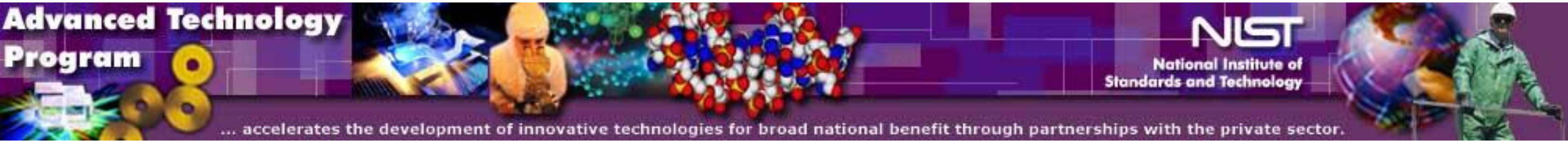
BGA Package Underfilm for Autoplacement

Jan Danvir
Tom Klosowiak

NIST-ATP Acknowledgment



Project Brief

Microelectronics Manufacturing Infrastructure (October 1998)

Wafer-Scale Applied Reworkable Fluxing Underfill for Direct Chip Attach

Develop new materials and technology needed to allow existing integrated-circuit fabrication facilities using conventional surface mount technology to handle new "direct chip attach" components, enabling more efficient production of these high-performance devices.

Sponsor: Motorola, Inc.
1301 East Algonquin Road
Schaumburg, IL 60196
• Project Performance Period: 4/9/1999 - 10/8/2003

Principal Investigator
Janice Danvir

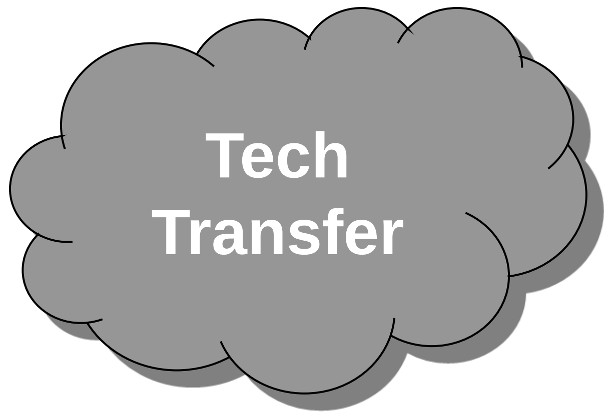
Active Project Participants
o Auburn University (Auburn, AL)
o Loctite Corporation (Rocky Hill, CT)

ATP Project Manager
Francis Barros, (301) 975-2617
francis.barros@nist.gov

Inserted from <http://jazz.nist.gov/atpcf/prjbriefs/prjbrief.cfm?ProjectNumber=98-06-0008>

The Development / Transfer Process

Motorola Labs
- Gap Assessment
- Benchmarking
- Technology Development



Business
- Validation
- Ramp to Production

BGA/CSP Package Risk

- Flip Chip
  - Primary concern is CTE mismatch
    - Mitigate difference between silicon and laminate
    - Thermal cycling
    - Full, void-free coverage

- Packages
  - Primary concerns are drop and bend
    - Mechanical Reinforcement
    - Full coverage not required

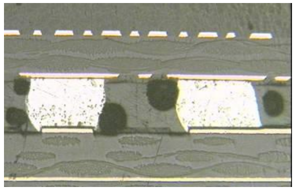
The Manufacturability Issues

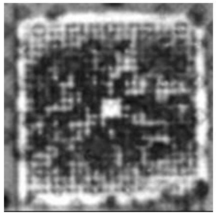
- Capillary dispense underfill is a difficult process for an SMT factory
  - Extra Equipment / Floor Space
  - Cycle Time
  - Material Storage
  - Material Handling
  - Clean-up
  - Rework

Underfill Alternatives

- *No underfill still preferred*
  - ***Design solutions to mitigate bend***

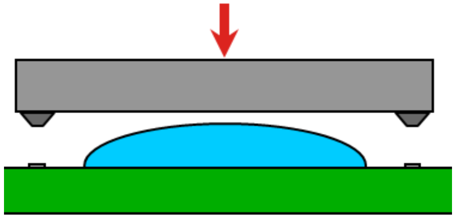
- Alternatives Circa 2000
  - **Post –reflow capillary flow**
    - **Applied flip chip underfills as immediate solution**
  - **Pre-reflow corner dots**
    - **Easier dispensing, cure in reflow (no cure oven)**
    - **Lower material usage**
  - **Pre-apply underfill to package**
    - **Film or B-stage liquid**
    - **Supplier-dependent**





