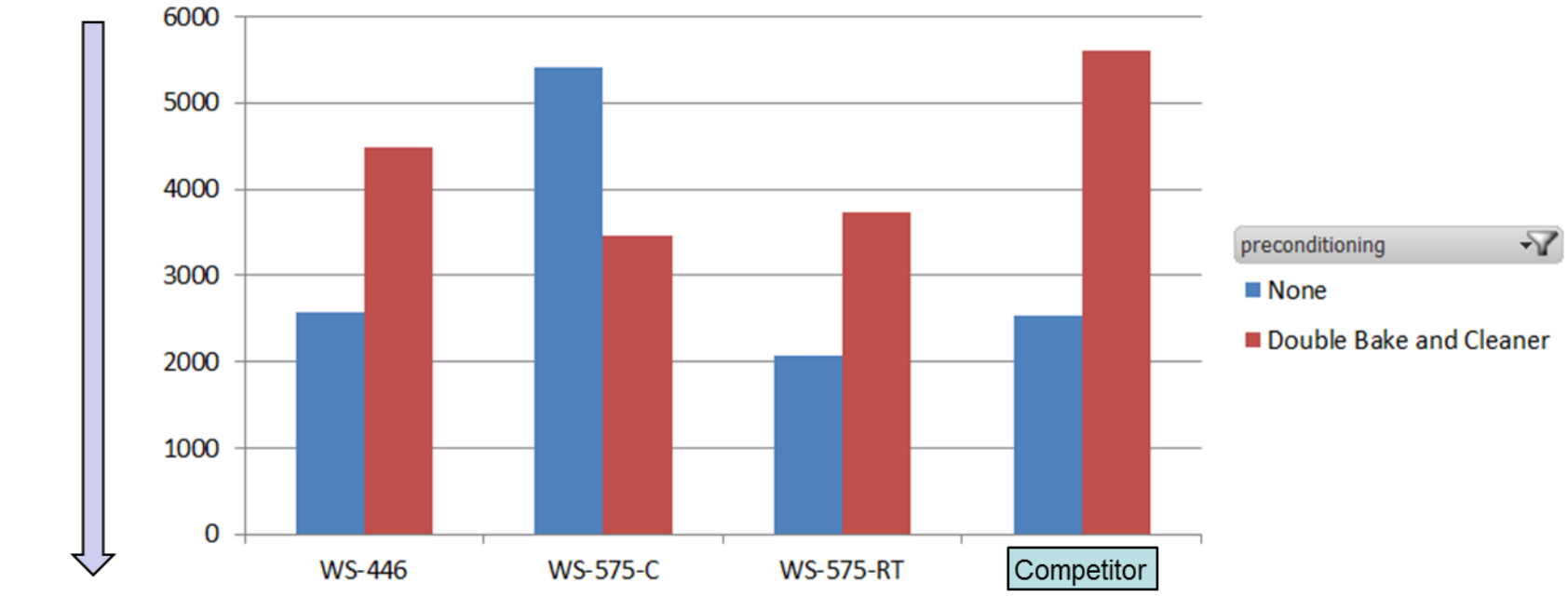
- **Flux viscosity**
  - Less critical
    - Room temperature viscosity



- **Solderability**
  - Key: Early activation and reflow

Movement During Reflow (MDR)

BAD



GOOD

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Ideal BGA Flux

- Good solderability / No missing ball
- **Long consistent usage life**
- Cleanability

Materials Lifetime by Usage Type

Proposed Name			Container Opened?*	Description: "How long the material will still be useable in its application..."	By Application: May also be called...		
					Printing	Dipping	Dispense
Material Life	Shelf-life	Andy Mackie	No	..under the recommended storage conditions"	Shelf-life		
	Floor-life		No	...after sealed container is warmed up to ambient after cold storage"	Unrefrigerated-life		
	Working-life		Yes	...after being placed in the equipment (tool)"**	Print-life / Stencil-life	Pot-life / Dipping life	Dispense-life
	Tack-life	Exposure-life (tack + staging life)	Yes	...after deposition and before component/die placement."	Open-time / Abandon time	[None? - placement usually immediate]	Open-time / Staging time
	Staging-life		Yes	...after component/die placement and before reflow."	Staging time	Open-time	
	Residue-life		Yes	...after reflow."	n/a		

