One Step Chip Attach Materials (OSCA) for Conventional Mass Reflow Processing

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Overview

- Introduction to Kester & ITW

- Conventional Flip Chip Assembly Process
- One Step Chip Attach Process (OSCA)
  - Materials for reflow processing (OSCA-R)
- OSCA-R Material Design
  - Dispense
  - Die placement
  - Fluxing & cure kinetics
  - Successful assemblies
  - OSCA-R material properties
  - OSCA-R reliability
- Summary
- Acknowledgements
- Questions

A diversified manufacturer of advanced industrial technology

Headquartered in Chicago, founded 100 years ago with an initial focus on metal cutting tools

- Decentralized organization
- More than 150 divisions in 57 countries
- 60,000 employees
- 19,000 global patents & patent applications

kester

ITW Electronics Group Overview

Kester (materials)

Speedline (equipment)

Vitronics – Soltec (equipment)

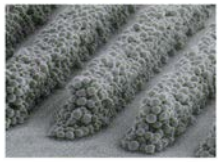
Kester can leverage relationships with sister ITW divisions to produce collaborative solutions for customers

- Highly engineered electronic components and assembly systems for the electronics industry
- Major applications in consumer electronics, medical, automotive and defense markets

Kester's Product Lines

Liquid Fluxes

Tacky Fluxes



Fluxing Underfills

One Step Chip Attach
(OSCA)
Process & Materials

Built on Kester's 100+ years of experience in flux and solder chemistry

Solder Pastes

Solder Wire

Solderforms

Bar Solder

Thermal Interface Materials

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- One Step Chip Attach Process & Materials (OSCA)
  - Materials for reflow processing (OSCA-R)
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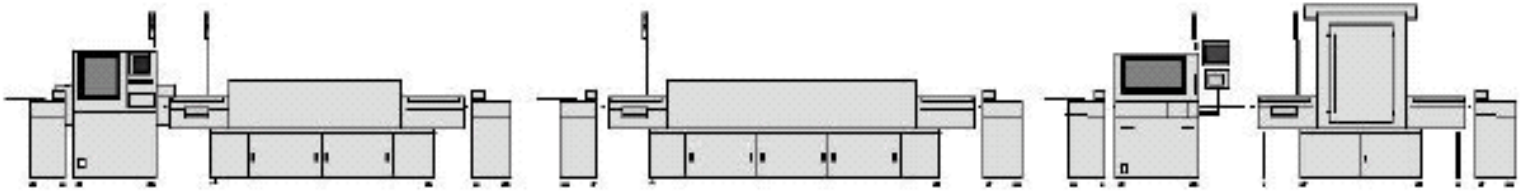
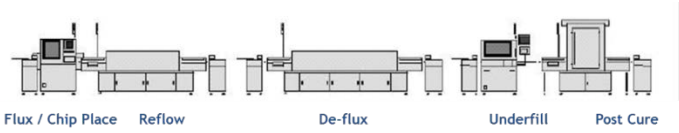
Conventional Flip Chip Assembly Process

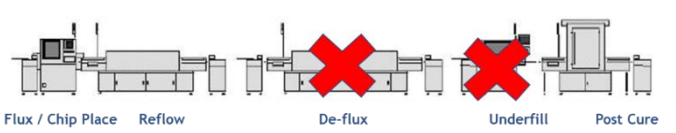


Flux / Chip Place Reflow De-flux Underfill Post Cure

Why a One Step Chip Attach (OSCA-R) Solution?

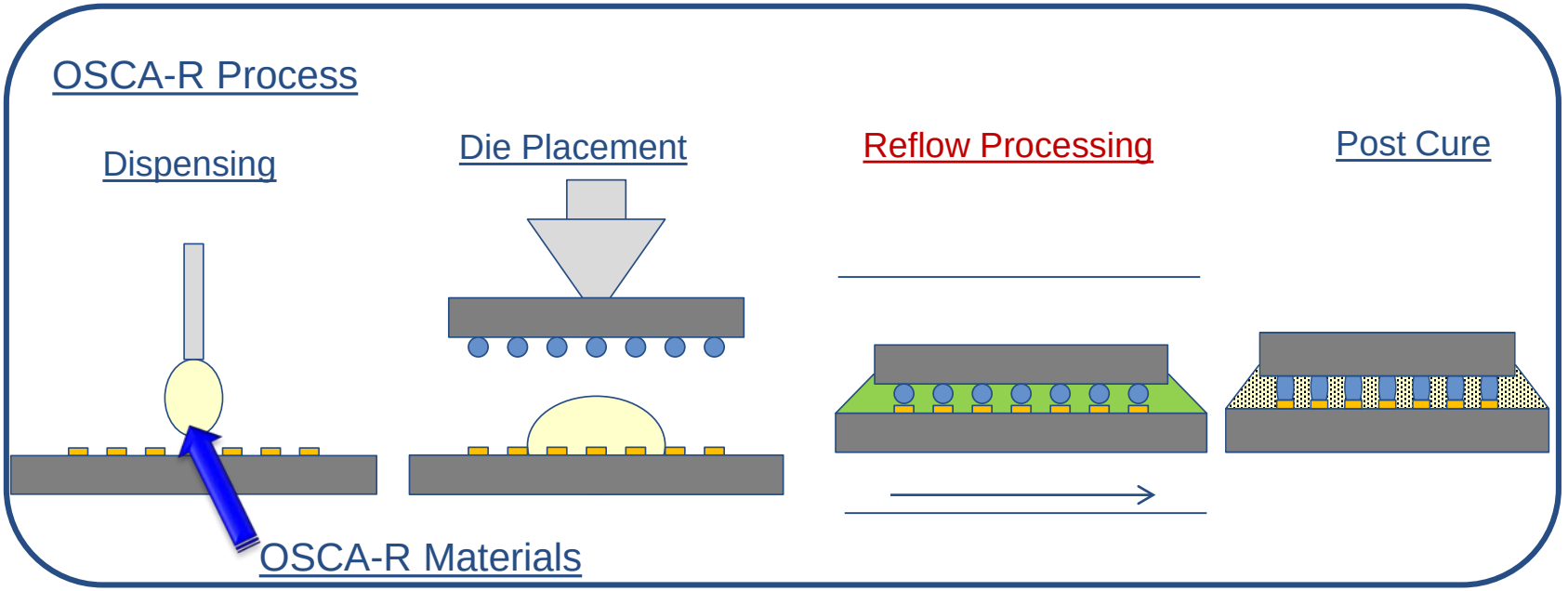
- OSCA-R Materials → Enable OSCA Process
  - Process Simplification + Throughput



