VESTFOLD UNIVERSITY COLLEGE

imst
Department of Micro and Nano Systems Technology

SINTEF

Bonding technology for rough environments
Seminar at HiVe (Vestfold University College)

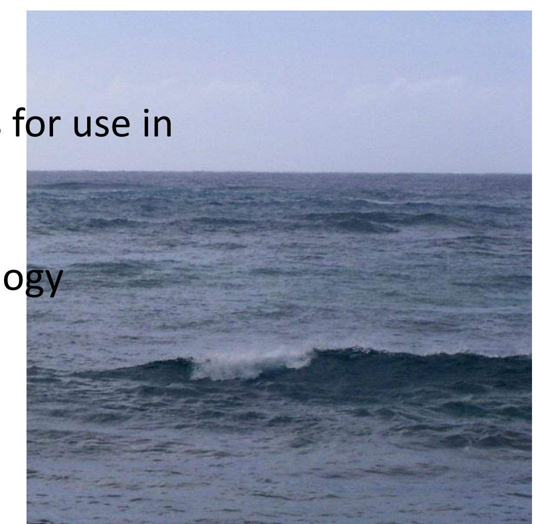
3 December 2010, Auditorium "Tønsberg"

Schedule

12.30 Welcome (Knut Aasmundtveit, HiVe)
High Temperature Power Electronics Packaging –
Presentation of KMB project HTPEP (Andreas Larsson, SINTEF)
High Temperature SiC Power Transistors (Anders Lindgren, TranSiC)
PhD in HTPEP (Torleif Seip, SINTEF/ HiVe)
Discussion

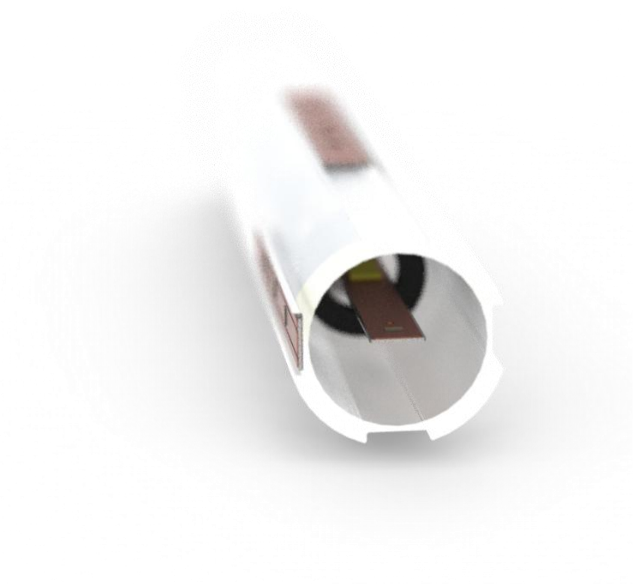
14:00 Fine Pitch Interconnect of Microelectronics and Microsystems for use in
Rough Environments (ReMi) –
Presentation of KMB project (Maaike V Taklo, SINTEF)
Metal coated polymer spheres, novel interconnection technology
(Helge Kristiansen, ConPart)
PhD in ReMi (Hoang-Vu Nguyen, HiVe)
Discussion

15:00 Concluding remarks



High Temperature Power Electronics Packaging
HTPEP

HiVe 03.12.2010



SINTEF

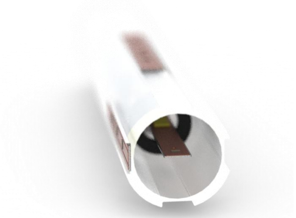
Andreas Larsson

Funding and partners

- Norwegian research project
  - PETROMAKS program
    - 2009 – 2012
    - 6,4 MNOK
- Partners
    - 1,6 MNOK

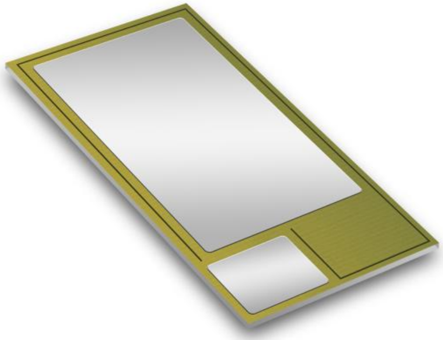
Project keywords

- Packaging
- High power
- Harsh environment
  - High temperature
  - High pressure
  - Vibrations
- Reliability
  - Downhole operation
- Silicon carbide (SiC) bipolar transistors (BJT)
  - Power module design for electric motor

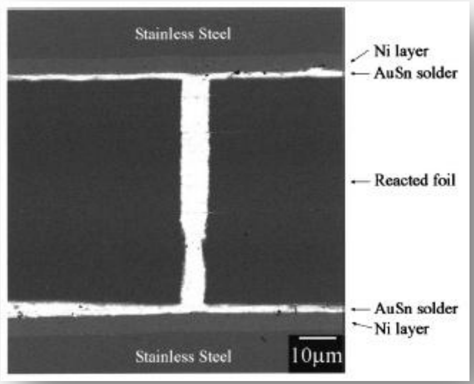


Die attach technology

- SiC BJT from TranSiC
- AuSn SLID bonding
- Nano foil bonding
- Standard high temperature soldering

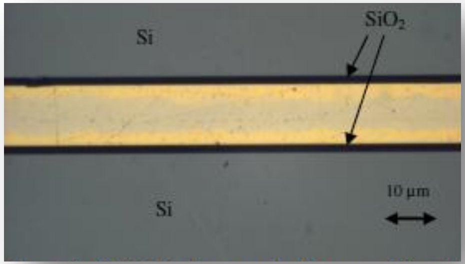


BitSiC BT1206AA/P1



Nano foil

Wang J. et al. 2004

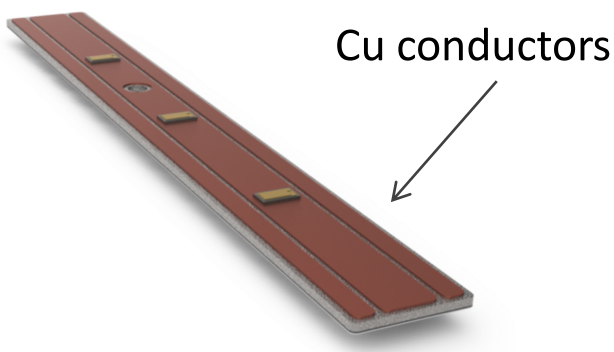


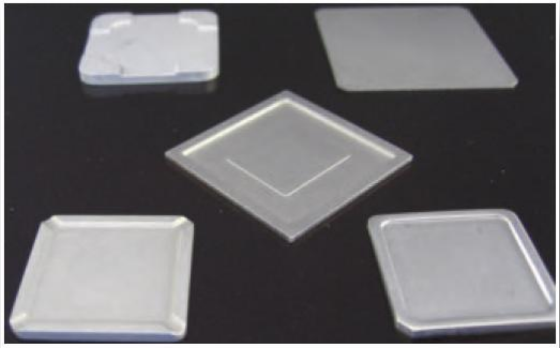
AuSn SLID

Knut Aasmundtveit et al. 2009

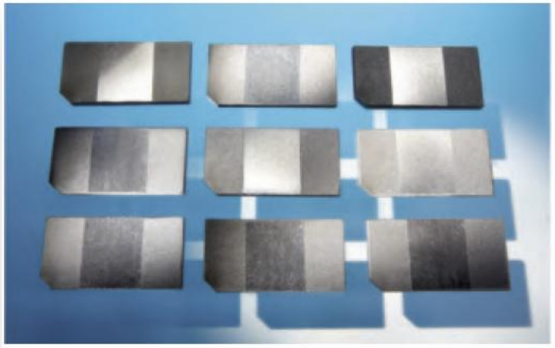
Substrate technology

- Silicon nitride, Si_3N_4
- Aluminum nitride, AlN
- Advanced materials
  - SiC particle−reinforced Al (AlSiC)
  - Diamond particle−reinforced SiC (DR−SiC)





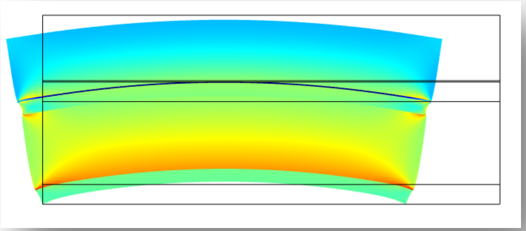
SiC particle−reinforced Al



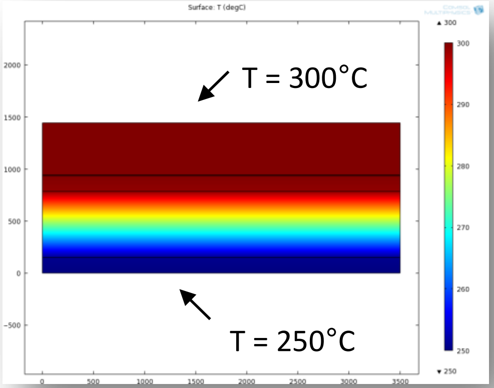
Diamond particle−reinforced SiC

Simulation aided design

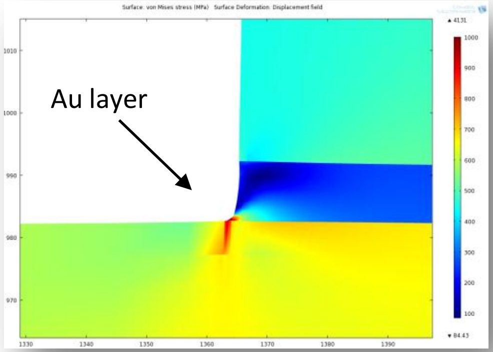
- COMSOL Multiphysics



Warpage

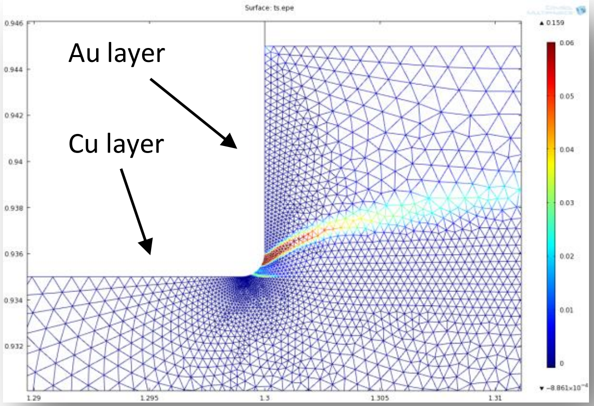


Thermal performance



Hot spots

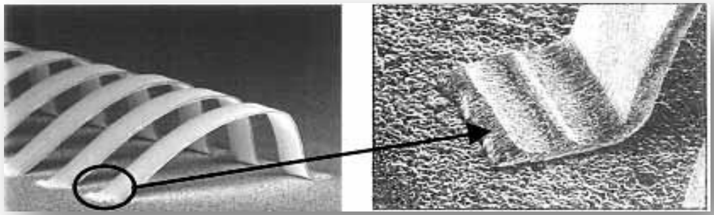
(Stress concentrations)



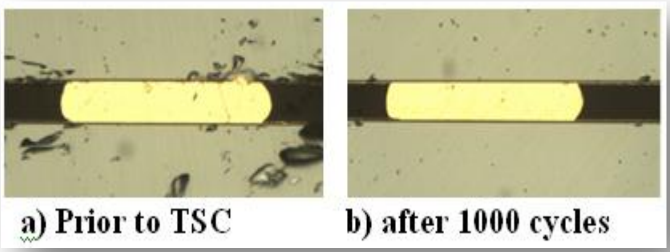
Plastic strain & fatigue

Top side interconnect

- Au ribbon bonding
  - Large cross−sectional area
- Au stud bumps possible for sandwich solution



Ribbon bonding



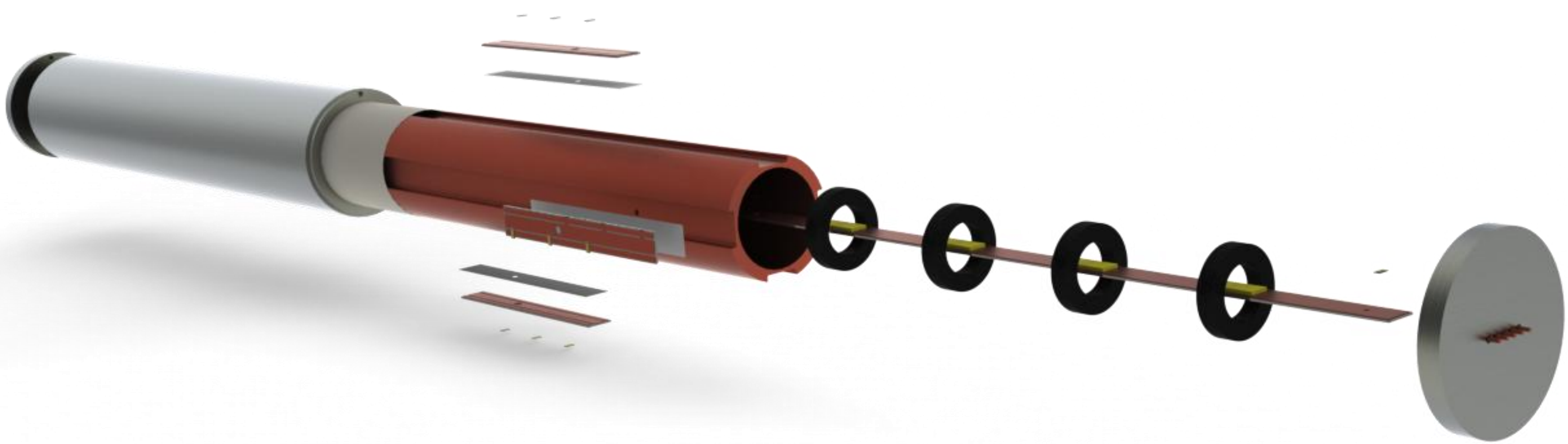
Au Stud bump
Luu T. T. et al. 2010

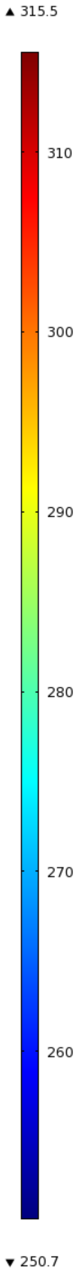
Case study

Concept development

Case study

Concept development





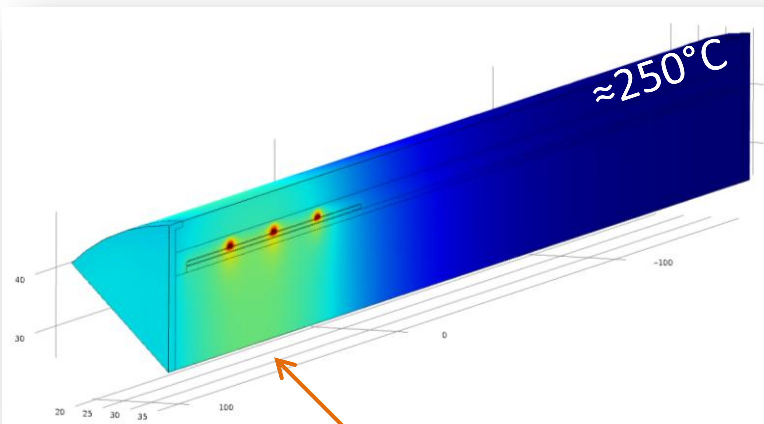
Case study

Concept development

- Version 1.1
  - Thermal distribution

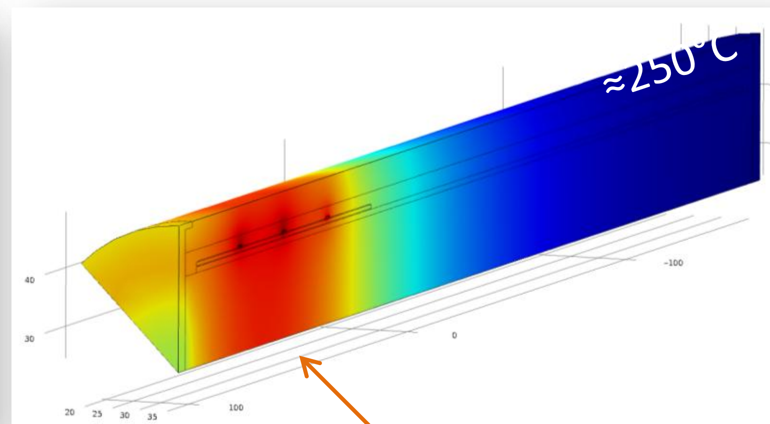
    (Heat transfer coefficients used for convective flow)