***Packages supplied by material manufacturer - and directly contacting material - opened or uncapped and material directly exposed to air*

Viscosity (t)

Tack (t)

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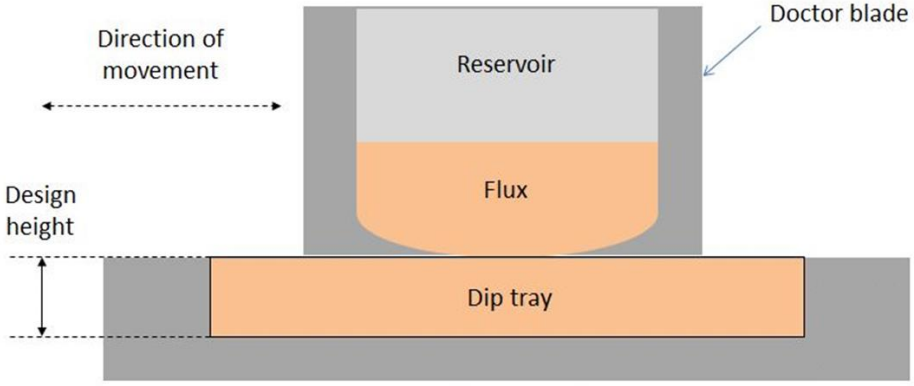
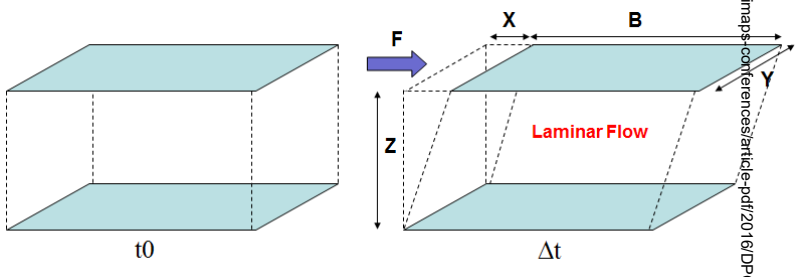
Rheology Measurements and Relation to Dipping



Cross Section of Ideal Flux Dipping System



Shear stress $\tau = F / (B.Y)$

Shear $\gamma = X / Z$

Shear rate $\dot{\gamma} = \Delta\gamma / \Delta t$

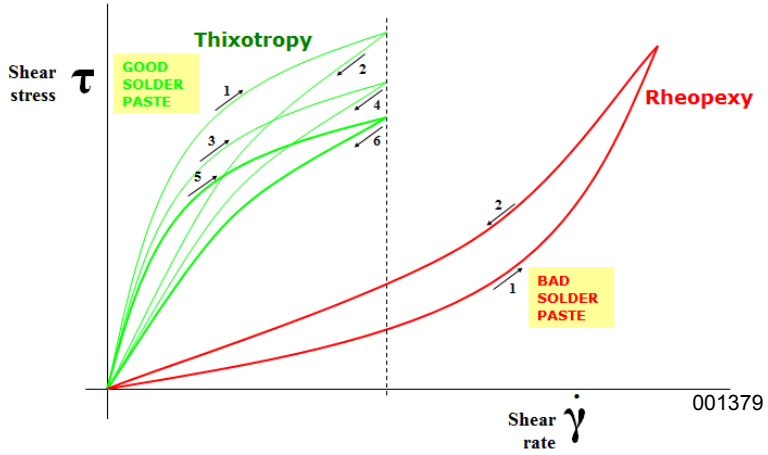
Viscosity η = Shear stress τ / Shear rate $\dot{\gamma}$

