Rheology Design Considerations for One Step Chip Attach Materials (OSCA) used for Conventional Mass Reflow Processing

D. Duffy, M. Desai, H. Bhavsar
L. Xin, J. Liu, B. Tolla
Kester Inc. Itasca, IL 60143

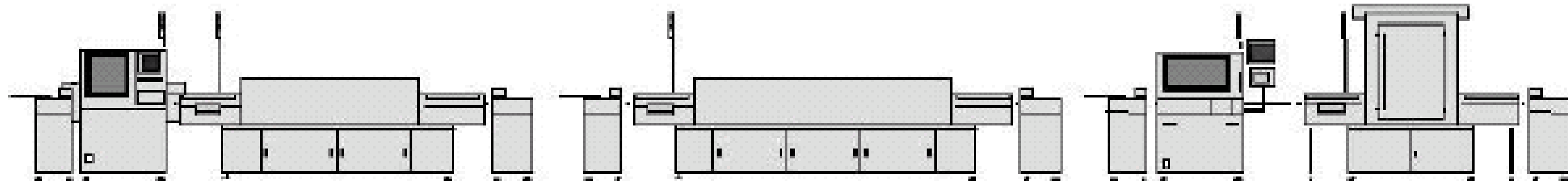
Agenda / Outline / Overview

- Introduction
  - Conventional Flip Chip Assembly Process
  - One Step Chip Attach Process & Materials (OSCA)
- OSCA Materials for Reflow Processing (OSCA-R)
  - OSCA-R Material Design
  - Rheology Design for Jet Dispense
  - Forces During Die Placement
    - Compression & Squeeze Flow Rheology
  - High TC OSCA-R, Interconnected Assemblies
- Summary & Conclusions
- Acknowledgements

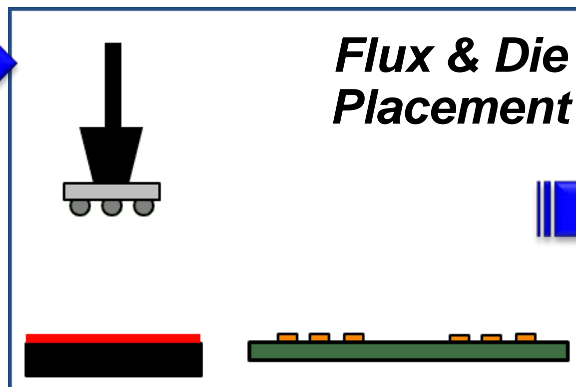
ECTC 2015
The 65th Electronic Components and Technology Conference

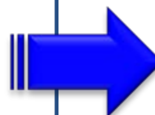
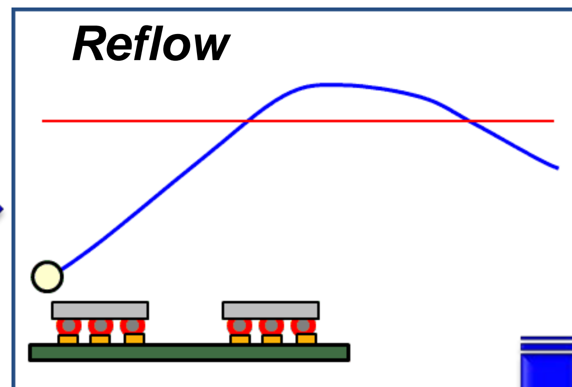
kester

Conventional Flip Chip Assembly Process

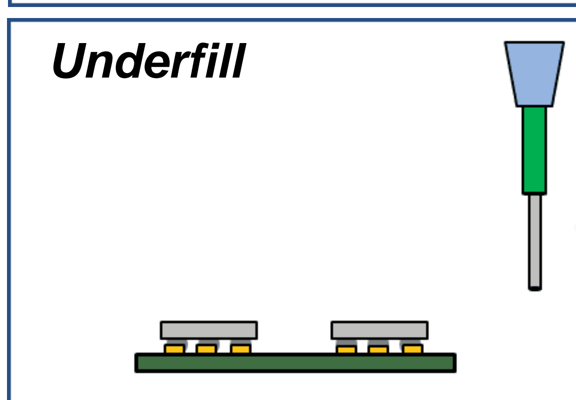


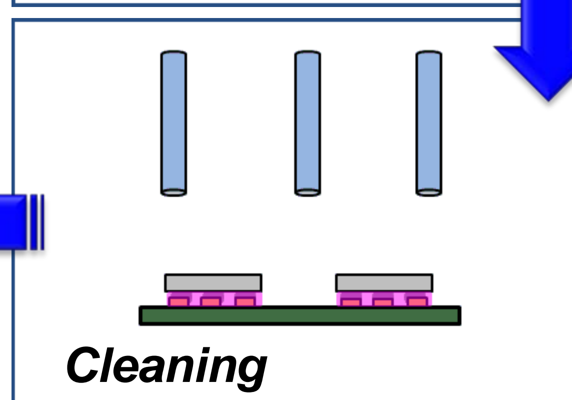
Flux / Chip Place | Reflow | De-flux | Underfill | Post Cure



Post Cure Underfill



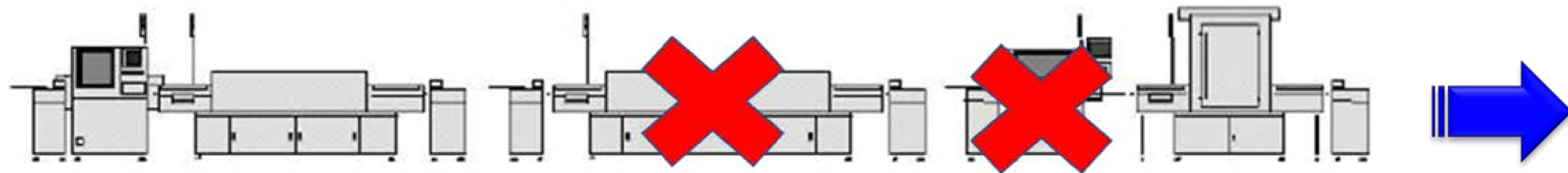


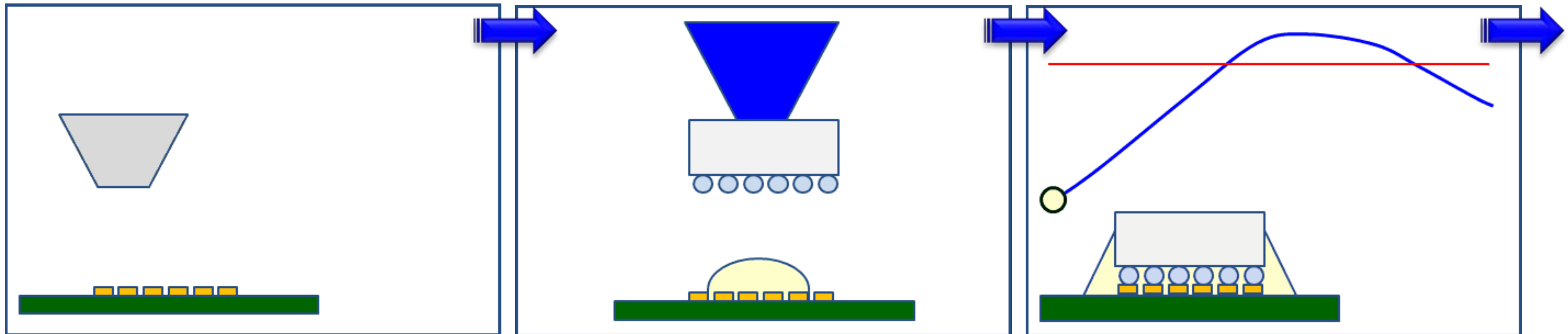
ECTC 2015 The 65th Electronic Components and Technology Conference