Still

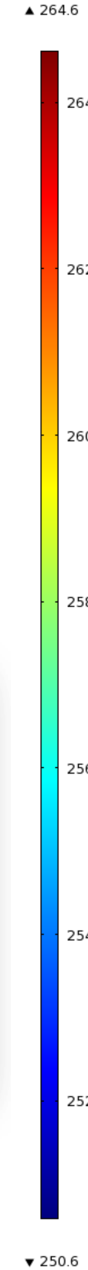


$T_j \approx 315$°C

Forced convection



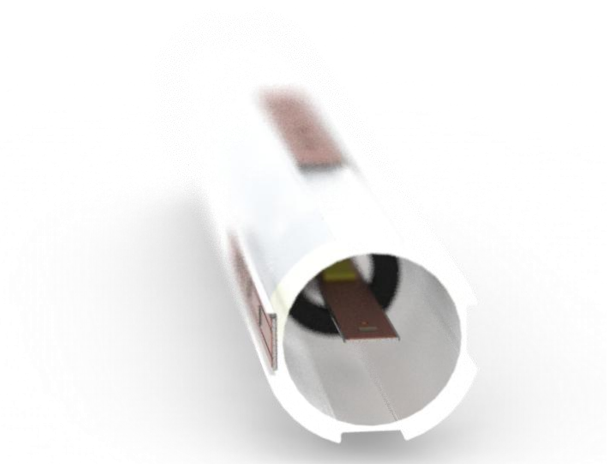
$T_j \approx 265$°C



NB! Different scales on the plots, hence the dissimilar color distribution

Thanks for your attention!
HTPEP

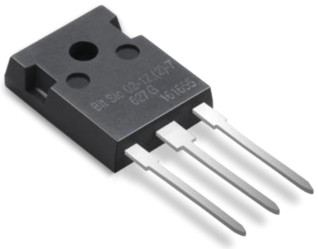
Andreas Larsson
SINTEF ICT, Instrumentation dept.
andreas.larsson@sintef.no



TranSiC

Power Transistors in

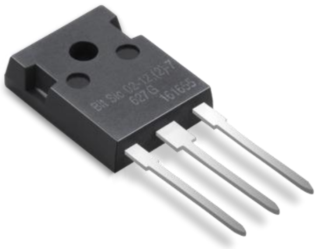
Silicon Carbide



Company Profile

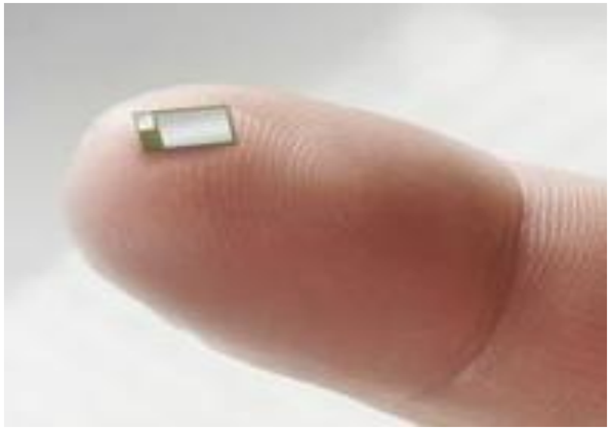
- TranSiC was founded in 2005
- Spin-off from the Royal Institute of Technology, Stockholm
- Products available since 2009
- R&D, Production, Testing and Sales
- Adding foundry production
- Current investors:
  - Volvo Technology Transfer AB
  - Industrifonden
  - Midroc New Technology

Silicon Carbide characteristics



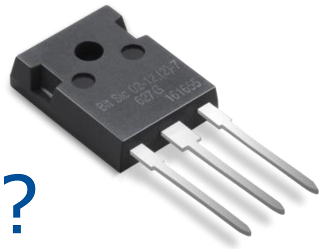
Key Features SiC:

- ❑ Wide Band Gap (3 times)
- ❑ High Breakdown Field (10 times)
- ❑ High Thermal Conductivity (3 times)



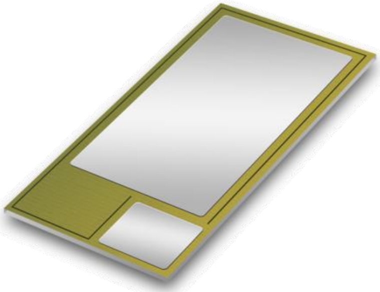
SiC compared to Si in Power Transistors:

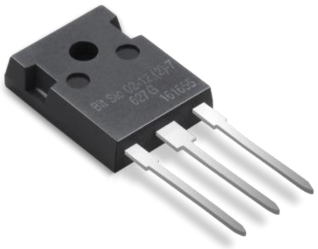
- ❑ High operational temperature
- ❑ High radiation tollerance
- ❑ Increased efficiency
- ❑ Smaller devices
- ❑ Faster Switching Capability
- ❑ Robust and reliable



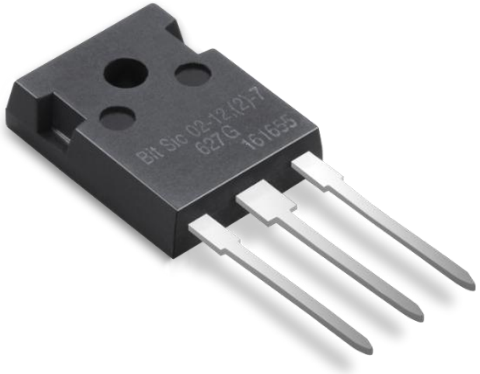
Why Bipolar Junction Transistors?

- ❑ Low Vcesat
- ❑ More efficient
- ❑ Better utilization of material
- ❑ Higher current density
- ❑ Faster switching
- ❑ Easy paralleling
- ❑ No active Si-oxide
- ❑ Low leakage at high temperatures





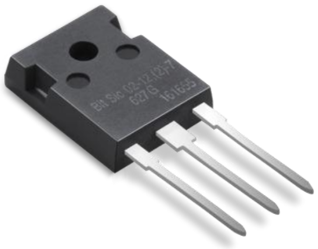
Available products 2010



- High Efficiency discreets
  - 1200V 6A and 20A
  - TO-247
  - Low Vce(sat)
  - Fast switching
  - Tolerant to natural radiation

- High Temp / Hi-Rel discreets
  - 1200V 6A and 20A
  - TO-258
  - Operational temp up to Tj 250°C
  - Radiation Hard
  - Low Vce(sat)
  - Fast switching

TranSiC
POWER TRANSISTORS IN SILICON CARBIDE

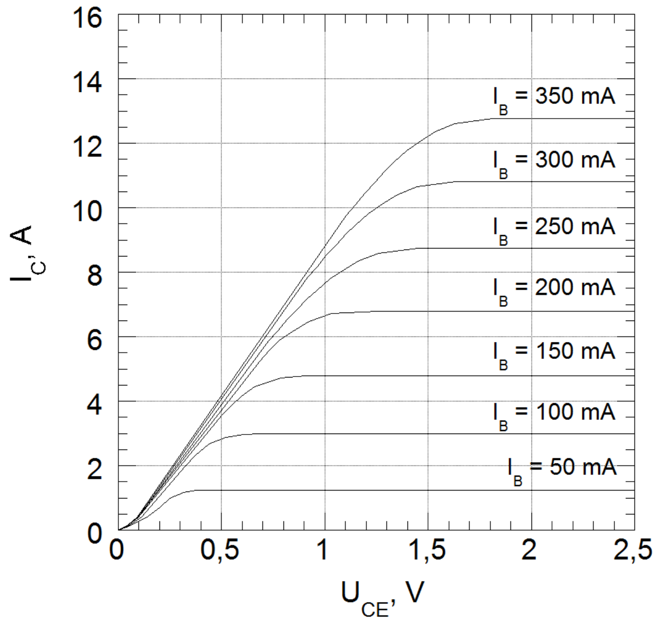


High temp packages

- ❑ Based on mil TO-258
- ❑ Isolated design
- ❑ Added SiN substrate
- ❑ High temp substrate attach
- ❑ High temp die attach
- ❑ Polyimide coating

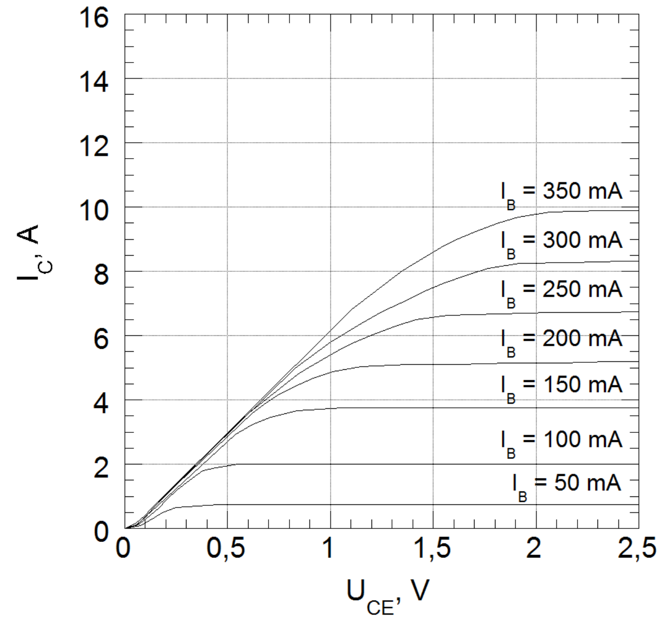
Static I-V Characteristics

150°C



U_{CE} = 0.75V Gain = 35

250°C

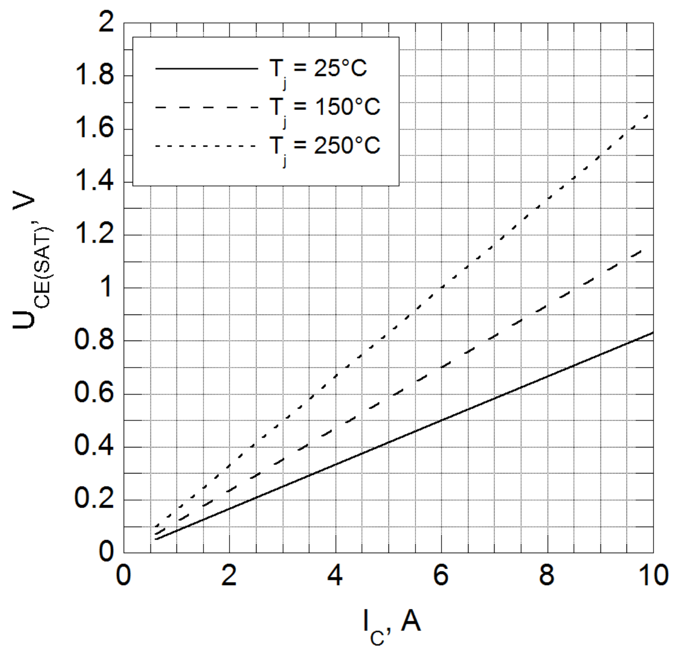


U_{CE} = 1V Gain = 28

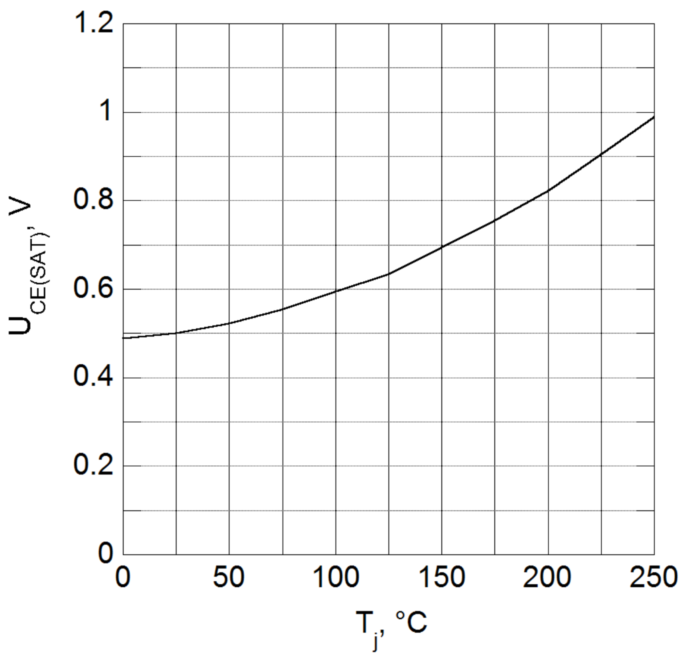
TranSiC
POWER TRANSISTORS IN SILICON CARBIDE

