SSI Dresden 2011

Interconnects based on metal coated polymer spheres for improved reliability

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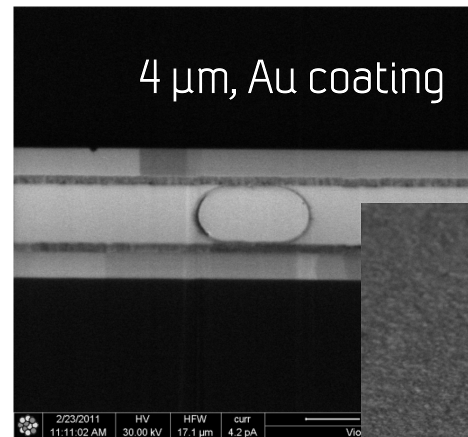
The presented project, ReMi, is sponsored by the BIA program of The Norwegian Research Council

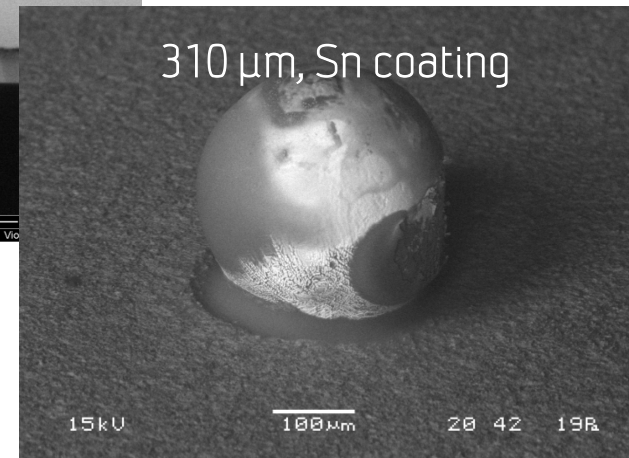
Outline

- Motivation: Reliability challenges in harsh environments
- Basic properties of metal coated polymer spheres

- Isotropic conductive adhesive
- Anisotropic conductive adhesive
- Ball Grid Array assembly
  - With case studies for each
- Outlook and summary



Metal coated polymer spheres. Various sizes for various applications.



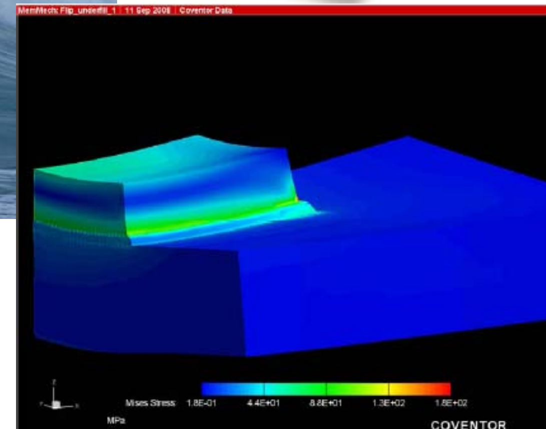
ReMi: Fine Pitch Interconnect of Microelectronics and Microsystems for use in Rough Environments

- Fine pitch
- Harsh environment
  - Thermal cycling
  - Thermal storage
  - Vibrations

- Project duration 2008 – 2012
- Project size ~0.85 MEUR

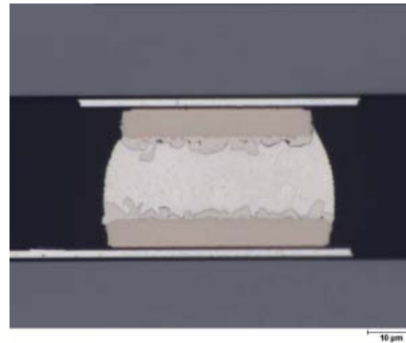
Fine pitch

Harsh environments for offshore applications



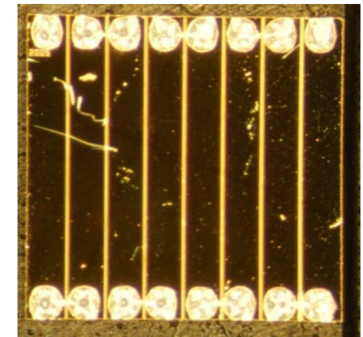
Large stresses during firing of missiles

