Evaluation of Adhesive Materials for use in High-Reliability Flip-Chip Assembly

Ireland's ICT Research Institute

Finbarr Waldron,
NMRC, Cork, Ireland.

European Space Agency

Programme Aims & Objectives

- Evaluate reliability of commercially-available flip-chip adhesives for use in space applications.
- Study a representative range of materials.
- Determine thermomechanical properties & behaviour.
- Assess quality of assembly achievable.
- Measure thermal performance.
- Investigate ability to withstand harsh environmental stresses.

Work Undertaken by:

- NMRC, Cork, Ireland (Prime Contractor)

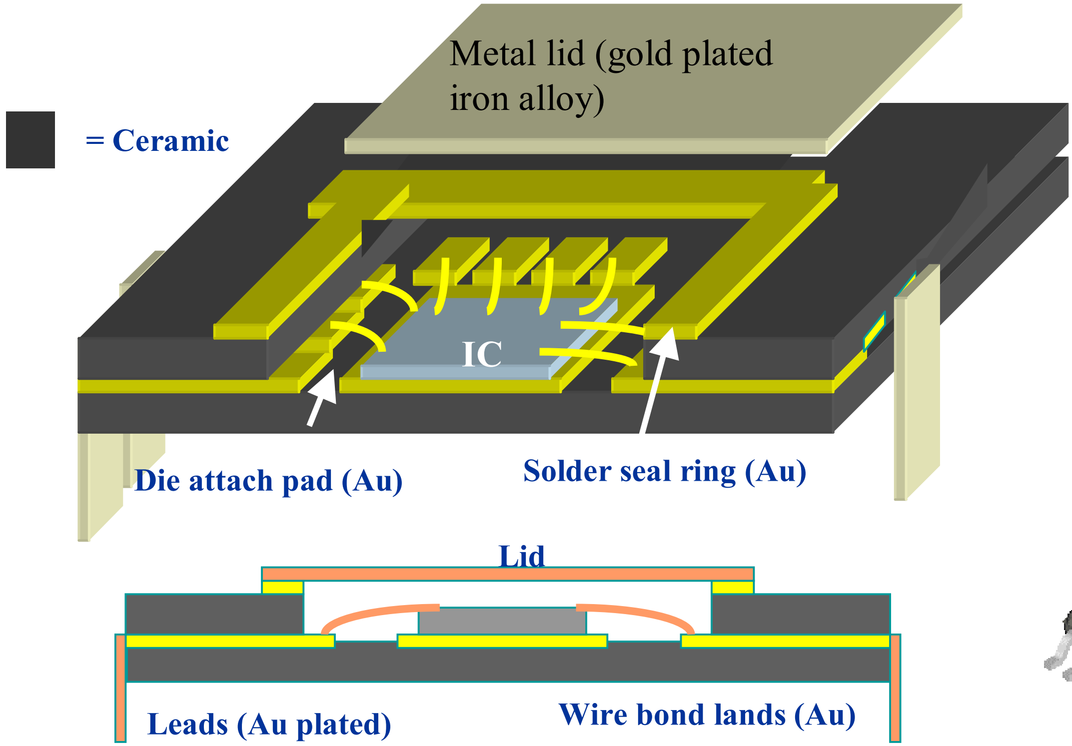
- ASTRIUM, Velizy, France (VFL substrates)

Presentation Outline

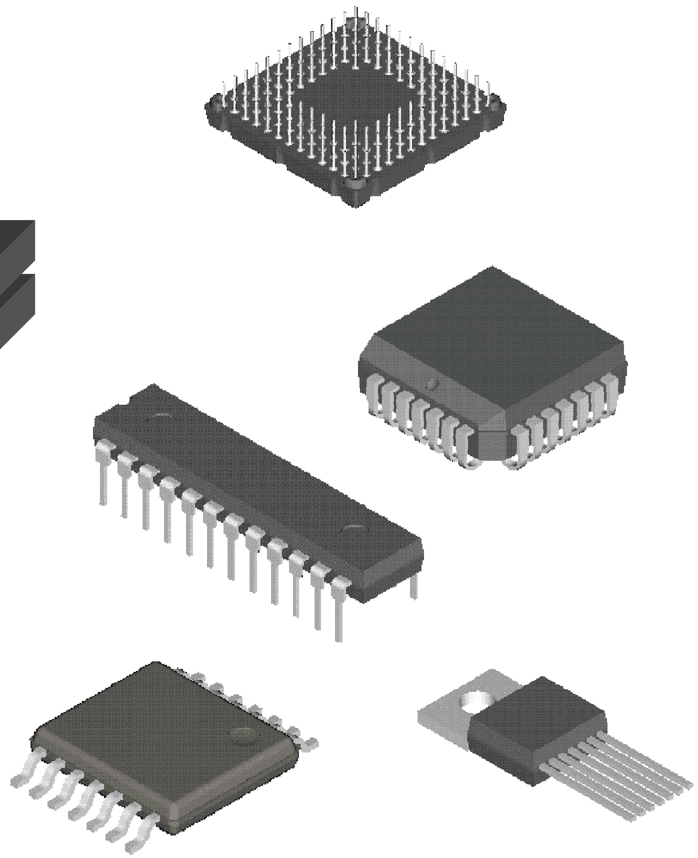
- Introduction ←
- Flip-Chip Assembly Technologies
- Evaluation Programme:
  - *Approach*
  - *Materials Evaluation*
  - *Test Vehicle Details, Assembly & Verification*
  - *Reliability Testing*
  - *Results to Date*
- Conclusions / Summary / Acknowledgements

Introduction

Traditional Packaging Technologies:

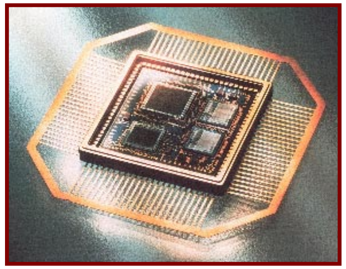


Hermetic Ceramic Packaging



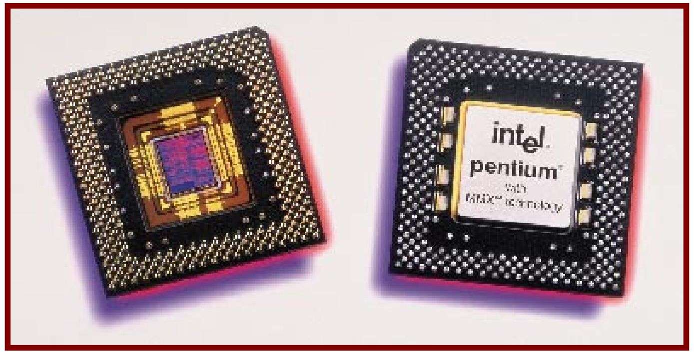
Plastic Packaging

Introduction



Traditional Packaging Technologies:

- **Advantages:**
  - **Well proven technologies**
  - **Robust & Reliable (especially ceramic & metal-can)**
  - **Good thermal performance (ceramic / metal)**
  - **Cost-effective (plastic)**
- **Drawbacks:**
  - **More complex than necessary**
  - **Electrical performance**
  - **Limited density**
  - **Size & weight**



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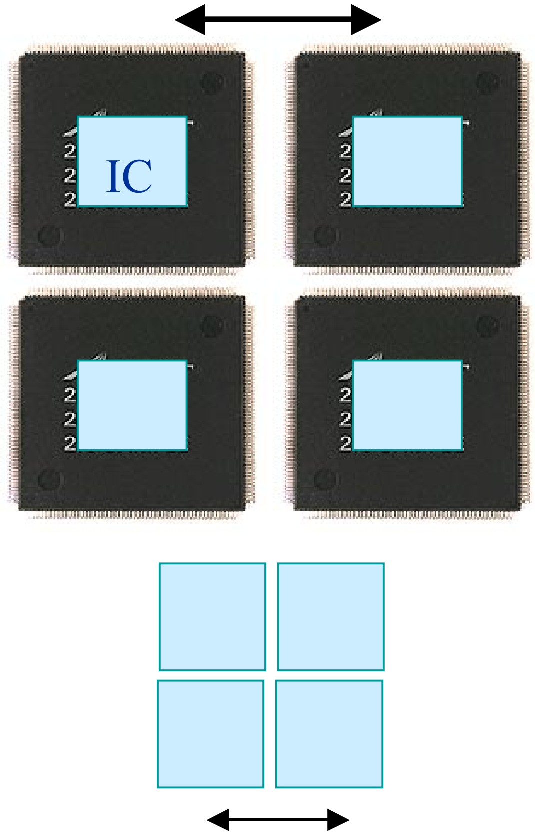
Introduction

Flip-Chip Packaging:

- **What?**
  - *Direct attachment of the IC to a substrate*
- **Why?**
  - *Almost zero interconnection parasitics between chip and package*
  - *Possible to put chips almost edge to edge*
  - *High packing density of ICs*
    - Standard PCB: 10% of area occupied by silicon ("packing density")
    - Flip-chip PCB: 75% packing density
  - *Very short interconnect – high speed*

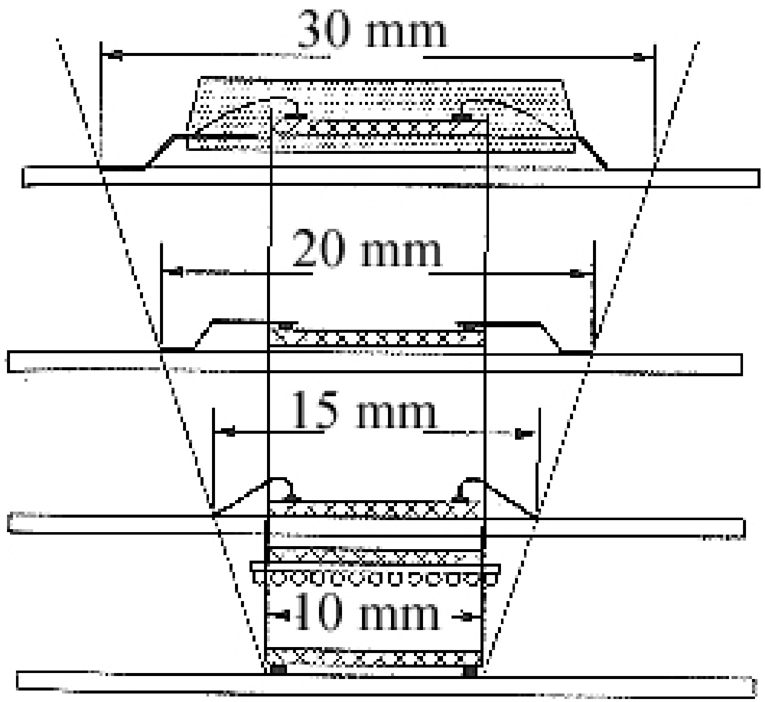
IC edge to edge distance using plastic packages



IC edge to edge distance using flip-chip

Introduction

Comparison of Alternative Packaging Options:

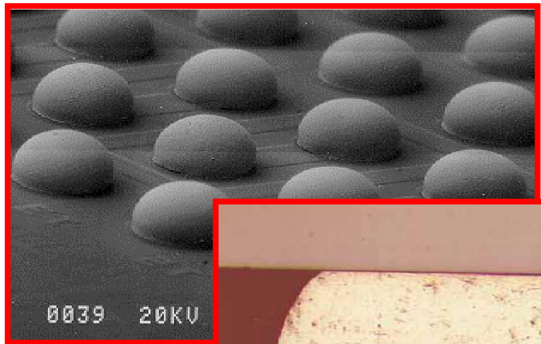


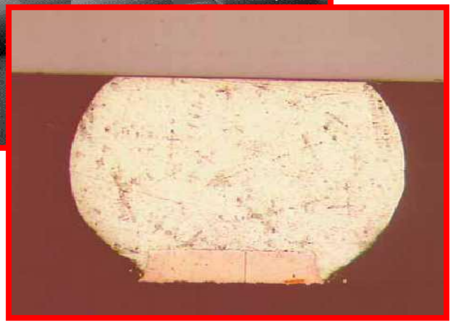
Type	Footprint Area
QFP:	900 mm² - 100%
TAB:	400 mm² - 44%
COB:	225 mm² - 25%
CSP:	115 mm² - 13%
Flip-Chip:	100 mm² - 11%