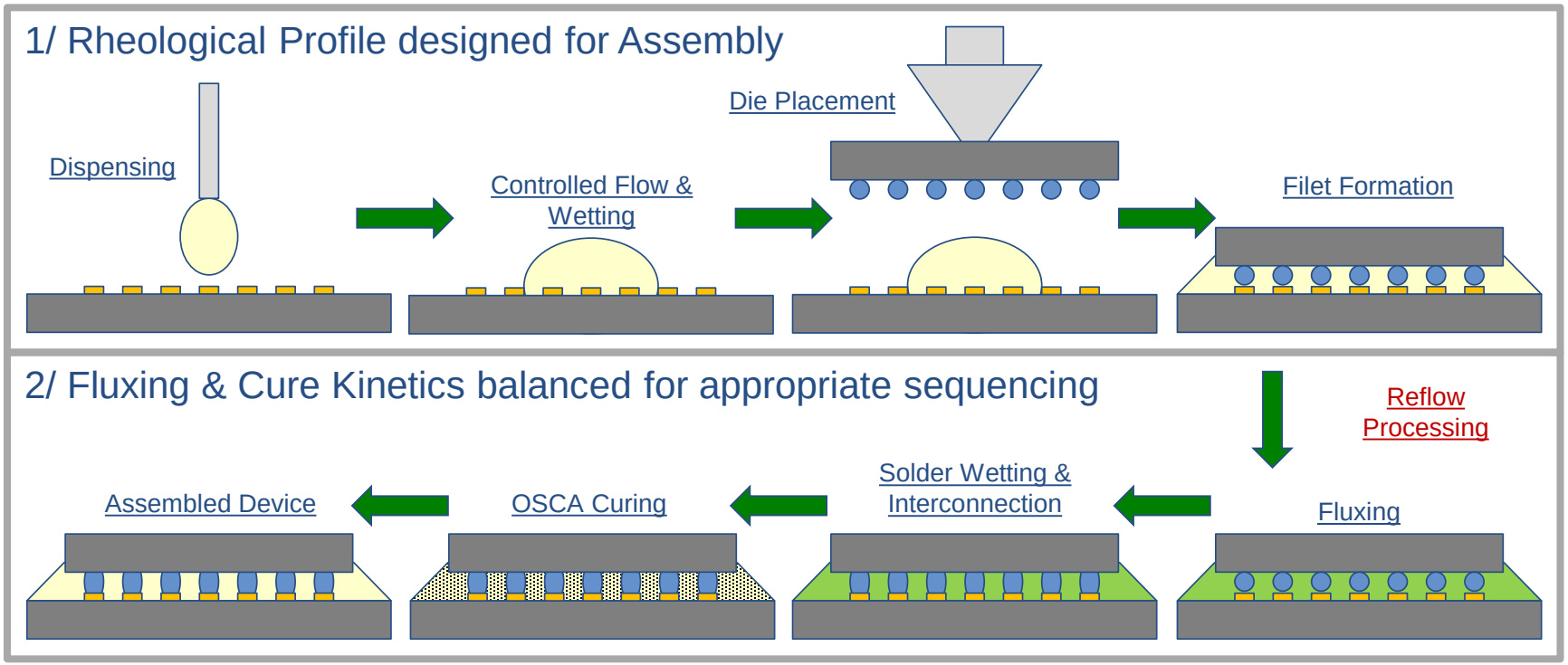


6+ Process steps
3 Materials - Flux, Cleaner, Capillary Underfill

4 Process Steps
1 Material – OSCA-R



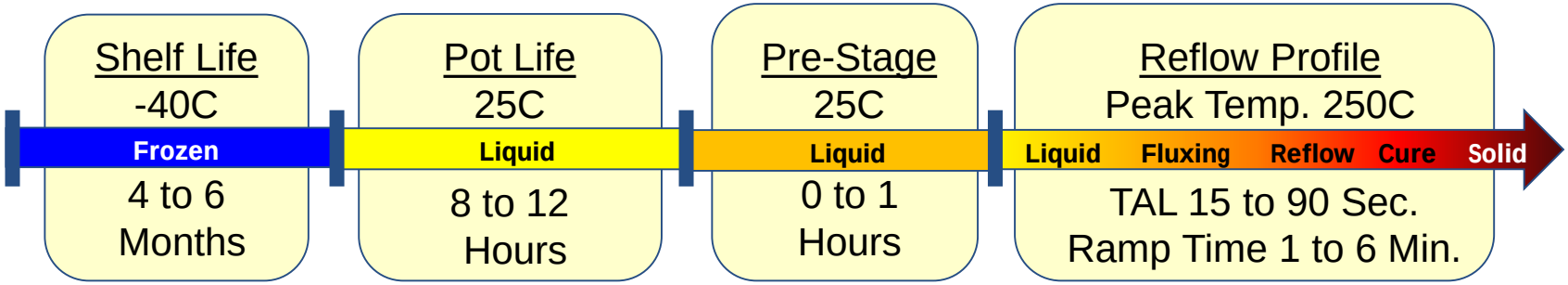
One Step Chip Attach Process & Materials



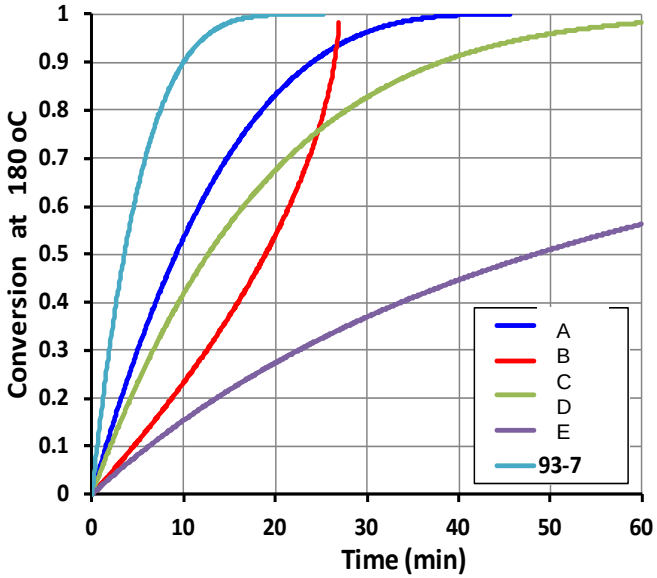
- Key formulation design considerations for OSCA-R materials
  - Rheology/flow for dispensing and die placement
  - Balance of fluxing & cure chemistry during reflow processing
  - Final cured properties, interconnection and reliability

OSCA-R Material Design

- Full life cycle and thermal requirements are implicit considerations for OSCA-R design
  - Thermal requirements are application specific