kester

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

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



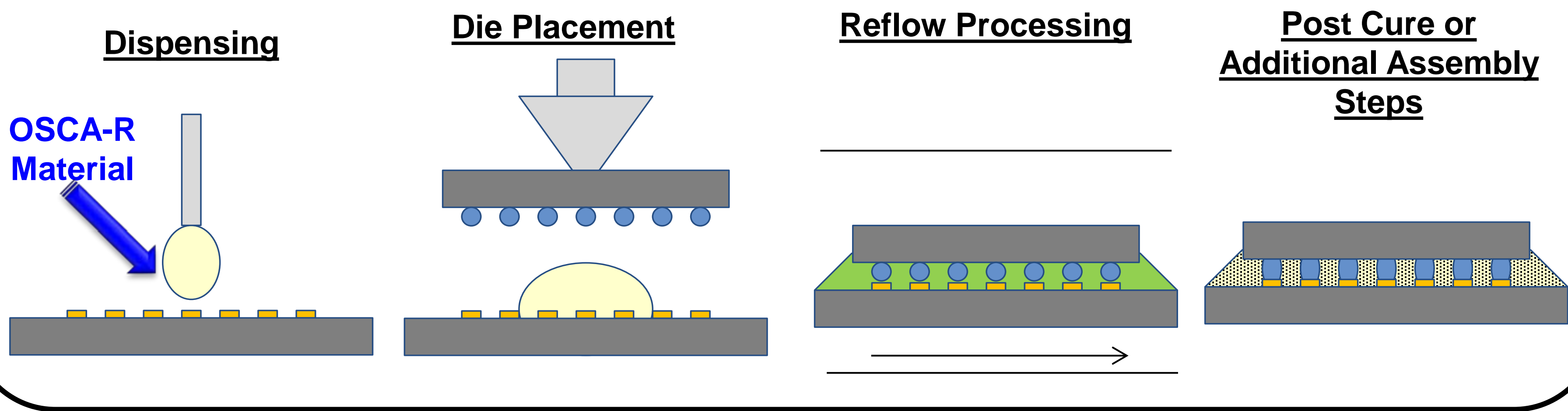


ECTC 2015 The 65th Electronic Components and Technology Conference

kester

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

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



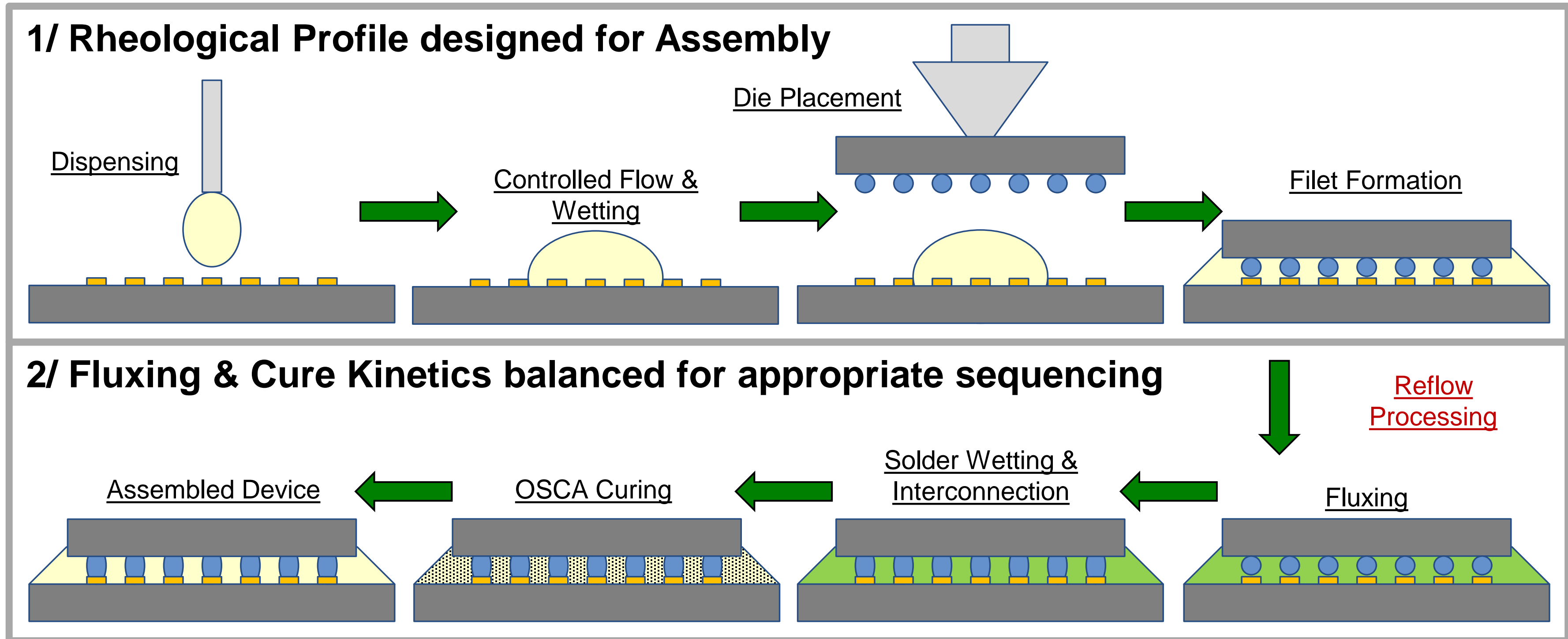
Rheology Wetting & Flow Design

Cure Kinetics & Thermomechanical Design

ECTC 2015 The 65th Electronic Components and Technology Conference

kester

One Step Chip Attach Process & Materials



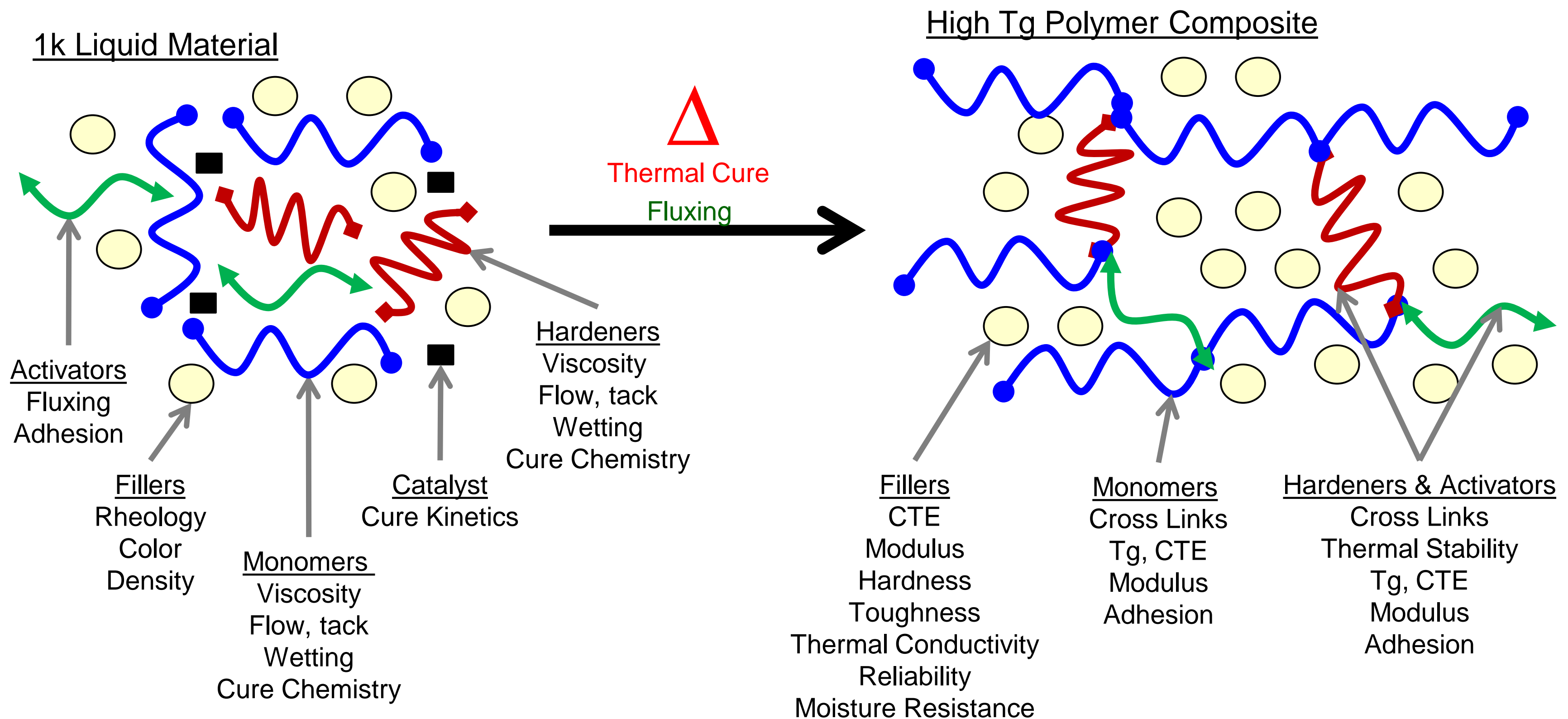
- Key formulation design considerations for OSCA-R materials
  - Rheology/flow for dispensing and die placement
  - Balance of fluxing & cure chemistry during reflow processing
  - Final cured properties, interconnection and reliability