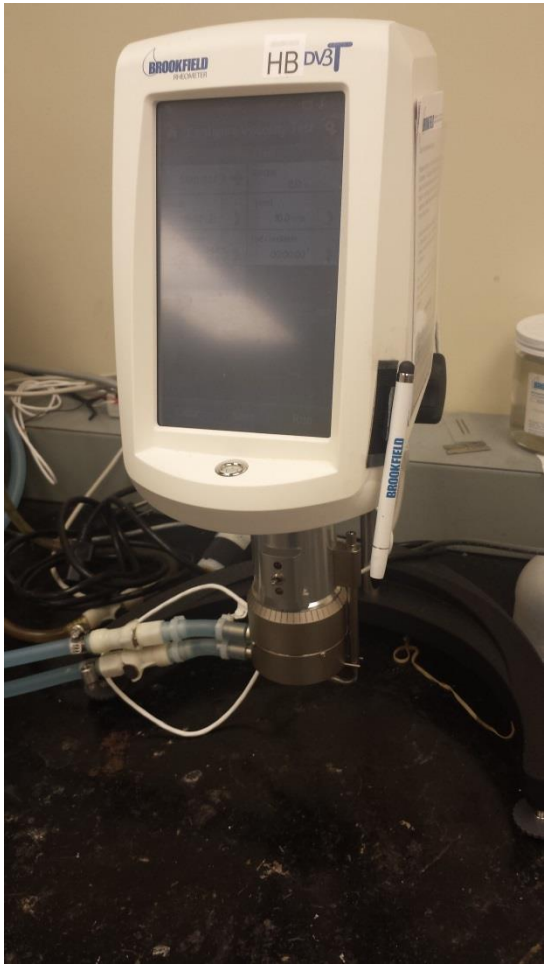
Movement speed / Design height = Shear rate

Viscosity Test Method

- **Equipment:**
  - Brookfield Cone and Plate
  - Model: DV3THBCB
- **Parameters:**
  - Spindle: CP-51
  - Temperature: 25°C
  - RPM's: 20 RPM (50/s)

Viscosity is just one aspect of rheology





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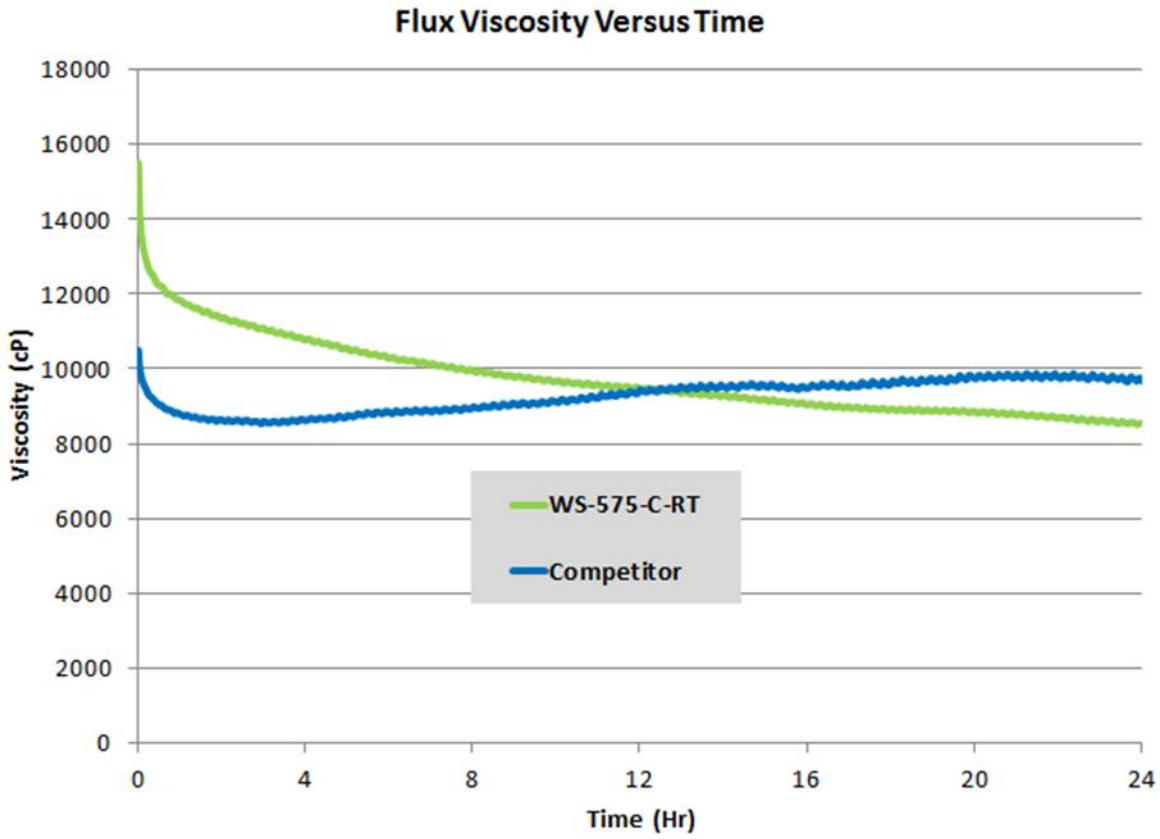
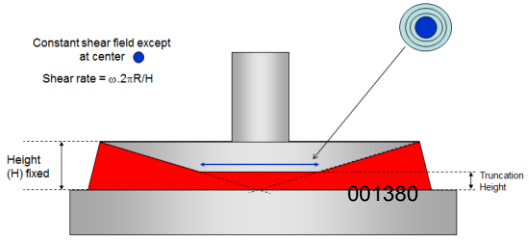
Comparative Viscosities as a Function of Time