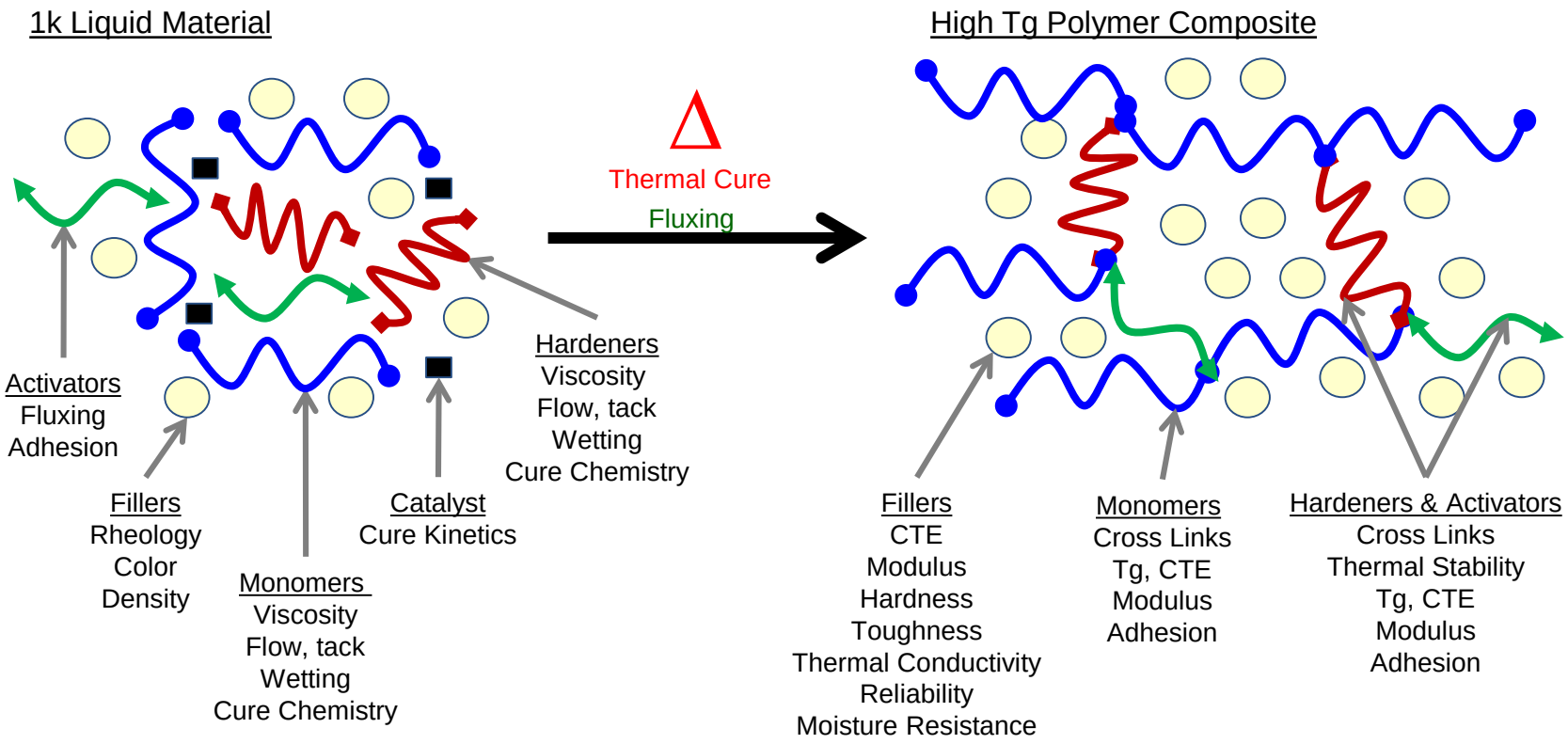


- Curing kinetics can be tuned to match application reflow profile within certain limits



OSCA-R Material Design

- OSCA-R materials are multi functional reactive mixtures that thermally cure to a high performance thermoset polymer composite during reflow processing
  - Selection of components key for fluxing, cure kinetics, final composite performance



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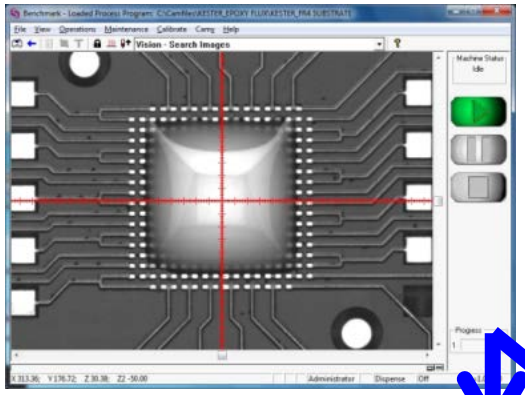
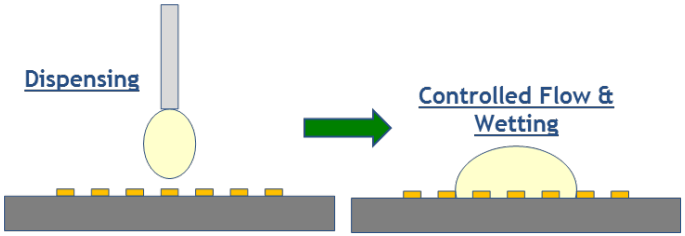
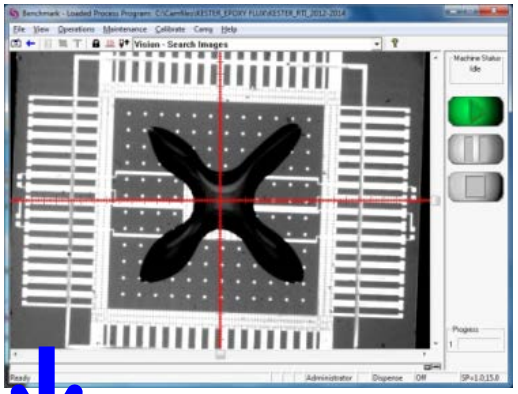
OSCA-R Rheology Design - Dispensing

- OSCA-R materials designed for compatibility with different dispense processes







Time-Pressure

Finetech

R&D Equipment

Auger

Asymtek

Assembly Equipment

Jet

SmartStream™

NanoShot™

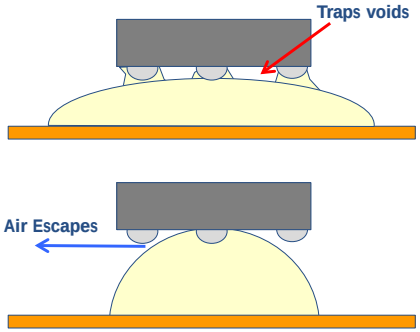
Speedline

Partnership with Sister Company

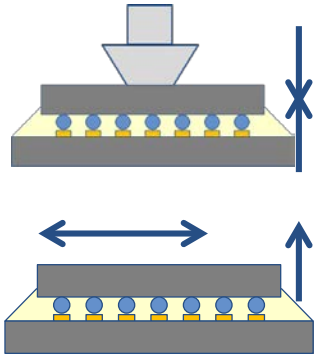
OSCA-R Rheology Design - Die Placement

- OSCA-R materials designed to overcome key placement difficulties

Placement Voids



Rebound (viscoelasticity)



Pick & Place

Finetech

Kester
R&D Equipment

Juki

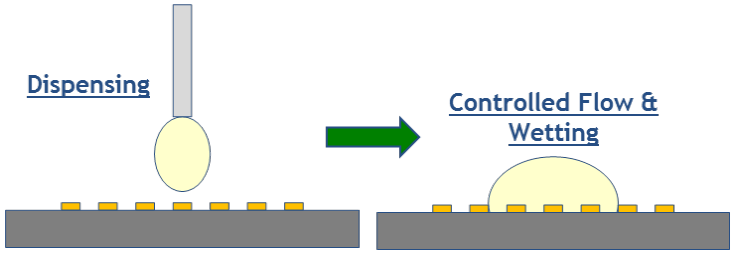
Kester
Pilot Equipment
KE 1080 (±50 micron)