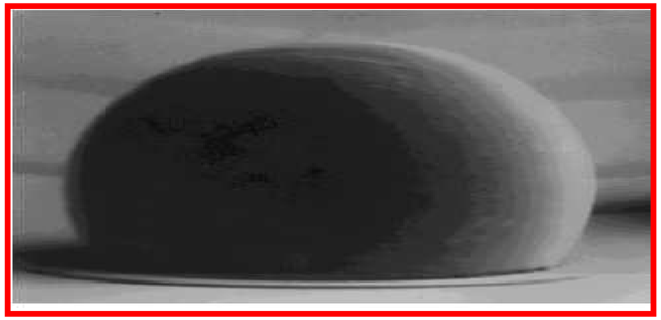
(Source: Hewlett Packard)

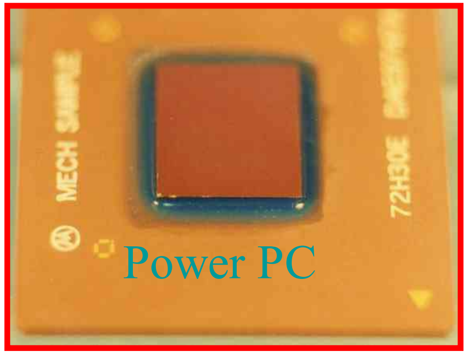
Introduction

Flip-Chip Packaging Examples:



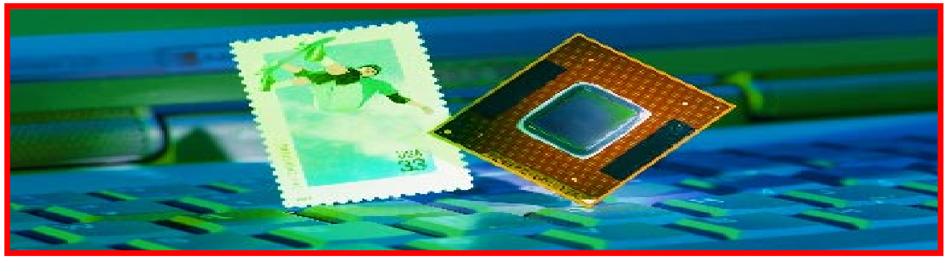






Power PC

Pentium III



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- Introduction
- Flip-Chip Assembly Technologies
- Evaluation Programme:
  - *Approach*
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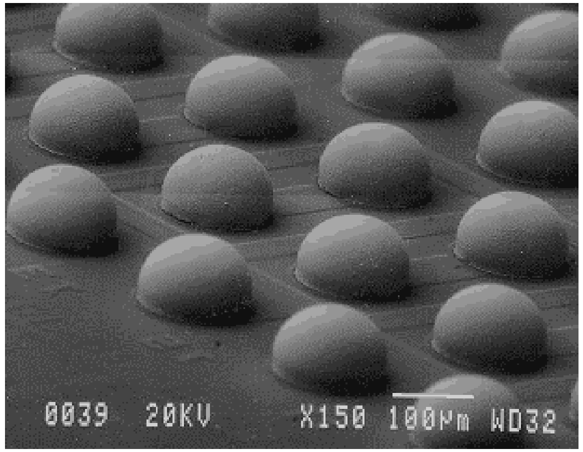
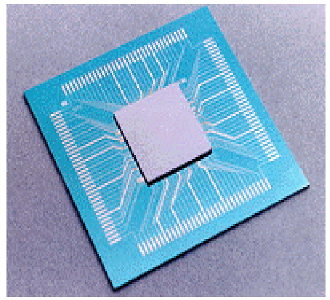
Flip-Chip Assembly Technologies

Solder-based Flip-Chip Assembly:



- Controlled Collapse Chip Connection (C4)
- Originally developed by IBM in 1960's.
  - Form solder bumps on chip pads
    - *Mask & deposit*
    - *Plated bumps*
  - Place chip on substrate & align accurately
  - Reflow (high temp.)
  - Underfill (increases bond area – reduces stress)

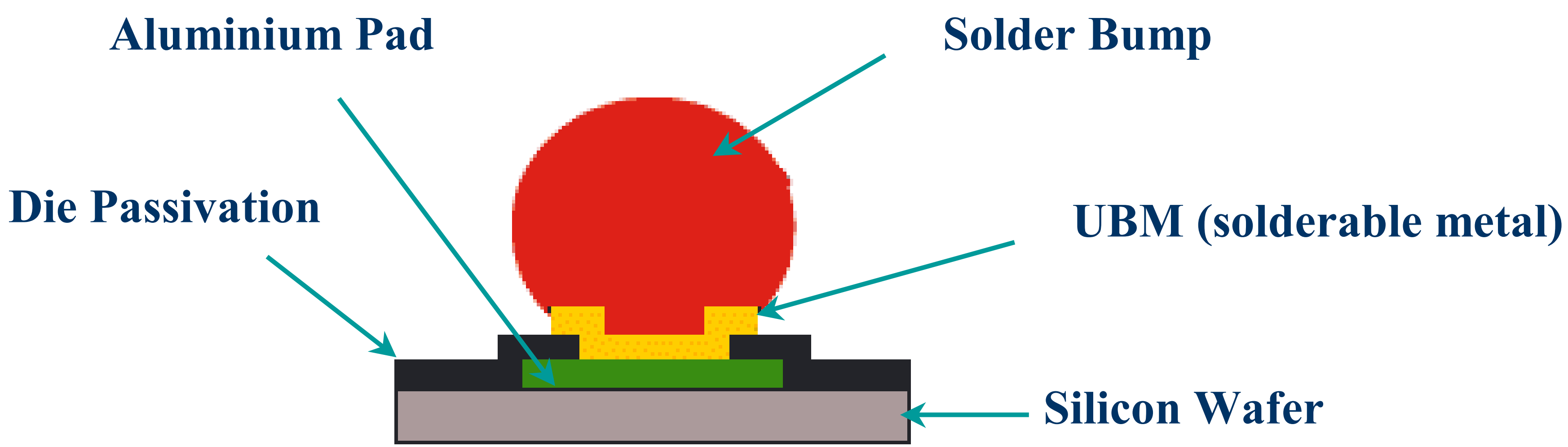
Adhesive-based Assembly:

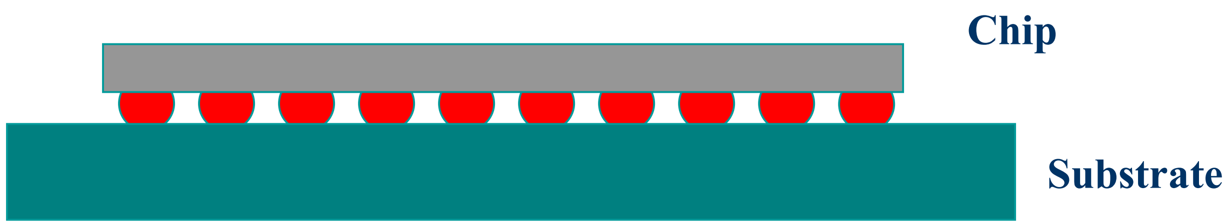


- Chip bumps not always required
- Typical bump metalisation Ni/Au (Electroless deposition)
  - Adhesive applied to substrate (blanket or selective deposition)
  - Place & align chip
  - Cure adhesive (usually low temp. process).

Flip-Chip Assembly Technologies

Solder Flip-Chip Assembly:

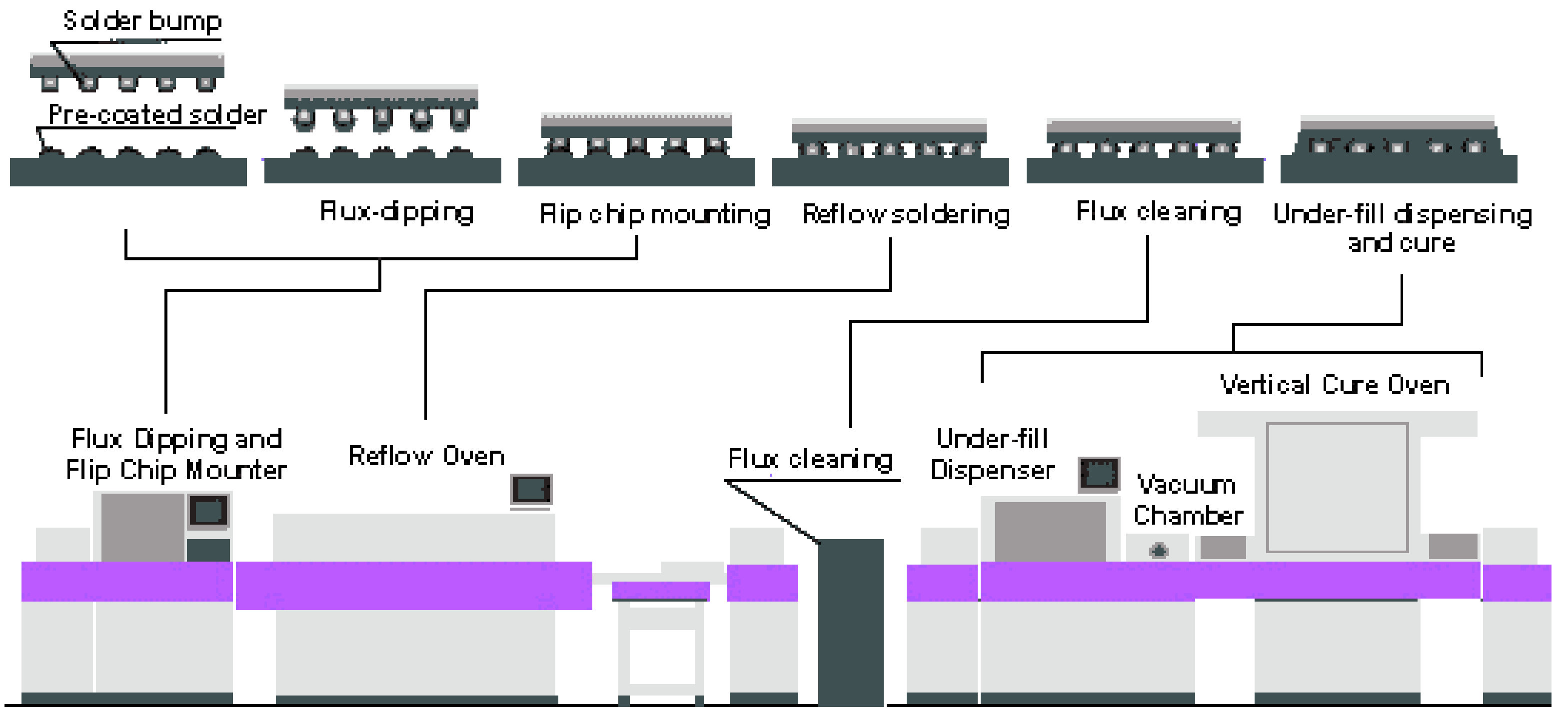




Robust Rigid Connection, but Joint Stresses are High

Flip-Chip Assembly Technologies

Solder Flip-Chip Assembly:



Typical Solder Flip-Chip Process Flow

Flip-Chip Assembly Technologies

Solder-based Flip-Chip Assembly:

- **Advantages:**
  - Very robust joints
  - Solder wetting forces aid alignment during reflow
  - Good thermal performance – heat transfer through joints
  - Good electrical performance
  - High density, small size & weight
- **Disadvantages:**
  - Thermo-mechanical stresses can be high – joints unyielding
  - Requires very well controlled assembly / reflow process
  - High temperature process
  - Cost – need high density to justify additional cost.