ECTC 2015 The 65th Electronic Components and Technology Conference

kester

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

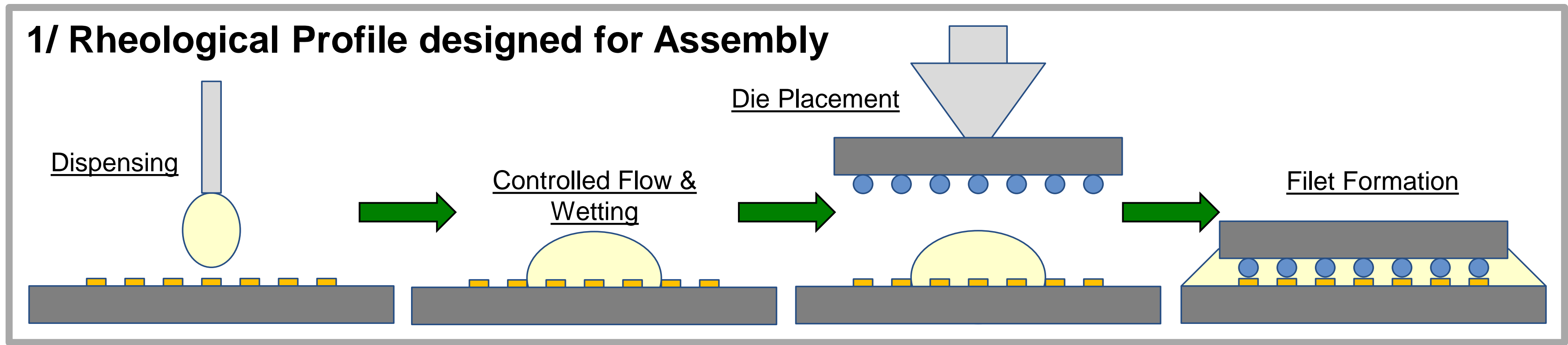


ECTC 2015 The 65th Electronic Components and Technology Conference

kester

One Step Chip Attach Process & Materials

- Design Considerations (CTQs)



- Filled system that can dispense by auger or jet

- Stays where it is intended to after dispense
- Retains dispense pattern
- Presents proper height profile

- Yields and flows during die placement
- Maintains alignment, no die floating, drift or tilt
- No placement voids

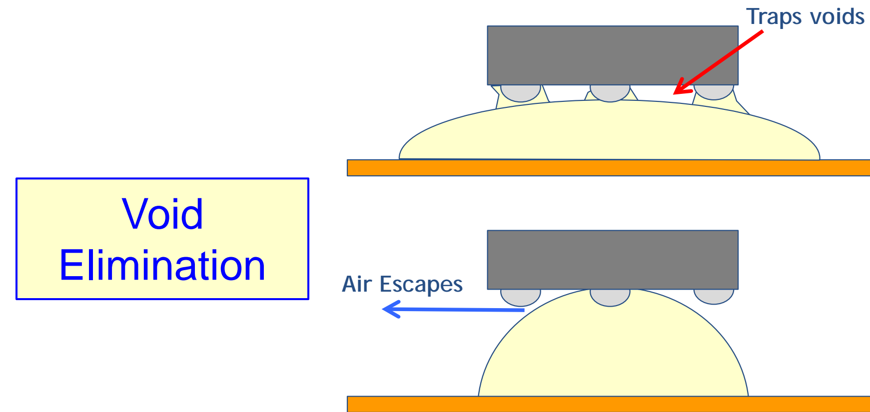
- Forms fillet and remains in intended area after placement
- Flows during reflow to allow wetting and interconnection

ECTC 2015 The 65th Electronic Components and Technology Conference

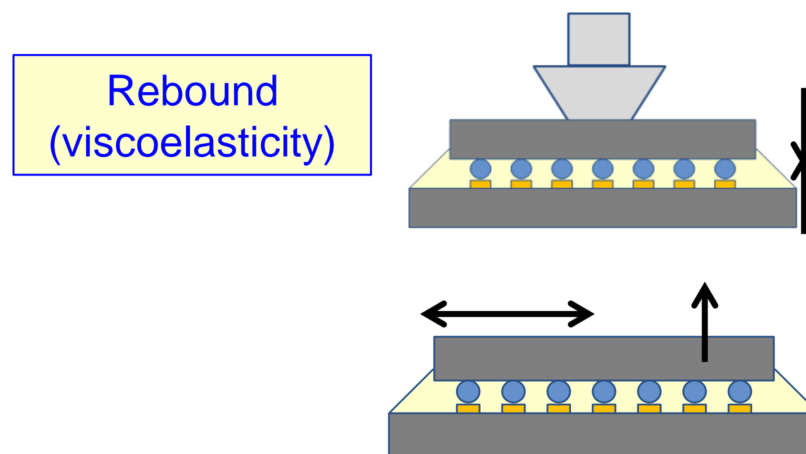
kester

OSCA-R Rheology Design – Die Placement

- OSCA-R materials designed to overcome key placement challenges
- Flow properties enable dispense pattern and void elimination



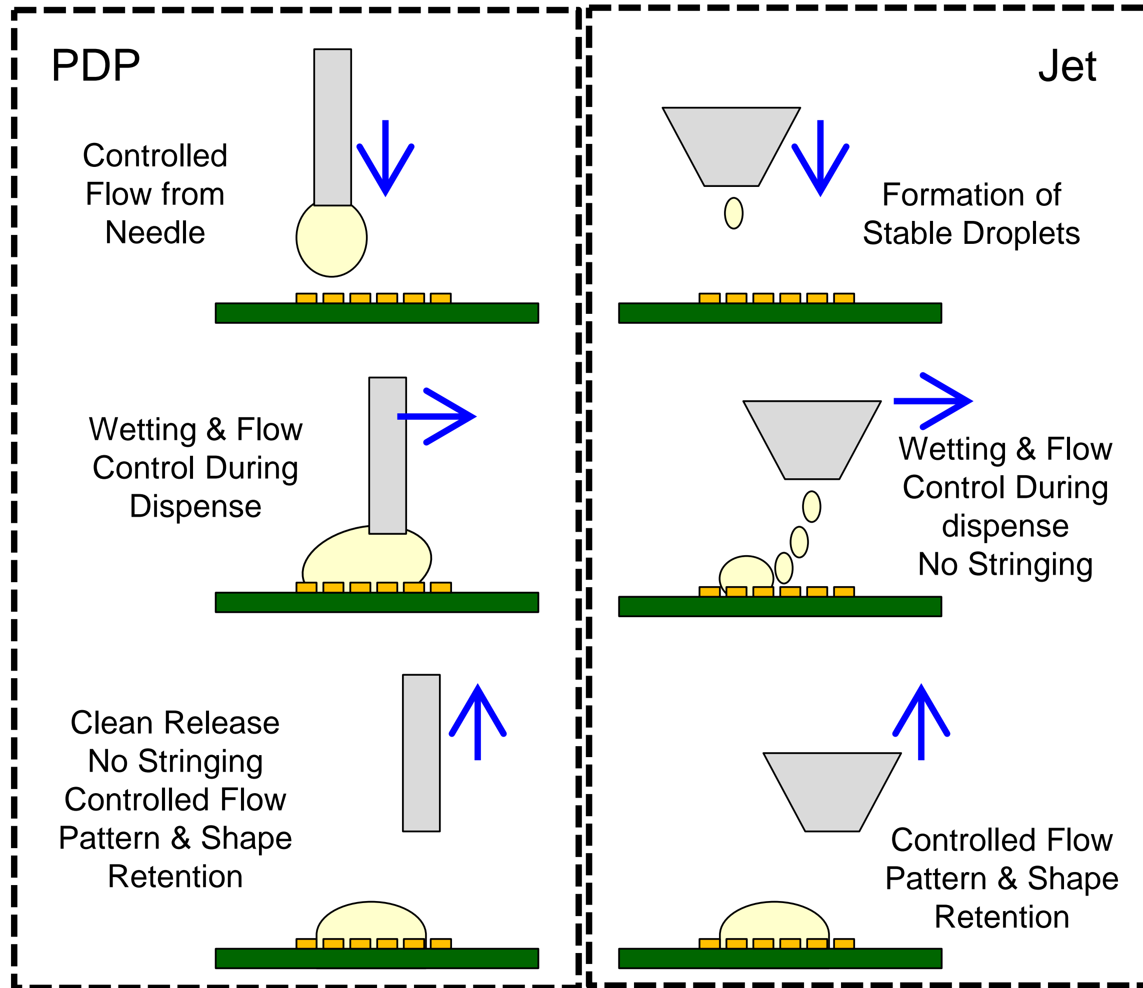
- Flow behavior during die placement under compression can complicate accurate die placement



ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Performance Considerations During Dispense



ECTC 2015 The 65th Electronic Components and Technology Conference

kester

OSCA-R Rheology Design - Dispensing

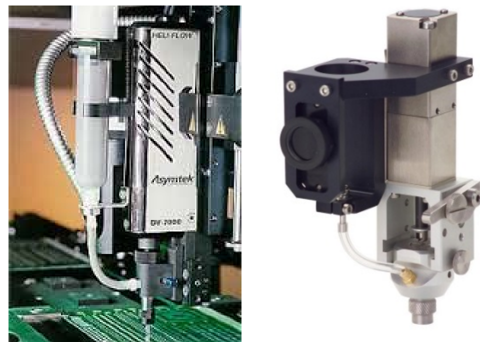
- OSCA-R materials designed for compatibility with different dispense processes