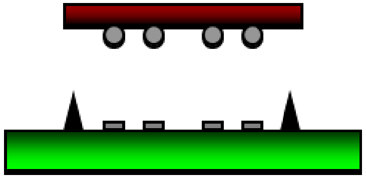
The Alternatives

- Present (eg: Henkel*)



No-Flow Underfill

Epoxy Flux (dipped)



Corner Bond

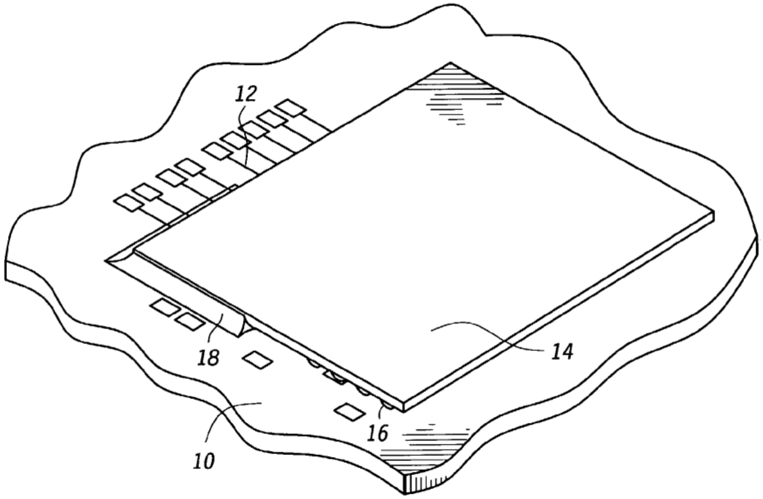
Post-Reflow Edge Bond

*Courtesy of Dr. Brian Tolleno,Director Technical Service, Henkel

The Solution

- Underfill that is compatible with SMT processing
  - Solid film underfill for pick and place
  - Fits in typical process with no additional equipment / floor space requirements
  - Leverages best expertise of SMT process engineers

Auto-Placed Underfilm



Auto-Placed Underfilm Development

1. Establish feasibility

2. Establish manufacturability
   - Consider mechanism
   - Consider and control potential variables
   - Address supply logistics
   - Remove objections and drive implementation

3. Establish reliability
   - Packaging mechanics must be sound
   - Testing as confirmation

Manufacturability Considerations

Placement

- Self-supporting film
- Picking from tape
- Placement accuracy
- Staying in place

Reflow

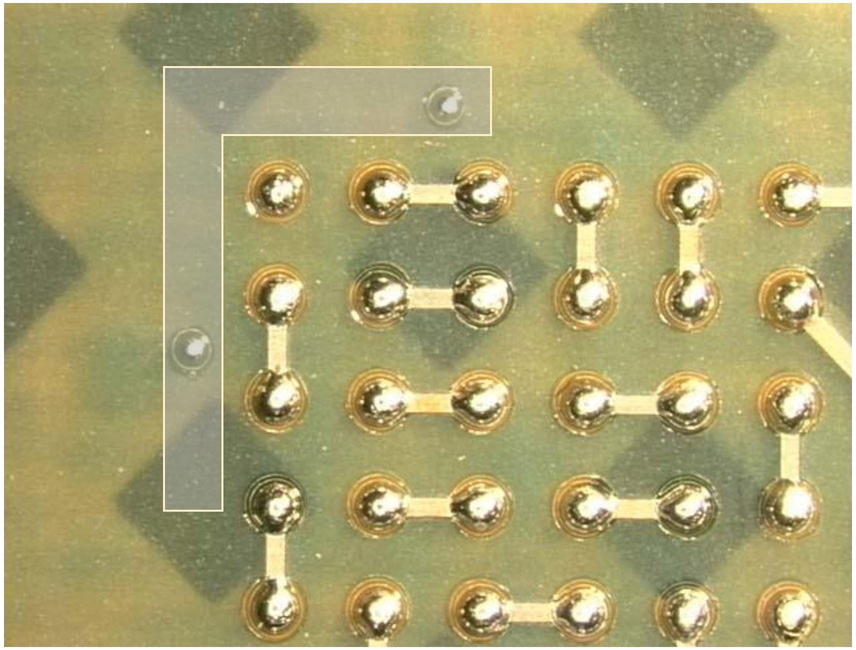
- Melting point / range of material
- Wetting board and package substrate
- Possible interference with solder joint formation, self-centering