Flip-Chip Assembly Technologies

Adhesive-based Flip-Chip Assembly:

Advantages of Adhesives:

- Compliant nature – low stresses
- Easy assembly process – low temp, no fluxes
- Fine pitch capability

Three Principal Adhesive Families:

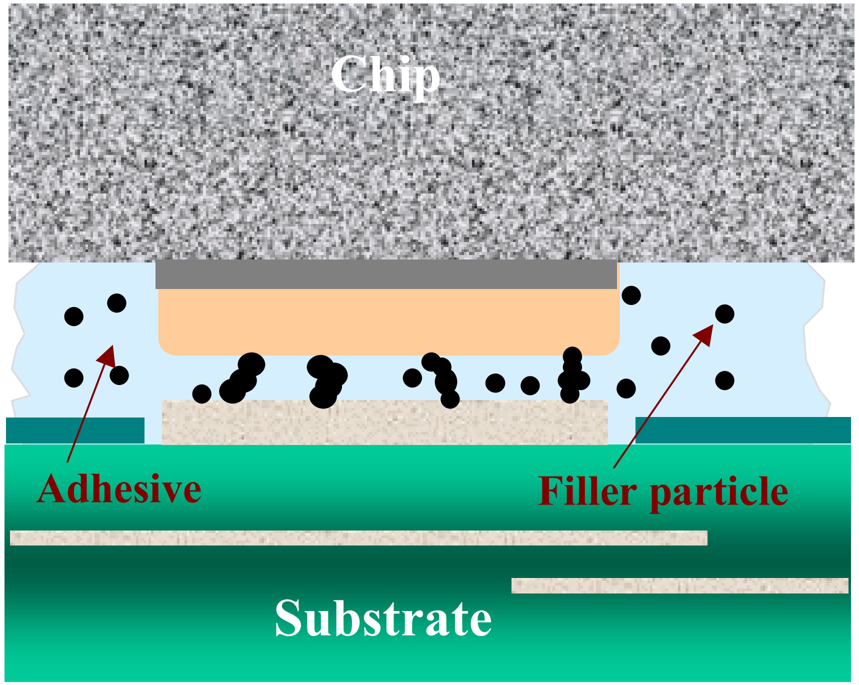
- Anisotropic Conductive Adhesives (ACA)
- Isotropic Conductive Adhesives (ICA)
- Non-Conductive Adhesives (NCA)

Drawback:

- Long-term reliability for certain applications questionable

Flip-Chip Assembly Technologies

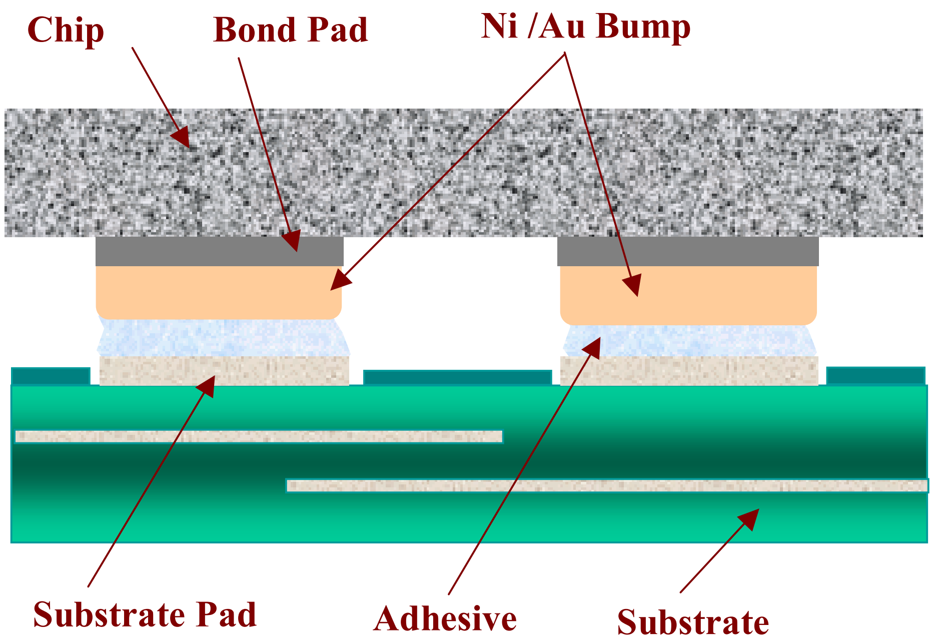
Anisotrtopic Conductive Adhesives (ACAs)



- Need not be selectively deposited
- Low filler particle loading
- Particles form connections when adhesive is compressed
- Z-axis conduction only
- Filler types:
    - *Au-coated polymer spheres*
    - *Solid metal spheres (plated)*
    - *LMP Solders (Sn-Bi)*

Flip-Chip Assembly Technologies

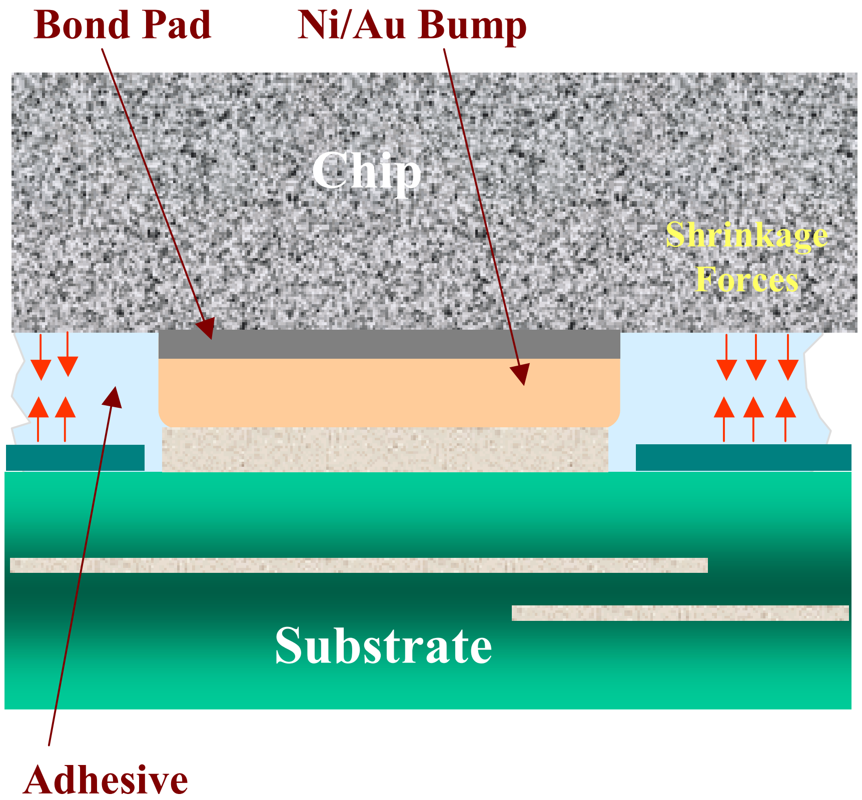
Isotropic Conductive Adhesives (ICAs)



- High filler particle loading (typically Ag flake)
- Conductive in all directions
- Must be selectively deposited:
  - *Screen / stencil printing with very accurate alignment*
  - *Transfer by contact with thin film*

Flip-Chip Assembly Technologies

Non-Conductive Adhesives (NCAs)



- Deposited on entire placement area
- Non-conductive – no filler particles
- Connection formed by pressure
- Connection maintained by high shrinkage forces after cure
- Connection quality enhanced by surface asperities
- Can be used with fusible solder coatings on contact surfaces
  - *Reflow after high-temp cure*
  - *Robust connection*

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- **Evaluation Programme:**
  - ***Approach***
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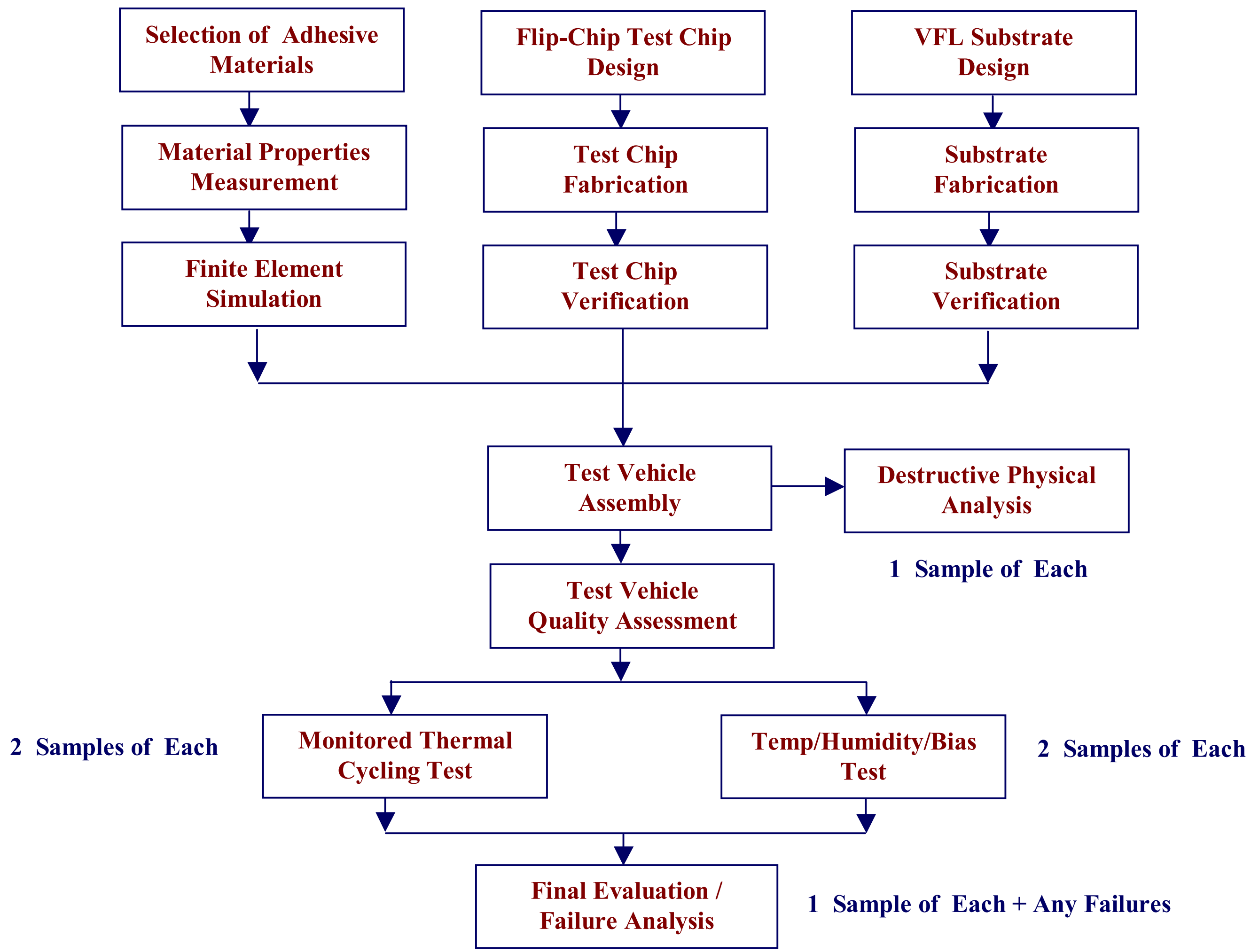
Evaluation Programme

Aims & Objectives:

- Evaluate reliability of commercial flip-chip adhesives for use in space applications
- Adhesive materials will include ICAs, ACAs & NCAs
- Key factors affecting reliability will be studied:
  - *Basic material properties / behaviour*
  - *Quality of assembly achievable*
  - *Thermal performance*
  - *Ability to withstand environmental stresses*

Evaluation Programme



Evaluation Programme

Phase 1: Materials & Technology Selection and Procurement

- ***Selection of Adhesives & Physics-of-Failure Investigation (NMRC)***
- ***Design & Fabrication of Flip-Chip Test Chips (NMRC)***
- ***Design & Fabrication of VFL Substrates (Astrium)***

- **Phase 2: Manufacturing & Reliability Evaluation of Test Samples**
  - ***Assembly of Test Structures & Non-Des. Evaluation (NMRC)***
  - ***Reliability Performance Testing (NMRC)***

Summary of Selected Materials

Anisotropic Conductive Adhesives (ACA)

- Loctite 3441 - Anisotropic Conductive Adhesive, Gold-coated polymer filler.
- Loctite 3446 - Anisotropic Conducive Adhesive, Fusible Bismuth Spheres filler.
- Bondline 2909 - Anisotropic Conductive Adhesive, Gold-coated polymer filler.
- Creative Materials Inc. - CMI 121-23, Anisotropic Conductive Adhesive, Silver flake filler.
- Dexter TG 9001 R1 - Anisotropic Conductive Adhesive, Gold particle filler.

Isotropic Conductive Adhesives (ICA)

- Loctite 3880 - Isotropic Conductive Adhesive - Silver flake filler.
- Delo ICABOND IC182 -Isotropic Conductive Adhesive - Silver flake filler (75% wt.)
- Bondline 2920 - Isotropic Conductive Adhesive - Silver Flake filler.
- Creative Materials Inc. - CMI 118-06-SD -Isotropic Conductive Adhesive - Silver (74% wt.)