Stable Viscosity



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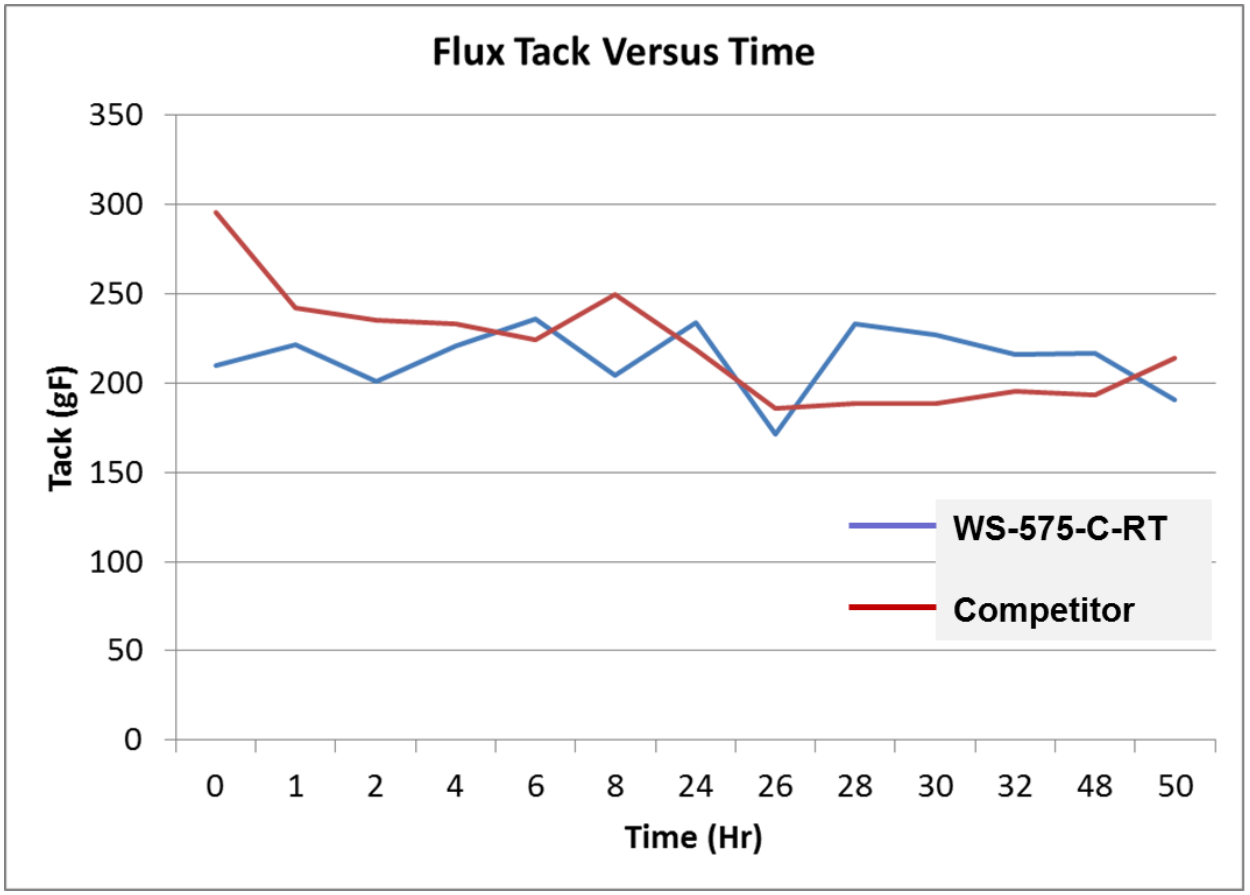
Tack Test Method