Solidify

- Fillet
- Adhesion
- Reworkability

Tack pads

- Must stay in place
  - Tacky film surface would hamper picking
  - Small dots of paste hold piece in place



Dimensional Tolerances - Thickness

Too Thin

Film is not self-supporting

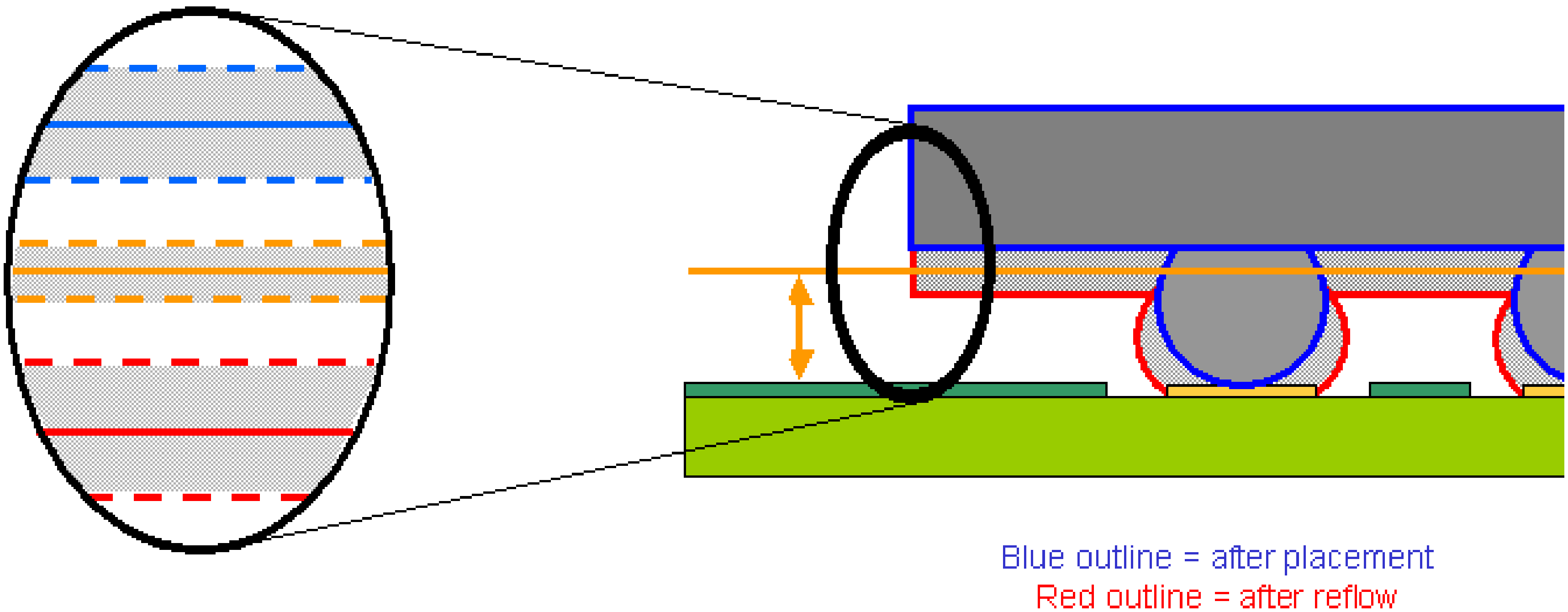
Insufficient material to form a fillet

Too Thick

Bumps cannot contact paste

Lifts package upon melt

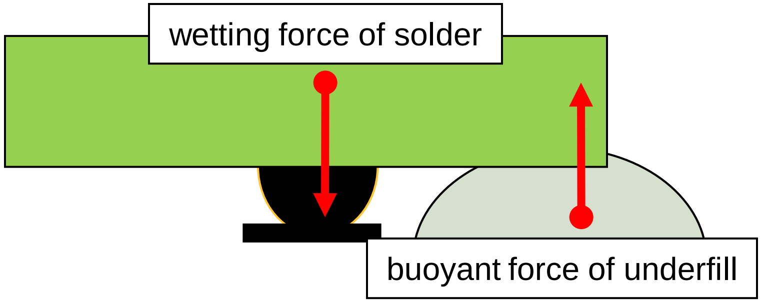
Dimensional Tolerances - Thickness



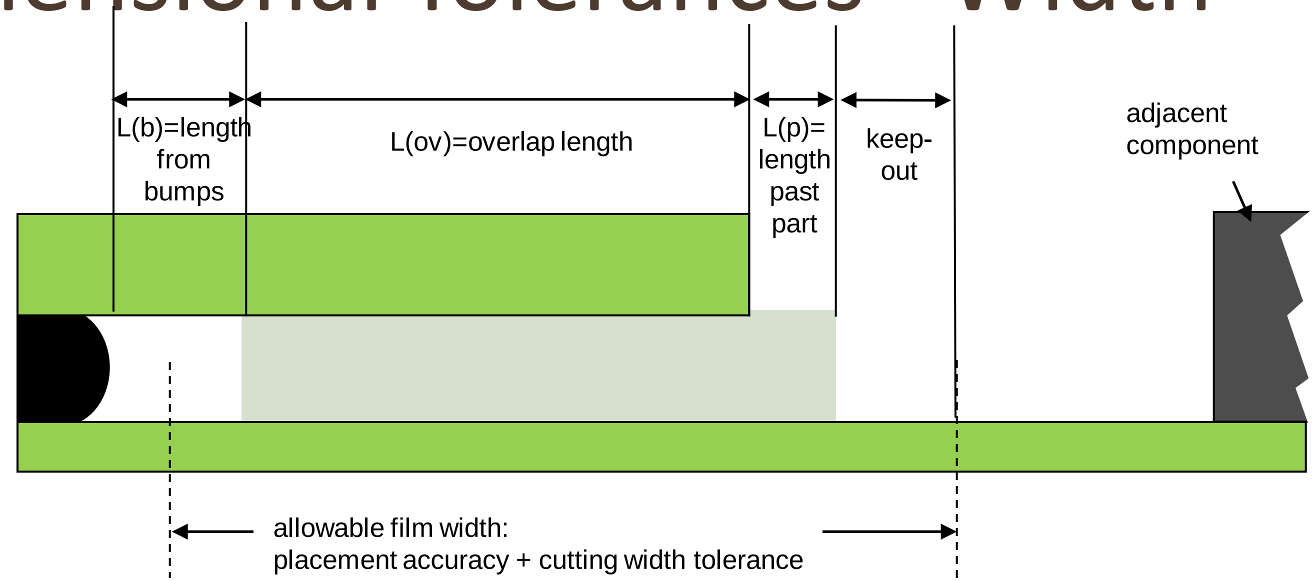
- Most influential on fillet volume
- Large variation in as-received material, +/- 20%

Thickness Conclusions

- Minimum thickness needed for stiffness
- Excess material forms fillet