Non-Conductive Adhesives (NCA)

- Loctite 3565 - Non-Conductive Underfill Adhesive
- Hysol QMI 536 Non-Conductive Adhesive, PTFE-filled.
- Creative Materials Inc. - CMI-122-24 Non-Conductive Low-Stress Underfill - Nitride filler.
- **Bondline 6900 - Low Viscosity Non-Conductive Underfill Adhesive**

Materials Property Evaluation Results

Key Material Properties Measured:

- Coefficient of Thermal expansion (CTE) – Thermo-mechanical Analyser (TMA)
- Glass Transition temperature (T_g) – Differential Scanning Calorimeter
- Young's Modulus (ε) – DMTA / Instron Tester
- Lap Shear Strength – Instron Tensile Tester

Adhesive	Type	Measured Tg (°C)	Datasheet T_g (°C)
Loctite 3441	ACA	146.3	150
Loctite 3446	ACA	151.7	156
Bondline 2909	ACA	117.8	121
CMI-121-23	ACA	107.3	105
Dex TG9001-R1	ACA	109.3	110
Loctite 3880	ICA	95.3	64
Delo AC-182	ICA	86.7	90
Bondline 2920	ICA	110.6	113
CMI-118-06	ICA	98.1	100
Loctite 3565	NCA	145.3	155
Hysol QMI 536	NCA	N/a	-31
CMI 122-24	NCA	95.3	127
Bondline 6900	NCA	125.4	Not Quoted

Measured Glass Transition Temperature (T_g) Values v Datasheet Values.

Materials Property Evaluation Results

Adhesive	Measured Values CTE below Tg (ppm)	Measured Values CTE above T_g (ppm)	Datasheet Values CTE below T_g (ppm)	Datasheet Values CTE above T_g (ppm)
Loctite 3441	57.3	151.2	55	140
Loctite 3446	54.0	147.8	55	140
Bondline 2909	36.3	104.1	35	100
CMI-121-23	58.7	160.2	Not Quoted	Not Quoted
Dex TG9001-R1	70.1	154.2	67	Not Quoted
Loctite 3880	68.7	191.2	110	188
Delo AC-182	88.3	197.2	Not Quoted	Not Quoted
Bondline 2920	76.7	173.2	79	189
CMI-118-06	28.7	148.2	17	147
Loctite 3565	28.7	92.4	25	80
Hysol QMI 536	N/a	190.9	93	174
CMI 122-24	38.2	160.2	55	168
Bondline 6900	60.5	120.1	31	31

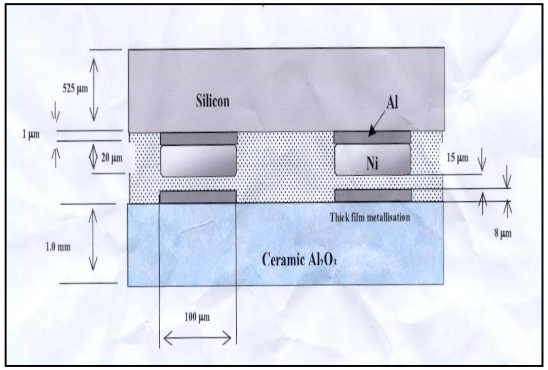
Measured CTE Values v Datasheet Values.

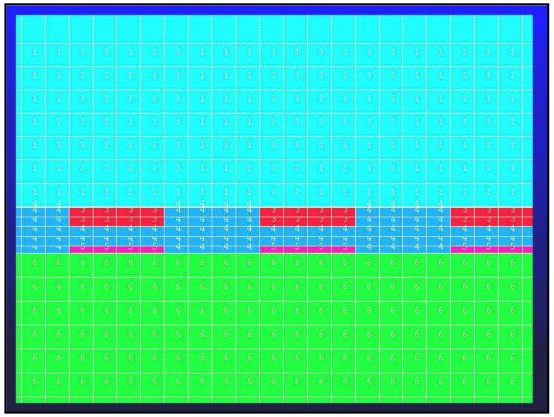
Conclusions - Material Properties Measurements:

- **CTE, Tg and Bond Strength show reasonable agreement with manufacturer's values (where quoted).**
- **For CMI-122-24, Measured T_g = 95.3° (Manufacturer's T_g = 127°C).**
- **In many cases Tg < 125°C**
- **Modulus values not quoted in many cases.**
- **Bond strengths generally high, butLoctite 3565 has quoted bond strength of 4.9 MPa.**

Thermo-mechanical Modelling

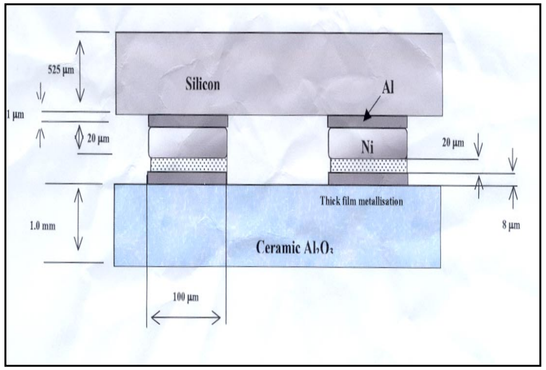
ACA:

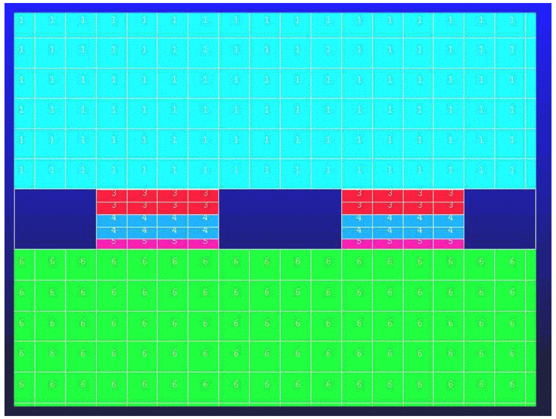




Blanket deposited ACA
with thickness = 8.0 µm

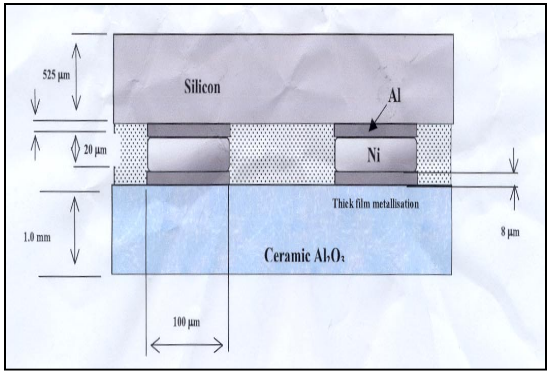
ICA:

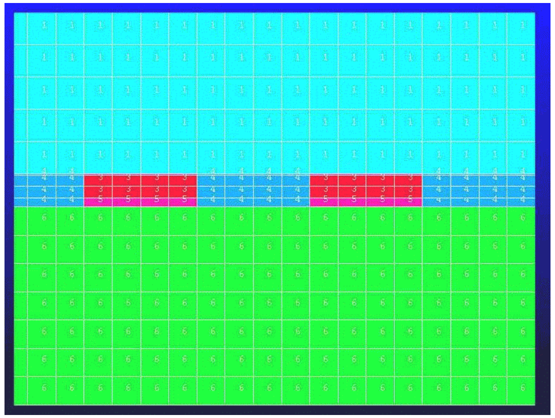




Selectively-deposited ICA
with thickness = 8.0 µm

NCA:

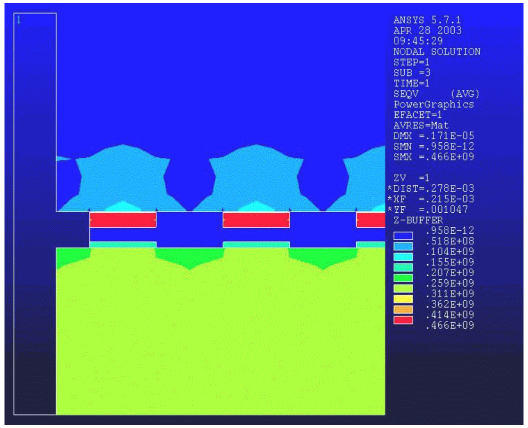




Blanket-deposited NCA
No adhesive assumed in joints

Thermo-mechanical Modelling Results

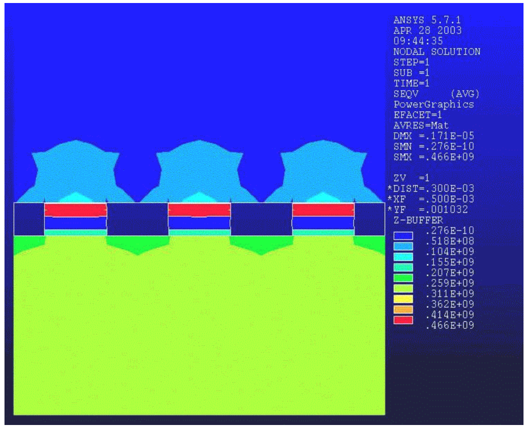
ACA Results:



Finite Element Model at +125°C showing worst case stress condition for ACA materials.

- Acts as own underfill – large bond.
- Compliant & relieves stress.
- Stress negligible at each temp (-55°C and +125°C).
- Unlikely to fail due to stress
- Conduction may be disrupted by movement – 3 µm possible.

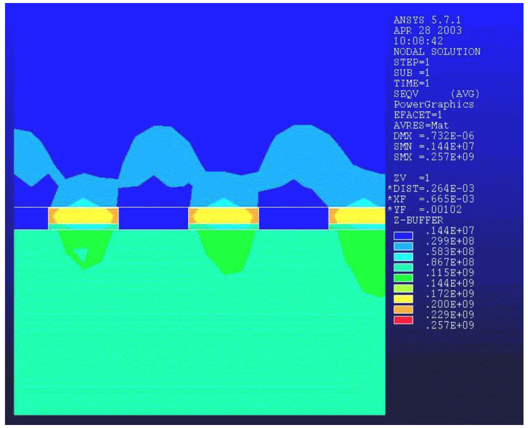
ICA Results:



Finite Element Model at +125°C showing worst case stress condition for ICA materials.

- Smaller bond area.
- Also compliant.
- Stresses higher than ACA, but still low overall.
- Unlikely to fail due to stress
- High filler density – less Affected by movement.

NCA Results:



Finite Element Model at -55°C showing worst case stress condition for NCA materials.

- No adhesive in joint area.
- Compliant.
- Slightly higher stresses than ACA.
- One material could fail due to stress > bond strength (Loctite 3565).

Conclusions – Materials Evaluation

- Greatest choice of adhesives for flip-chip assembly were in the ACA category.
- Measurement of CTE for all of the selected materials showed good agreement with manufacturers values (where quoted).
- Measurements of T_g for the adhesives also agreed closely with the manufacturers figures (except one NCA - CMI-122-24 where T_g = 95.3° (CMI T_g = 127°C).
- T_g in many cases is lower than the target 125°C upper operating temperature.
- Modulus information not quoted for many adhesives.
- Expected stresses in all materials are low due to their compliant / soft nature.
- ACA may be prone to movement of up to 3.0 μm leading to a risk of open circuits.
- ICA also prone to risk of movement, but open circuits less likely due to filler density.
- Highest risk of stress failure is with NCA material (L 3565) at 125°C where model predicts Von Mises stress of 3.9 MPa. Loctite 3565 has quoted bond strength of 4.9 MPa.