Vce(sat) Characteristics

Vce(sat)vs. Collector current



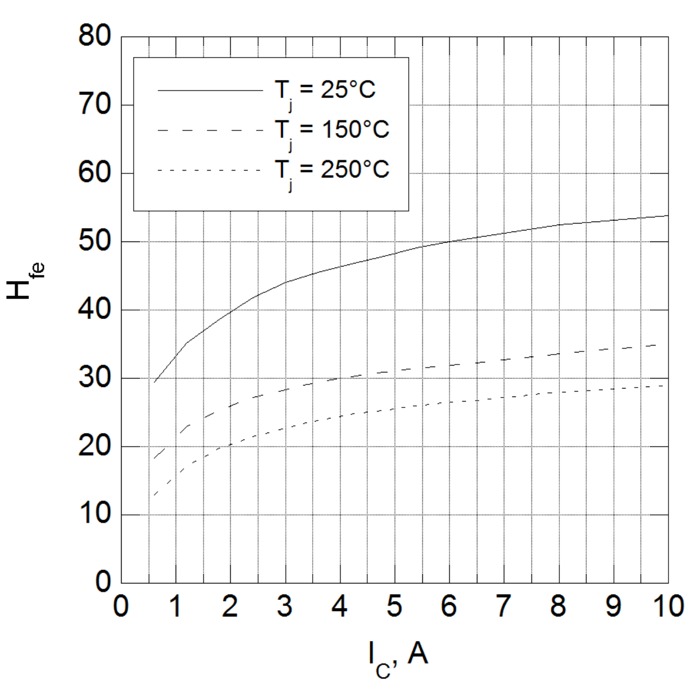
Vce(sat) vs. temperature



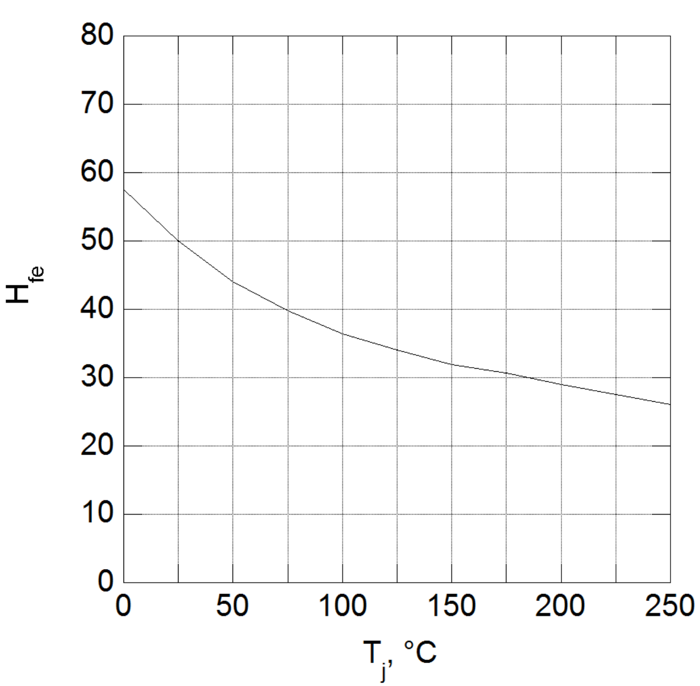
TranSiC
POWER TRANSISTORS IN SILICON CARBIDE

Gain Characteristics

Gain vs. Collector current



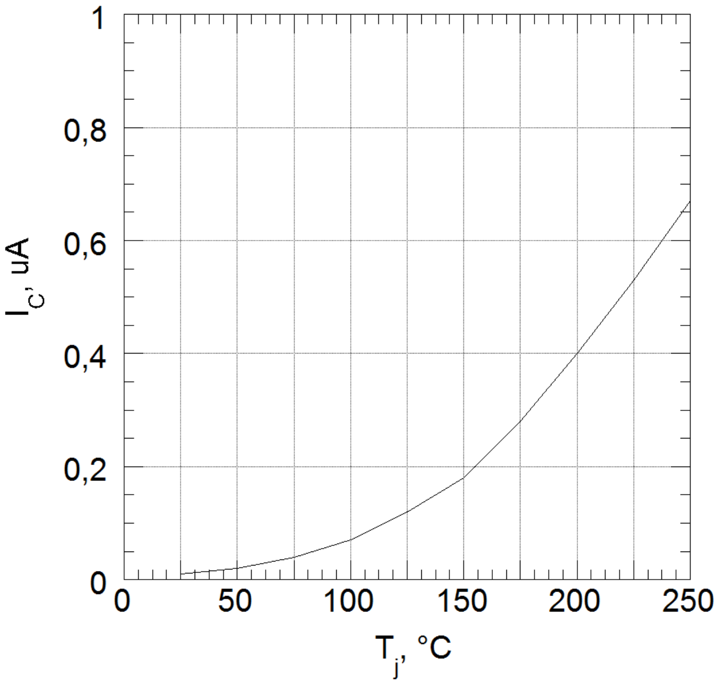
Gain vs. temperature



Leakage Characteristics

- Very low leakage
- Low thermal generation rate of charge carriers due to the wide band gap

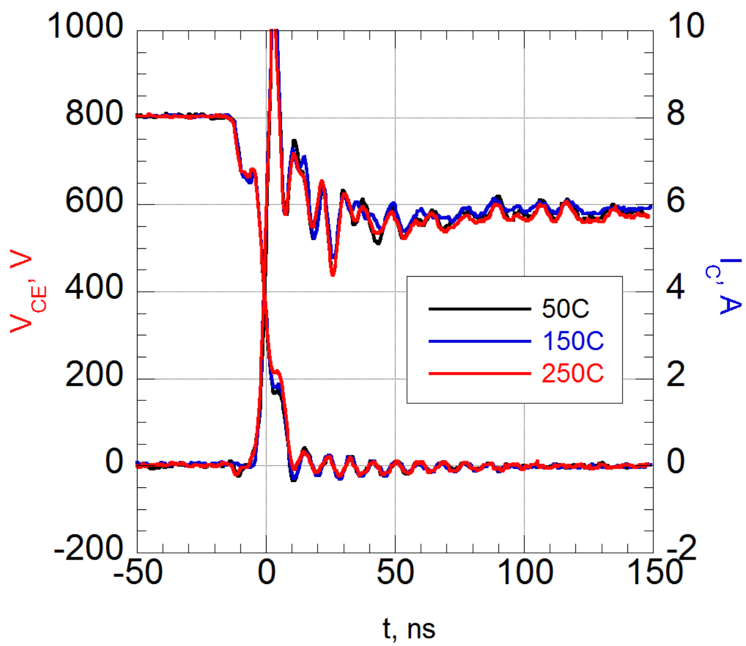
Leakage current @ 1200V



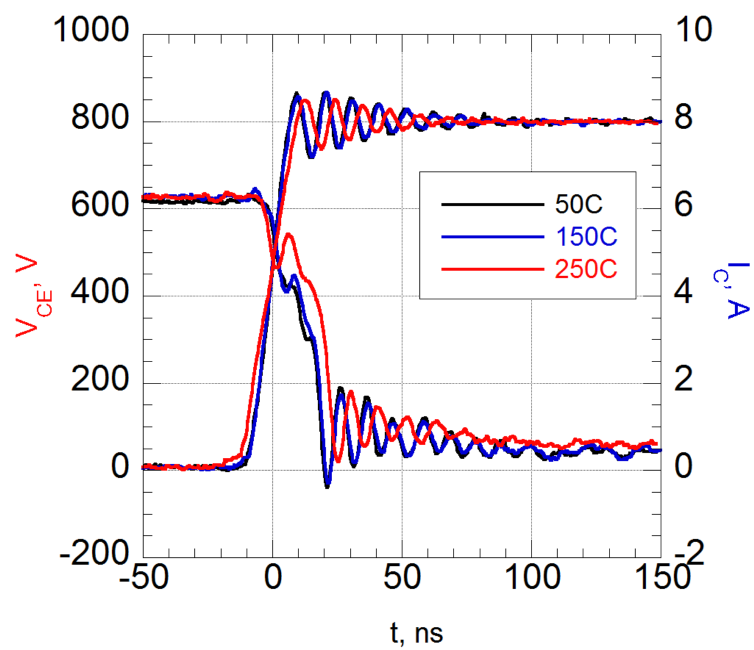
TranSiC
POWER TRANSISTORS IN SILICON CARBIDE

Switching Temperature Dependence

Turn on

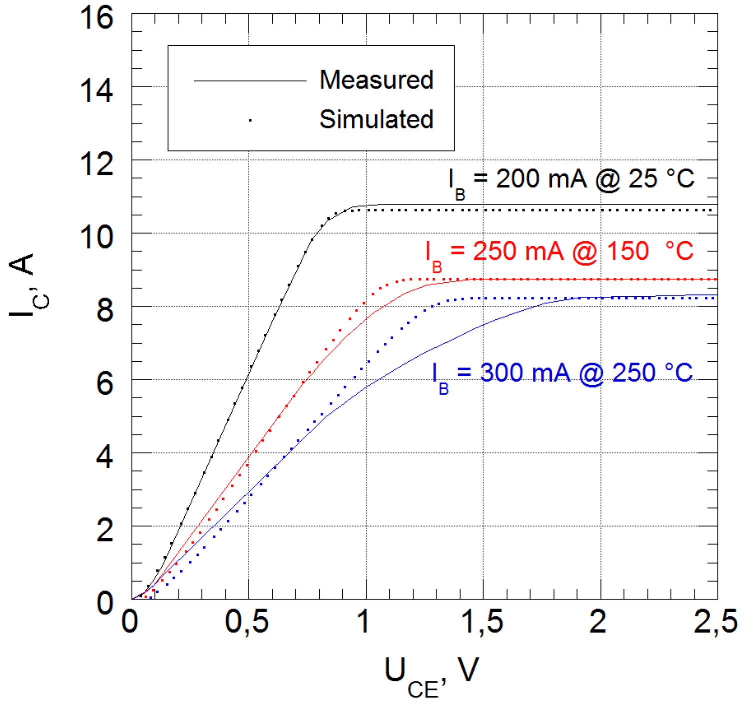


Turn off

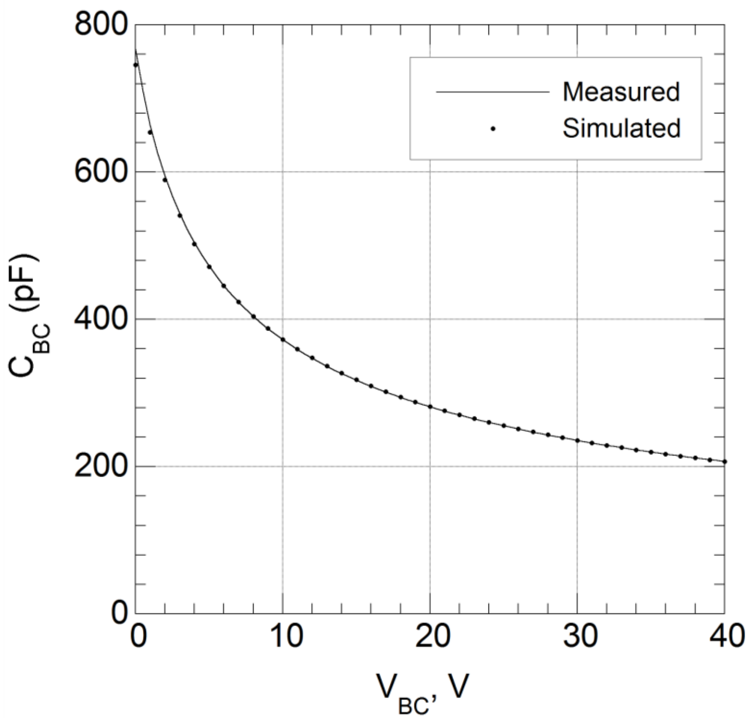


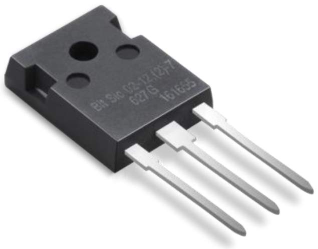
SPICE Model Agreement

I-V Characteristics



Base-Collector Cap

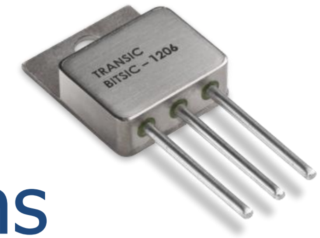




High efficency applications

- PV Inverters
- Industrial Drives
- Wind Power
- Electrical Hybrid Vehicles

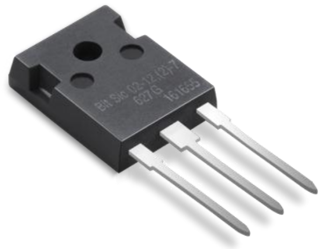
TranSiC
POWER TRANSISTORS IN SILICON CARBIDE



High temp / Rad hard applications

- Oil and Gas
- Geothermal
- Aerospace
- Space
- Defense

TranSiC
POWER TRANSISTORS IN SILICON CARBIDE

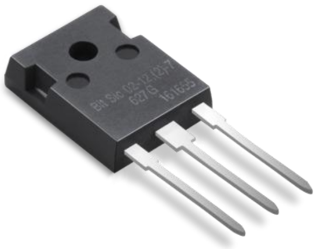


TranSiC Projects Q4 2010

Key Projects October 2010:

❑ Geothermal / Drilling	8	US + Norway
❑ PV Inverter	6	Eu + US
❑ HEV	3	US + Sweden
❑ Space	2	US

TranSiC
POWER TRANSISTORS IN SILICON CARBIDE



Contact

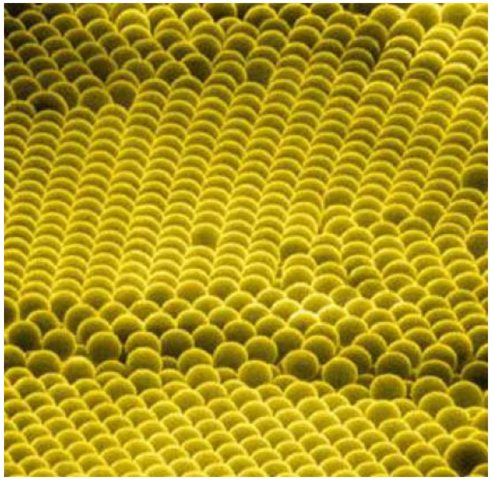
Thank you for your attention!

www.transic.com
anders.lindgren@transic.com

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

ReMi

HiVe 03.12.2010



Funding and partners

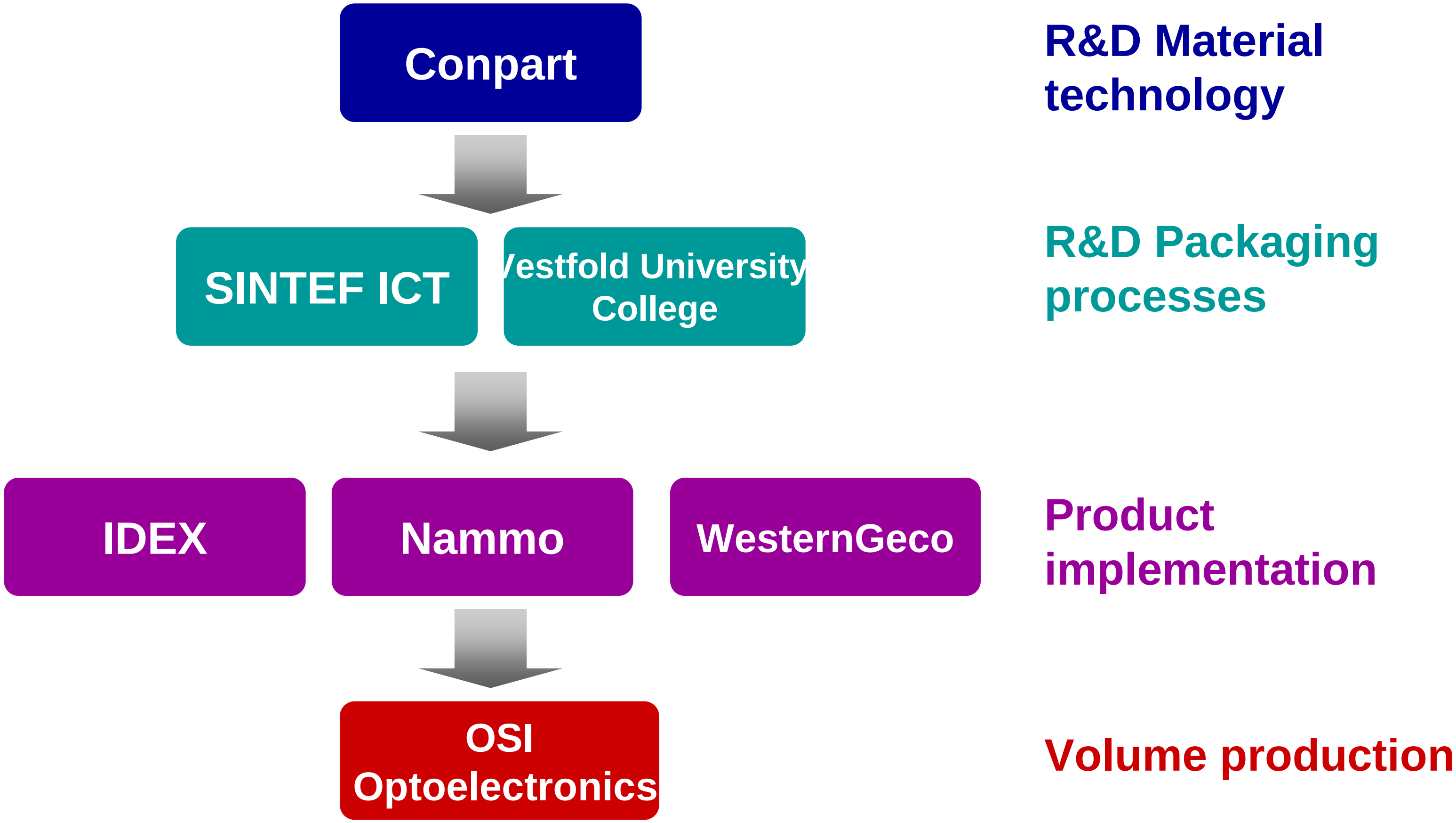
- Norwegian research project
  - BIA program
    - 2008 – 2012
    - 6.8 MNOK
- Partners
    - 1.7 MNOK