Challenges with reliability



Brittle IMC formed in a SnAg microbump (Johannessen et al., IEEE Trans. Adv. Packag. 2009)

- Thermal mismatch of substrate, chip, interconnect and fill materials
  - Thermo mechanical stress during cycling can lead to failures
- Brittle intermetallic phases in interconnects
  - Mechanical stress from shocks/vibrations can lead to failures
- Fine pitch
  - Lack of process control can lead to failures

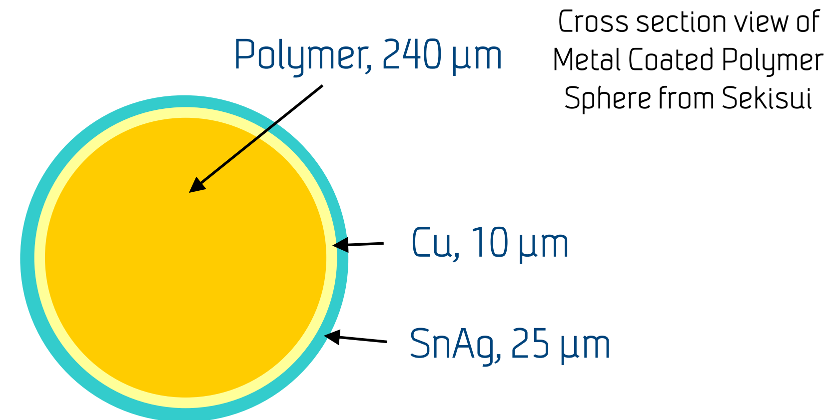


Ag Epoxy dispensed on fine pitch MEMS device

- **How can reliability be improved by introducing metal coated polymer spheres?**

Metal Coated Polymer Spheres (MPS)

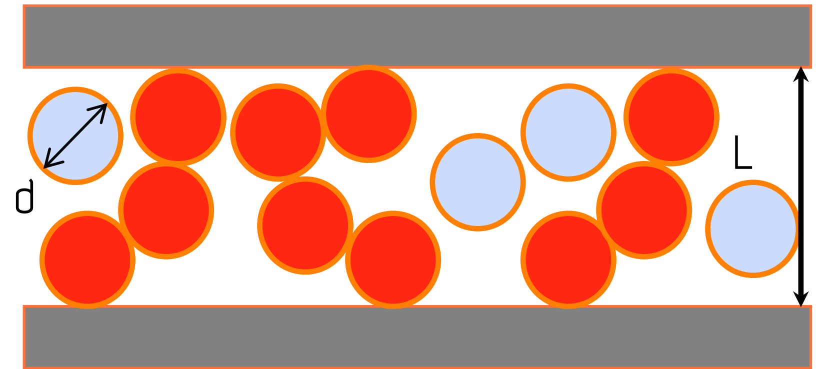
- Polymer core
  - Dimension controllable by Conpart to <2%
    - "Small" 4-30 µm: Mixed into matrixes at certain volume concentrations
    - "Large" 250-800 µm: Positioned as single balls like regular BGA balls
  - Elastic properties controllable by adjusting chemical contents
    - Collapse or stiff
- Metal coating
  - "Small": Ni and Au or Ag (20-80 nm layers)
  - "Large": Cu and Sn (10-25 µm layers)
- Advantages
  - Significantly reduced metal consumption
  - Optimise mechanical properties and electrical conductivity independently
  - Optimise T_g of polymer with respect to matrix
  - Match CTE to that of the matrix
  - Use cure shrinkage to increase particle-particle contact area



Cross section view of Metal Coated Polymer Sphere from Sekisui

Percolation

- Continuous (electrical) network
- Particle to particle interaction
- Strongly dependent on "characteristic length"
  - L/d
- Dependent on "orientation" of particles (non-spherical)