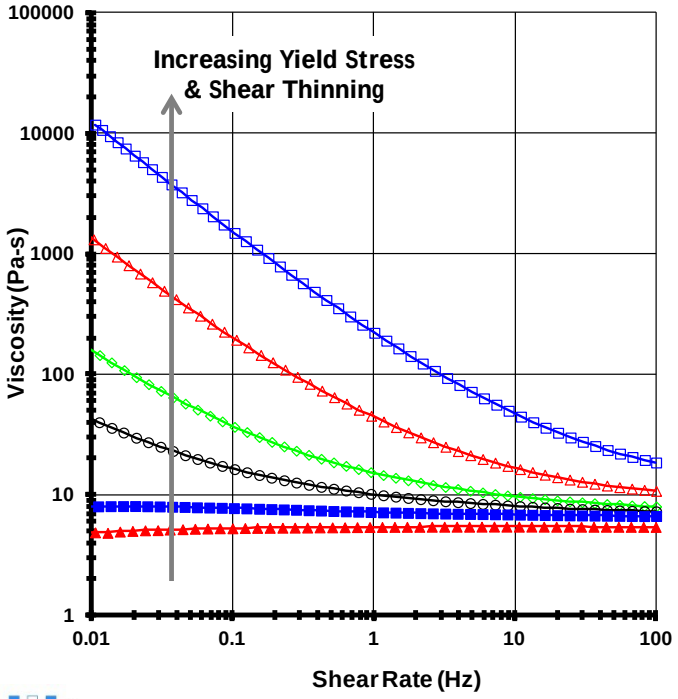
Universal

Production Equipment
Advantis (25-50um)
Genesis SC (± 5-10um)

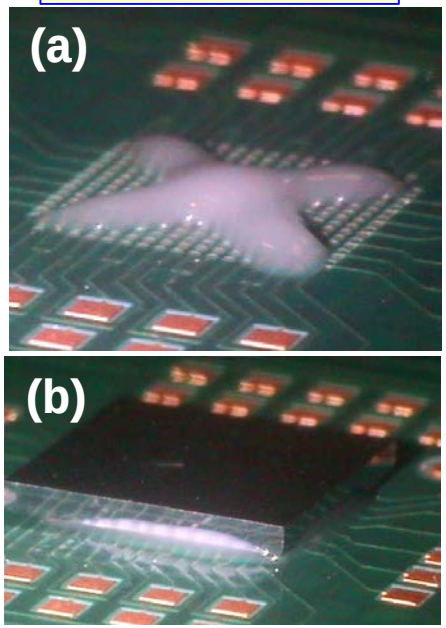
OSCA-R Rheology Design – Dispense/Placement

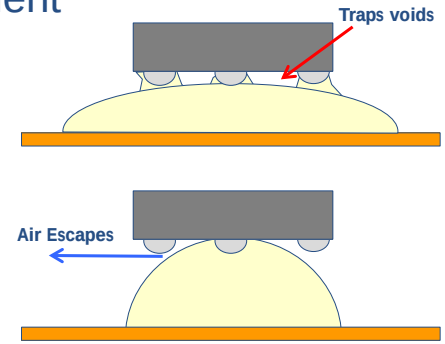
- OSCA rheology design to build shear thinning, viscosity and yield stresses
- CSAM images illustrate impact of yield stress on void entrapment