Project keywords

- Packaging
- Fine pitch
- Harsh environment
  - Thermal cycling
  - Temperature storage
  - Vibrations
- Reliability
  - Ammunition, consumer application, geophysical survey
- Interconnects based on
  - Metal coated polymer spheres (MPS)

www.conpart.no

Project structure

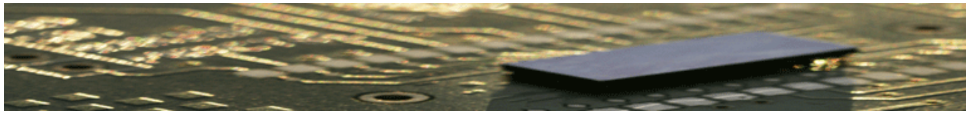


Project tasks

- Case I: Fuse
  - FFI and Nammo

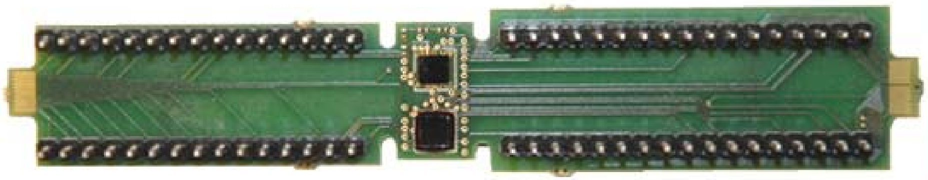
- Case II: Fingerprint sensor
  - Idex

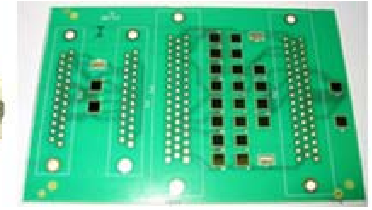
www.idex.no



- Case III: Ceramic package
  - WesternGeco

- PhD study: Hoang Vu Nguyen

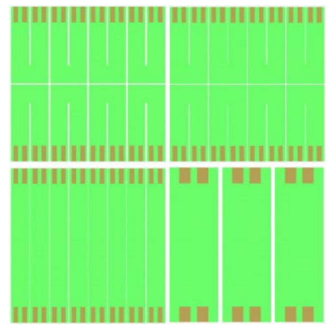


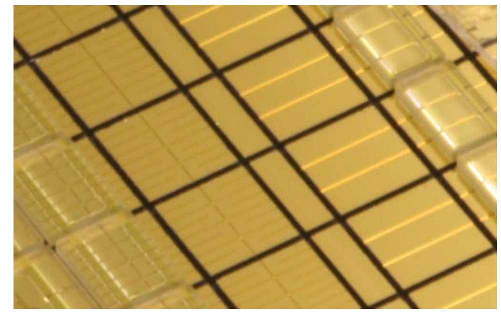


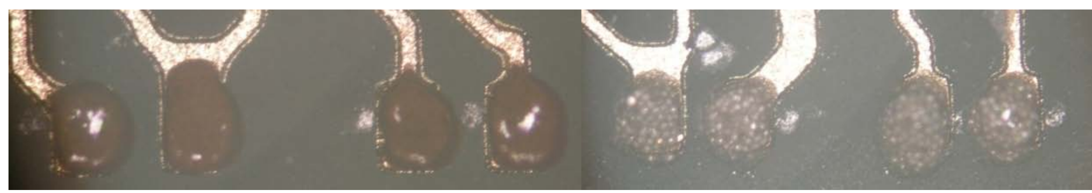
Case I: Fuse

- Interconnect challenge: MEMS onto PCB

- Isotropic conductive adhesive (ICA)
  - 4-30 µm particle sizes in Epotek 353
  - Stensil printing
  - Amount of MPS above percolation limit
- 2008-2009
  - Design of MEMS and dummies
  - Design of PCB test cards
  - Mounting of chips (process development)
  - Thermal cycling until short
- 2009-2010
  - Design of card for shooting tests
  - Mounting of chips
  - Limited thermal cycling
  - Shooting tests







- Characterization by electrical measurements and cross sections

- Conclusions
  - ICA with MPS is applicable for the application
  - Stencil printing must be optimised for the finest pitch when using the largest spheres

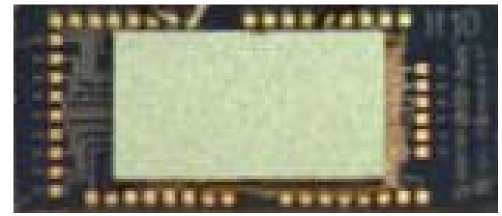
Case II: Fingerprint sensor

- Interconnect challenge: MEMS onto ASIC

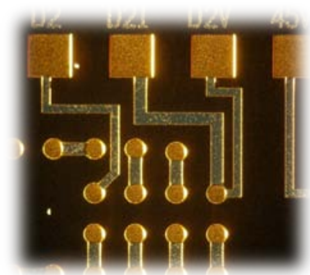
- Anisotropic conductive film (ACF)
  - Film from subcontractor (using MPS from Conpart)
  - Lamination
  - Amount of MPS below percolation limit

- 2008-2010
  - Literature review
  - Assembly (VUC/Tampere)
    - Lamination (below Tg)
    - Bonding (above Tg)
  - Cross-section & surface analysis
  - Thermal analysis (Tg)
    - TGA/DSC
  - Testing
    - “Reflow”
    - TSC
    - Humidity

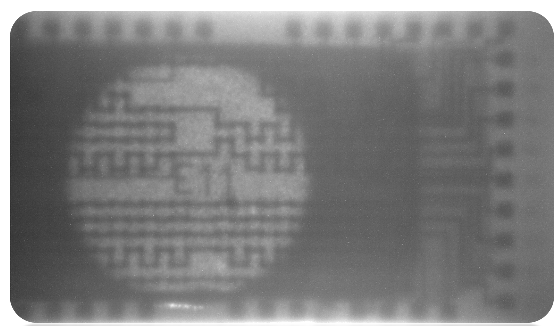
- 2011: Publication planned



Assembly at Tampere University of Technology (pressure needed)



Pads for daisy chains



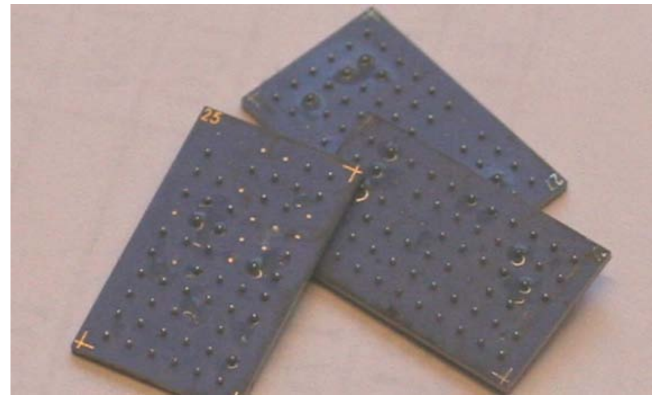
IR for inspection

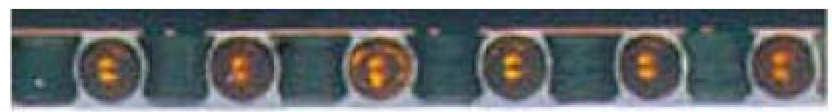
Case III: Ceramic package

- Interconnect challenge: Ceramics onto PCB

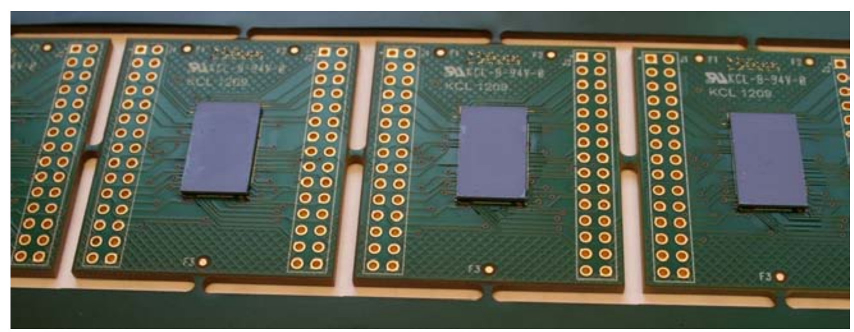
- MPS with solder as BGA
  - Spheres from Sekisui and Conpart
  - References: SnPb and SnAgCu BGAs
  - Solder onto LTCC
  - Mounting onto PCB

- 2008-2010
  - Review
  - Chip design
  - Board design
  - Mounting of balls on chip
  - Mounting of chip on board
- 2011
  - Thermal cycling, shock, vibrations
  - Publication?



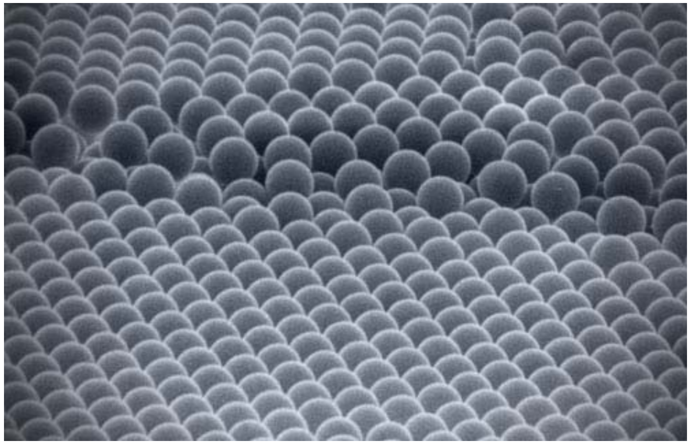


http://www.sekisui-fc.com/



Thanks for your attention!
ReMi

Maaike Taklo
SINTEF ICT, Instrumentation dept.
maaike.taklo@sintef.no

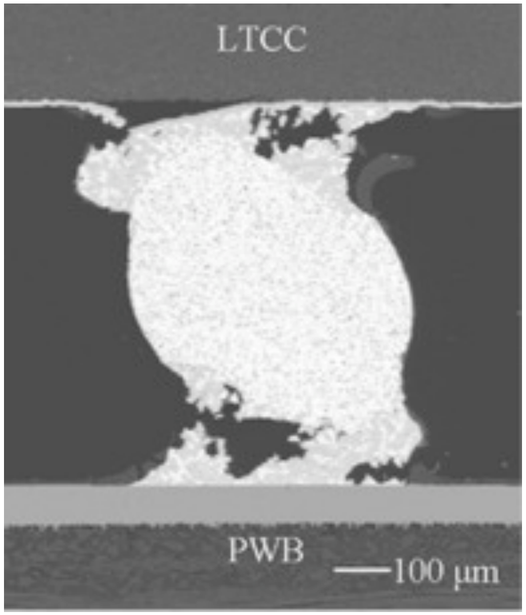


www.conpart.no

Polymer-particles
for
Electrical interconnects

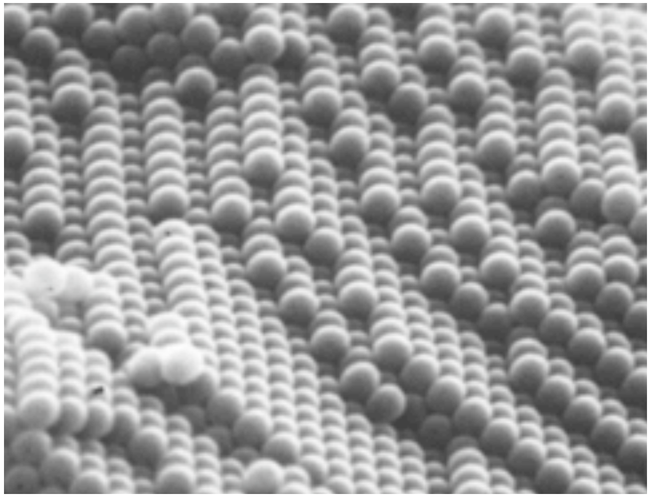
conpart®

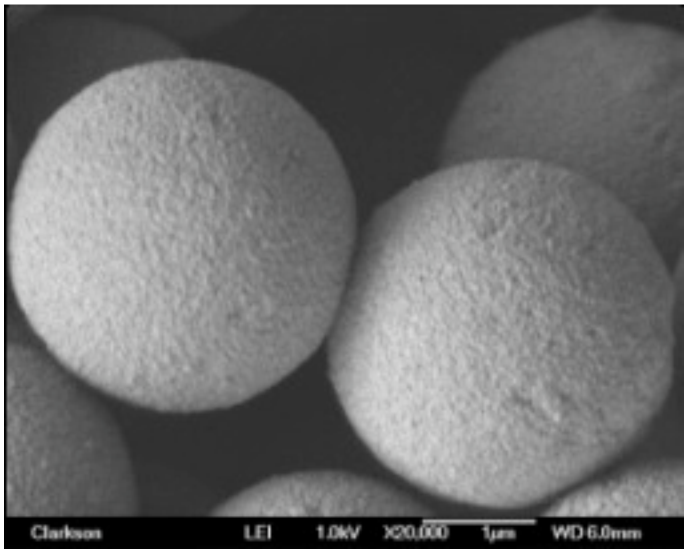
The challenge



- Electrical contacts are exposed to severe cyclic strains as well as potential mechanical shocks during its life-time.
- Combining electrical conductivity of metal with the mechanical elasticity and toughness of a polymer