- Thickness variation found to not impact manufacturability
  - **Solder wetting force > Upward force of film**



Dimensional Tolerances - Width

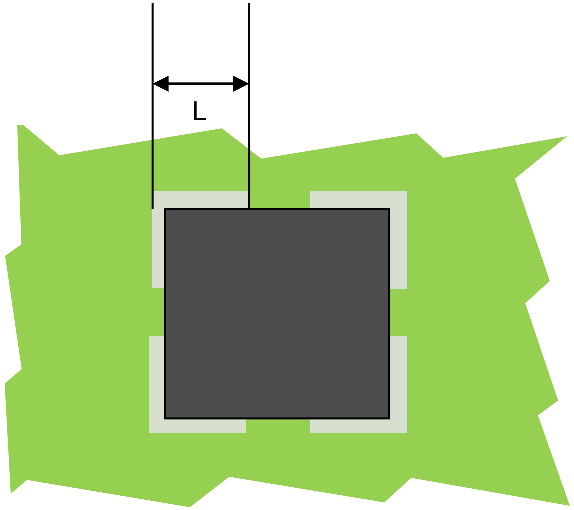


- Package clearance and keep-out
- Placement tolerance
- Cutting
  - Method, tooling
  - Material utilization
  - Process efficiency

Width Conclusions

- Modeling shows strength sensitive to width
  - Wide for reliability, narrow for layout
  - Target best possible tolerance
    - Excess material interferes with adjacent parts
    - Film melt encroaching on solder found not to interfere with joint formation – *paste dependent*
- Laser cutting
  - Tolerance < +/- 1 mil
  - Narrower widths possible
  - Better material utilization
  - No tooling