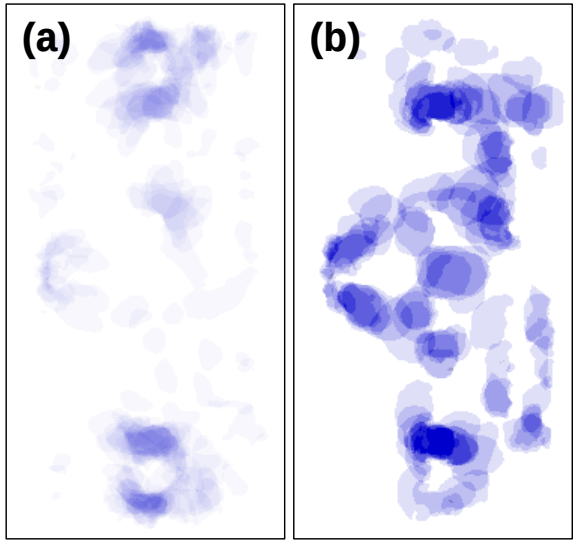




Dispense Patterning & Fillet Formation

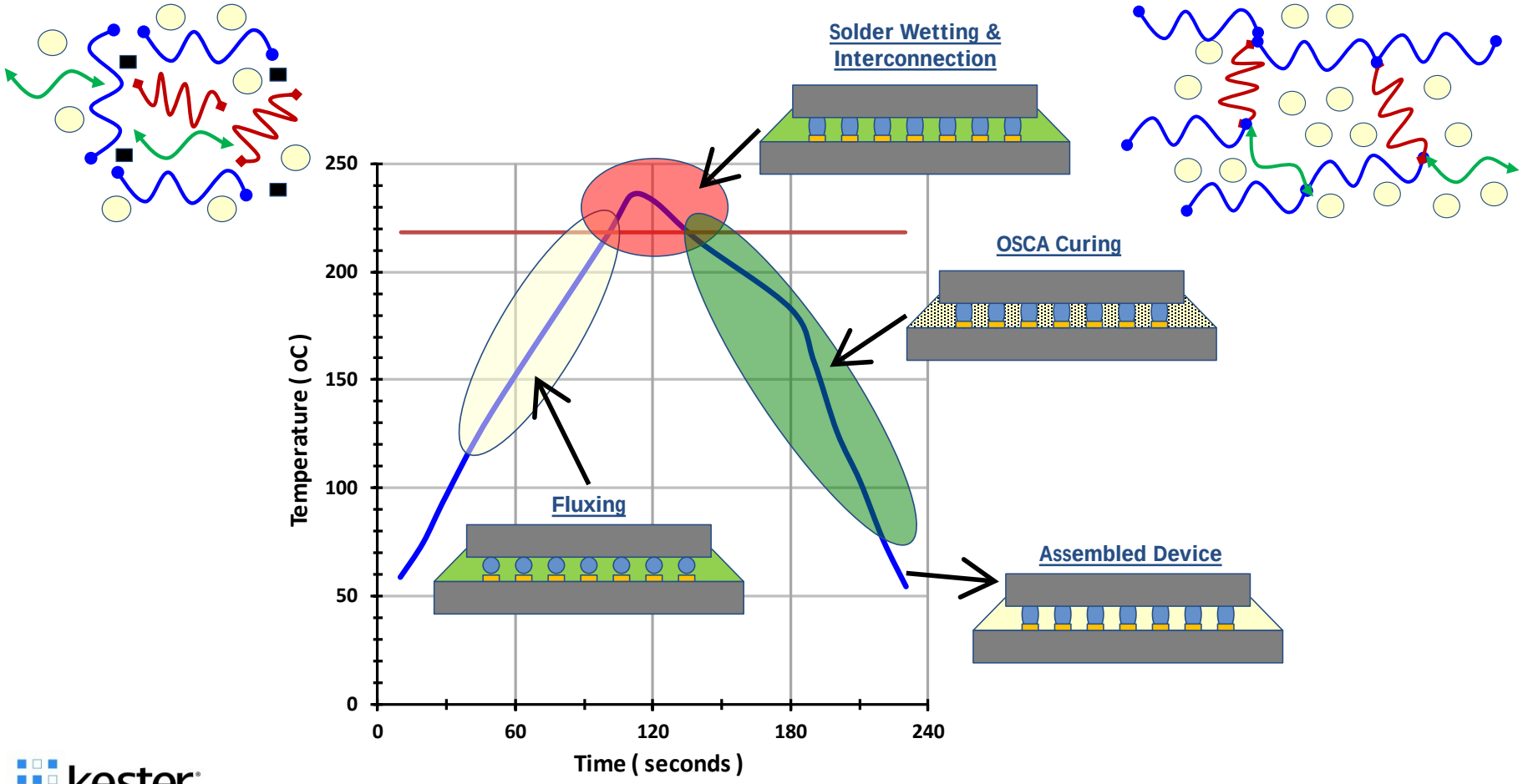






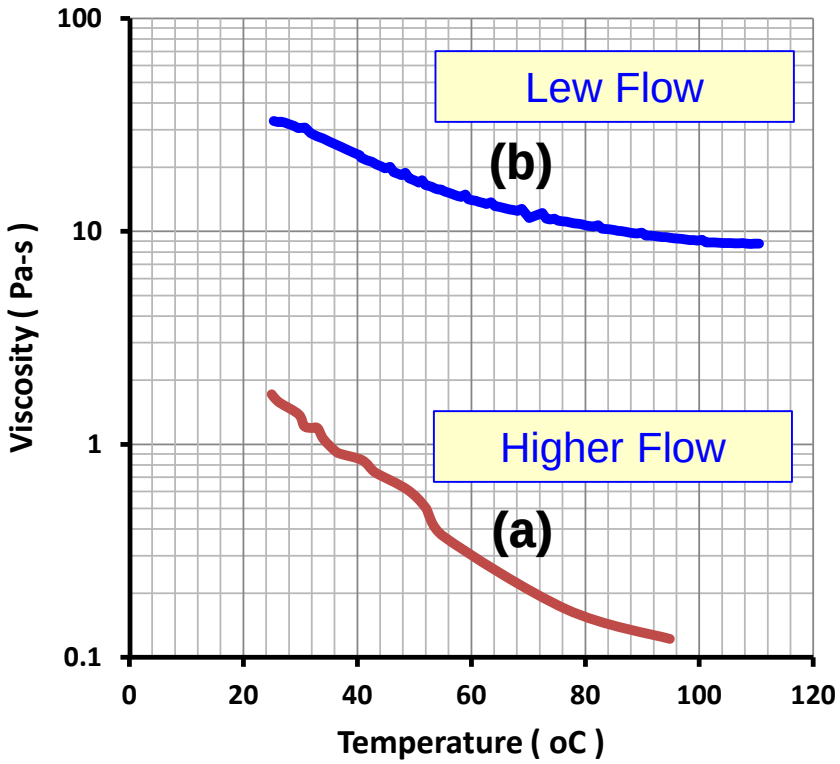
OSCA-R Design – Fluxing & Cure Kinetics

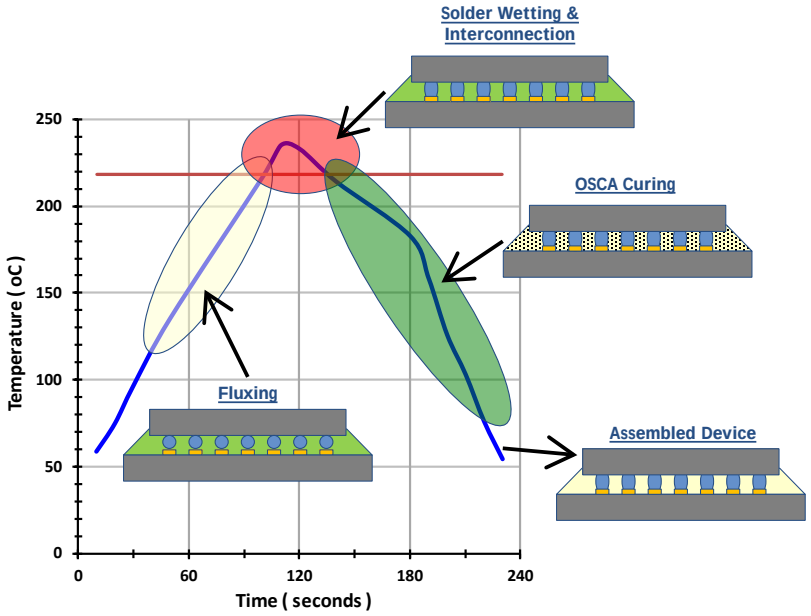
- Balancing Fluxing and Cure Chemistries with Flow
  - Sequencing, timing of events is critical

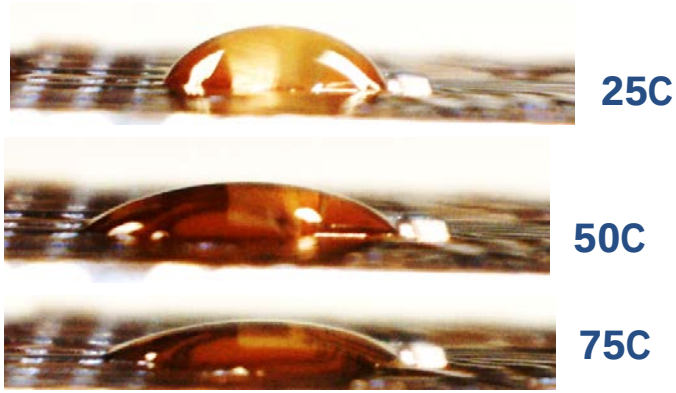


OSCA-R Design – Cure Kinetics & Flow

- Temperature dependence of OSCA-R rheology critical for fillet formation and solder interconnection