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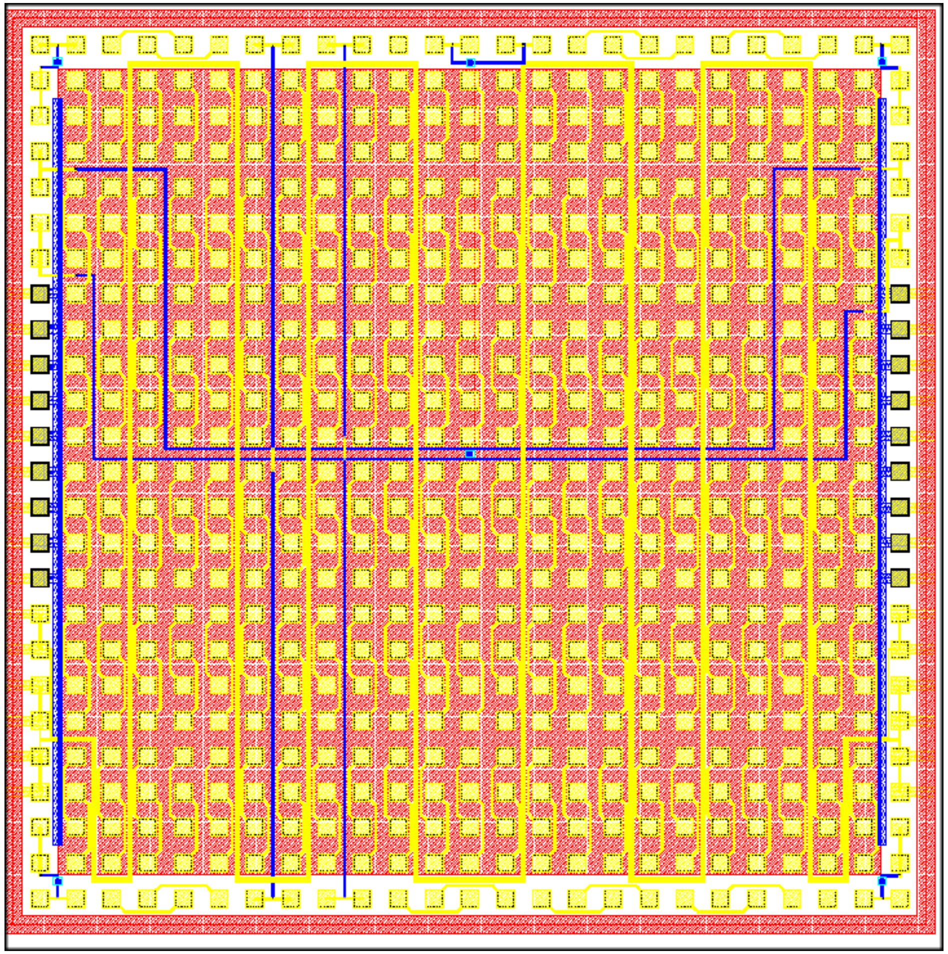
Flip-Chip Test Chip (FCTC1)



Test Structure Summary

- **1 Polysilicon Heater Resistor**
- **6 Temp-Sensing Diodes**
- **1 Triple-track Corrosion Monitor**
- **14 Peripheral Daisy Chains**
- **1 Pad Array (23 X 23)**
- **Unit size = 5 mm X 5 mm**
- **Pad size = 100 µm X 100 µm**
- **Pad Pitch = 200 µm**

FCTC1 Specification

Corrosion Monitor

Line Width:	**5 μm**
Line Spacing:	**4 μm**
Line Lenth:	**43 μm**
Thickness:	**1 μm**
Resistance:	**270 Ω**
Max Bias:	**20 V**

Heater Resistor

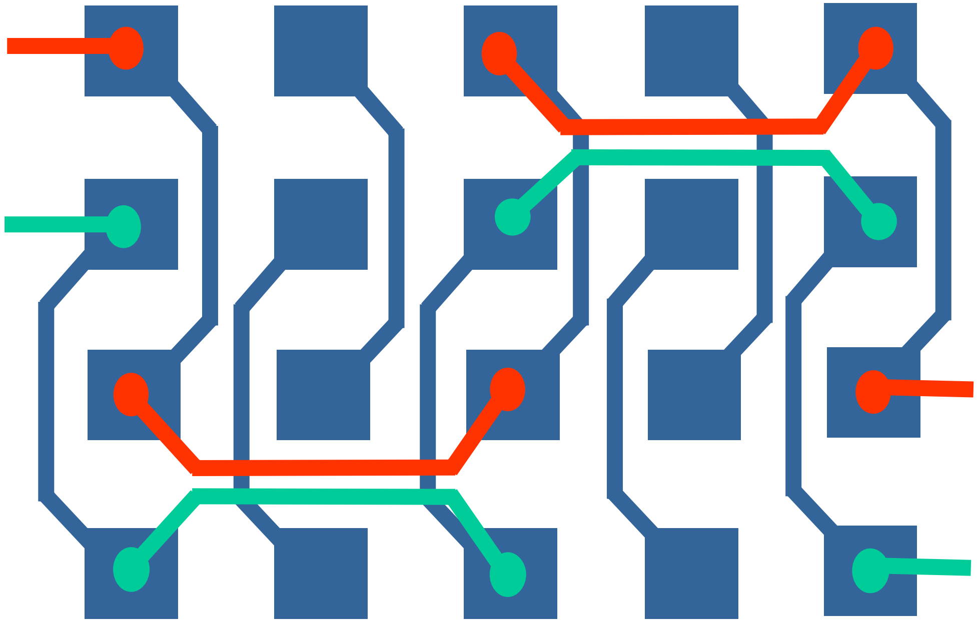
Dimensions:	**4,594 μm X 4,531 μm**
Area:	**20.82 mm^2**
Resistance:	**20 Ω**
Max Power:	**3.5 W**

Temperature-Sensing Diodes

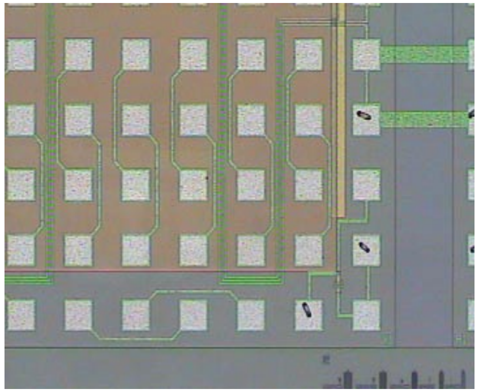
Fwd V	***@ 1 μA:***	**0.45 V**
	@ 10 μA:	**0.50 V**
	@ 100 μA:	**0.55 V**
Breakdown:		**80.0 V**

Flip-Chip Pad Array

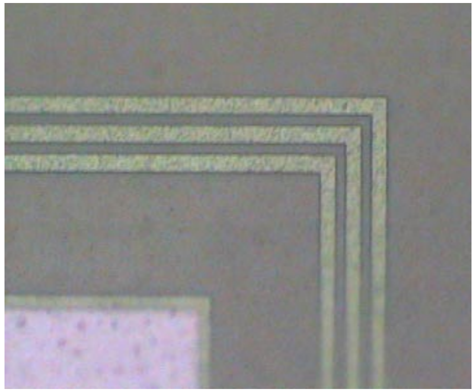
Line Width:	**10 μm**
Line Lenth:	**320 μm**
Thickness:	**1 μm**
Resistance:	**1.5 Ω**



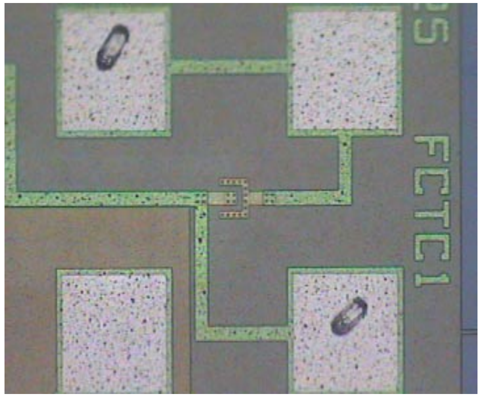
Test Chip Verification



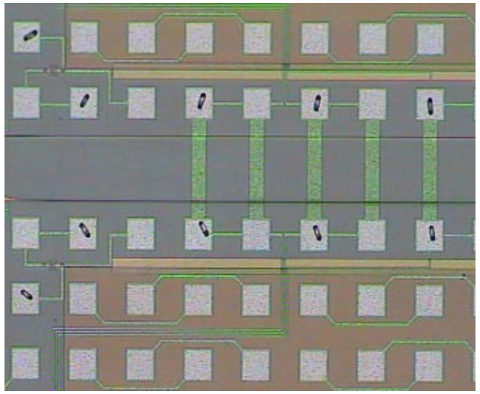
Flip-Chip Pad Array



Corrosion Monitor Structure



Temp Sensing Diode



Heater Resistor Interconnect

Fabrication Details:

- NMRC 1.5 µm CMOS Process
- 6 4” Wafers Fabricated
  - *1,152 Chips*

Verification:

- Optical / SEM Inspection
- Functional Test
  - *Overall Yield = 90.5%*
  - *1,042 functional chips*
  - *840 Required*

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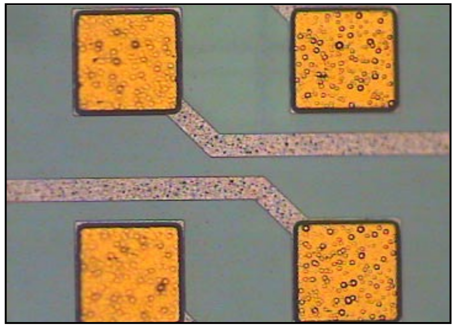
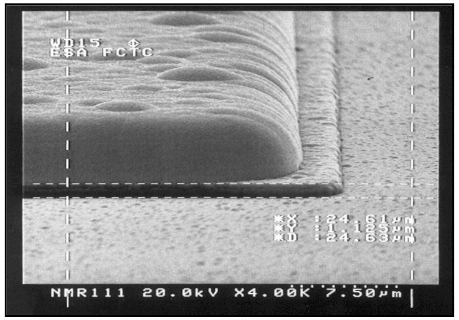
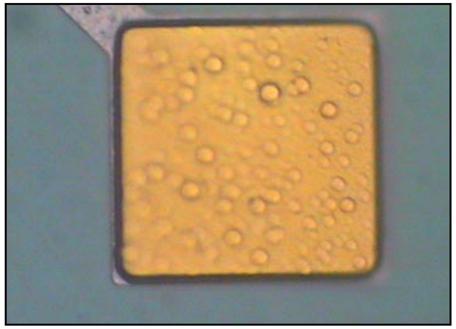
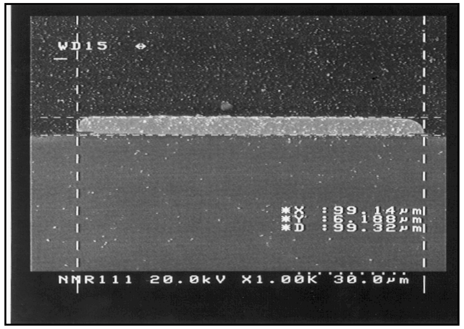
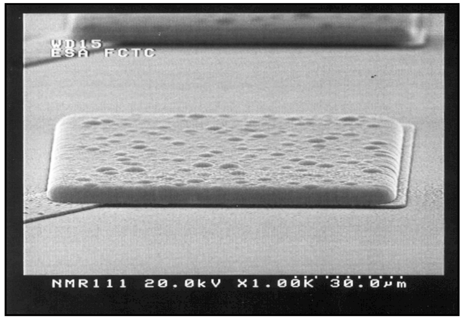
Wafer Bumping

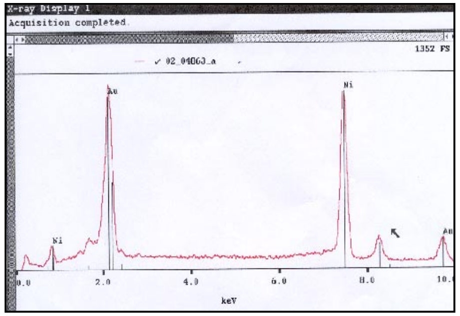












Bumping Details:

- PacTech GmbH, Nauen, Germany
- Electroless Ni/Au Metalisation
- Ni = 6.0 µm
- Au = 0.5 µm

Verification:

- Optical / Electron Microscopy
- Cross-section
  - *Quality check*
  - *Thickness measurement*
- EDX Analysis
  - *Compositional Check*