Time-Pressure

Finetech

R&D Equipment

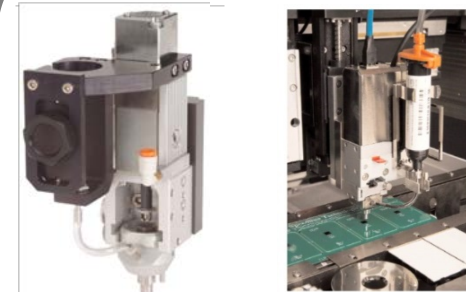
Auger



Asymtek

Assembly Equipment

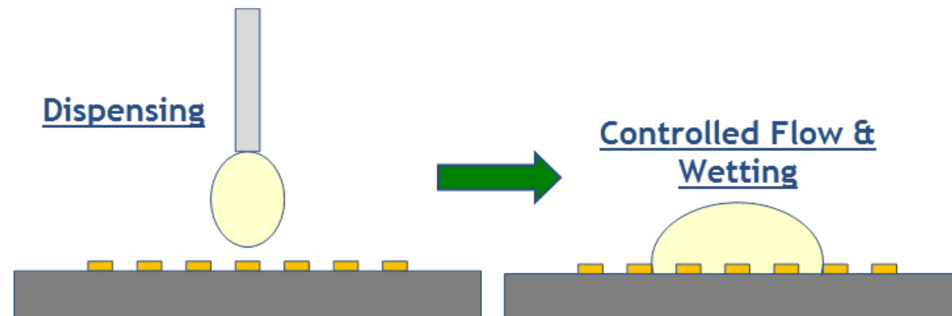
Jet



SmartStream™ NanoShot™

Speedline

Assembly Equipment

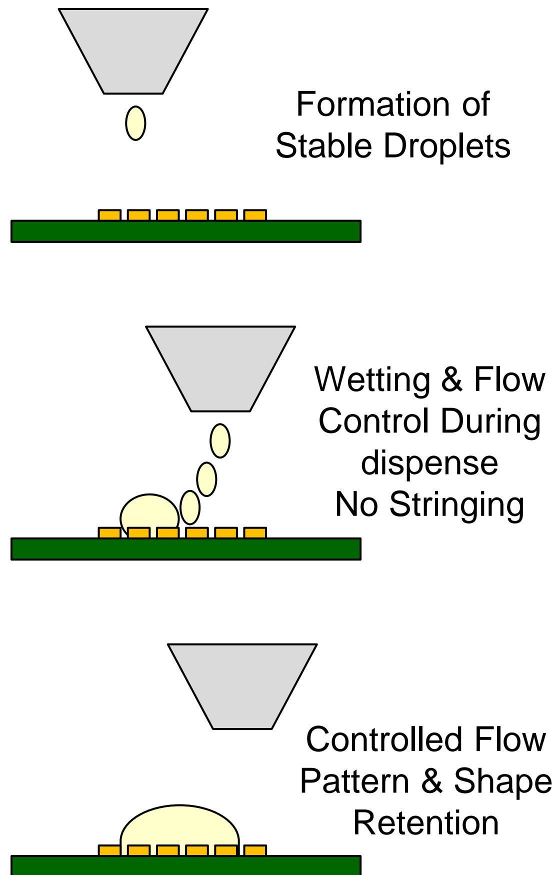


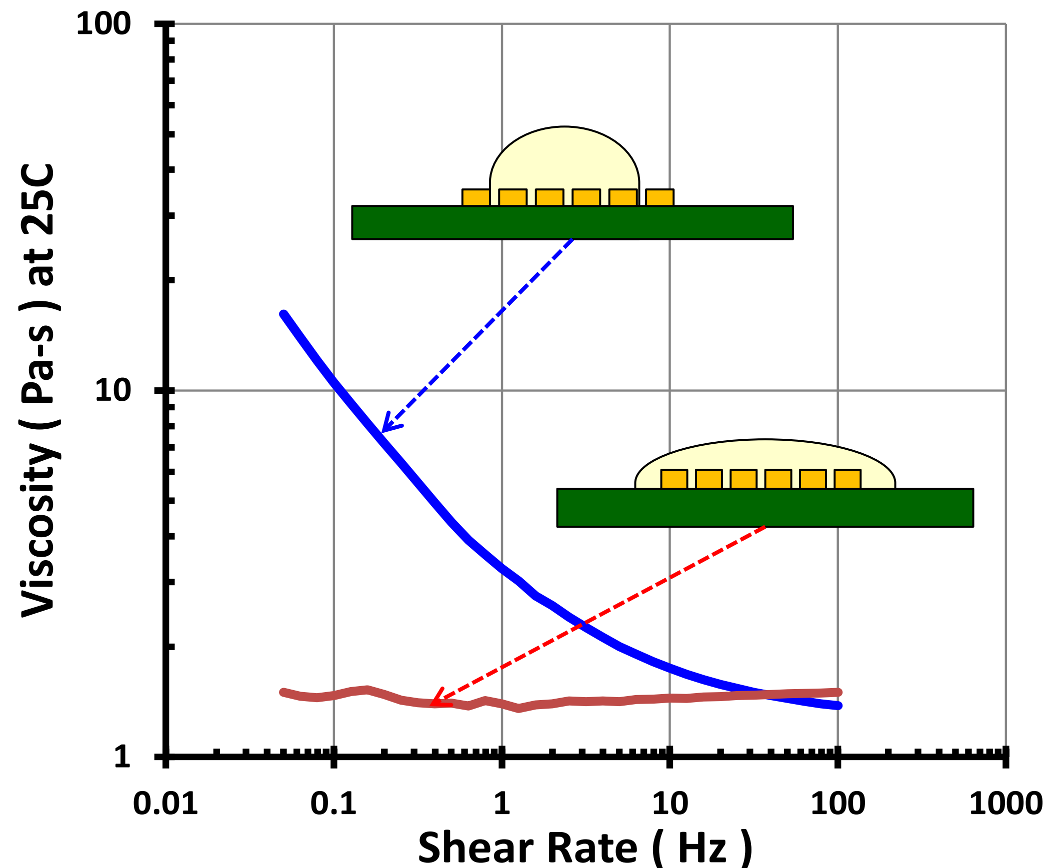
The 65th Electronic Components and Technology Conference

kester

Reology & Dispensing Behavior

- Both fluids jet dispensable but fluid with shear thinning behavior meets patterning & post dispense flow control CTQs





ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Properties of OSCA-R Materials

- Comparison of OSCA-R properties
  - Rheology, viscosity, flow properties related to dispensing and flow during die placement

Property (method)	Units	A	B	C	D
Filler %	Wt%	40	55	0	40
Filler Size	micron	0.5	0.5		5
Tg (a)	°C	159	125	116	125
CTE-1 (a)	ppm/K	46	36	68	49
CTE-2 (a)	ppm/K	138	117	212	163
ΔH (b)	J/g	235	165	348	212
T-onset (b)	°C	129	118	160	157
T-peak (b)	°C	197	162	204	203
Viscosity(c)	**Pa-s**	**49**	**26**	**2.6**	**6.8**
Viscosity(d)	**Pa-s**	**14**	**40**	**2.6**	**6.7**
STI (e)	**Ratio**	**3.5**	**0.5**	**1.0**	**1.1**
Yield Stress (f)	**Pa**	**2**	**0**	**0**	**0**
Temperature Thinning (g)	**Kelvin**	**2200**	**7300**	**5000**	**6900**

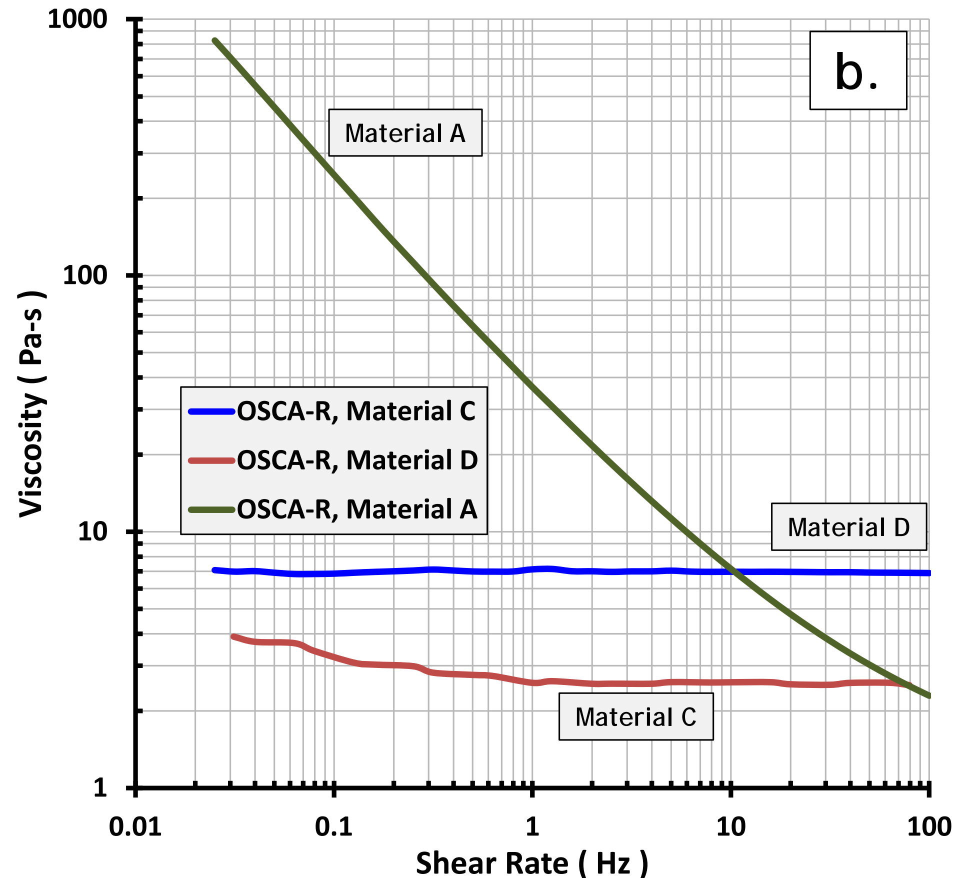
Flow Properties

ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Reology & Dispensing Behavior