- **Equipment**
  - Texture Technologies TA.XT2
- **Parameters**
  - Ambient Conditions
  - Humidity: 50% ± 3%
  - Room Temperature: 21.5°C ± 2°C

Comparative Tack as a Function of Time



Stable Tack

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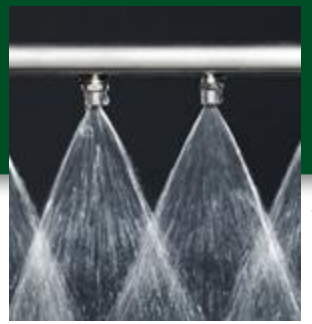
Ideal BGA Flux

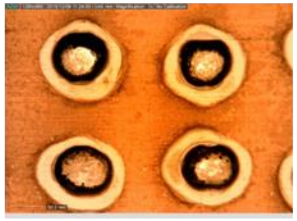
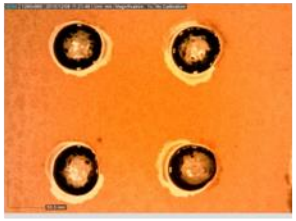
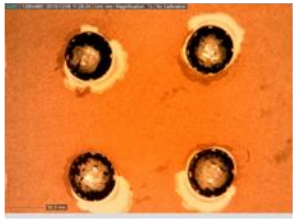
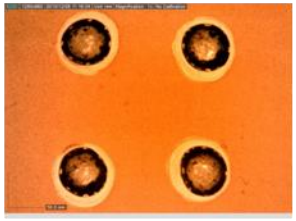
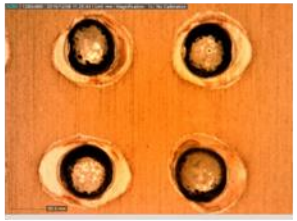
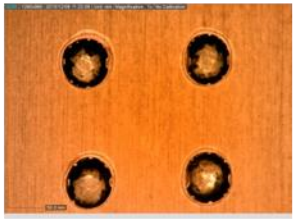
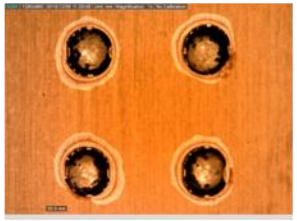
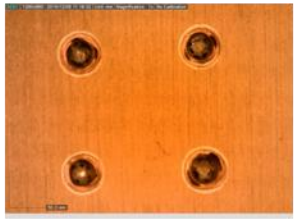
- Good solderability / No missing ball
- Long consistent usage life
- **Cleanability**

Cleaning Test



- **Very mild (forcing) condition**
  - Deionized water temperature: 36°C
  - Deionized water conductivity <=1.00µS/cm
  - Zero Pressure
  - Flow rate 5cc/minute
  - Time of cleaning: 1 minute

Cleaning on OSP Substrates

	WS-446	WS-575-C	WS-575-C-RT	Competitor
Bare OSP				
	WS-446	WS-575-C	WS-575-C-RT	Competitor
Baked OSP				

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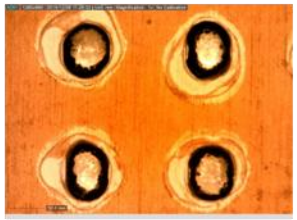
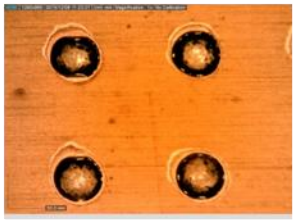
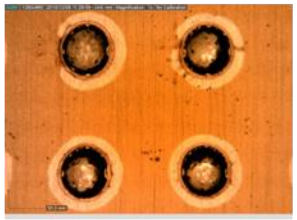
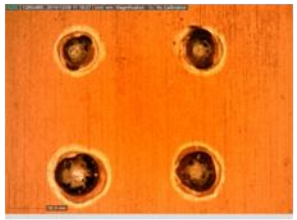
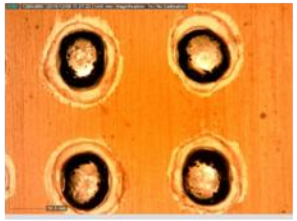
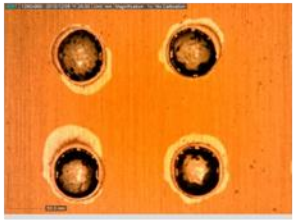
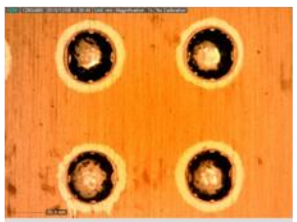
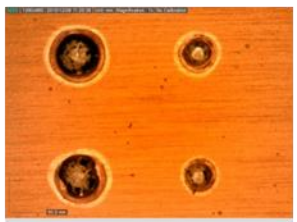
Cleaning on OSP Substrates