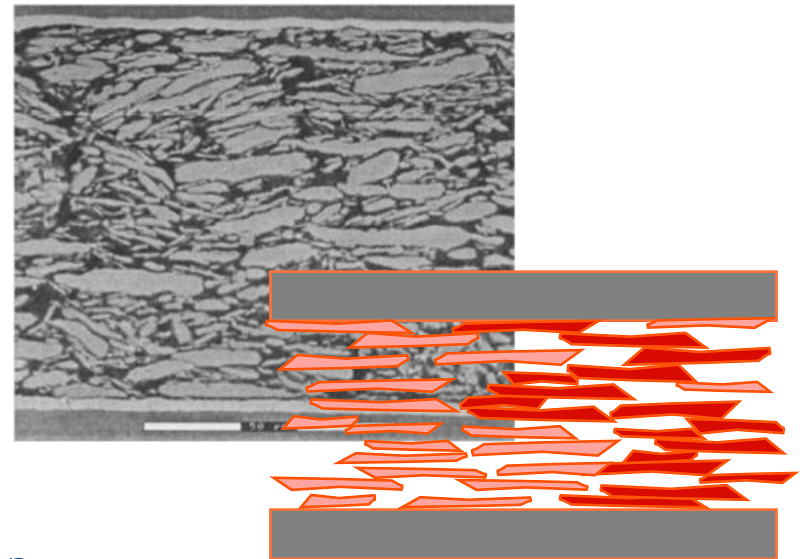


Kristiansen et al., Pan Pacific 2009

Rheology: Handling of adhesive

- Viscosity increases as volume % is increased
  - Lubricants
  - Solvents
- Shear-flow induced orientation

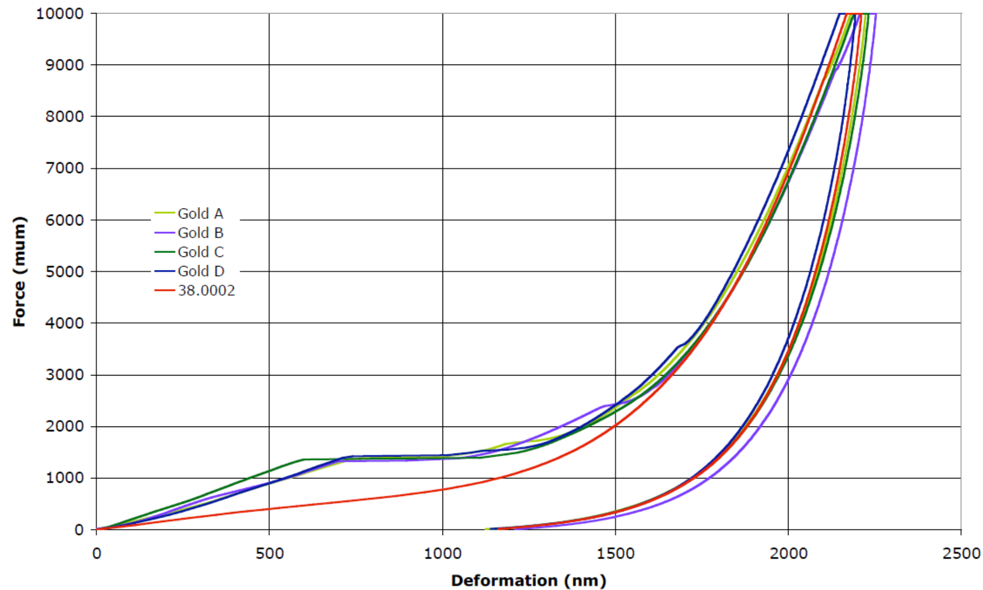
- MPS: Larger volume % possible and no orientation