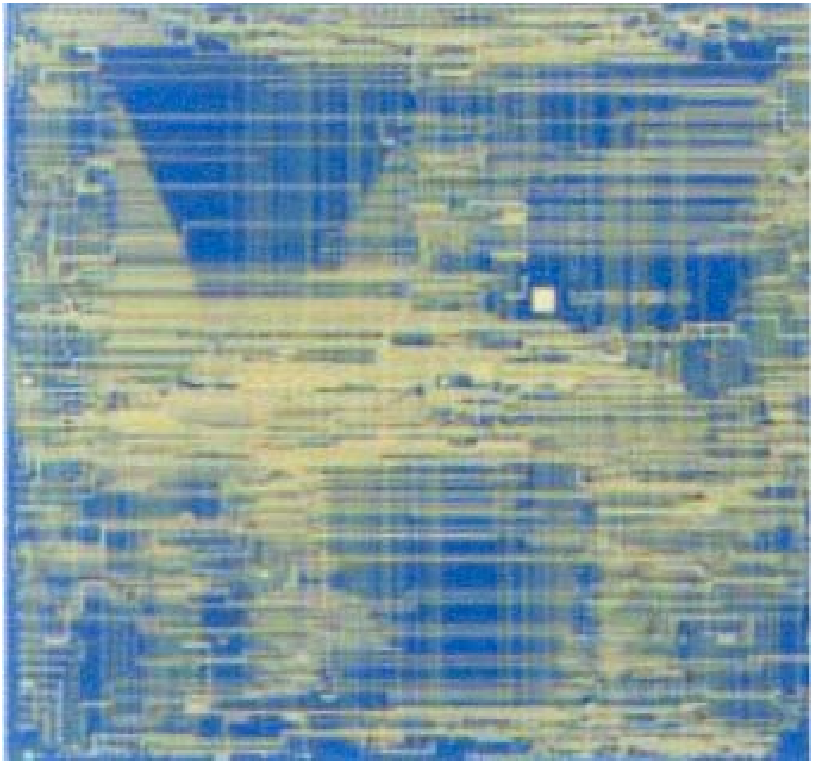
Evaluation Programme

Phase 1: **Materials & Technology Selection and Procurement**

- ***Selection of Adhesives & Physics-of-Failure Investigation (NMRC)***
- ***Design & Fabrication of Flip-Chip Test Chips (NMRC)***
- ***Design & Fabrication of VFL Substrates (Astrium)***

- **Phase 2:** **Manufacturing & Reliability Evaluation of Test Samples**
  - ***Assembly of Test Structures & Non-Des. Evaluation (NMRC)***
  - ***Reliability Performance Testing (NMRC)***

Astrium VFL Substrate Technology

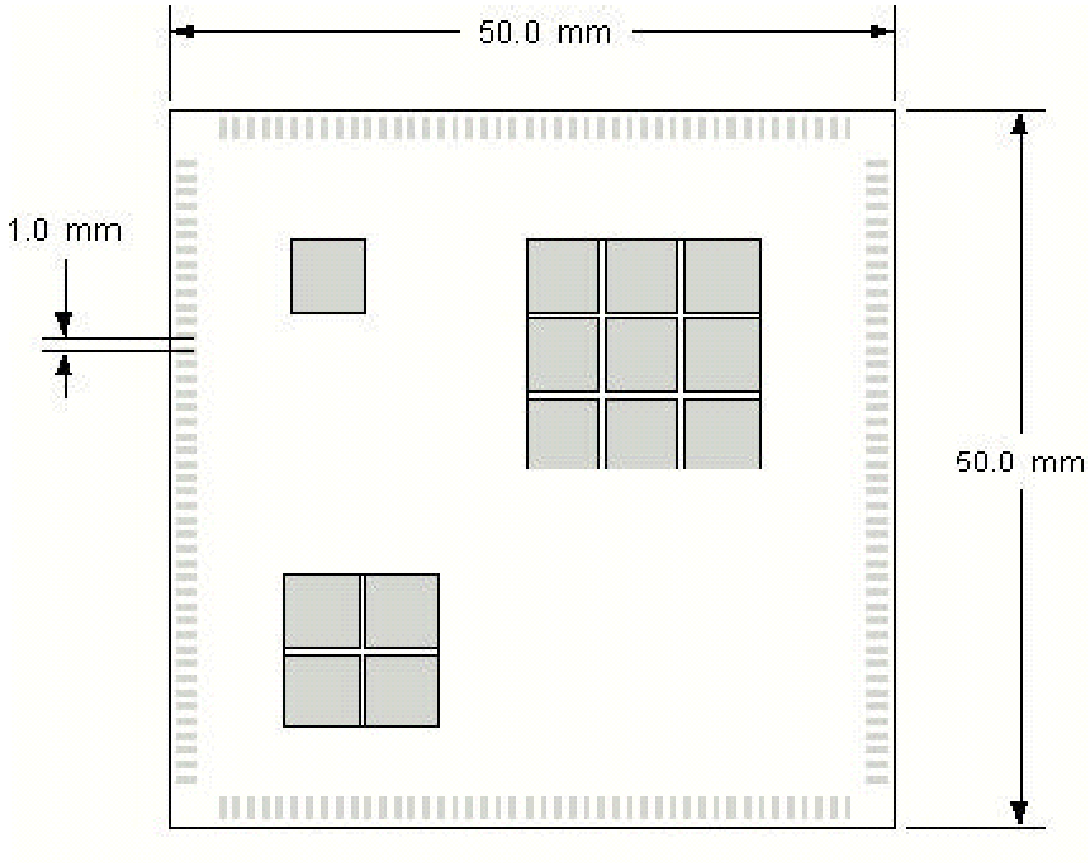


Typical VFL Substate

Very Fine Line (VFL) Technology

- High-reliability Hybrid & MCM substrates
- Thick-film-based technology
- Ceramic & glass materials
- 38 µm track & gap
- 38 µm via diameter (excimer laser drilled)
- Multiple interconnect layers

VFL Substrate Layout



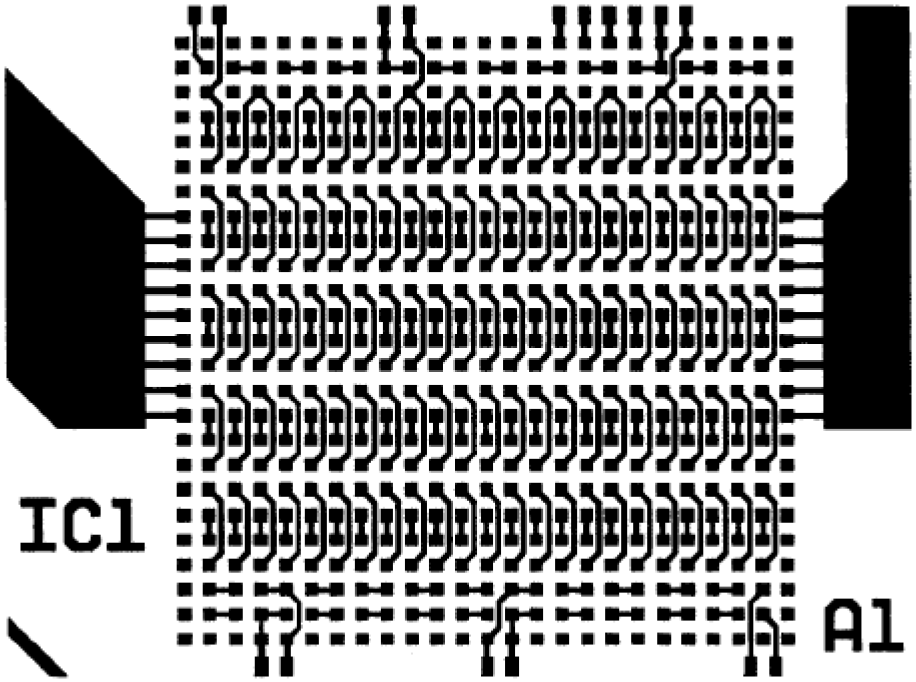
180 I/O substrate

Layout Details

- Single interconnect layer
- 3 chip sizes per substrate
    - *5 mm X 5 mm*
    - *10 mm X 10 mm*
    - *15 mm X 15 mm*
- 50.0 mm X 50.0 mm
- 50 µm track & gap
- Edge connector
- 180 i/o

VFL Substrate Details

Single Chip Site Details (5 mm X 5 mm)



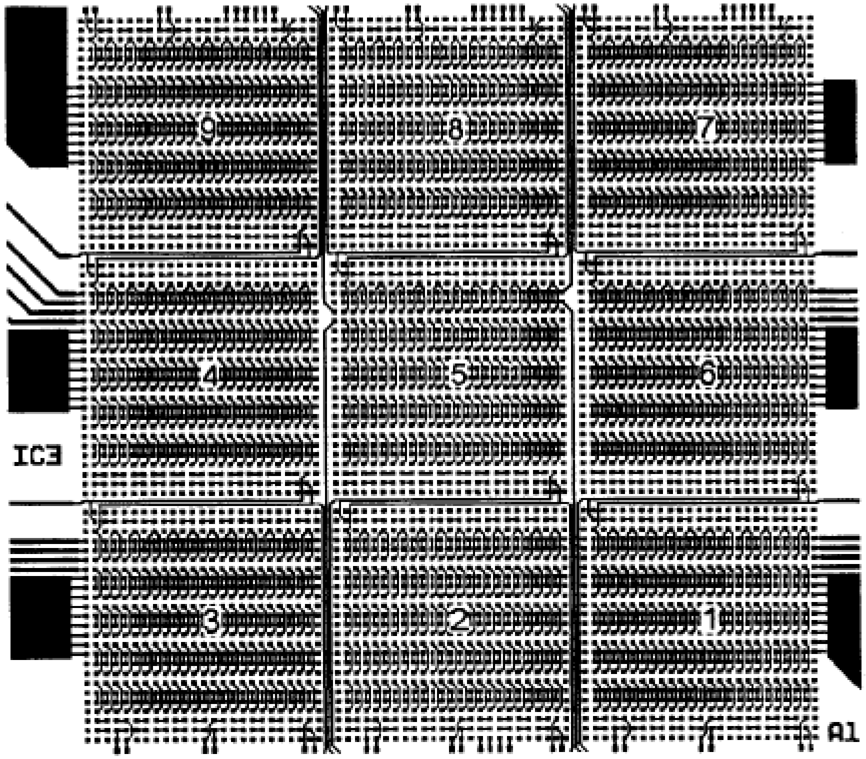
IC1 View side pad

Daisy Chain Details

- 2 daisy chains per chip
- Continuity & isolation measurements
- 2 inputs, 2 outputs & 2 intermediate
- 1 set of heater & diode connections

VFL Substrate Details

3 X 3 Chip Site Details (15 mm X 15 mm)

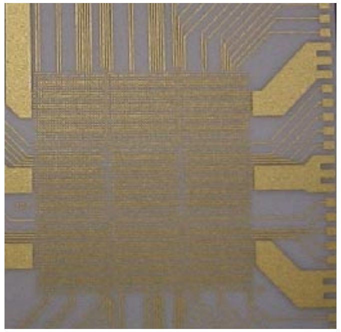


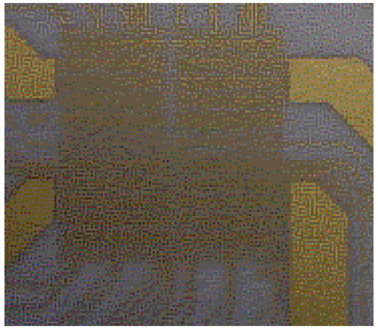
IC3 View side pad

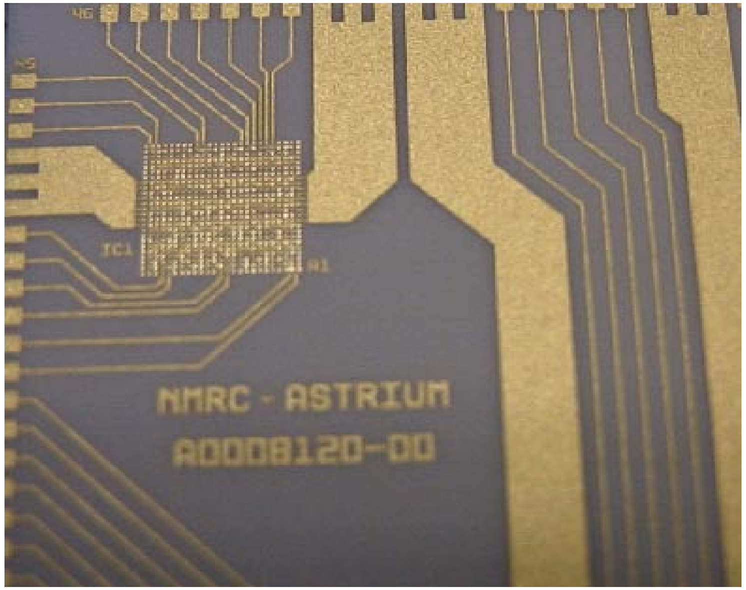
Details

- 2 daisy chains per single chip
- Continuity & isolation measurements across full area of 10 mm X 10 mm chip.
- 2 inputs, 2 outputs & 11 intermediate connections in total.
- Only 2 intermediate connections for dice 4,5,6
- 6 sets of heater & diode connections