- All three materials are jet dispensable
  - Material C, is near Newtonian and continues to flow after dispense
  - Material D, higher in viscosity but also Newtonian and flows after dispense
  - Material A, with shear thinning behavior and a yield stress retains shape after dispense but will thin during die placement

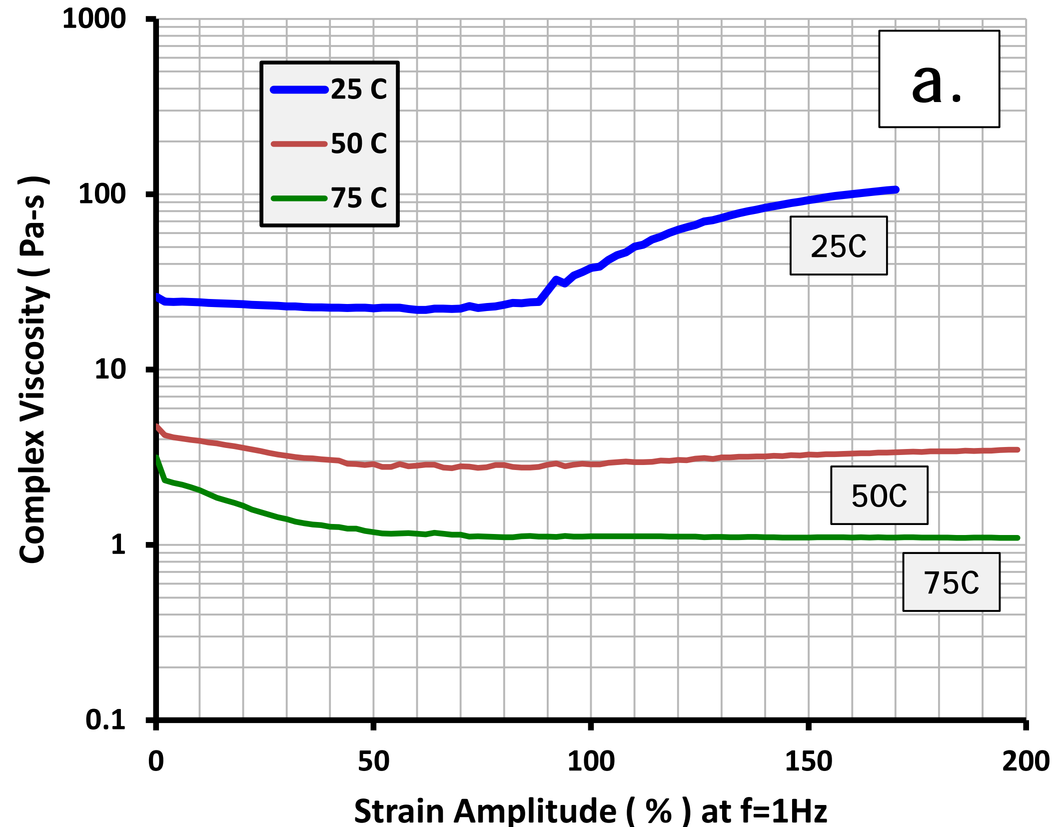


ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Rheology & Dispensing Behavior

- Highly filled materials can exhibit shear thickening behavior
  - Thickening under shear strain leads to poor jet dispensability
  - Material showed excessive stringing at ambient temperature
  - Increasing the jet dispense nozzle to 75C enabled jet dispensability

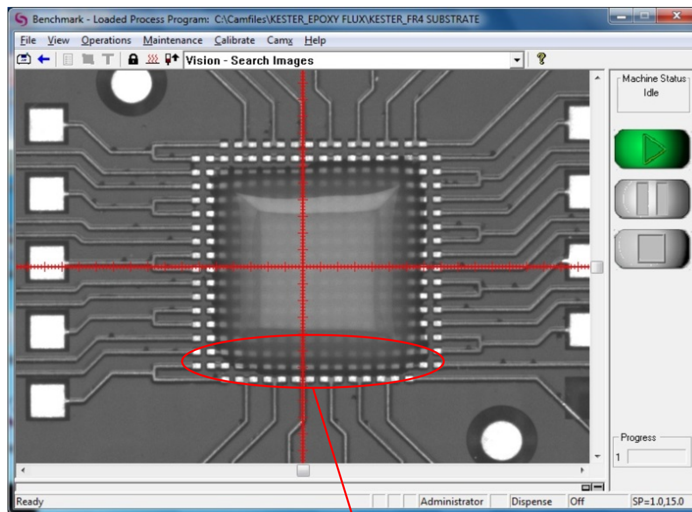


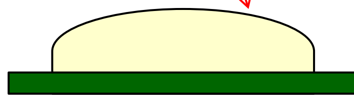
ECTC 2015 The 65th Electronic Components and Technology Conference

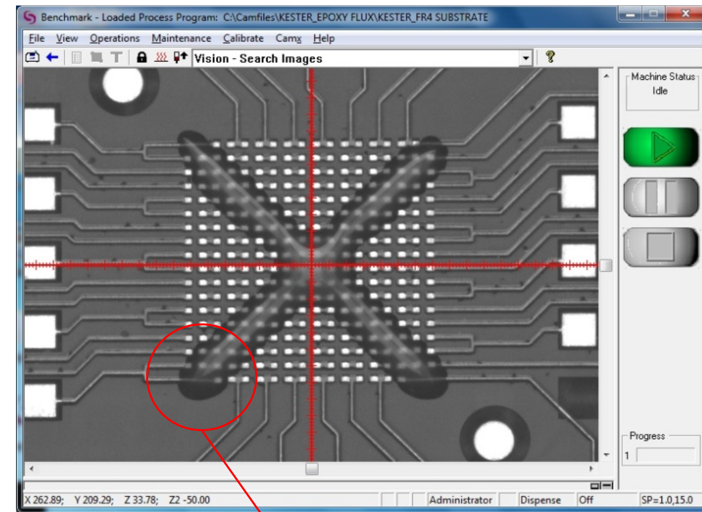
kester

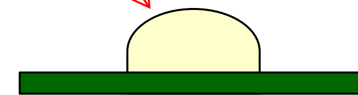
Jet Dispensing Trials; OSCA-R Materials

- OSCA-R formulation jet dispense performance
  - Rheology enables dispense pattern stability
  - No flow or bleeding after patterning, will shear thin during die placement
  - Rheology also enables tall z-profile of deposition









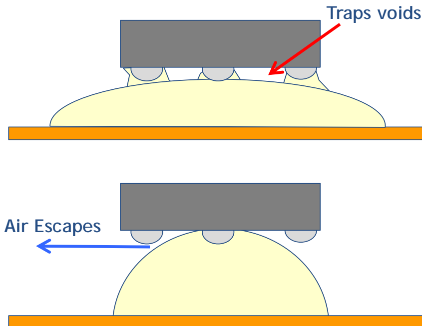
ECTC 2015 The 65th Electronic Components and Technology Conference

kester

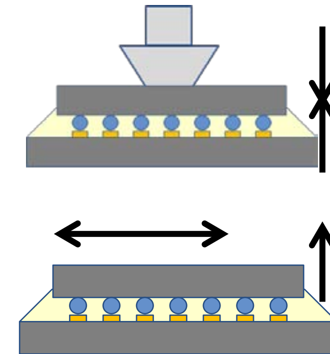
OSCA-R Rheology Design - Die Placement

- OSCA-R materials designed to overcome key placement challenges

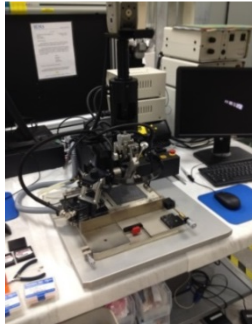
Placement Voids



Rebound (viscoelasticity)



Pick & Place



Finetech

Kester
R&D Equipment

Juki

Kester
Pilot Equipment
KE 1080 (±50 micron)