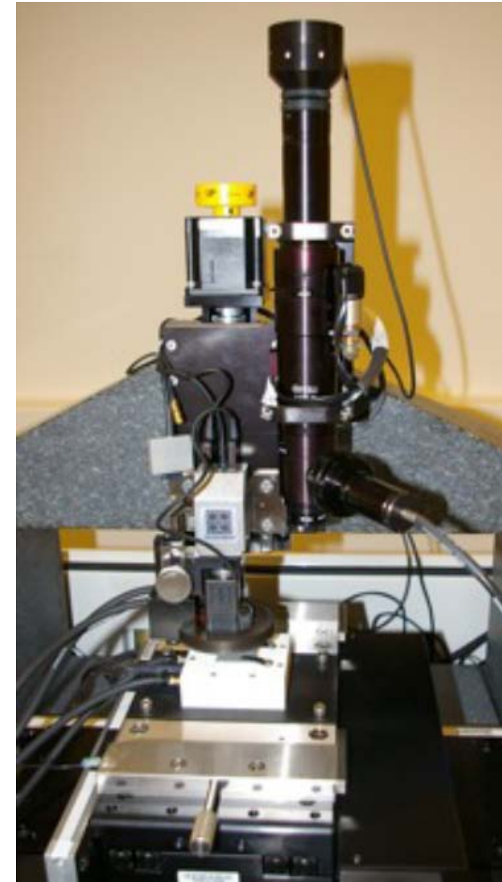


H. Kristiansen, Seminar at HiVe., Vestfold University College, Des 03 2010

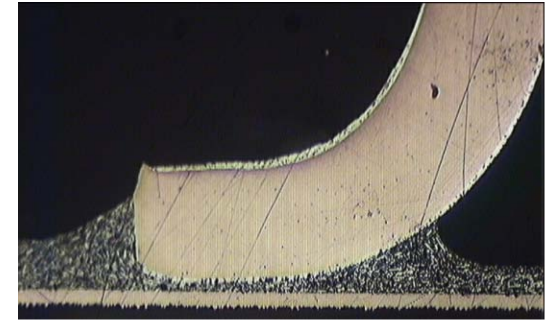
Mechanical properties of MPS

- Measurements performed with nanoindentation at NTNU in Trondheim, Norway



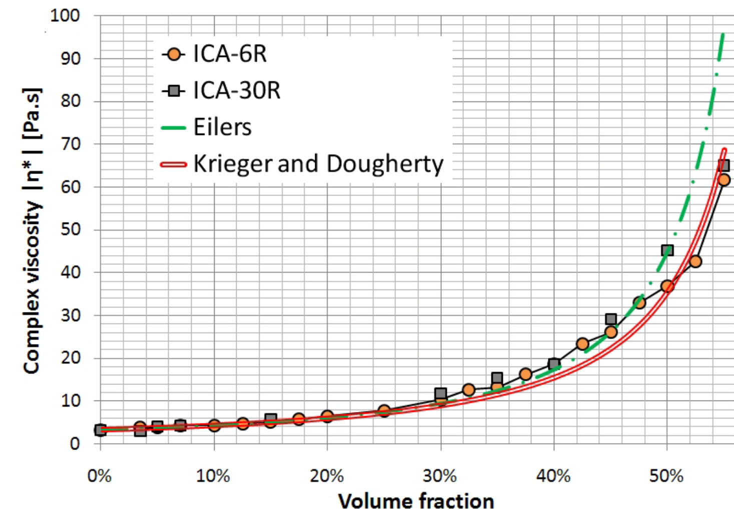


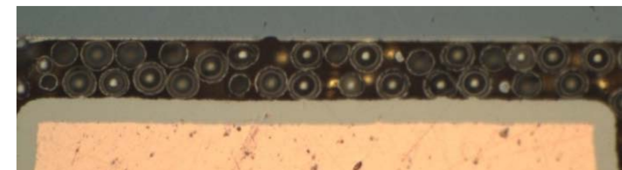
Isotropic conductive adhesives (ICA)



Silver epoxy, a traditional ICA

- Used in electronics pack-aging and interconnect for decades
  - Composite material
    - Adhesive resin
    - Conductive particles (metals)
- Typically known as silver epoxies
  - Epoxy adhesive loaded ≈ 30% Ag (volume %)
  - Matrix and fillers are very different materials
    - E-modulus ratio: 2-orders of magnitude
    - Large CTE miss-match
  - Micro-cracking between filler and matrix
- Brittle behaviour
  - Introduce plasticisers, reduce T_g of matrix
    - Increases CTE miss-match
- **Replace Ag with MPS to improve reliability**