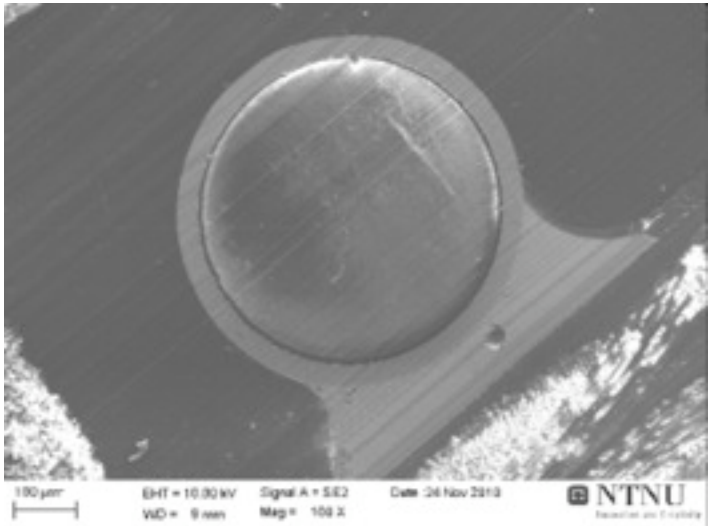
Conpart solution



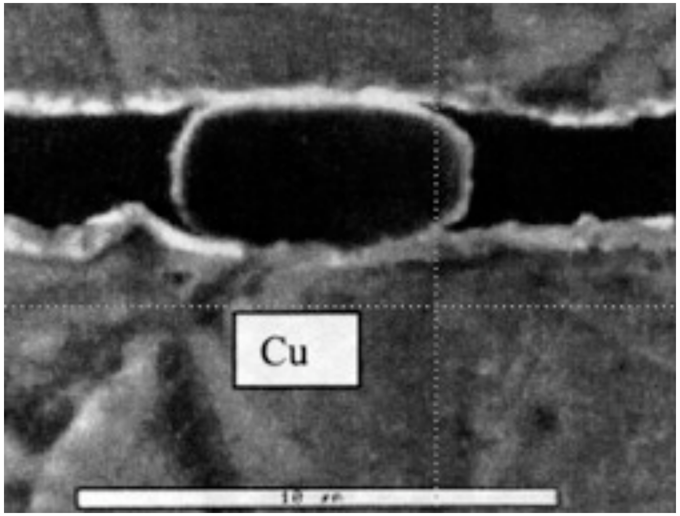


- Develop materials where the mechanical and electrical properties are de-coupled
- Use of metal plated polymer balls
  - Combining the mechanical properties of polymers with the conductivity of metals
- Tailor-making mechanical properties of the polymer
- Unique manufacturing process for unsurpassed size distribution and homogeneity of material

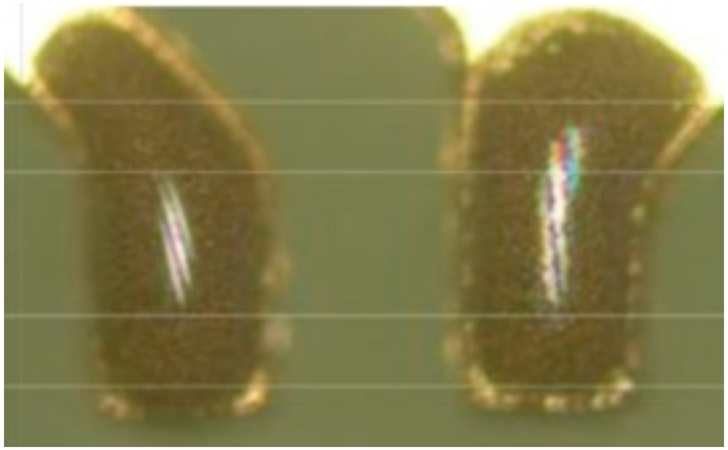
Numerous applications



BGA / CSP technology

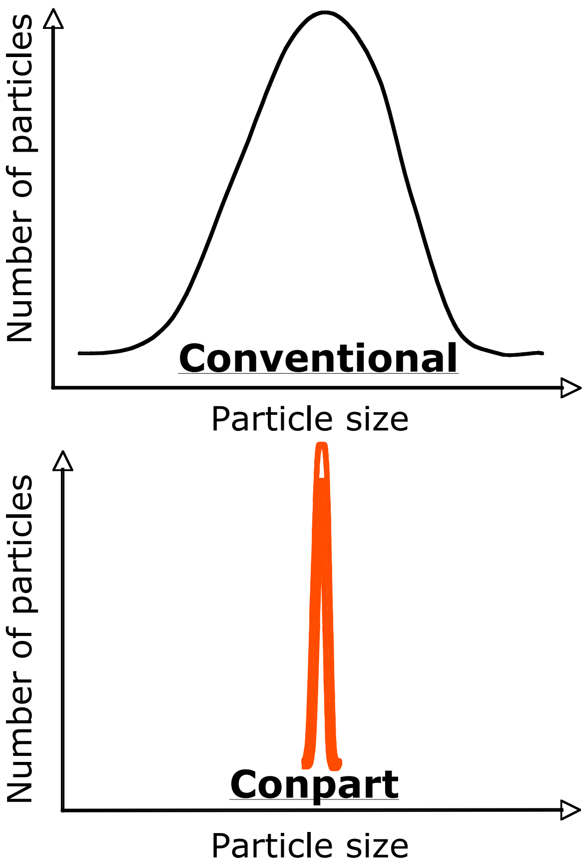


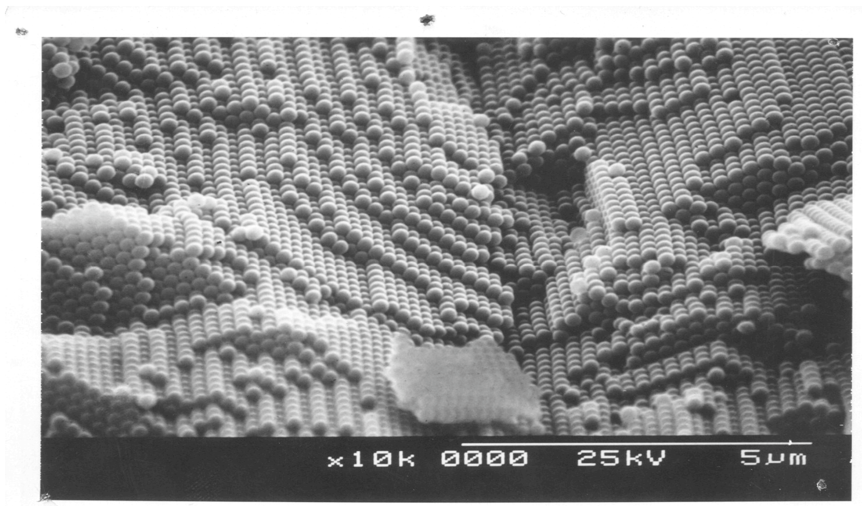
Anisotropic Conductive Adhesive



Isotropic Conductive Adhesive

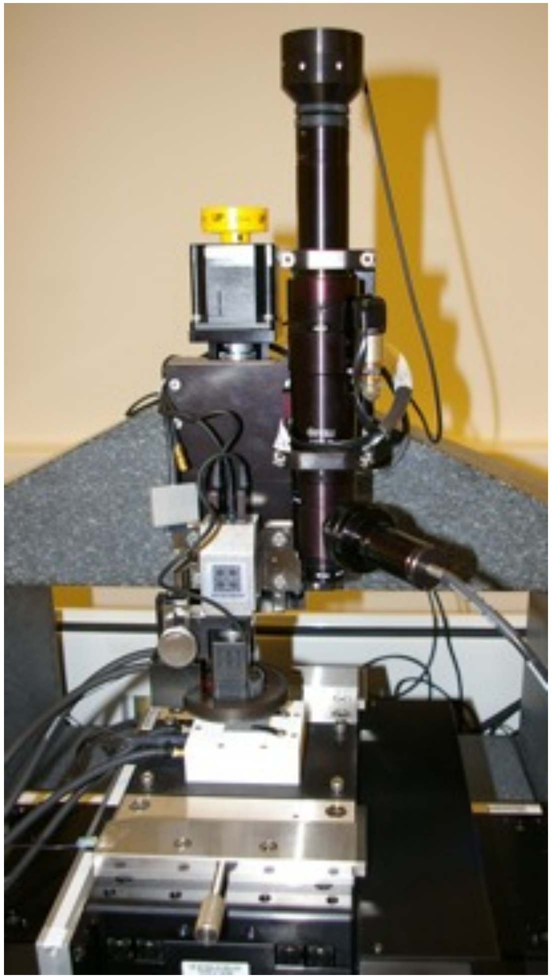
Unique particle technology





- **Extremely narrow size distribution**
- **Predefined size**
- **No need for size classification**
- **Tailor made properties**

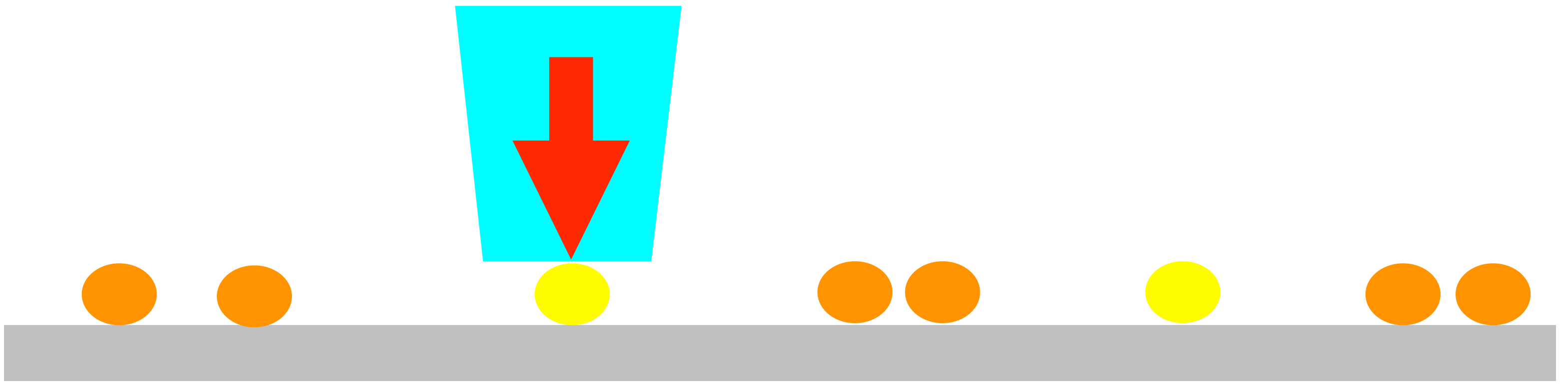
Mechanical testing



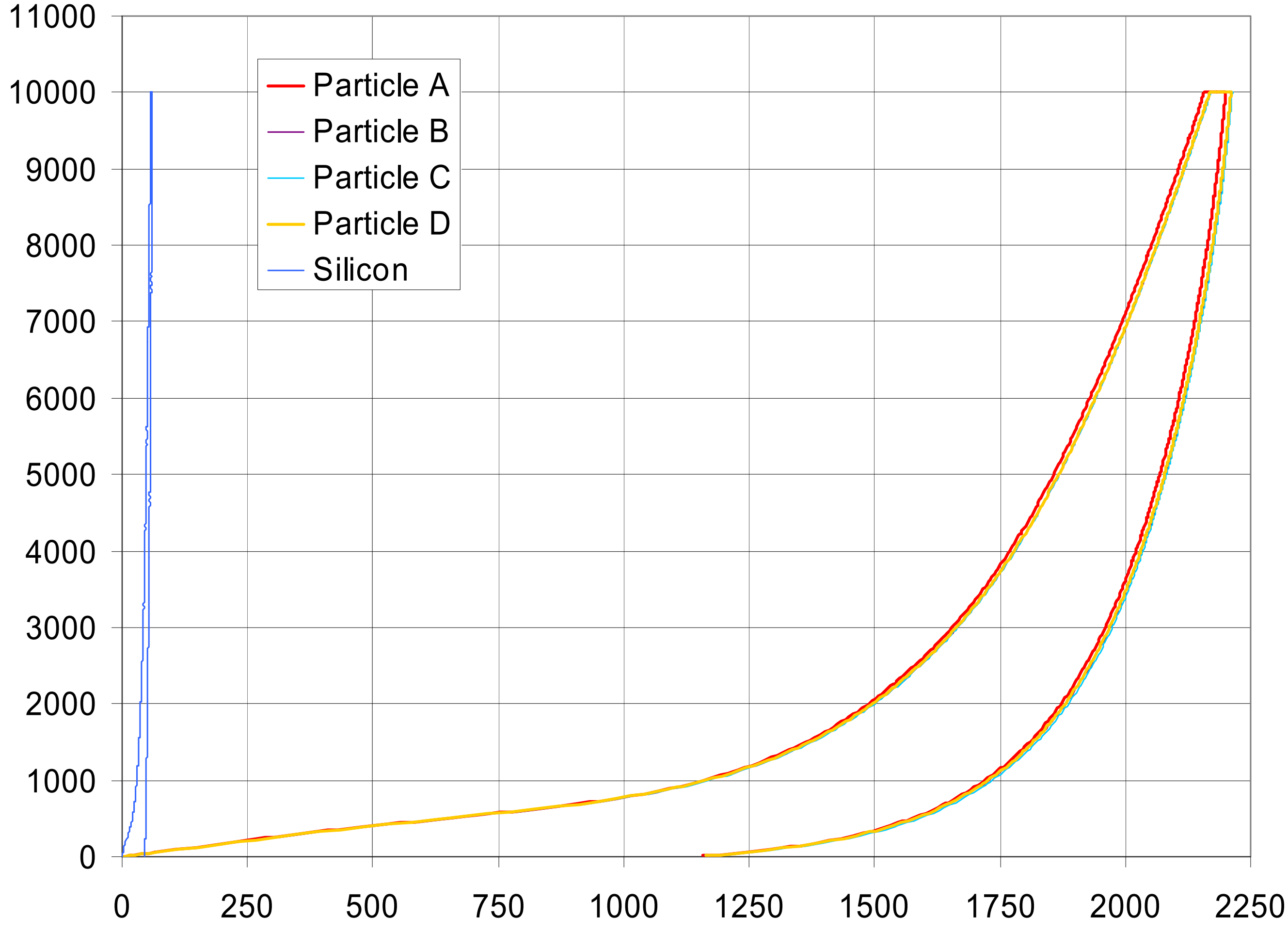
- Deformation during uniaxial load
  - Deformation as a function of load
  - Measure deformation as a function of applied load