VFL Substrate



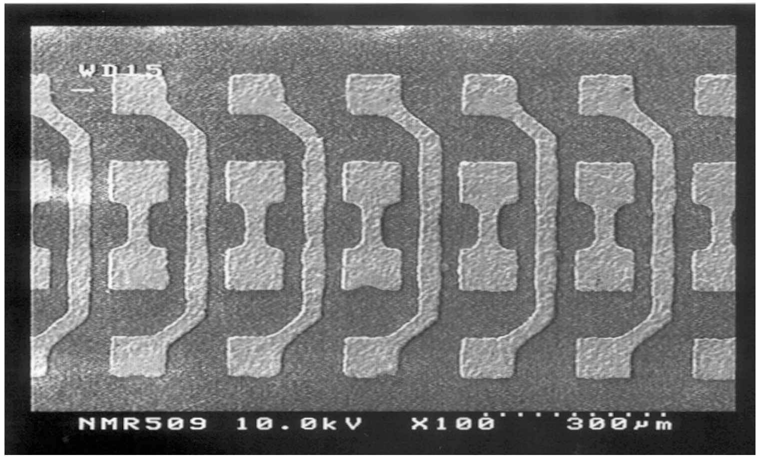




VFL Substrate – Optical Inspection

Substrate Verification:

- **Electrical continuity**
  - *Flying probe tester (Astrium)*
- **Optical & SEM Inspection (NMRC)**
  - *Dimensions & pitch etc. correct*
  - *Metalisation quality / composition*
- **Metal tape adhesion test**
- **80 manufactured / 60 required**



VFL Substrate – SEM Inspection

Evaluation Programme

Phase 1: Materials & Technology Selection and Procurement

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  - ***Assembly of Test Structures & Non-Des. Evaluation (NMRC)***
  - ***Reliability Performance Testing (NMRC)***

Test Vehicle Assembly

Process Flow:

Dispense Adhesive on Substrate
- *Dispense pressure*
- *Volume / thickness*

↓

Align Chip and Substrate
- *X, Y, θ*

↓

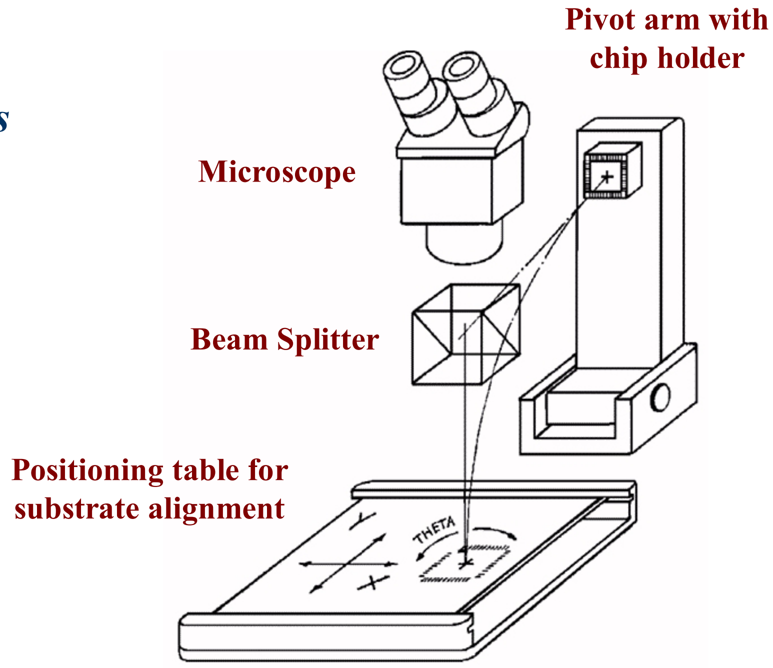
Place in Contact
- *Light Pressure*

↓

Apply Pressure
- *Load per bond*

↓

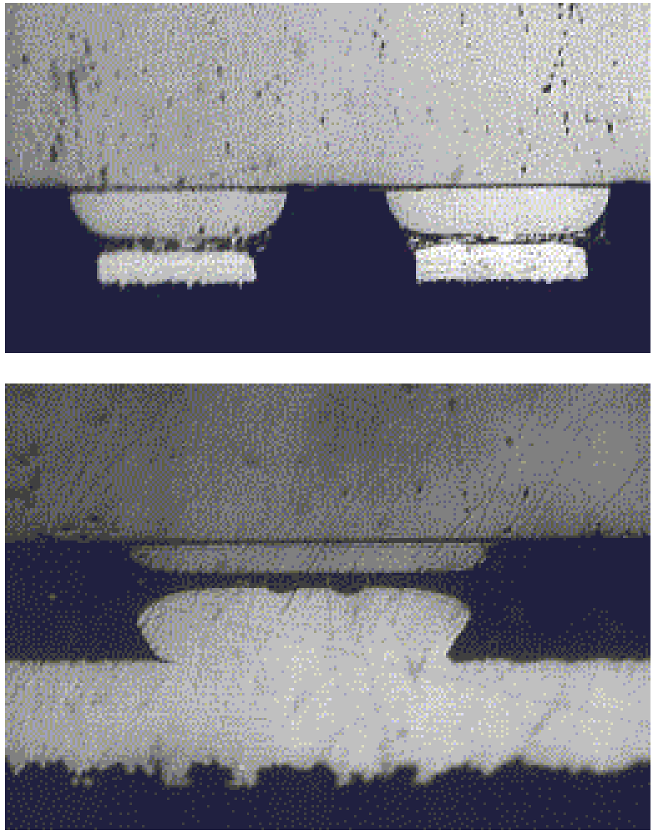
Cure at elevated Temperature
- *Temperature*
- *Curing time / profile*



Flip-Aligner / Bonder Diagram (FINETECH Electronic GmbH)

Test Vehicle Assembly

NMRC Fineplacer 145 PICO Chip Bonder



ACA Flip-Chip Bonds

Test Vehicle Assembly

Example (1) - Bondline 2909 ACA:

• Recommended cure:	175°C for 30 sec @ 35 Mpa
• NMRC optimised cure:	140° for 30 sec, 160°C for 5 sec Joint Loading = 40 MPa → Adhesive thickness = 7.0 µm (approx)
• Bond Strength:	> 5 Kg shear force for 5 mm X 5 mm die (non destructive test)
• Joint Resistance:	4.0 to 9.0 Ω

Test Vehicle Assembly

Example (2) - Loctite 3565 NCA:

- Recommended cure: 150°C for > 60 min
- NMRC optimised cure: 150° for 60 min
  Joint Loading = 50 Mpa

  → Adhesive thickness = 28.0 µm (approx)
  (between the joint areas)
- Bond Strength: > 5 Kg shear force for 5 mm X 5 mm die
  (non destructive test)
- Average Joint Resistance: 10.0 Ω

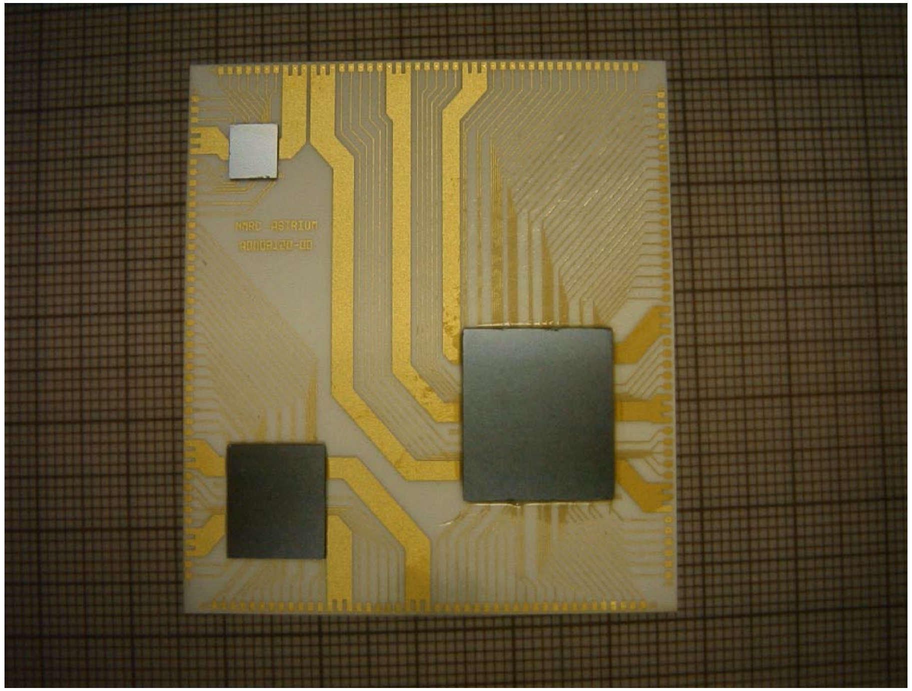
Test Vehicle Verification

Non DestructiveVerification:

- High Mag. Inspection
- X-Ray Inspection
- SAM Inspection
- Electrical Check
- Bond Test (5Kg Shear)
- Thermal Resistance

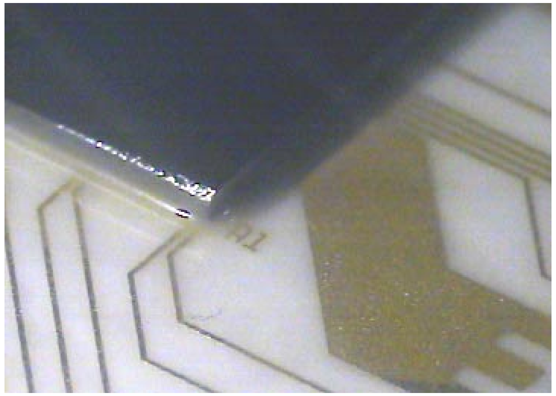
Destructive Verification:

- Bond Shear Test
- Microsection



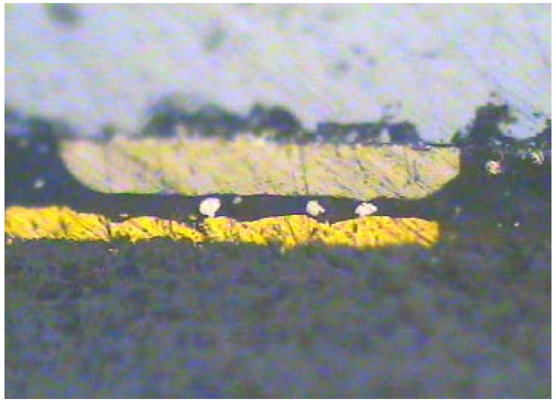
Overview of Typical Completed Test Vehicle