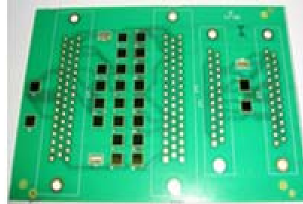


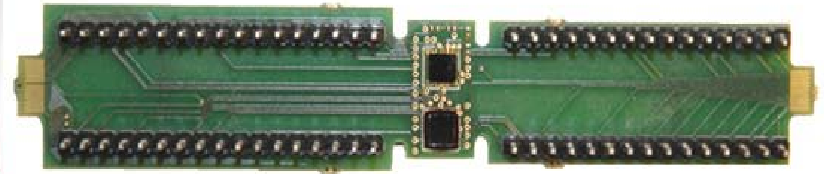


Viscosity and LM image of ICA with MPS, H-V. Nguyen, Seminar at HiVe., Vestfold University College, Des 03 2010

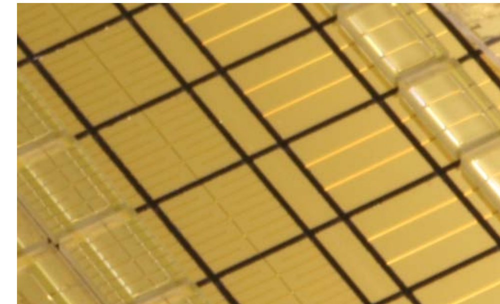
ICA case study: MEMS fuse

Gakkestad et al, Journal of Micro/Nanolithography 9 (4), 041108 (2010)

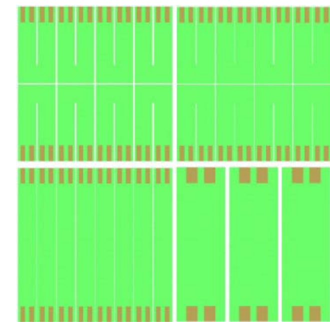




- MEMS device in SOI wafer
- Assembly directly on PCB
- ICA with 3-4 and 30 µm MPS
- Stencil printing issues for 30 µm



- Thermal cycling of chips assembled in parallel on large test boards
- Thermal cycling followed by firing tests of chips assembled on smaller boards
- Electrical testing, shear strength measurements and cross section inspection : Viable technology for the purpose!



Electrical results

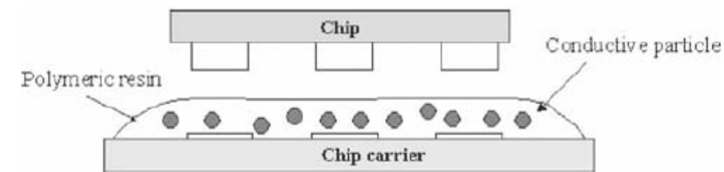
- ICA-A: 30 µm Ag coated MPS
- ICA-B: 4 µm Ni and Au coated MPS

ICA type	Board number	Number of temp cycles	$R_{average}$ (Ω) after temp cycling (std dev)	$R_{average}$ (Ω) after firing (std dev)	Percent change	Number of measured resistances
ICA-A	I1	100	0.675 (0.246)	0.733 (0.326)	8.6	8
	I2	10	0.224 (0.094)	0.205 (0.092)	–8.5	5
ICA-B	I3	100	0.217 (0.084)	0.257 (0.105)	18.4	8
	I4	10	0.082 (0.022)	0.097 (0.033)	18.3	6

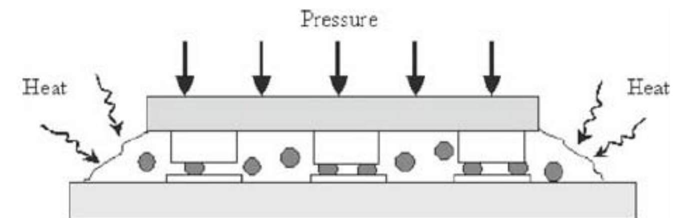
Gakkestad et al, Journal of Micro/Nanolithography 9 (4), 041108 (2010)

Anisotropic conductive adhesive/film (ACA/ACF)

- Provides unidirectional electrical conductivity
- The directional conductivity → relatively low volume loading of conductive filler (5-20 vol%)
- Fine pitch implementation
- ACF is commonly used in LCD screens



(a)