Mechanical testing II

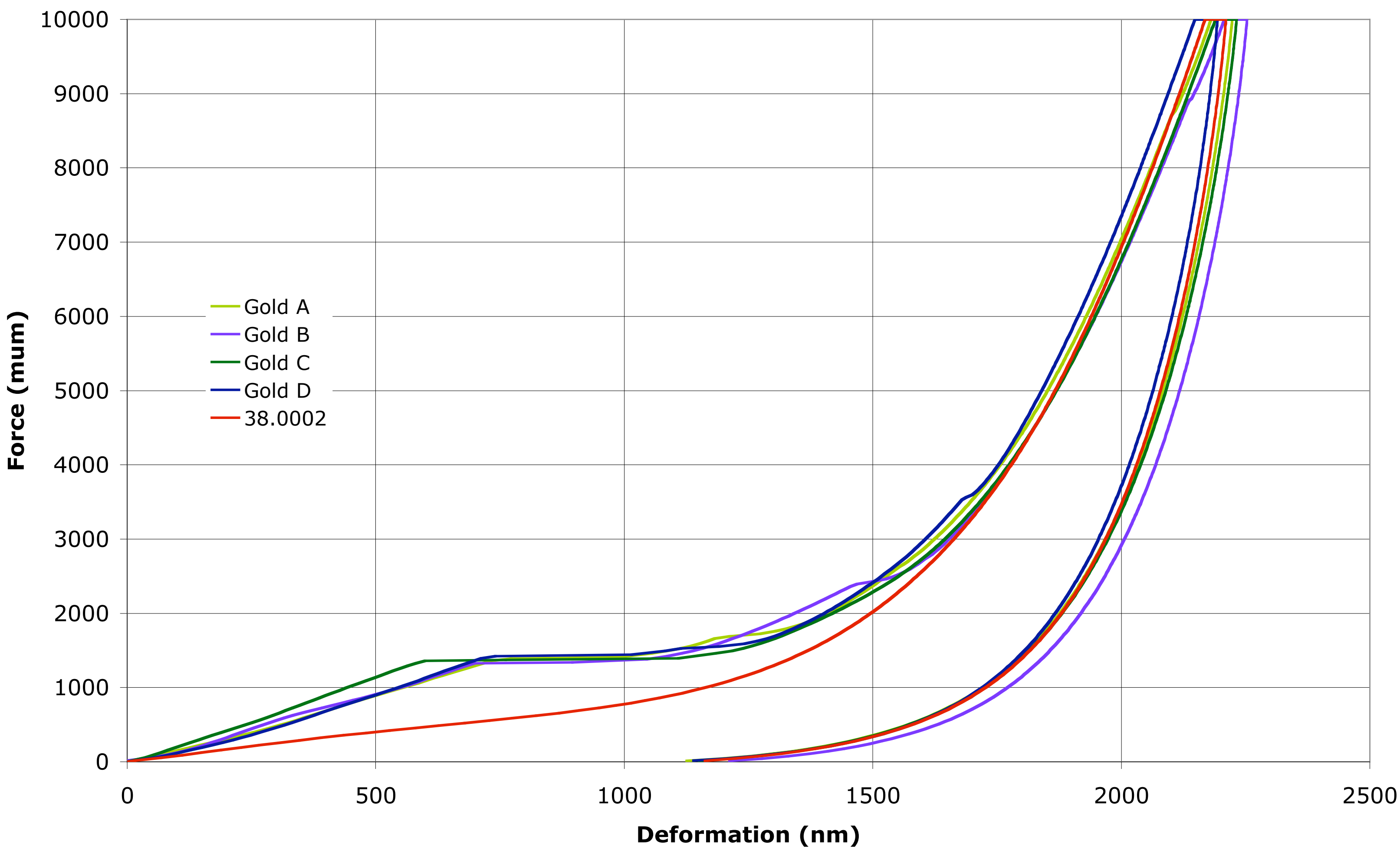
- Disperse particles on a suitable substrate
- Locate "individual" particles without any close neighbour
- Position indenter tip onto chosen particle



Mechanical properties

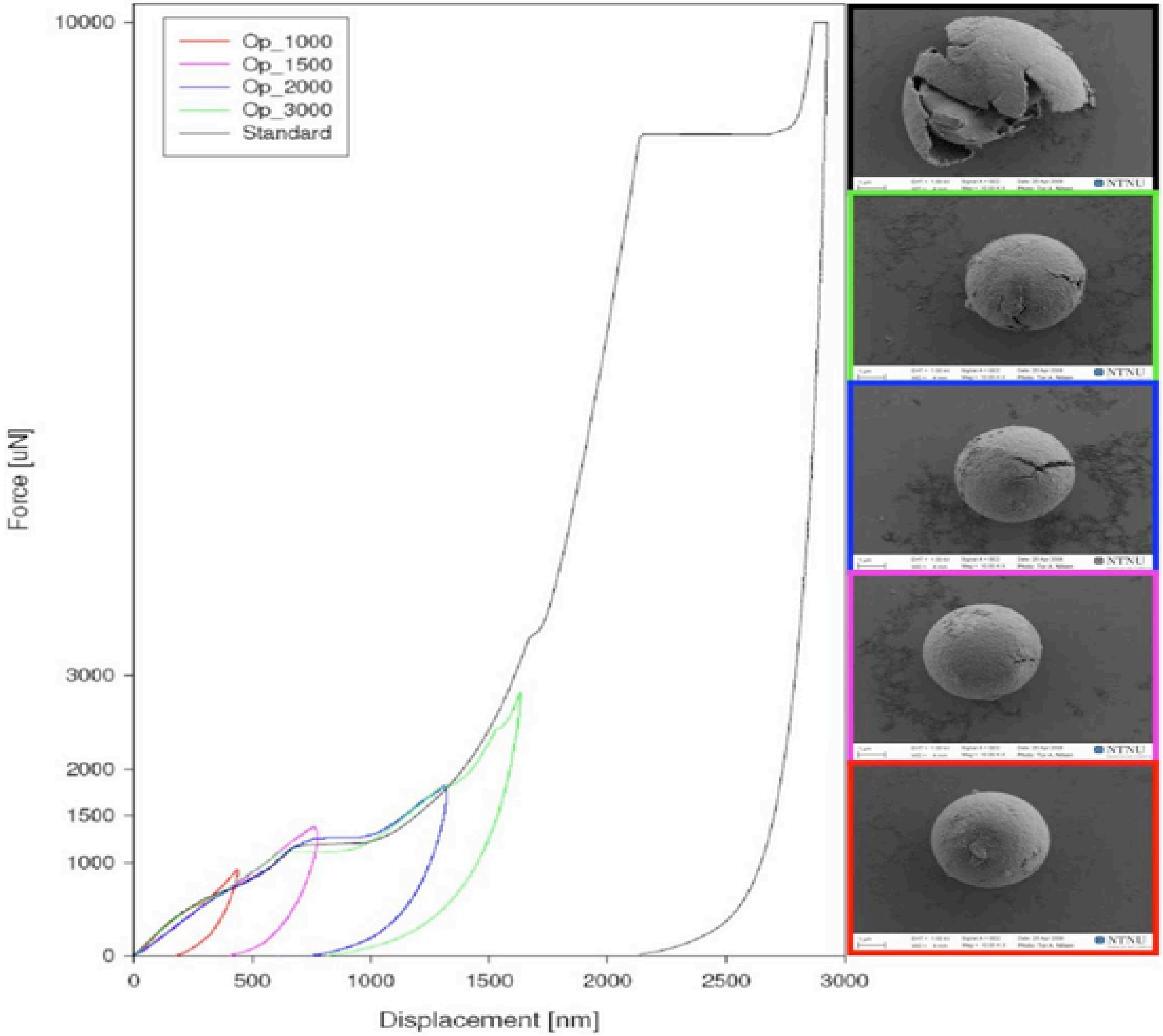


Metallised



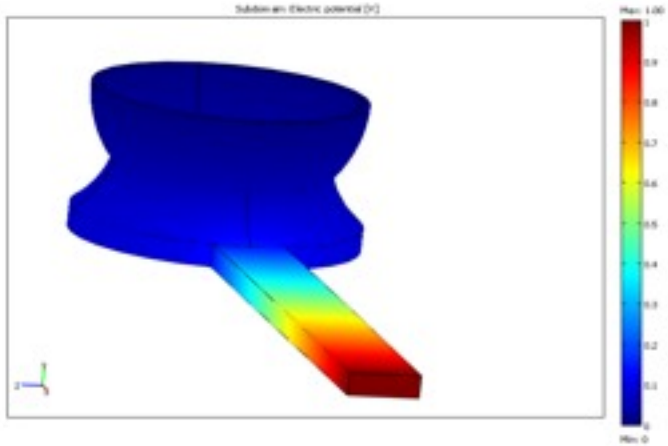
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Force (mum)
0
500
1000
1500
2000
2500
Deformation (nm)
Gold A
Gold B
Gold C
Gold D
38.0002

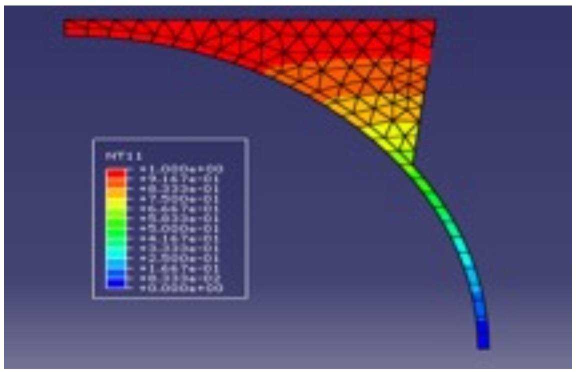
Metallised II

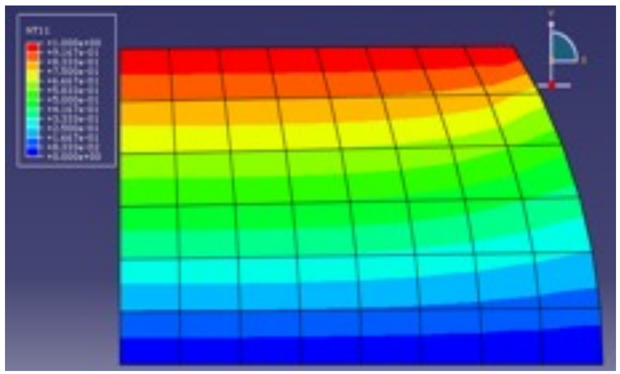


BGA: Electrical resistance

- Whalley used 2D FEA and analytical models
- Predicted an increase of around 4 × compared with solid solder ball e.g. 0.15mΩ to 0.54mΩ
- Is this significant? Unlikely!
- R of 100µm 1oz Cu track is ≈4.5mΩ/mm

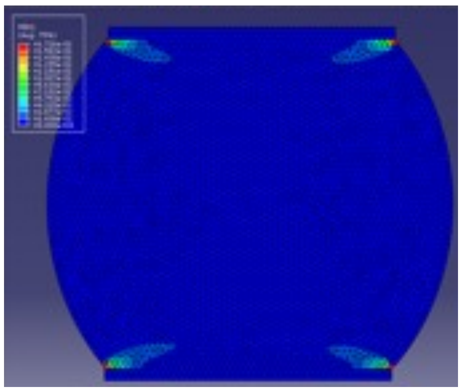


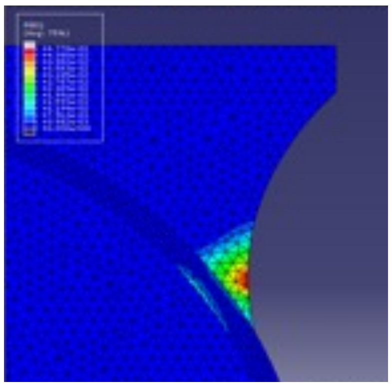




BGA: Reliability estimations

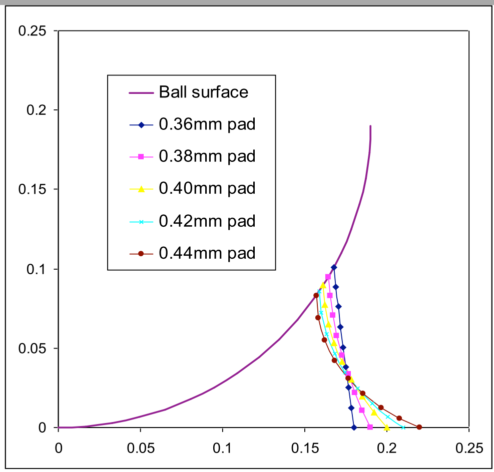
- Several computational modelling studies also presented
- Most modelling studies confirm reduced stress levels, but do not use non-linear cyclic analysis to predict life
- Guillén Marin et al. (2008) used cyclic models to estimate cyclic life and to explore some design variables

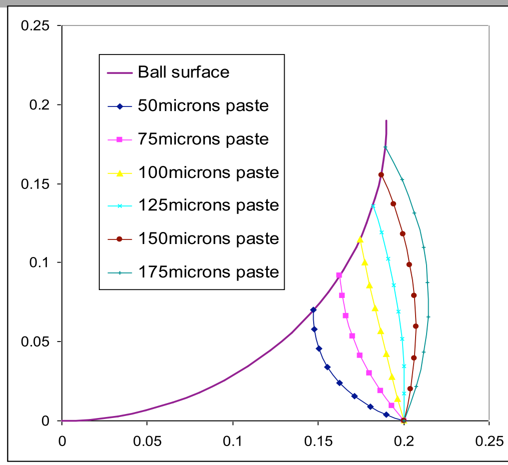


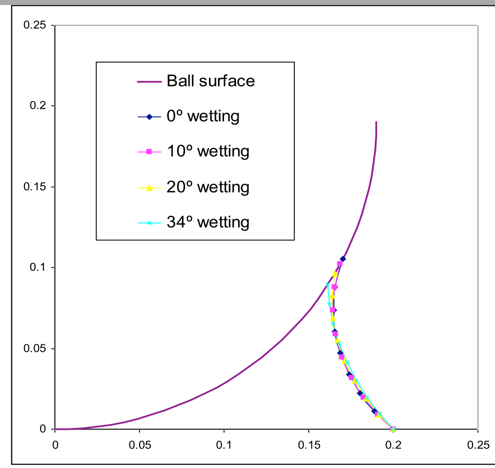


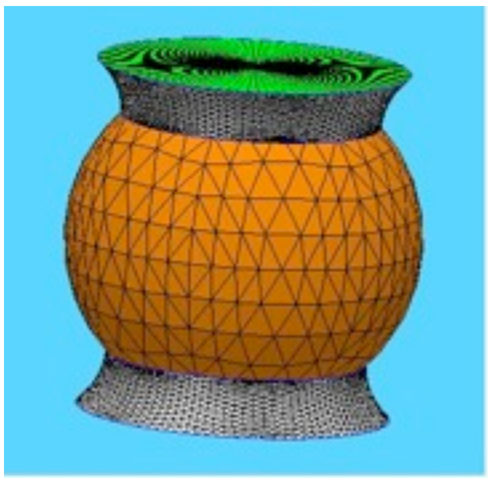
	$\Delta\varepsilon$	N_f
Conventional (SMD)	0.635	34
Conventional (NSMD)	0.387	56
Polymer core BGA	0.053	413