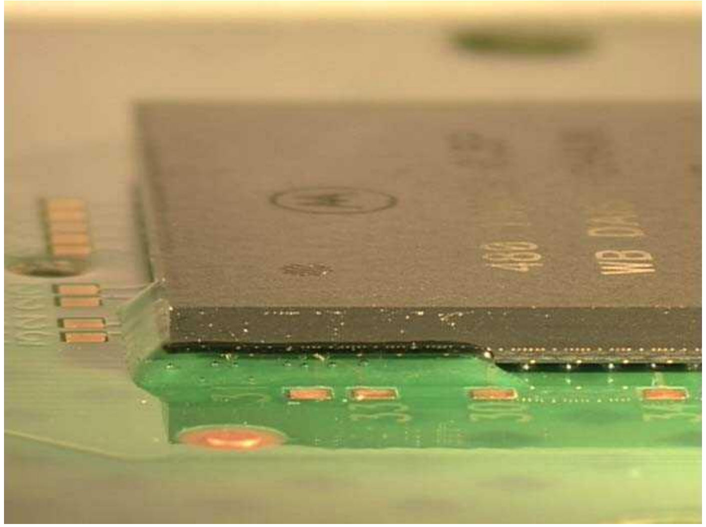
Dimensional Tolerances - Length



- Modeling shows strength least sensitive to length
- Allow gap for flux escape

Reflow

- Softening begins at 160^{o}C
  - Flows and bonds
    - To PCB - multiple solder masks tested
    - To package as collapse occurs
  - Flux protects solder joints



Manufacturability Summary

- Underfill film pieces can be supplied with correct dimensional tolerances
- Pieces can be loaded in tape and reel packaging
- Pieces can be picked and placed using automated SMT equipment
- Underfill melts, bonds and solidifies in reflow
- Underfill of choice for mobile devices

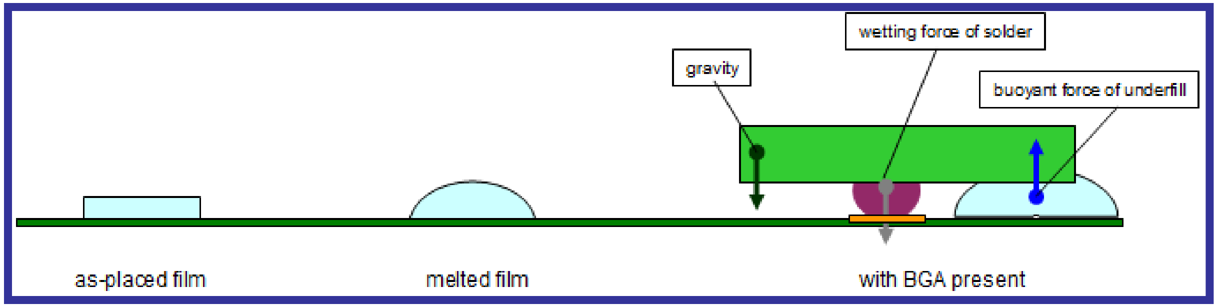
Package mechanics

- During assembly process
- During thermocycling
  - Vertical
  - Horizontal – shear and bending
- During mechanical loading
  - Static – pressing keys
  - Dynamic
    - impact /drop – directions
    - vibrations