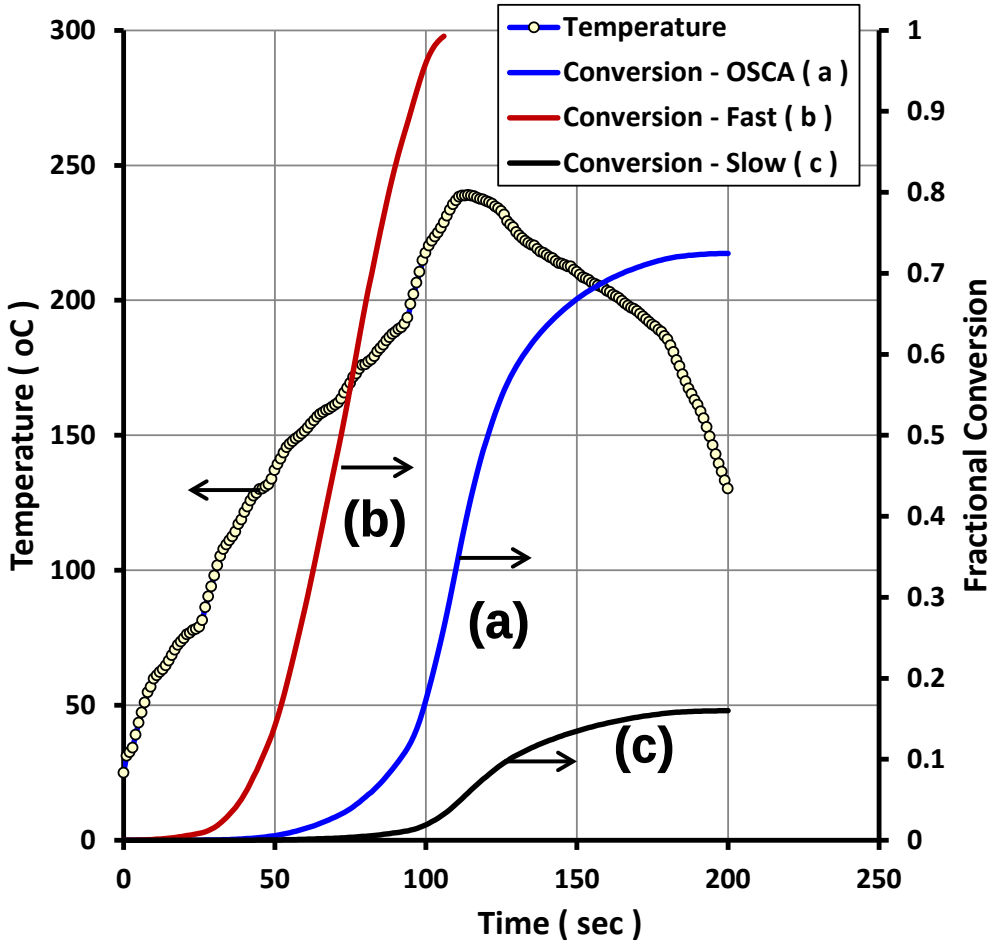
OSCA-R Design - Curing Kinetics

- The curing kinetics of OSCA formulations depend on the reflow profile
  - Curing kinetics tuned to match a particular reflow profile

(a) Tuned to Match Profile

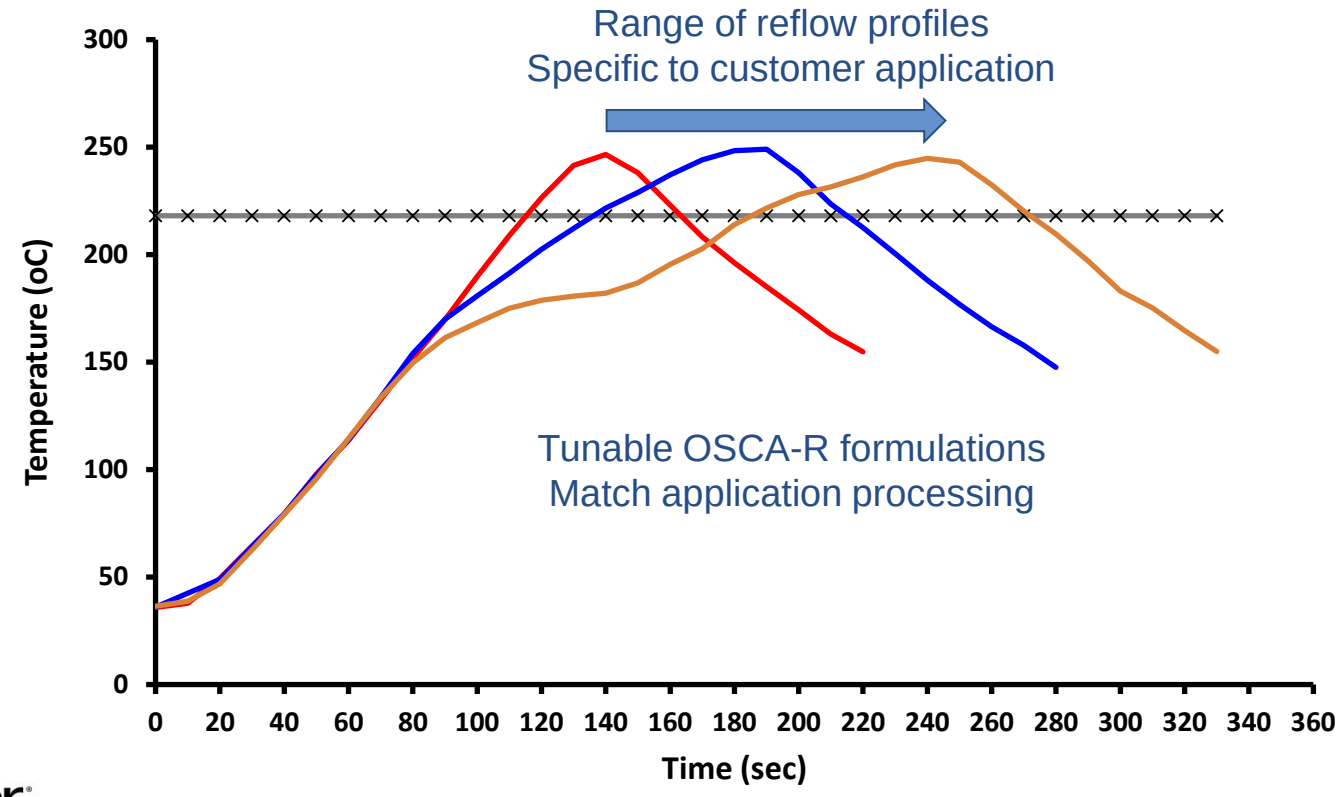
(b) For Fast Profiles (TCB)

(c) For Longer Profiles



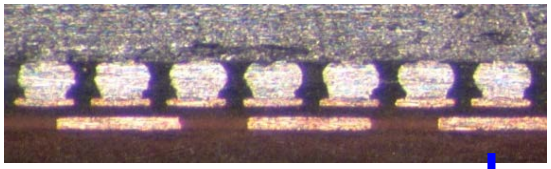
OSCA-R Performance Window

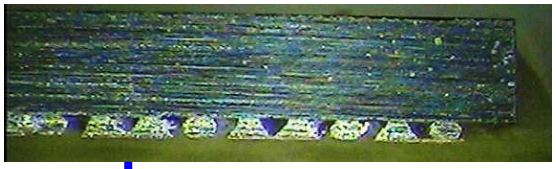
- Customers prefer different reflow profiles
  - Manufacturing equipment
  - Application specific optimized for yield
  - Die stress and substrate warping
  - Substrate type, component configuration