Universal

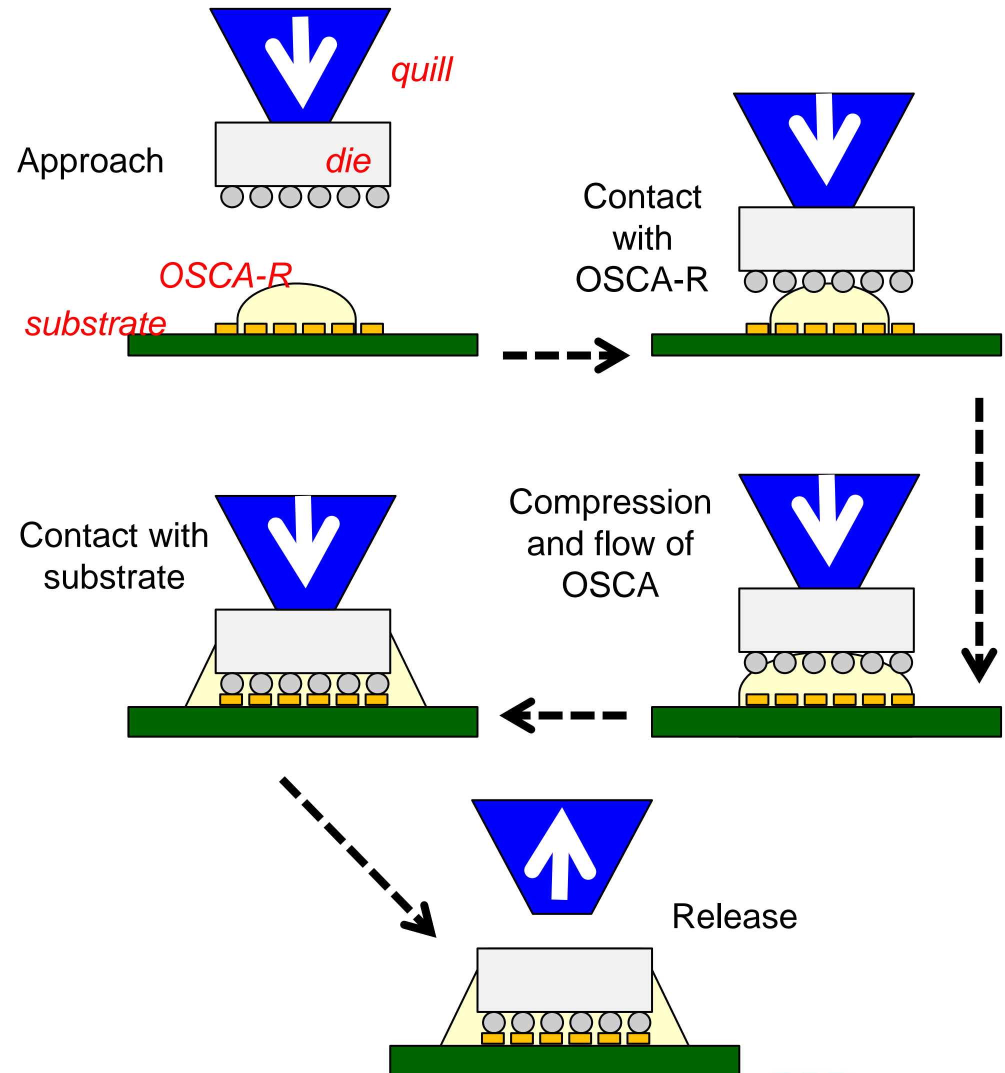
Production Equipment
Advantis (25-50um)
Genesis SC (± 5-10um)

ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Considerations During Die Placement

- Material Factors
  - Rheology
  - Filler loading
- Process Factors
  - Temperature
  - Placement Speed
  - Peak Force
  - Dwell Time
- Component Factors
  - Die Area
  - Bump Pitch
  - Bump Configuration
  - Substrate Topology



ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Experimental Compression Force Measurement

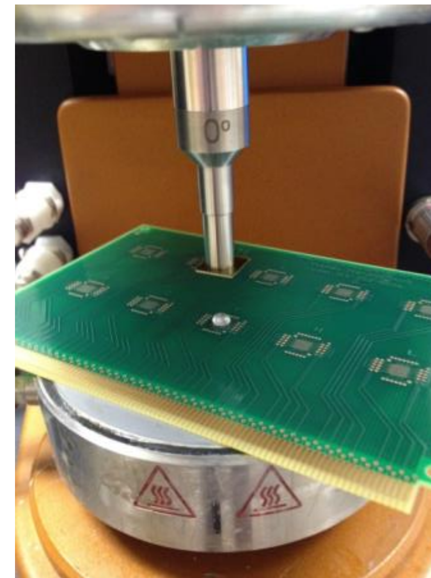
- Studies of compression forces using normal force transducer and a rheometer
  - Identify scaling behaviors and critical material properties

Parallel Plate Configuration

Fundamental Work

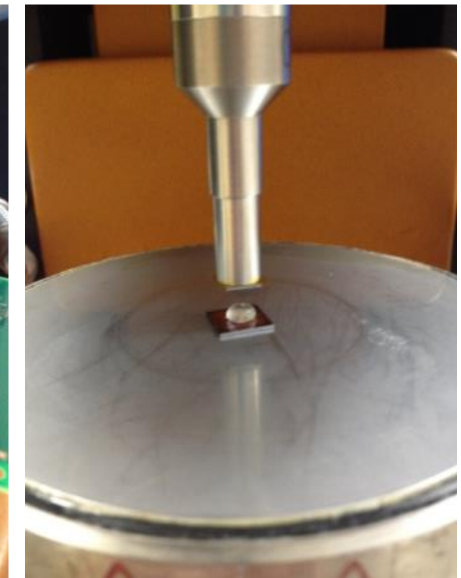
Die on Top

Explore Effects of Die Size, Bump Pitch, Bump Size, Configuration



Die & Substrate

Effects of Both Die and Substrate



Use of Silicon-Silicon Test Vehicles

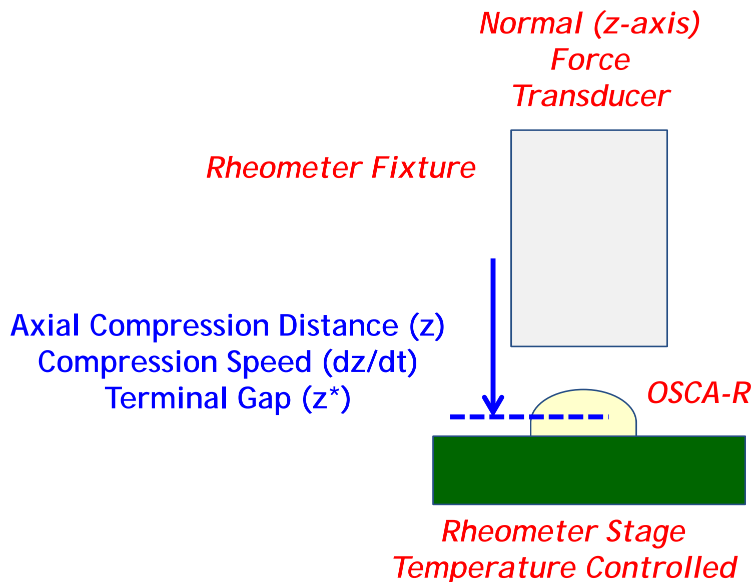
Effects on Inorganic Substrates

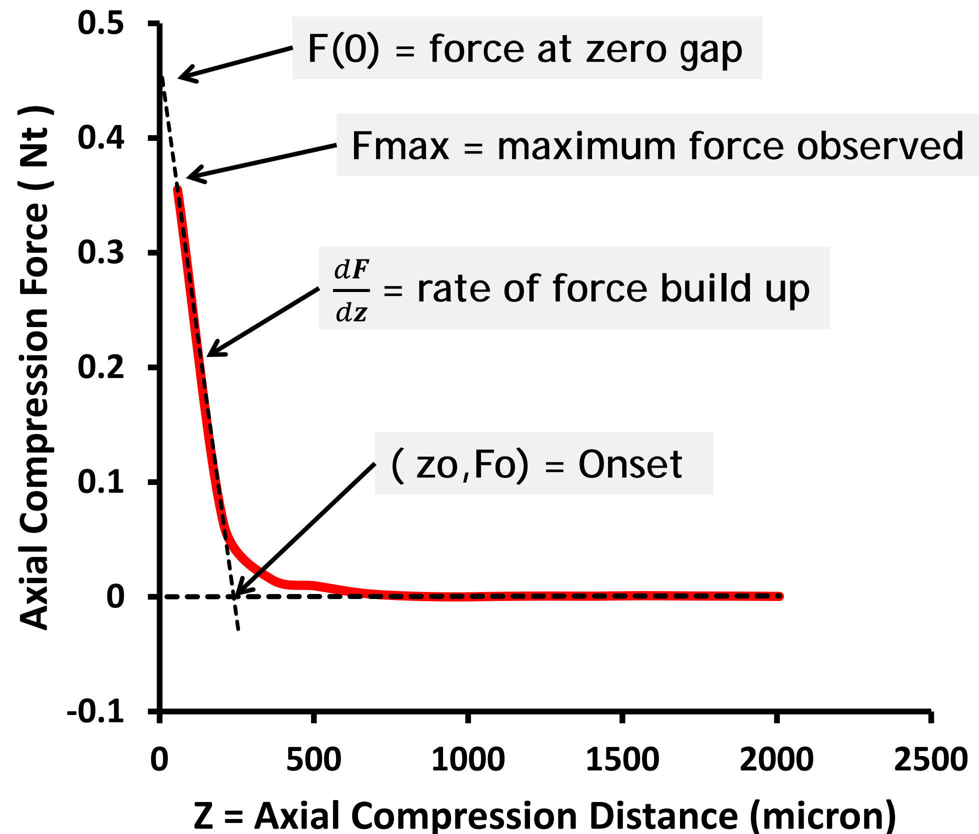
ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Analysis of Compression Force Curves