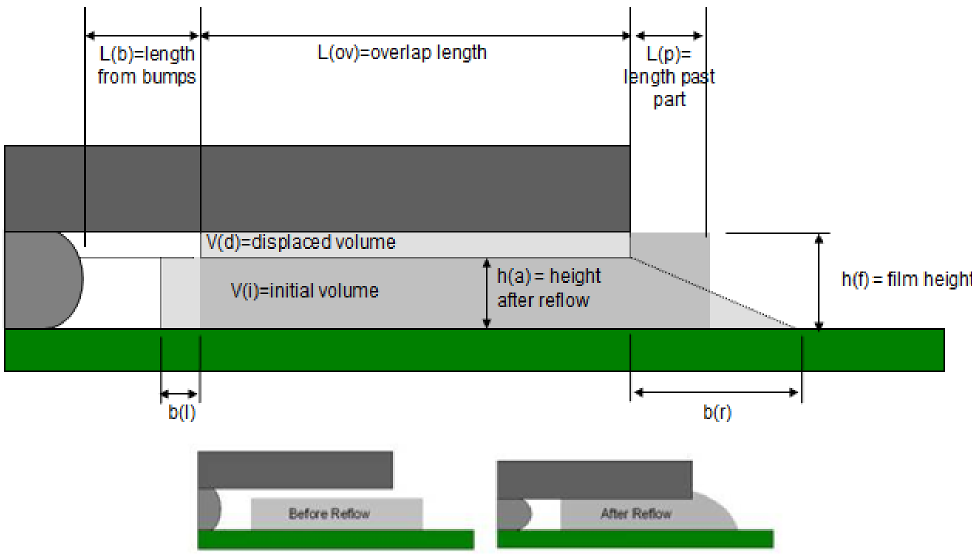
Package Mechanics

- During assembly process

All vectors shown symbolize forces acting on the package

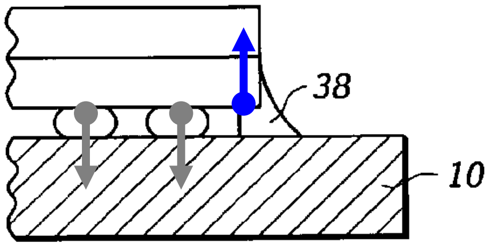


- Solder solidifies as underfilm shrinks (higher CTE)
- Underfilm pulls package down more than solder
  - Solder in compression
  - Underfilm in tension, adhesion a concern
  - Area of bumps : area of underfill
- Time behavior of underfilm
  - Stress dissipates over time (creep)



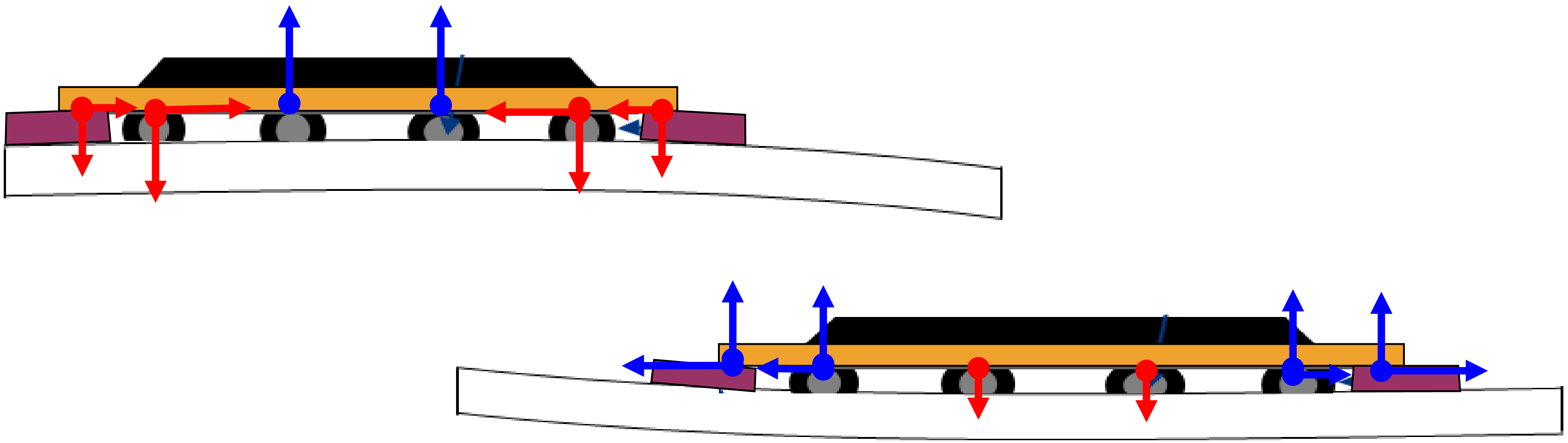
Package Mechanics

- During thermal cycling – heating / cooling from reference temperature.
  - Vertical plane
    - Underfilm expands more than solder
      - Driving force: CTE mismatch between solder and underfill; for example in the picture: solder in tension due to CTE mismatch ($CTE_{solder}=21*10^{-6}/^{o}C$; $CTE_{underfilm}=153*10^{-6}/^{o}C$)
      - Modulus ($E_{solder}=31GPa$; $E_{underfilm}=8MPa$)
      - Proportion of relative areas
      - Reaches equilibrium below delamination or cohesive failure for typical packages

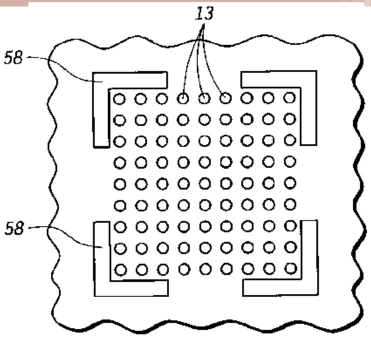


Package Mechanics

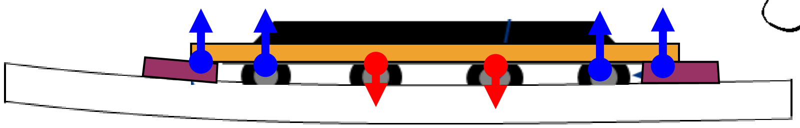
- During thermal cycling – heating / cooling from reference temperature.
  - Horizontal plane
    - Driving force – CTE mismatch between package and substrate. Package and substrate bows.
      - This may contribute to additional vertical stresses
      - Shear stresses greatest at corner bumps