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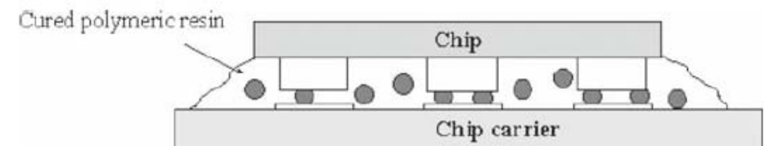

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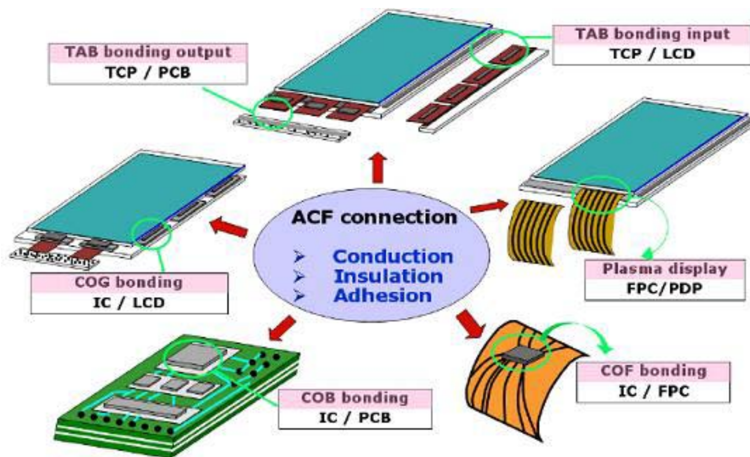
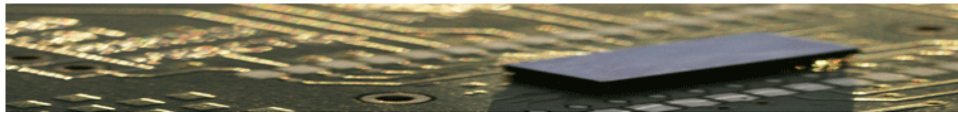


http://www.acffilm.com/

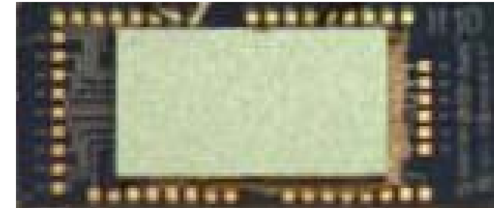


IDEX

www.idex.no

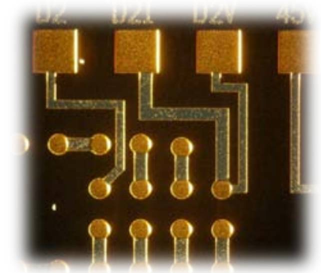
ACF case study: Fingerprint sensor

- MEMS onto ASIC, fine pitch
- Anisotropic conductive film (ACF)
  - Film from subcontractor (using MPS from Conpart)
  - Lamination
  - Amount of MPS below percolation limit

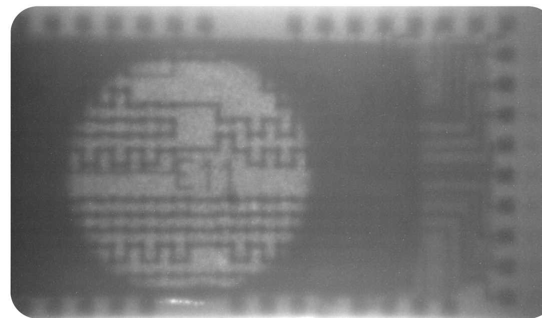


Assembly at Tampere University of Technology (pressure needed)

- Research tasks
  - Assembly (VUC/Tampere)
    - Lamination (below T_g)
    - Bonding (above T_g)
  - Cross-section & surface analysis
  - Thermal analysis (T_g)
    - DSC
  - Testing
    - "Reflow"
    - Thermal shock cycling
    - Humidity



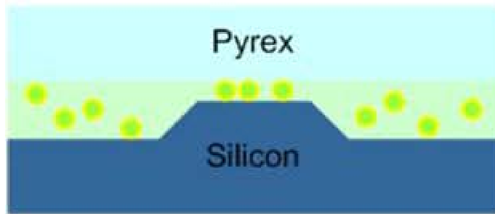
Pads for daisy chains and 4-ponit probing