	WS-446	WS-575-C	WS-575-C-RT	Competitor
Baked and Cleaner OSP				
	WS-446	WS-575-C	WS-575-C-RT	Competitor
Double Baked and Cleaner OSP				

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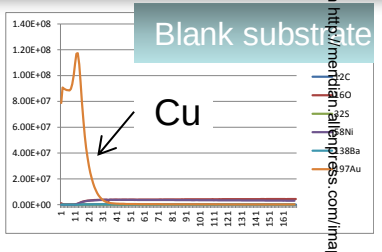
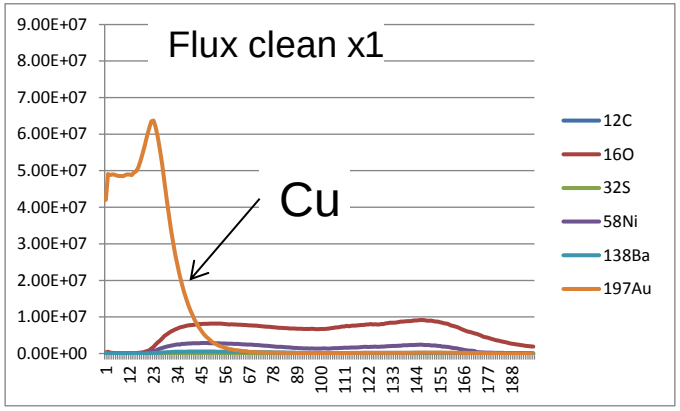
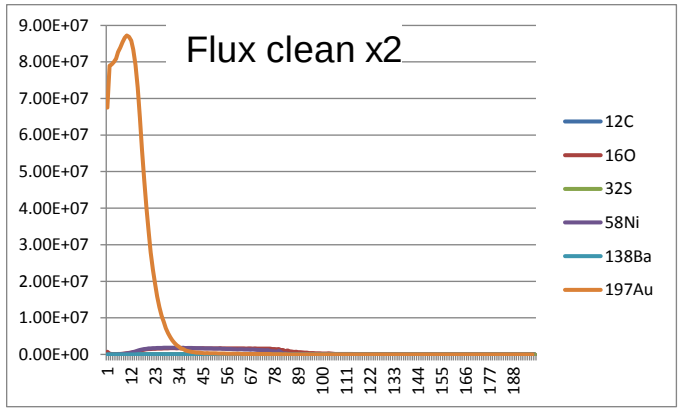
Cleanability: SIMS Analysis on Real Product

- The sample processes through full process –SMT/ Die Wire bond/ Molding.
- WS575-C SIMS element analysis show WS575-C can clean the surface as clean as bare substrate. While the competitor still has C, O after 1 time flux clean.