- Force versus distance measured during compression experiments and analyzed for several responses





ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Process and Material Variables Explored

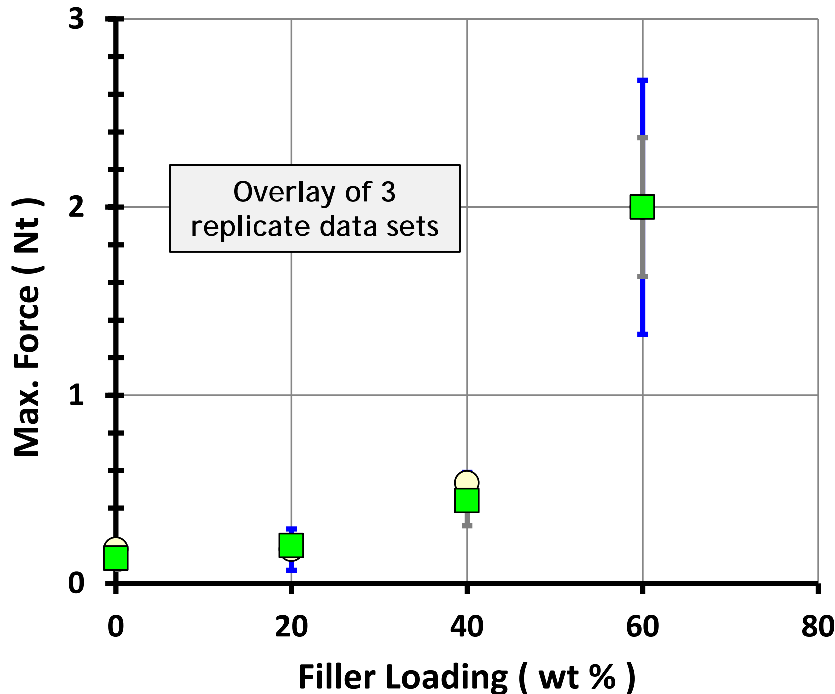
Property	Symbol	Range
Compression Speed	U = dZ/dt	5 - 500 microns/sec
Terminal Gap	Z*	5 to 250 microns
Fixture Area	Ax	55 to 1200 mm^2
Stage Temperature	T	10 to 100C
Filler Content	Wt%	0 to 80wt%
Filler Type & Shape		Silica, High TC Sphere, Plate, Rod
Filer Size	< d >	0.5 to 20 micron
Shear Thinning Index	STI	0.2 to 5
Temperature Thinning	Ea	1000 to 8000 Kelvin

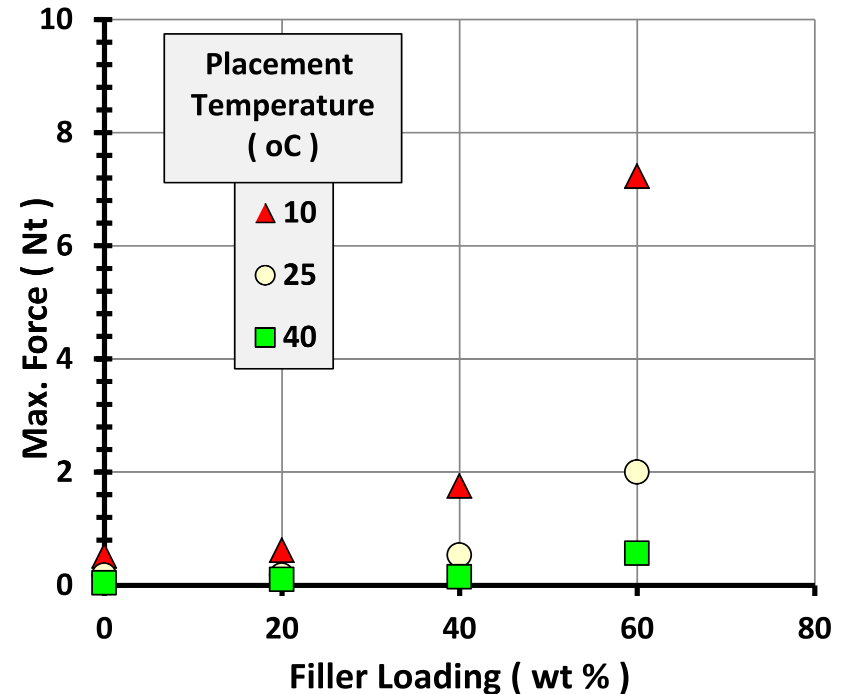
Process

Material (rheology)

Compressional Force Response to Terminal Gap & Placement Speed

- Force increases with filler loading and decreases with increasing temperature
  - Implies that compression forces can be moderated for highly filled systems using mild stage heating (40 to 50C)



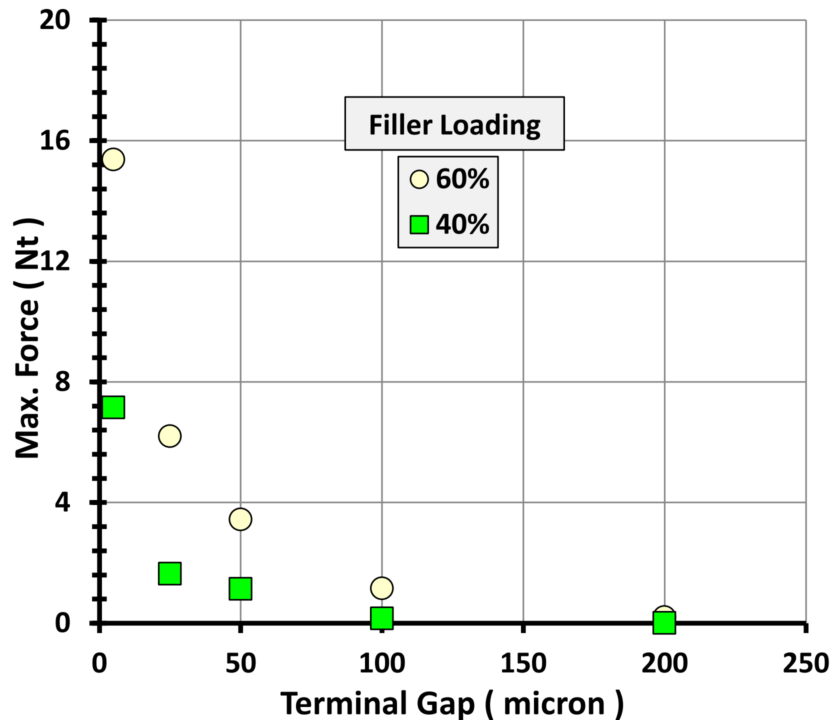


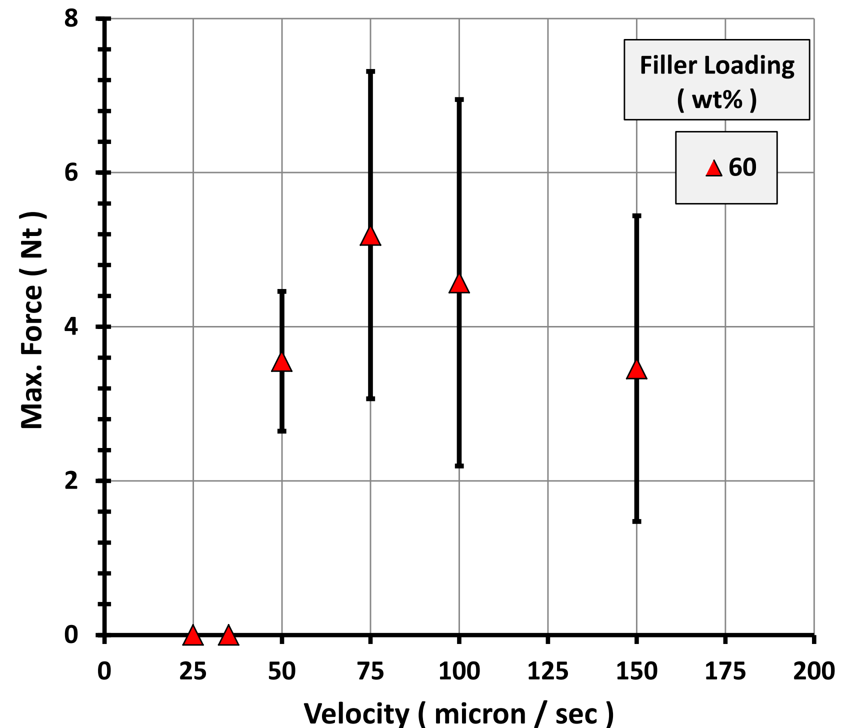
ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Compressional Force Response to Terminal Gap & Placement Speed