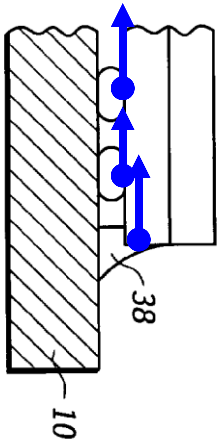
Package Mechanics



- During mechanical loading (static, dynamic)

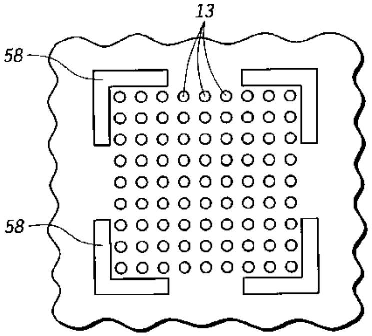


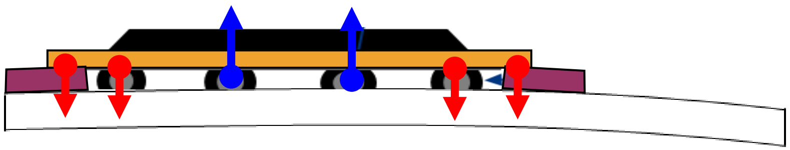
  - Static
    - Pressing keys – resulting in bending substrate
  - Dynamic
    - Drop in plane of substrate – shear stress in attachment
      - Inertia of package a decisive factor
      - Underfill takes part of the load – relieves solder joints

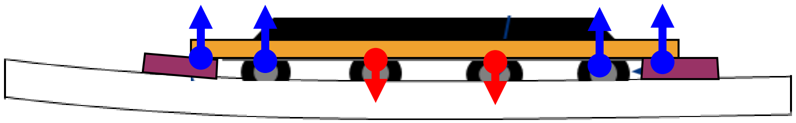


Package Mechanics

- Dynamic (continued)
  - Drop in plane perpendicular to plane of the substrate – resulting in bending of the substrate
    - Important are:
      - Inertia of substrate and components
      - Stiffness and supports of substrate
      - Attachment of component to substrate – in that solder joints and underfill joints

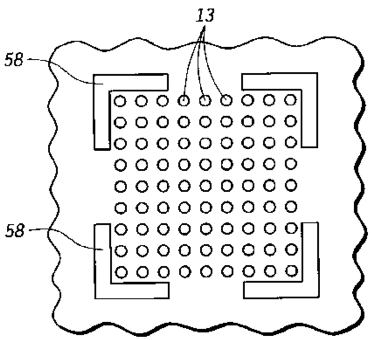


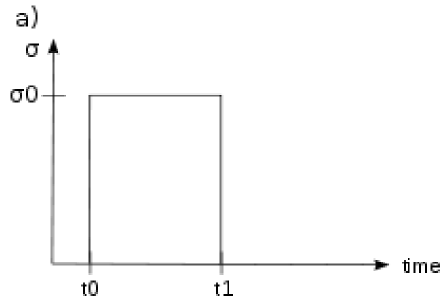


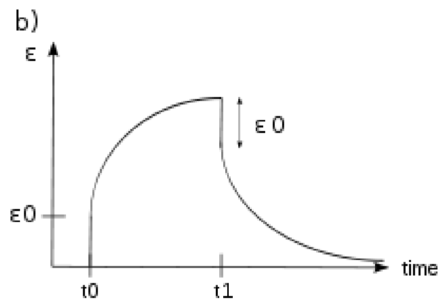


Package Mechanics

- Deformation, displacement and forces transferred to package
  - Through solder bumps and underfill / underfilm
  - Usually bumps and underfill are in complex state of stress – tension or compression and shear
  - In most cases (except pure vertical thermocycling) underfill reduces stress in solder bumps