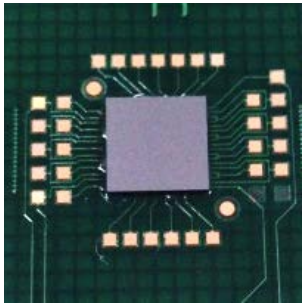


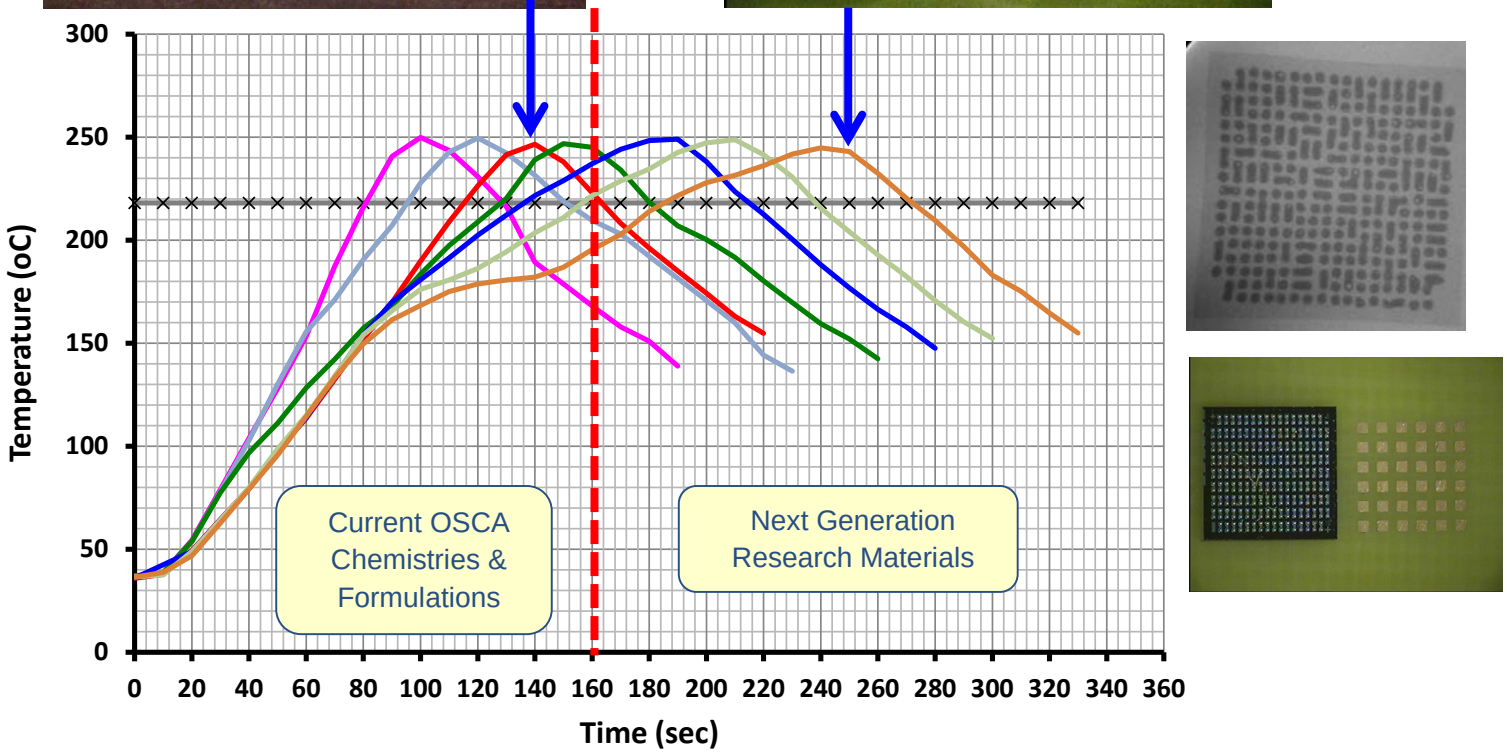
Formulation Design & Process Window

- Current OSCA-R Formulation Capabilities (pilot production scale)
  - Designed for fast to moderate length reflow profiles to enable high throughput
- Next Generation OSCA-R Chemistries & Materials (R&D scale)
  - Designed for longer reflow profiles with long soak times above





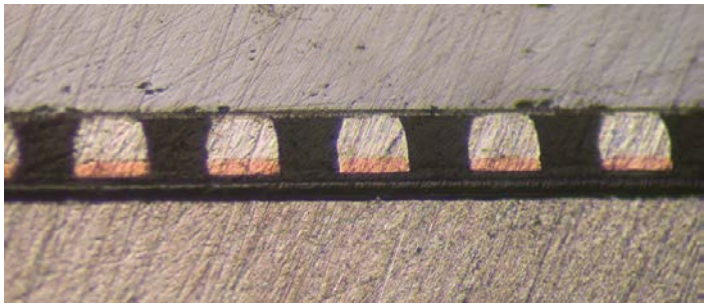


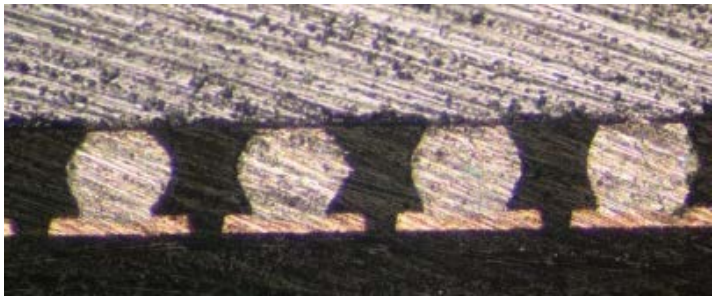


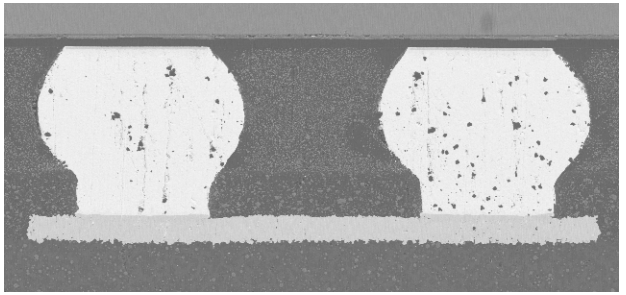
OSCA Application Testing Overview

- Successful use of OSCA-R materials on different devices and applications

Specifications
Substrate → Flex **Die → Silicon, 2x6x0.5mm, Bump Count ~ 120** **Cu pads, SAC Bumps- 80 micron, pitch 150 micron** **OSCA-R Unfilled, 40% filled** **Short Reflow Profile** **Voids < 10%**
Substrate → FR4 (thin) **Die → Silicon, SAC, 6x6x1mm, Bump Count ~ 1000** **Cu Pads and Bumps, 130 micron, pitch 170 micron** **OSCA-R Unfilled + 40% filled** **Medium, Long Reflow Profiles** **Voids < 10%**
Substrate → FR4 (thick) **Die → Silicon, 5x5x1mm, Bump count ~500** **SAC bumps, OSP Cu pads, 80 micron, pitch 254 micron** **OSCA-R Unfilled, 40%, 60% Filled** **Short Reflow Profiles** **Voids < 10%**



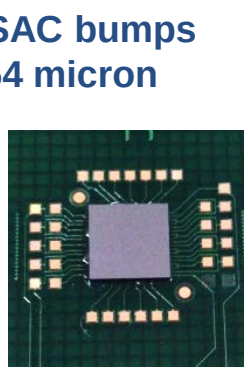


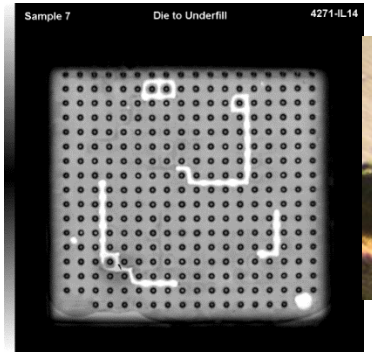


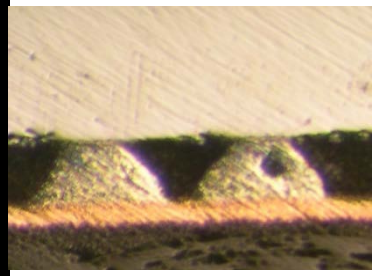
OSCA Application Testing Overview

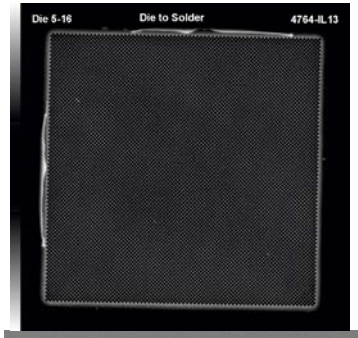
- Successful use of OSCA-R materials on different devices and applications