- Force increases as the terminal gap decreases and as placement speed increases
  - Implies placement conditions need to be adjusted for small features



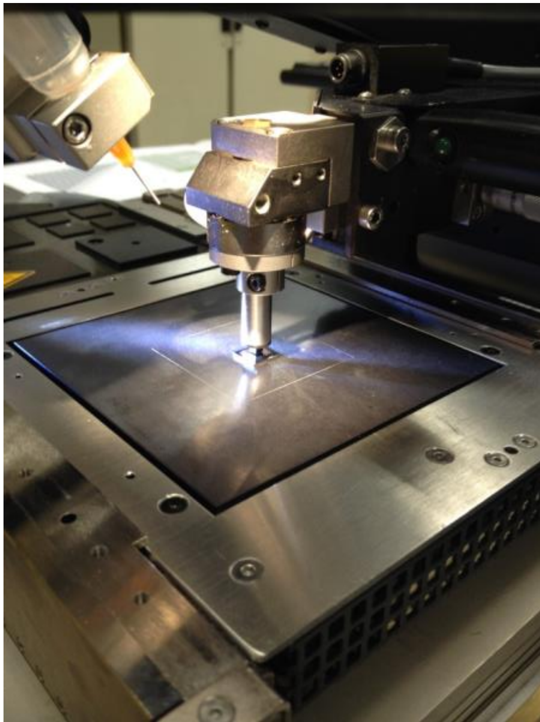


ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Design of Placement Process

- Placement process studies conducted using Finetech die bonder system
  - Multi step placement procedure ensures die contact and alignment



Approach Step 1

Approach Step 2 + Contact

Apply Force

Hold

Retract Placement Tool

High Speed

Change Over Distance 0.5 to 2 mm

Low Speed 0.5 to 3mm/sec

High Speed

Force 1 to 15 Nt (10x10 mm die)

Dwell 0.05 to 0.2 Sec

Depends on Deposit Profile & Die Size / Shape

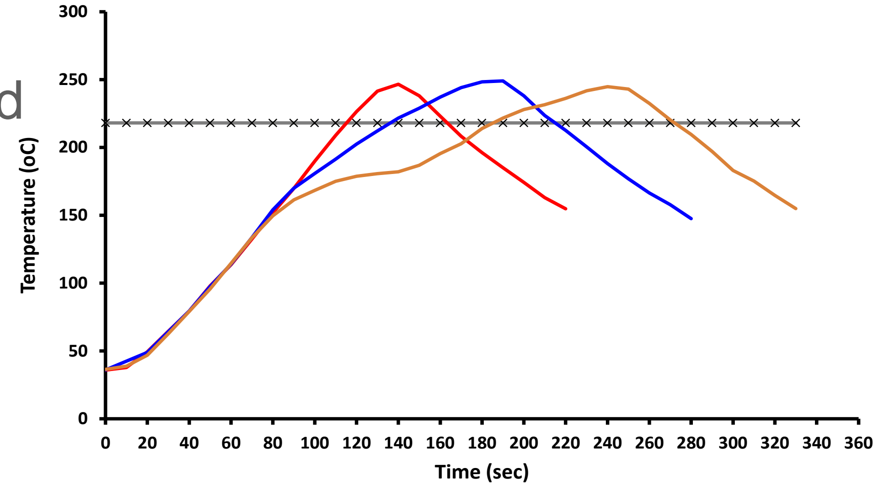
Make Contact with Substrate Drive to Target z-position

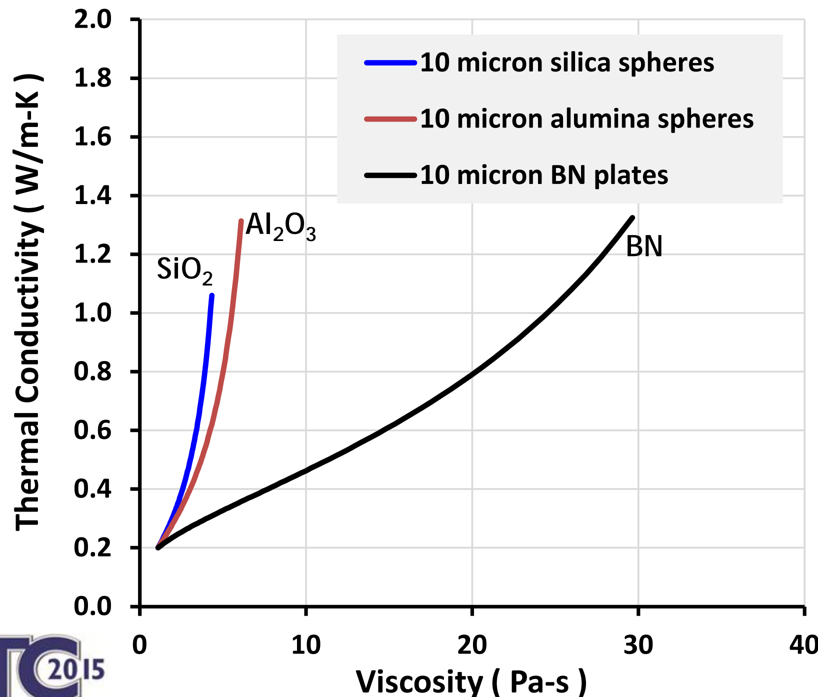
ECTC 2015 The 65th Electronic Components and Technology Conference

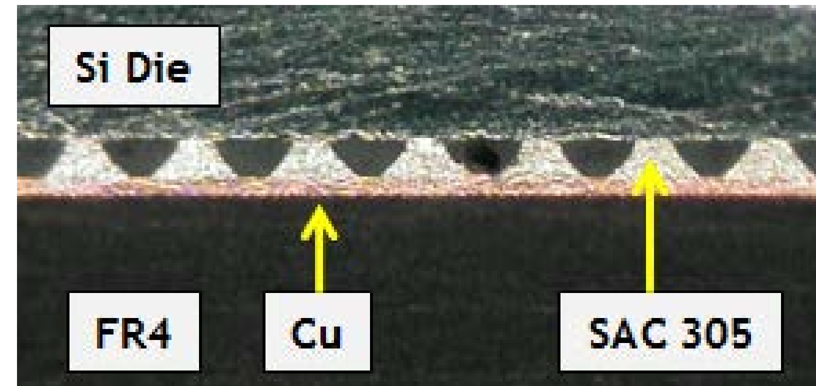
kester

Design of High TC OSCA-R Materials

- High thermal conductivity OSCA-R
  - High filler loading
  - Balance rheology for dispensing and device placement
  - Design of cure kinetics for reflow processing







ECTC 2015 The 65th Electronic Components and Technology Conference

kester

Summary & Conclusions

- One Step Chip Attach (OSCA-R) materials can be used to eliminate steps in flip chip assembly processing using convection or conduction mass reflow
  - Reduced complexity of manufacturing
  - Higher throughput with use existing processing equipment
- Approaches to overcoming the key technical challenges presented
  - Systematic studies of rheology and filler effects on used to design OSCA-R materials for dispensing and successful assembly
  - Die and substrate size, configuration and type are integral considerations for OSCA-R materials and process
- Process integration is key to enabling OSCA-R materials
  - Chemistry matched to desired reflow processing
  - Rheology adjusted for dispensing and die placement process

ECTC 2015
The 65th Electronic Components and Technology Conference

kester

Thank you for your attention

Questions?

- **Acknowledgements**
  - **Kester Inc.**
    - **David Eichstadt, Maulik Shah, Chris Klimaszewski, Jim Lowe, Kal Chokshi**
  - **ITW Innovation Center**
    - **Marina Litvinsky**
  - **Research Triangle Institute, Research Triangle Park, NC.**
    - **Chris Gregory, Alan Huffman**
  - **TA-nstruments**
    - **Gregory Kamykowski PhD, Kushal Modi**
  - **Finetech**
    - **Neil O'Brian, Adrienne Gerard, Wade Gay**
  - **Sonoscan**
    - **Michelle Forbes**

ECTC 2015 The 65th Electronic Components and Technology Conference

kester