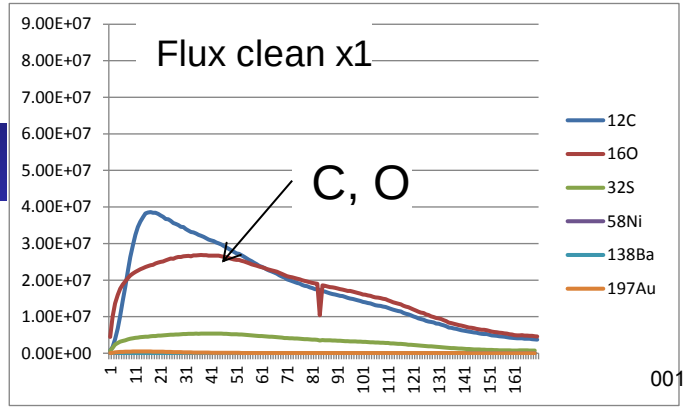


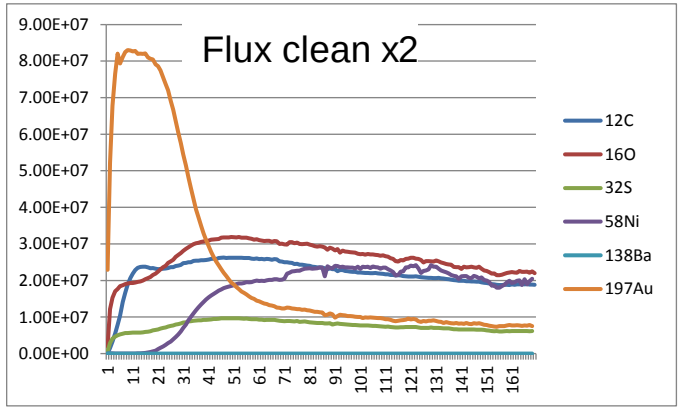
WS575-C





Competitor





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Problem: White Residue (Tin Oxide) Observed on Substrate

Reflow reaction:

$$SnO + Act \rightarrow SnAct + H_2O \uparrow$$

Tin/activator salt dissolves into flux residues, away from the metal surface

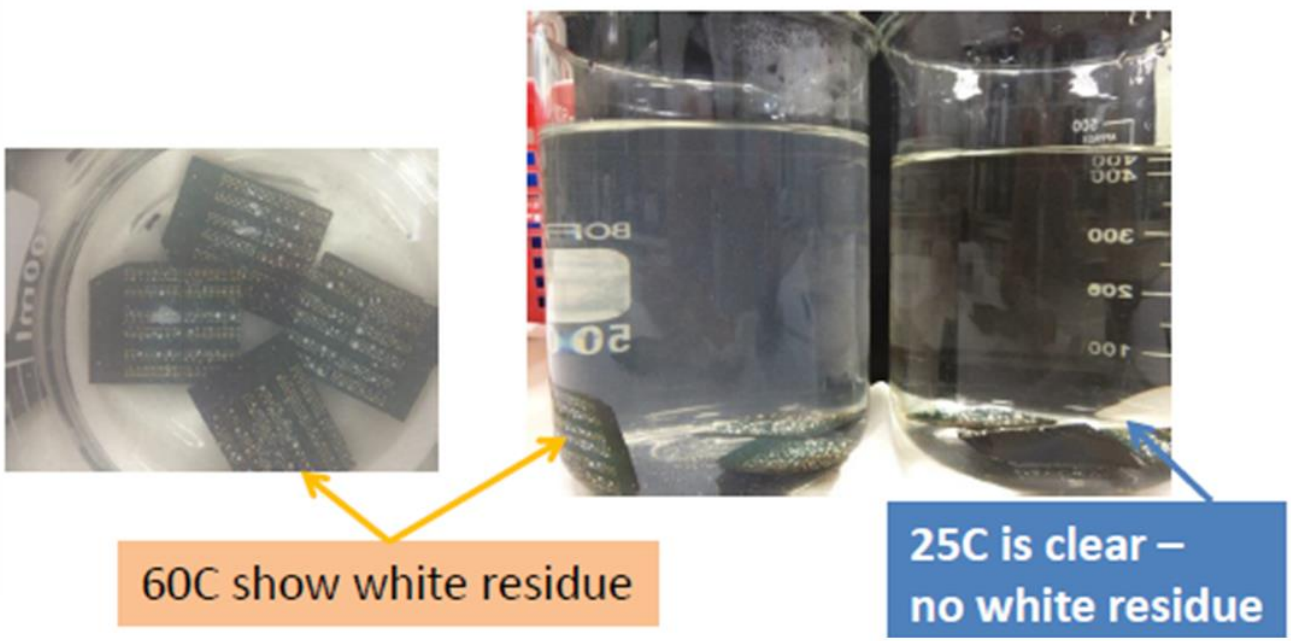
Cleaning: Hydrolysis reaction:

H_2O **H_2O/O_2**

$$SnAct \rightarrow ActH + SnO,\ Sn(OH)_2 \rightarrow Sn(OH)_4,\ SnO(OH)_2,\ SnO_2$$

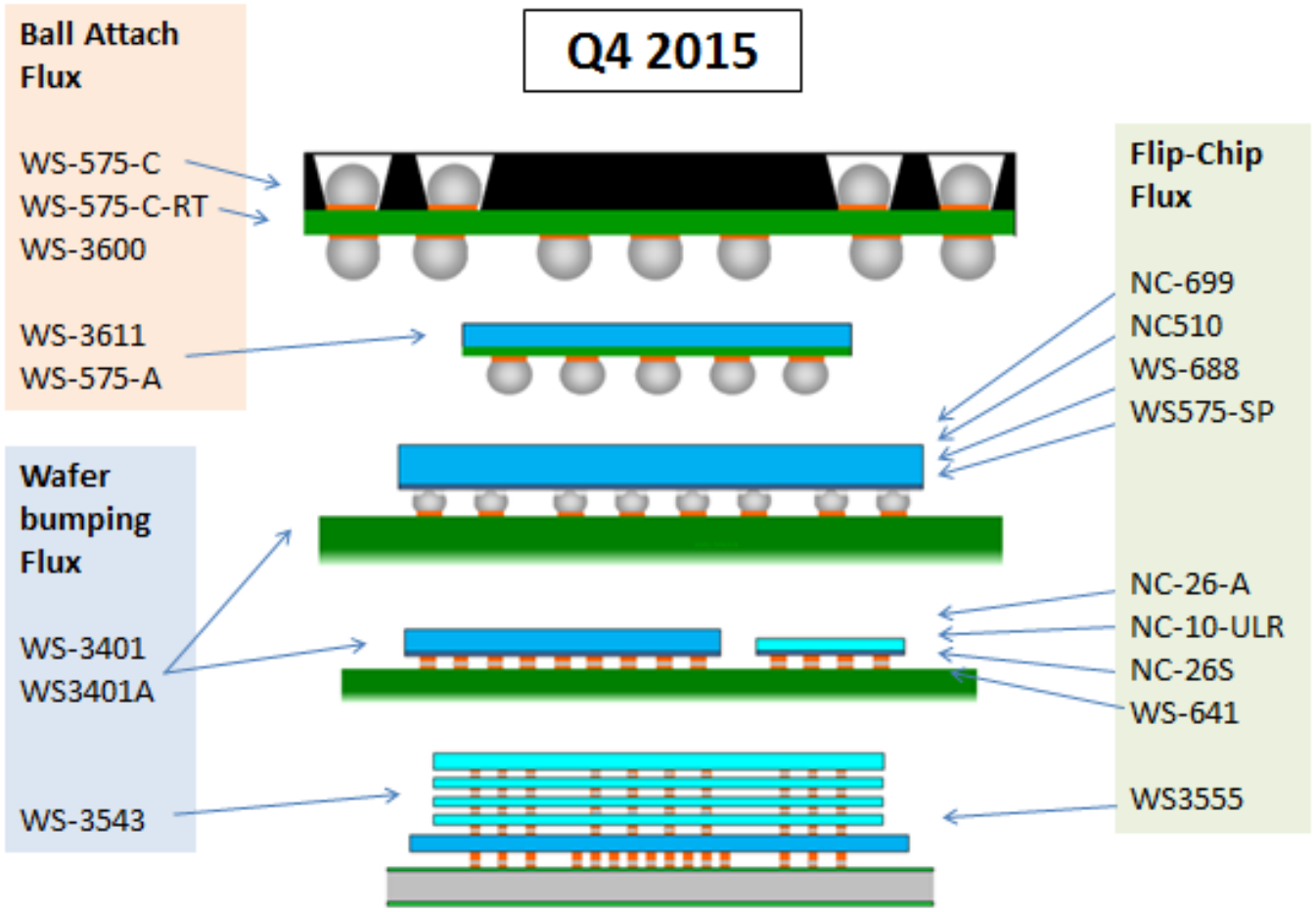
Rate affected by temperature

Effect of DI Water Cleaning Temperature



Customer reduced water temperature to eliminate white residues .: Cost saving

Thank you!



Note: Examples of customer usage only.
Some fluxes have multiple uses

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