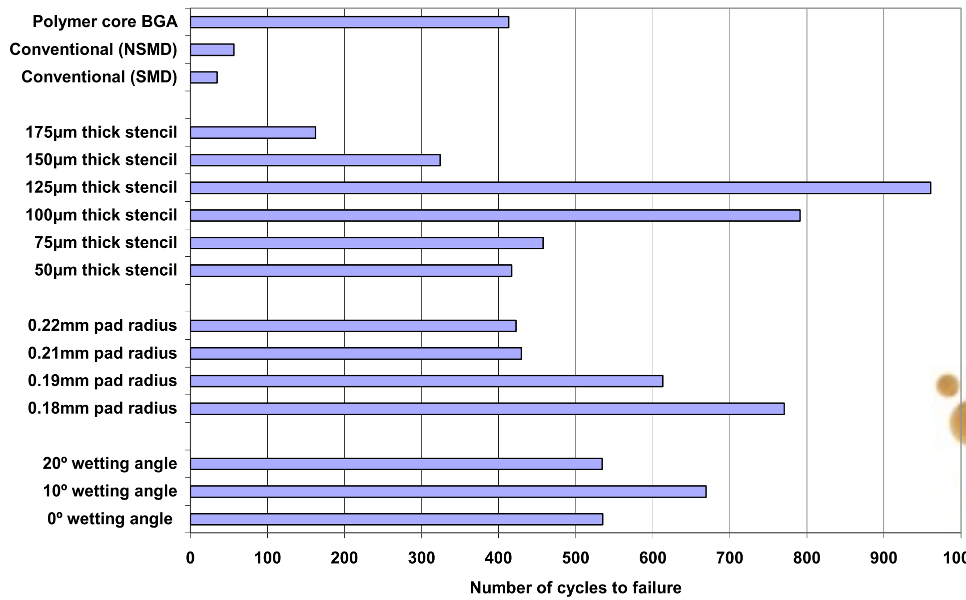
BGA: Thermo-mechanical fatigue



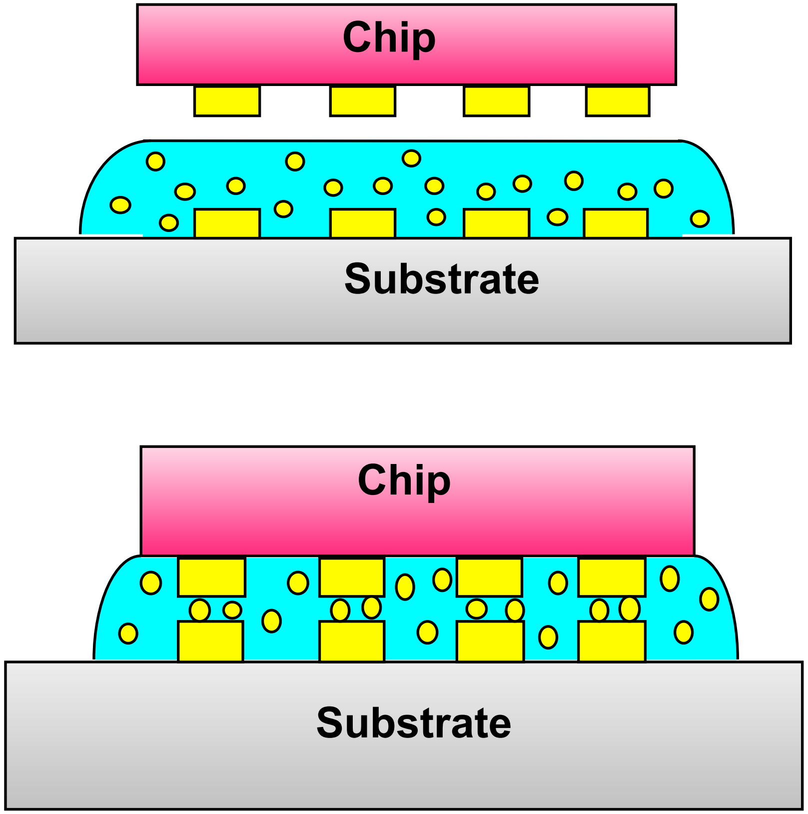






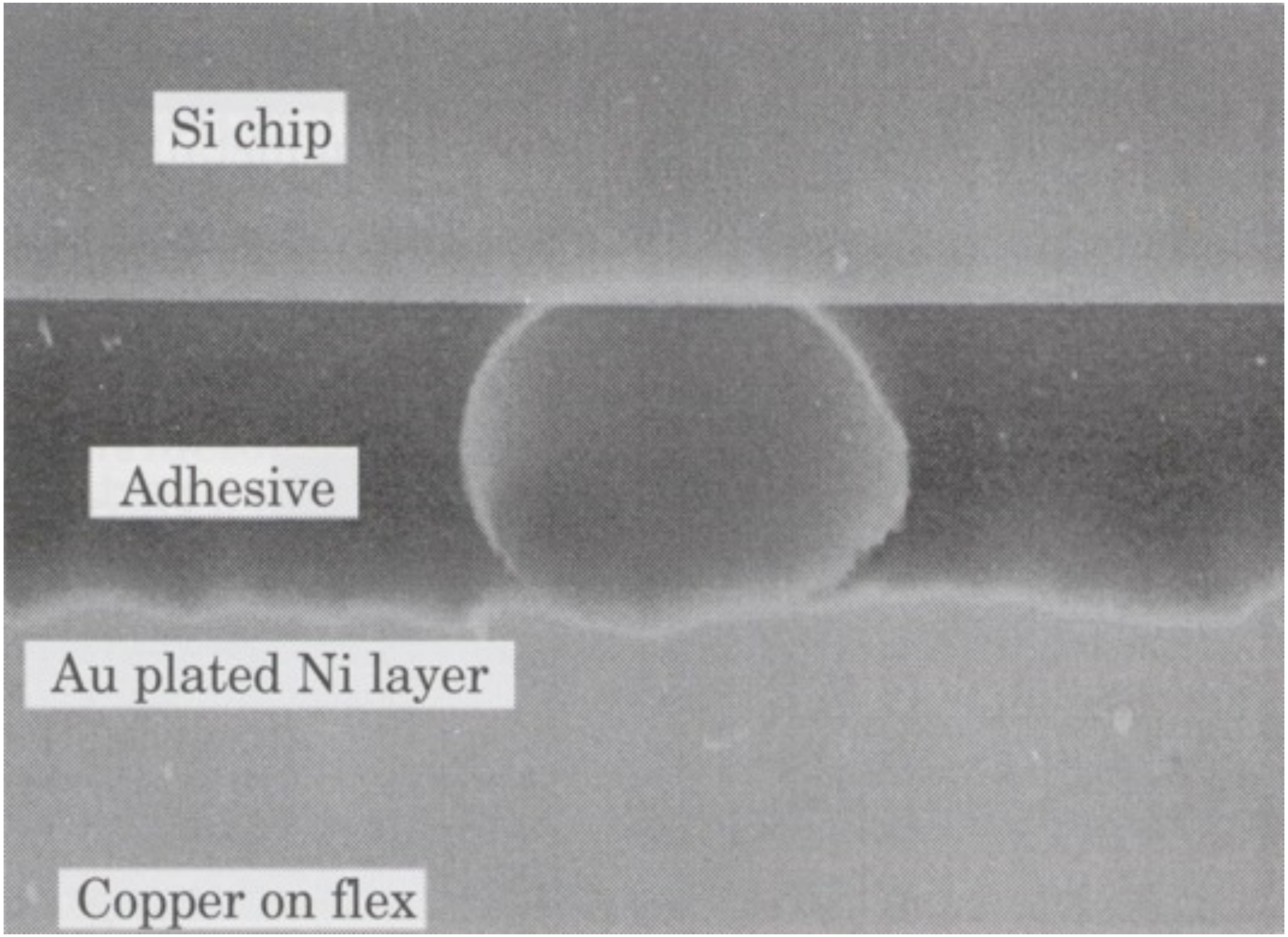


Anisotropic Conductive Adhesive

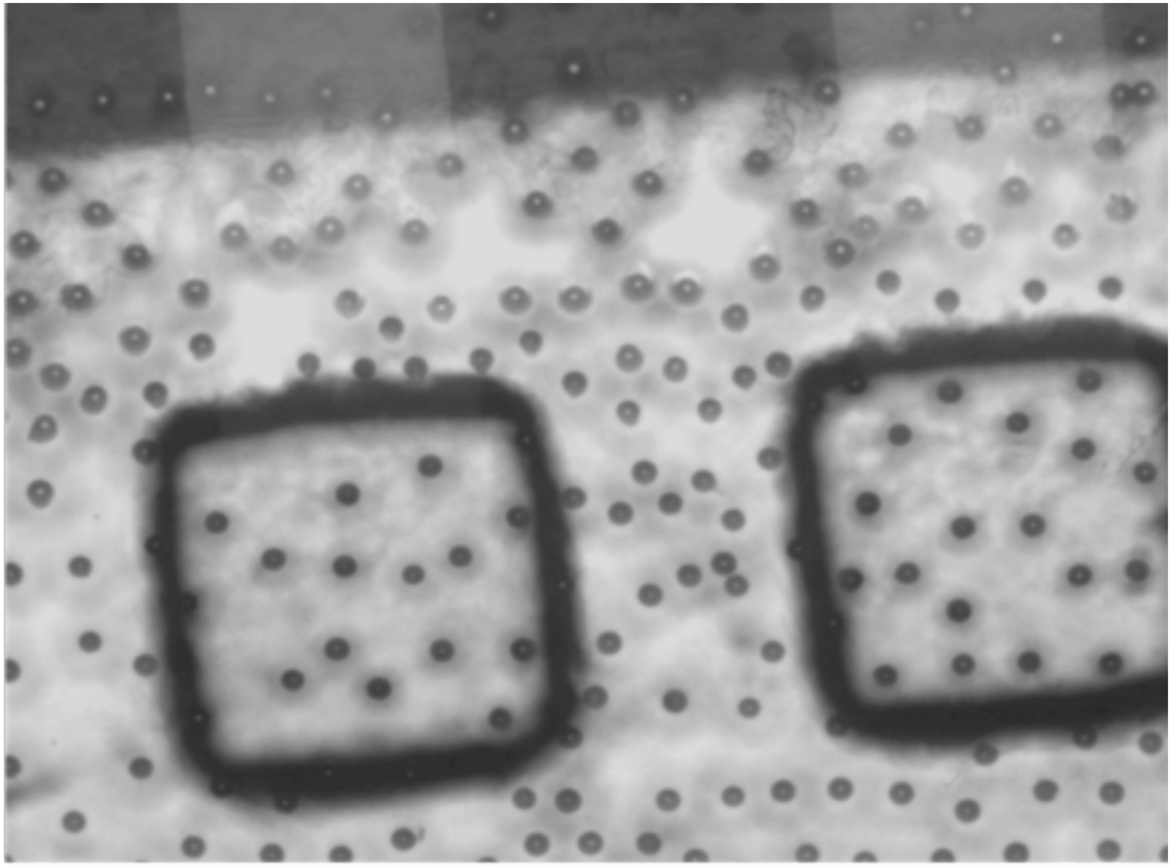


- The adhesive film is applied uniformly
- Pressure is applied during curing, giving conduction only between pads
- Thermoplastic or thermosetting
- Film (tape) or paste

Silicon on Flex



Magnetic ordering of particles



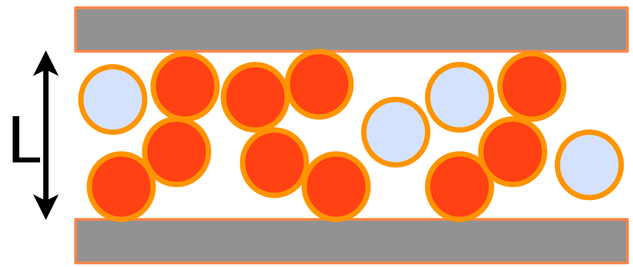
Particles trapped under a Flip Chip bump (Holloway, Interpack´99).

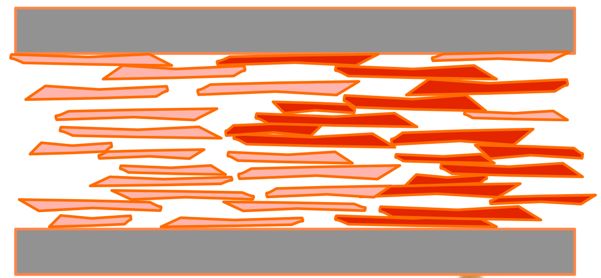
ICA: Percolation

- Continuous electrical network
  - Particle to particle
- Strongly dependent on "characteristic length"

$$\zeta = L/d$$

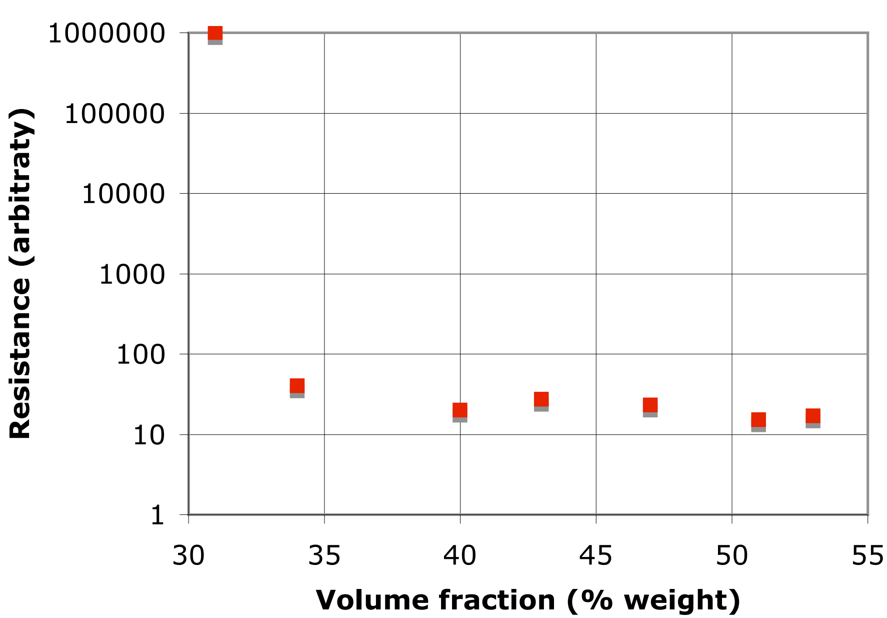
- Dependent on "orientation" of particles (non-spherical)



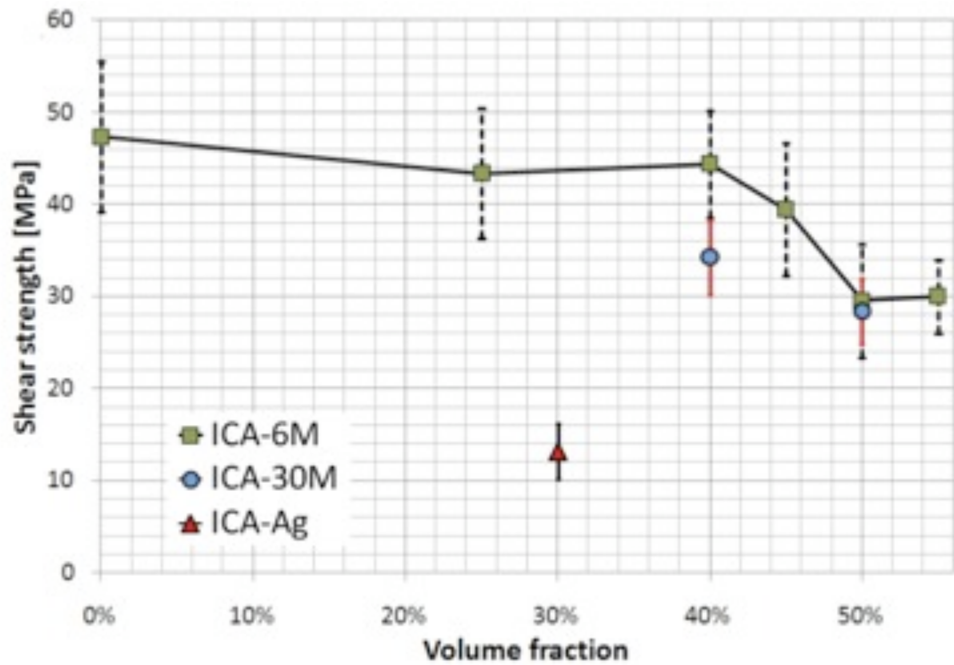


ICA: Interesting electrical and mechanical properties

Electrical



Mechanical



Seminar on Bonding Technology for Rough Environments

Metal Coated Polymer Spheres for Fine Pitch Interconnects Reliability and Failure Mechanisms