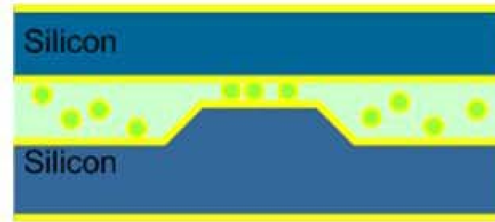


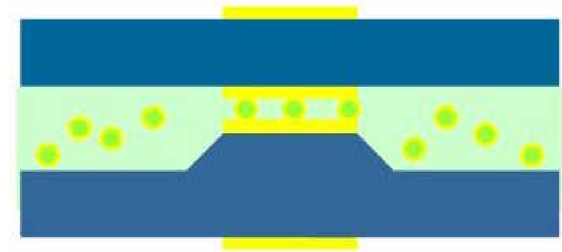
IR for inspection

ACA on wafer scale: Bonding for MEMS

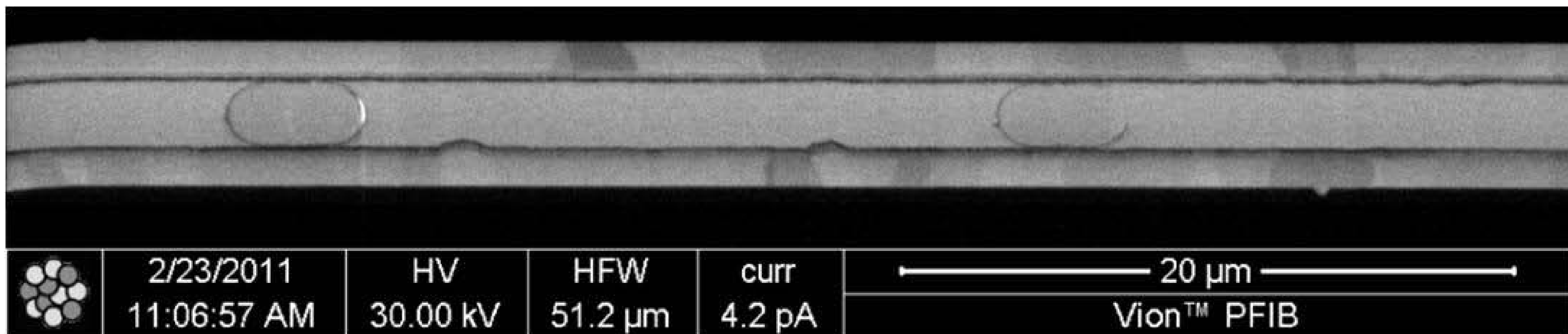
JEMSiP 3D







- Combining adhesive wafer level bonding (BCB) and principle of ACA
- MPS trapped in pad regions
- Applicable e.g. for MEMS wafers requiring electrical connection to cap wafer with TSV or electrodes
- Plasma-FIB image (by FEI) showing 4 µm MPS trapped in a bonded region assuring electrical connection between the wafers

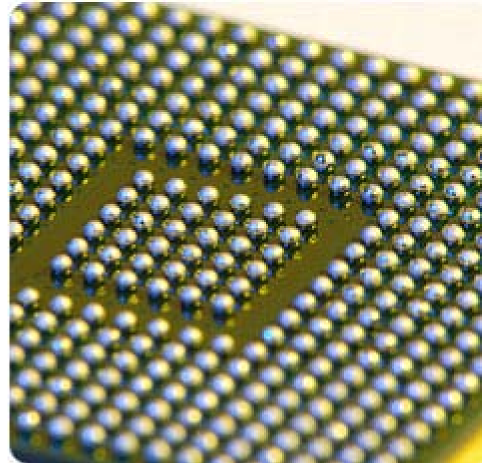


Taklo et al., Device Packaging Conference, March 2011

Ball Grid Array balls (BGA)