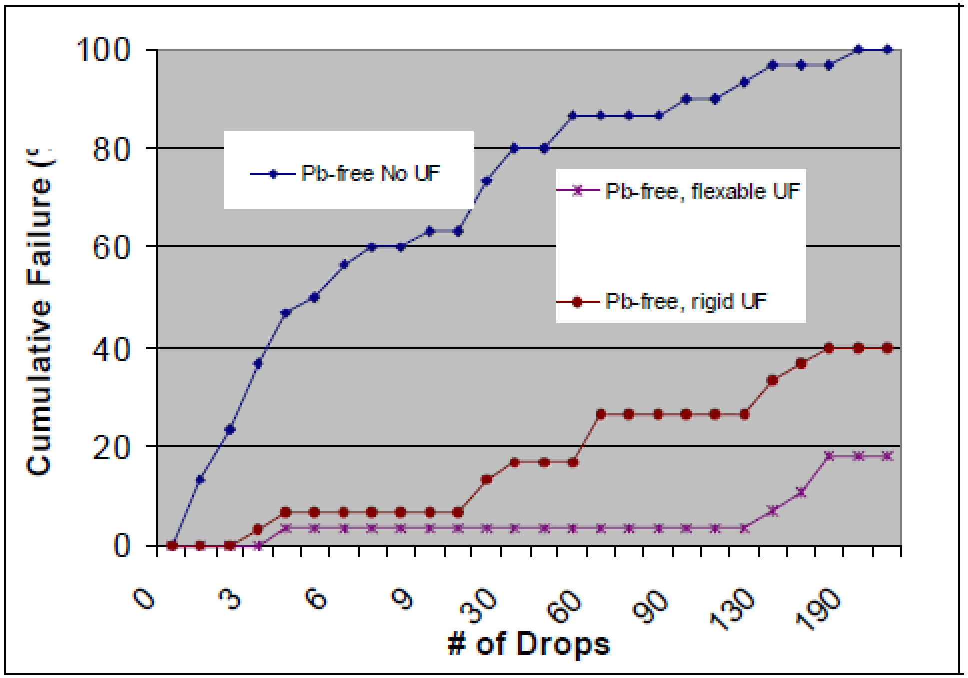






- Modulus of underfill is strain rate dependent (advantage of this viscoelastic behavior)
  - Stiffer in high ε rate (drop, fast vibrations)
  - Softer in slow ε rates (static loads, slow vibrations)

Performance example from Henkel Corporation



ADHESIVES FOR INCREASED RELIABILITY IN MEDICAL DEVICES

Brian Toleno, Ph.D. and Jeff Bowin
Henkel Corporation
Irvine, CA, USA
brian.toleno@us.henkel.com
jeff.bowin@us.henkel.com

Material Properties

Alltemated RP-113178 Raw Material Data Sheet

Feature: Film resin **Properties**	**Test Method**	**English** **Values Units**	**S.I.** **Values Units**
Physical [1]			
Shore Hardness	ASTM D 2240	95 A	95 A
Mechanical [2]			
Tensile Modulus 50% elongation 100% elongation 300% elongation	ASTM D 412	 1200 psi 1400 psi 3100 psi	 8.3 MPa 9.7 MPa 21.4 MPa
Ultimate Elongation	ASTM D 412	450 %	450 %
Ultimate Tensile Strength	ASTM D 412	5650 psi	38.9 MPa
Elongation Set After Break	ASTM D 412	60 %	60 %
Tear Strength, Die C	ASTM D 624	600 PLI	105 KN/m
Compression Set, Method B 22 hrs @ 25 °C 22 hrs @ 70C	ASTM D 395	 30 % 80 %	 30 % 80 %
Flexural Modulus	ASTM D 790	13,000 psi	89.6 MPa
Thermal			
Vicat Softening Point (120 °C/hr, 9.8N)	ASTM D 1525	177 °F	80.6 °C
Glass Transition Temperature	DSC	5 °F	-15 °C
CLTE, in-flow, -30 to -80 °C	ASTM D 696	85.0 in/in/ °F	153 mm/mm/ °C
Processing Conditions (Typical)			
Melt Temperature		365-378 °F	185-192 °C

1. Typical properties; not to be construed as sales specifications. Fabrication conditions, part design, additives, processing aids, finishing materials, and use conditions can all affect the integrity, performance, and regulatory status of finished goods.
2. Tests conducted on 0.125 inch (3.2 mm) injection molded specimen, unannealed, unless noted.

Package mechanics conclusions

- Package mechanics considerations and analysis lead to better understanding of underfill / underfilm functionality, and interrelation of all important design parameters.
  - It shows that when these parameters are properly chosen the solution described improves attachment strength and robustness

Acknowledgements

- Katherine Devanie
- Guoshu Song
- Jing Qi
- Tony Gallagher
- Lane Brown
- Mike Johnson