Ph.D. Candidate: Hoang-Vu Nguyen

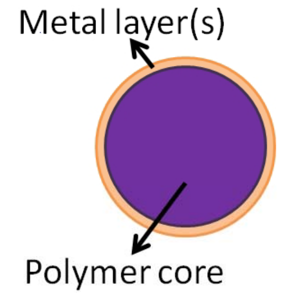
Principal supervisor: Asc. Prof. Knut Aasmundtveit

Subsidiary supervisor 1: Dr. Rolf Johannessen

Subsidiary supervisor 2: Prof. Yngvar Berg

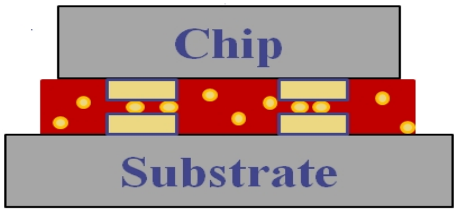
Interconnection technologies based on Metal coated Polymer Spheres (MPS)

- Increase the flexibility for interconnects
- Reduce stress induced on interconnects
- Potentially improve mechanical properties and reliability of systems
- MPS could be versatilely employed

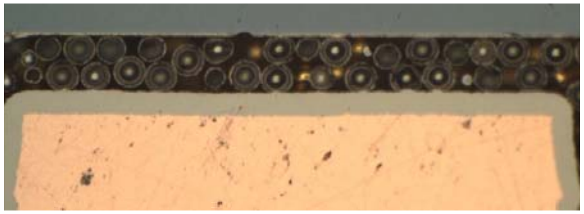


An illustration of MPS

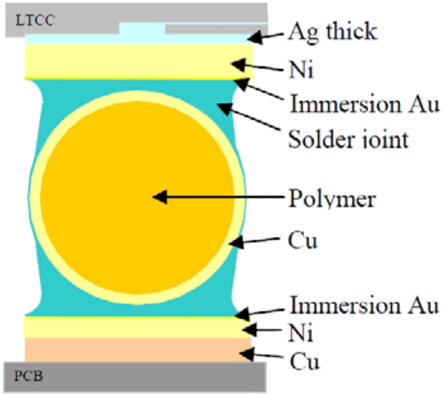
Anisotropic Conductive Adhesive Film



Isotropic Conductive Adhesive

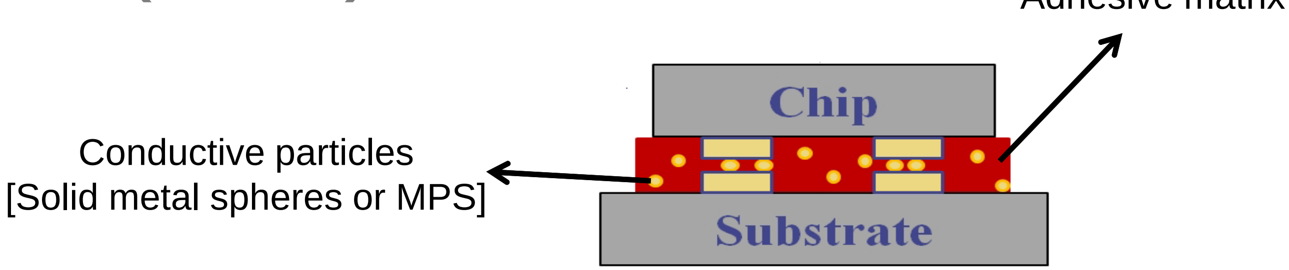


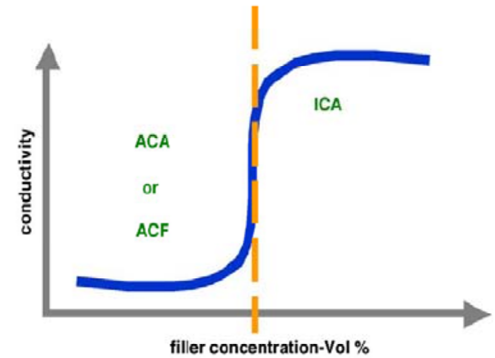
Polymer core solder ball for ball grid array/ chip scale package interconnects



VESTFOLD UNIVERSITY COLLEGE

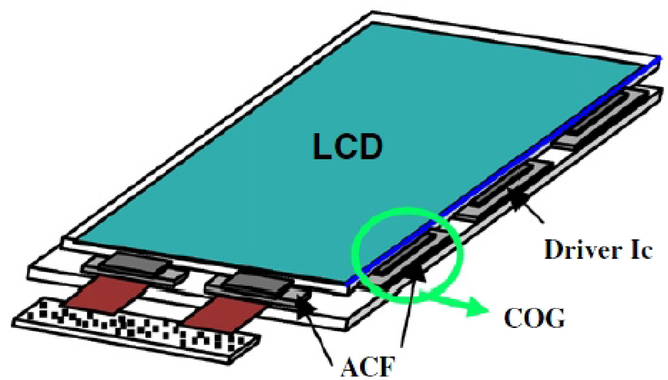
Anisotropic Conductive Adhesive Film (ACF)





Y. Li *et al.*, Materials Science and Engineering R 51 (2006), pp 1–35

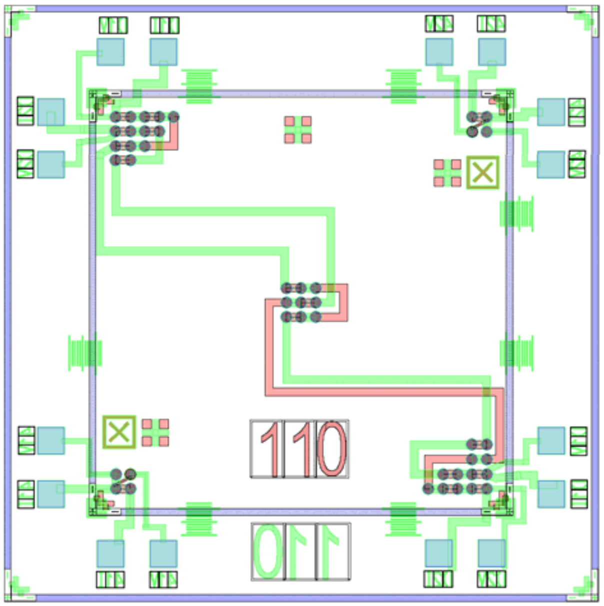
- Alternative to solder interconnects
- **Fine pitch**
- Improve mechanical properties
- Improve reliability in rough environments
- Low cost
- Environmental friendliness



M. J. Yim *et al.*, International Jounrnal of Adhesion & Adhesives 27 (2007), pp 77–84

Anisotropic Conductive Adhesive Film

Interconnect pitch: 110, 125, 150 and 200 µm

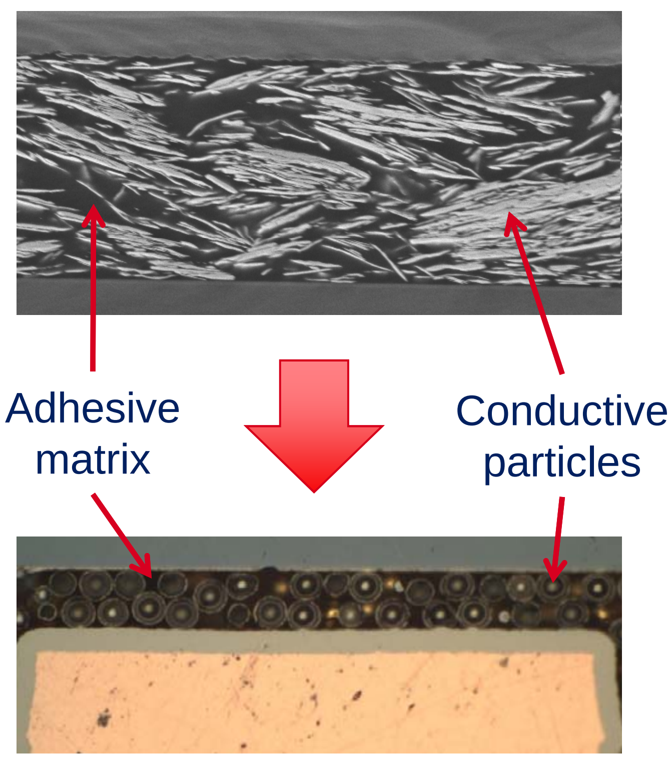


Silicon chips and substrates were fabricated by MiNaLab, SINTEF ICT, Norway

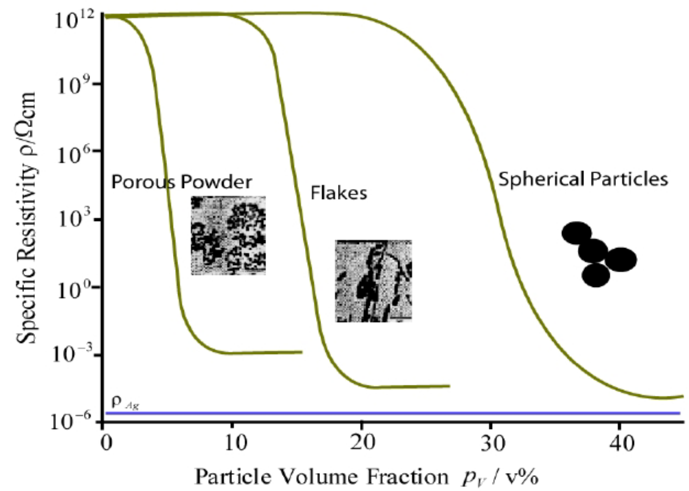
- Electrical properties:
  - Insignificant differences between samples with interconnect pitch from 110 µm to 200 µm
  - High bond yield
  - No short circuit between adjacent joints of the two daisy chains
- High mechanical shear strength
  - above 500 N for 3.1 x 3.1 mm^2 die
- Thermal shock cycling test (-40 - +125 ^oC)
  - 750 thermal cycles have been tested
  - Contact resistance slightly decreased
  - No open circuit or short circuit between the two daisy chains

Isotropic Conductive Adhesive (ICA)

Conventional ICA (Ag epoxy)



Novel ICA filled with MPS



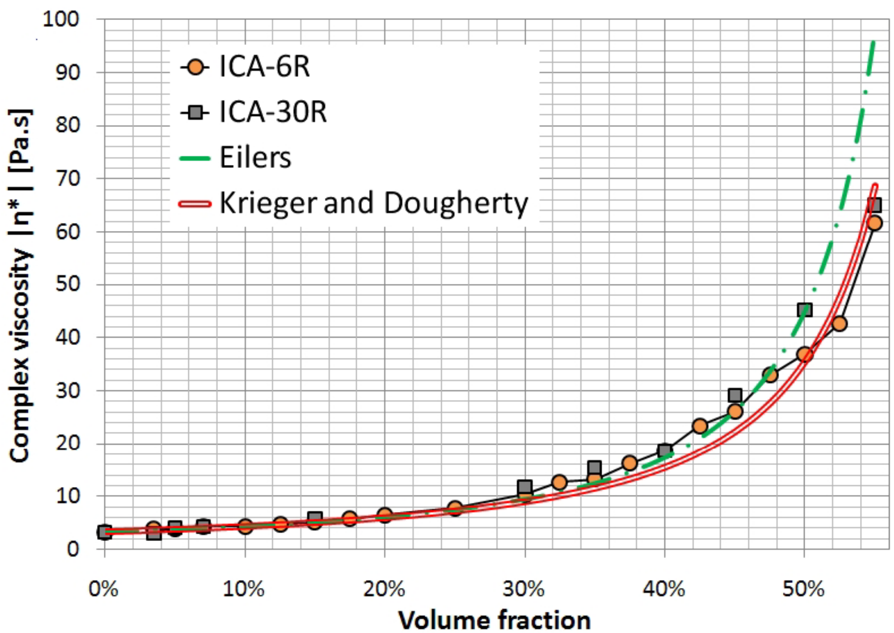
Percolation limits of different ICA filler particles

J. Morris, Lecture at Vestfold University College, Borre, Norway, 2008

- Critically increase the viscosity of the system?
  - limit the processing capabilities of the novel ICA
- Reduce adhesion strength?
  - reduce volumetric fraction of the adhesive matrix

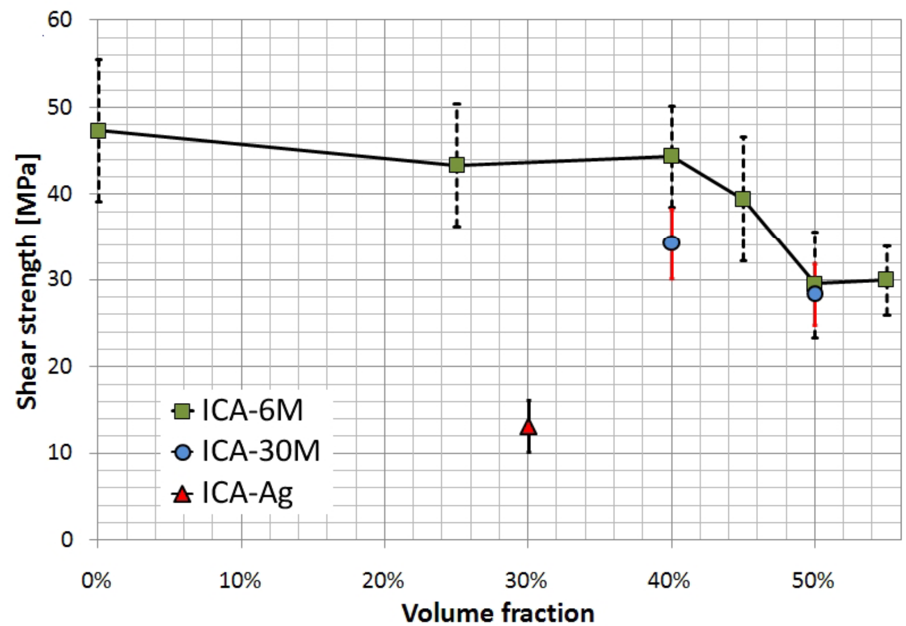
Feasibility study – Adhesive filled with non-metalized polymer particles

Rheological properties



ICA-6R: Resin of EPO-TEK 353ND mixed with Ø6 µm particles
ICA-30R: Resin of EPO-TEK 353ND mixed with Ø30 µm particles

Mechanical shear strength



ICA-6M: EPO-TEK 353ND mixed with Ø6 µm particles
ICA-30M: EPO-TEK 353ND mixed with Ø30 µm particles
ICA-Ag: Ag epoxy EPO-TEK H20E

- Well fitness of both semi-empirical models to the measured data
- Negligible long range interactions between particles in our system

H.-V. Nguyen, *et al.*, "Spherical Polymer Particles in Isotropic Conductive Adhesives - A Study on Rheology and Mechanical Aspects," in *The 3rd Electronics System Integration Technology Conferences*, Berlin, Germany, 2010.

imst
Institute of Micro and Nano Systems Technology

Summary

- Anisotropic conductive adhesive film
  - Insignificant differences between samples with interconnect pitch from 110 µm to 200 µm
  - No open circuit or short circuit between adjacent joints after 750 thermal shock cycles (-40 - +125 ^{o}C)
- Isotropic conductive adhesive
  - ICA filled with MPS is very promising
  - Further study for mechanical, electrical properties and reliability

Thank you for your attention!

Email: vhn@hive.no