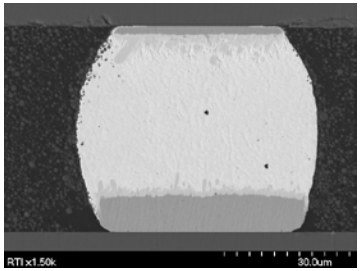
Specifications
Substrate → FR4, solder mask **Die →5x5x1mm, Daisy chained, full array, SAC bumps** **OSP Cu pads, diameter 80 micron, pitch 254 micron** **OSCA-R Unfilled** **Short Reflow Profiles** **Voids** **Air Release From Substrate**
Substrate → Silicon **Die → Silicon, 10x10x0.5mm** **SnAg Bumps, Cu Pads, 80 micron, pitch 150 micron** **OSCA-R Unfilled, 40%, 60%** **Short Reflow Profiles** **Voids < 2%**

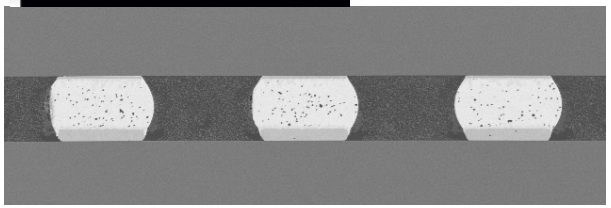










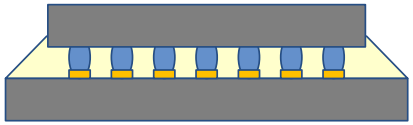


OSCA-R Final Properties & Reliability

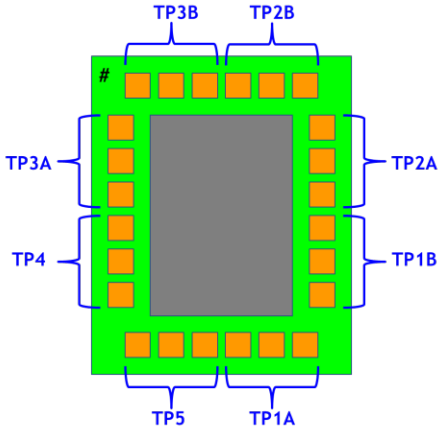
- Preliminary Thermal Shock Testing
  - Large IO full array devices assembled with OSCA-R materials
  - Pass 500 Cycles, -55C to 125CPost 500x T-Shock
  - OSCA-R materials pass 50hr. HAST testing

Final Properties & Reliability

Assembled Device

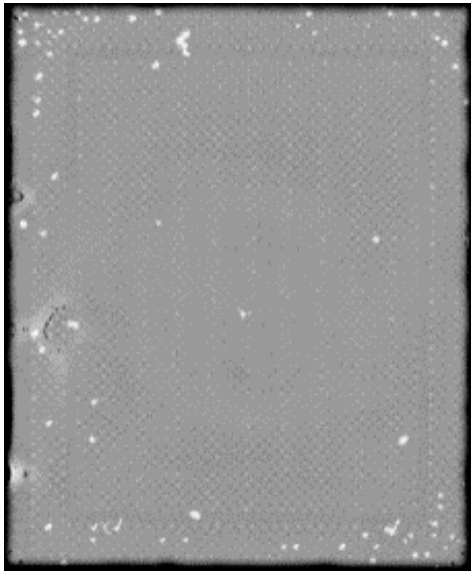


Layout



10x12x0.3mm
80 micron bumps/pads
150 micron pitch
~5000 bumps
3 test circuits

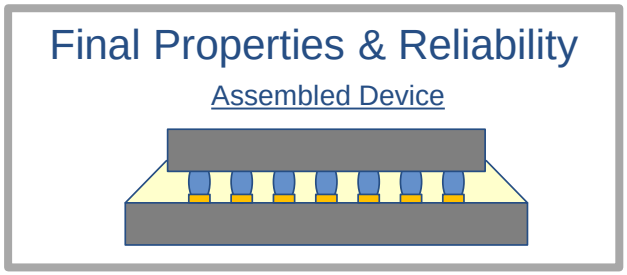
CSAM
No defect propagation at 500 cycles



Die shear before and after HAST testing (Autoclave, T = 121°C, 19 psig).

Time	0 Hr.	50 Hr.
Formula	(kg-force)	(kg-force)
OACA-1	39 (±10)	24 (±8)
OSCA-2	34 (±10)	31 (±10)
OSCA-3	35 (±10)	32 (±10)

OSCA-R Final Properties & Reliability



- OSCA-R materials can be formulated with a range of properties
  - Filler Loading & Size
  - CTE, Tg
  - Viscosity
  - Cure kinetics
  - Thermal Conductivity
- Materials can be adapted to application needs
  - Every application is different
  - Properties, Parts, Preferred Process

Property	Units	Range
Filler Loading	Wt%	0 to 60
Average Filler Size	Micron	0.5
Max. Filler Size	Micron	5
Weight Loss, T < 300°C	Wt%	4 to 16
Tg	oC	150 +/-10
CTE-1	ppm/K	30 to 70
CTE-2	ppm/K	85 to 210
Thermal Conductivity	W/m-K	0.2 to 0.5
Modulus at 25°C	Gpa	3 to 8
Ultimate Strength at 25°C	Mpa	50 to 95
Strain to Break at 25°C	%	1.4 to 2.5
Fracture Toughness, K1c	MPa-$m^{1/2}$	1 to 2
Adhesion	Kg-force	18 to 30
Adhesion 50 Hr. HAST	Kg-force	5 to 10
ΔH, Heat of Reaction	J/g	120 to 360
T_O, Onset Temperature	oC	110 to 130
T*, Peak Temperature	oC	160 to 200
% Cure After Reflow	%	> 80%
Reaction Order	Integer	0.9 to 1.3
Half Life at 180°C	Min.	4 to 5
Viscosity, 25C	Pa-s	4 to 65
Shear Thinning Index, 25C	Ratio	1 to 3
Yield Stress	Pa	0 to 10
Temperature Thinning	Kelvin/1000	2 to 8
Pot Life at 25°C	Hours	8

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  - Successful assemblies
  - OSCA-R material properties
  - OSCA-R reliability
- Summary
- Acknowledgements
- Questions

Summary & Conclusions

- One Step Chip Attach (OSCA) materials can be used to eliminate steps in flip chip assembly processing using convection or conduction mass reflow
  - Reduced complexity of manufacturing
  - Higher throughput
  - Use existing processing equipment
- Approaches to overcoming the key technical challenges presented
  - Matching flow and chemistry to reflow temperature profile
  - Rational Rheology and Chemical design
- Devices built with low void levels and good preliminary reliability performance
- Process integration is key to enabling OSCA-R materials
  - Chemistry matched to desired reflow processing
  - Rheology adjusted for dispensing and die placement process
  - Die and substrate size, configuration and type are integral considerations for OSCA-R materials and process

Thank you for your attention

Questions?

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