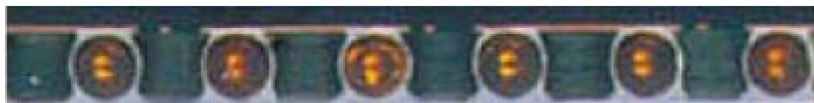
- Transition from SnPb to SAC has resulted in reduced cycles to failure
- Combination of
  - Thermal expansion miss-match
  - Non-compliant ball
- Causes reliability issues
  - Severe cyclic strain in solder
  - Severe stress in component
- Limits maximum size of component / Number of I/O's

Whalley, HDP Feb 2010



http://www.bga.net/

RoHS, since 1. July 2006

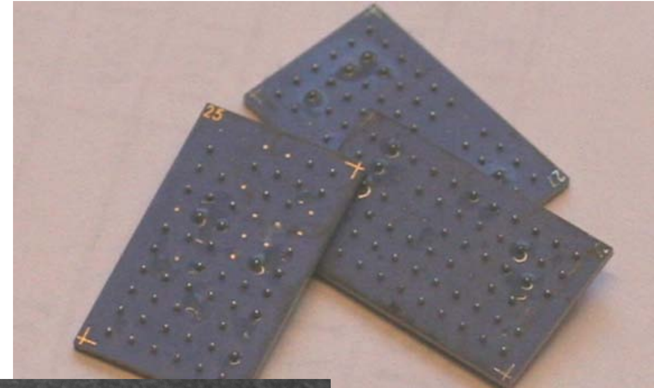


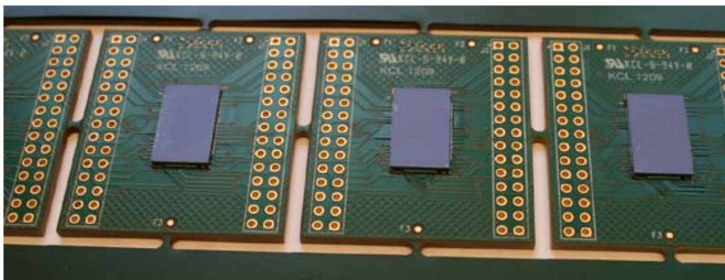
http://www.sekisui-fc.com/

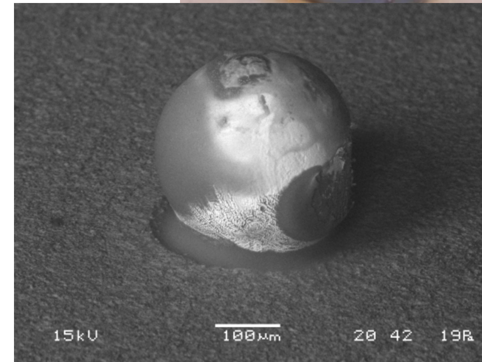
- **Replace SnPb/SAC with MPS to improve reliability**

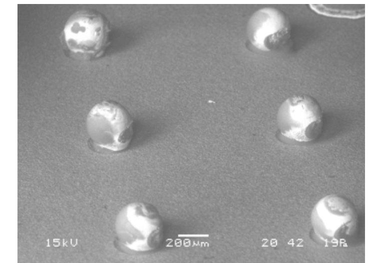
BGA case study: Ceramic package

- MPS with solder as BGA
  - Spheres from Sekisui and Conpart
- References: SnPb and SnAgCu BGAs
- Solder onto LTCC









- Mounting onto PCB
- Reliability studies

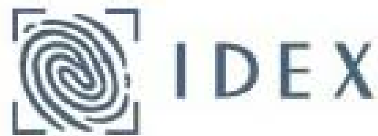
310 µm balls from Sekisui on LTCC

Outlook and summary

- Case study I, ICA for a MEMS fuse
  - Satisfactory results and the product is presently further developed
- Case study II, ACA for a Fingerprint sensor
  - Results show satisfactory resistance measurements and good reliability from stress tests
  - Closing tests are performed this spring and all results are to be compiled in a coming journal paper in 2011
- Case III, BGA with MPS for a ceramic package
  - Reliability tests to be performed

- All results achieved so far support the theory about increased reliability, in particular with regard to shock and thermal cycling, due to the **increased compliance** of a system with MPS

Nammo



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