Test Vehicle Verification



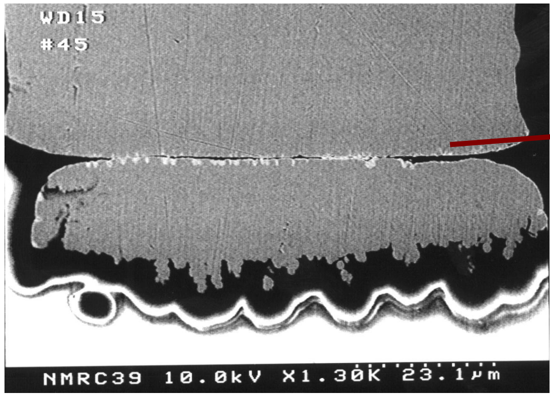
Good Edge Fillet - ACA

Good ACA Joint

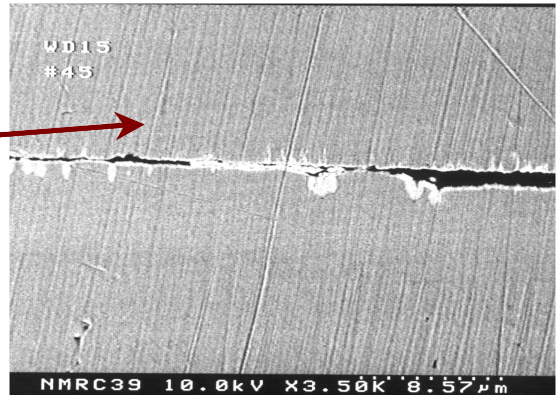


Good ACA Joint

NCA – Well Aligned

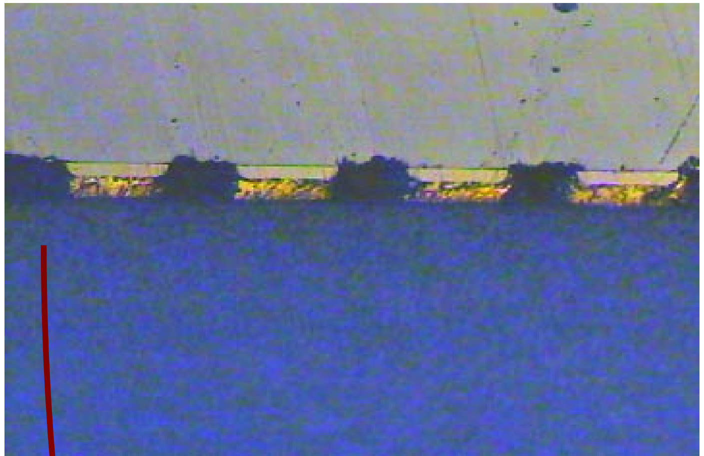


Good NCA Joint

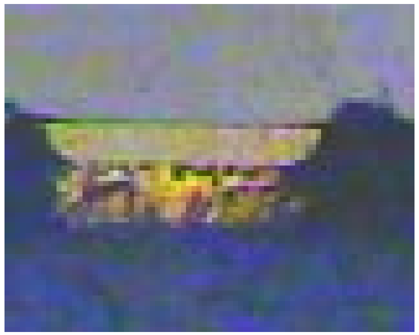


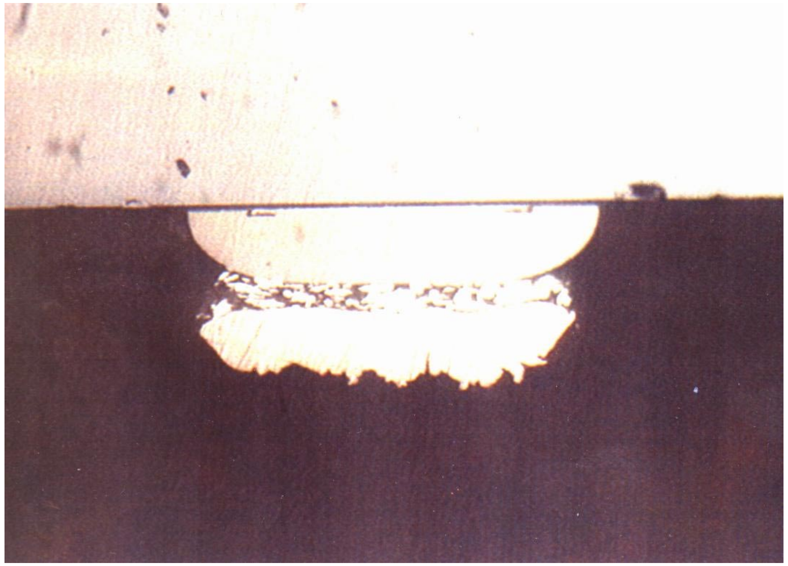
Good NCA Joint

Test Vehicle Verification



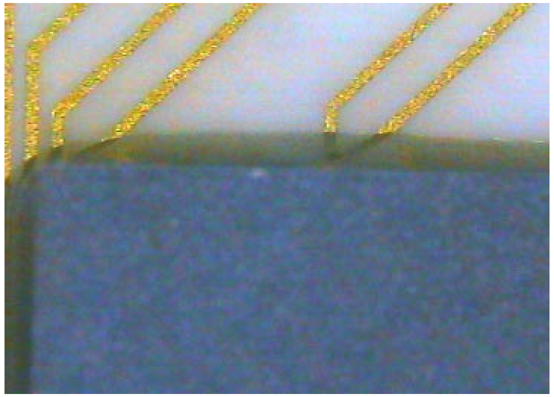
Illustrations of joints formed using Bondline 6900 NCA



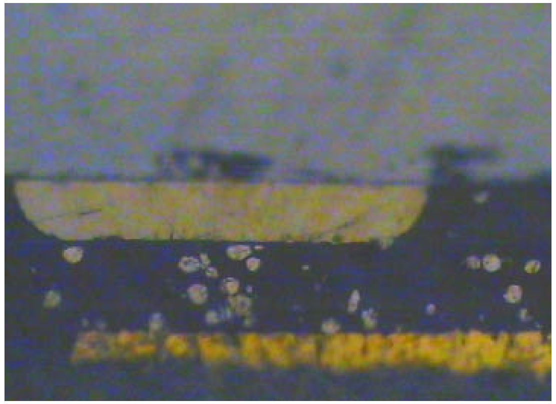


ICA Joint

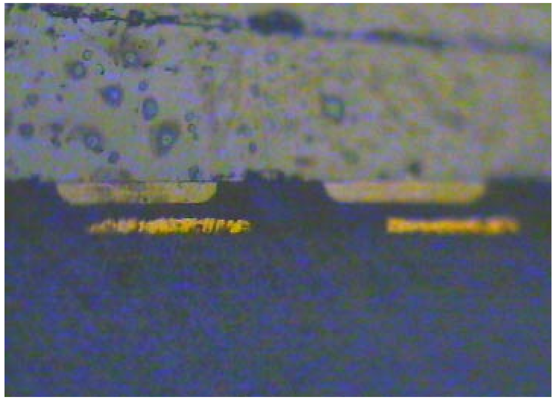
Test Vehicle Verification



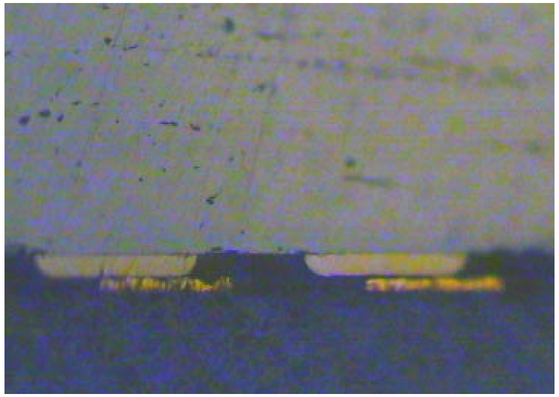
Excess adhesive - ACA



Poor ACA Joint



Open NCA Joint

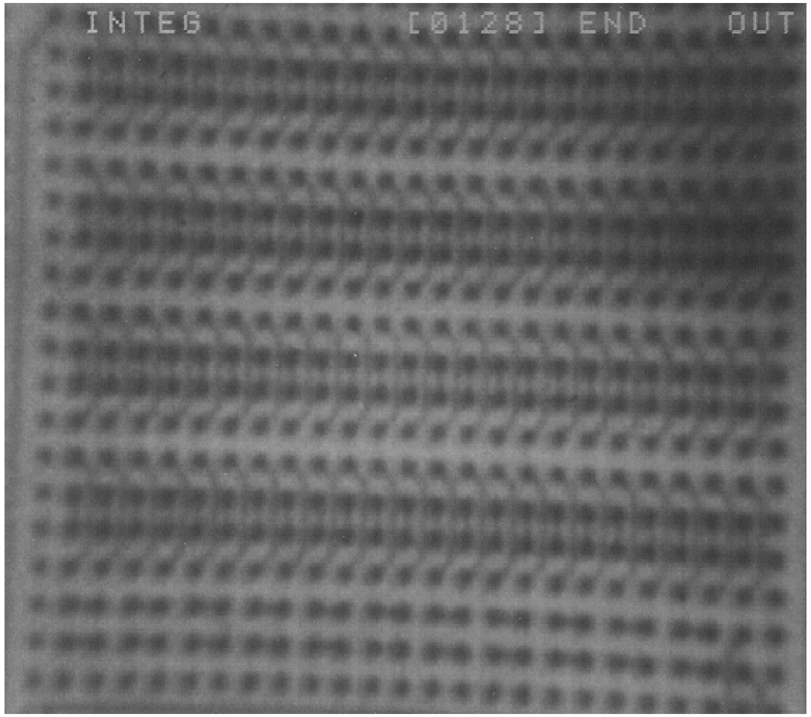


Misaligned NCA Joint

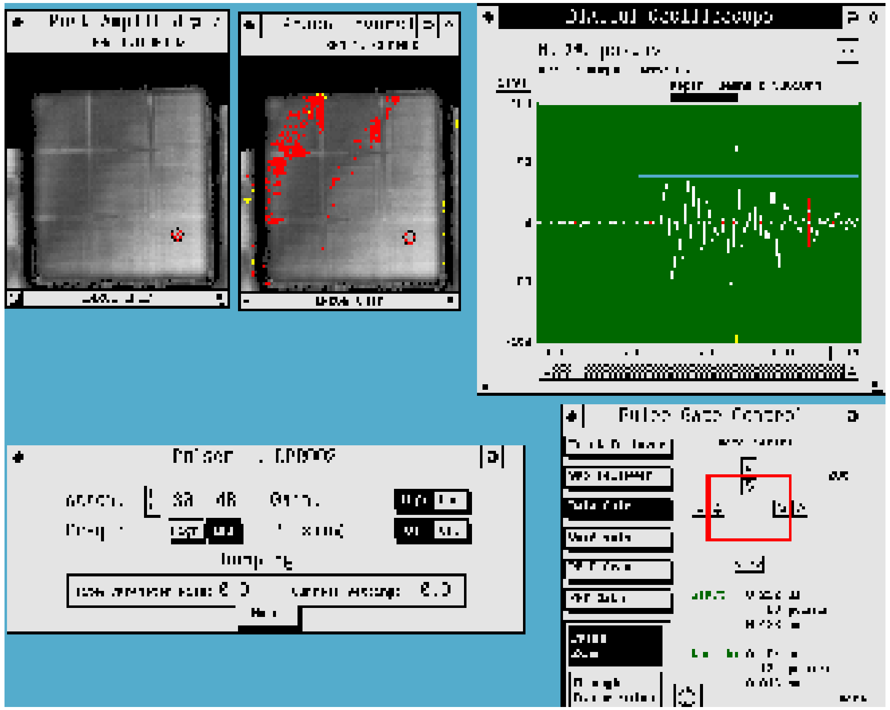
Main Problems Encountered:

- **Partial Misalignment**
- **Excess Adhesive / Inadequate Pressure**
  - ➢ ***Open Circuit Joints***

Test Vehicle Verification



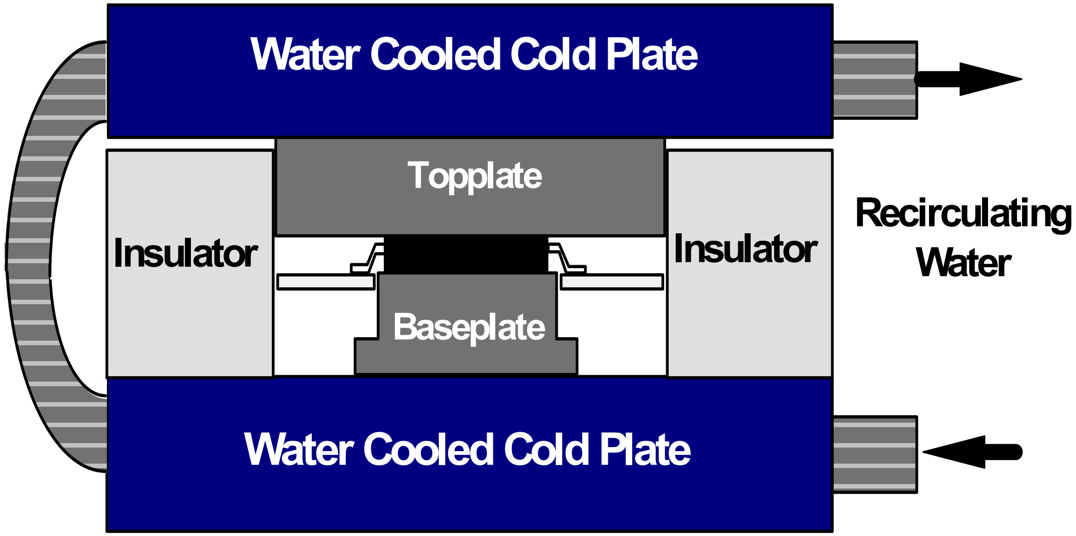
Verification of alignment quality by X-ray – noted to be good in this case.



Verification of adhesive coverage by SAM – note some thickness variation As with initial ACA samples.

Thermal Characterisation

Dual Cold Plate System



Schematic of NMRC DCP System

Key Features

- Two temp-controlled plates
- Boundary conditions well controlled
- Convection effects eliminated
- Heat paths controlled by selection of insulator or conductor plates

Thermal Characterisation

Summary of Thermal Conductivity Results

(1)	*ICA Materials:	Quoted:	2.00 – 3.20 W/m °K
		Measured (Av.):	2.57 W/m °K
		High Ag Content but selective deposition	
(2)	*ACA Materials:	Quoted:	0.70 - 1.20 W/m °K
		Measured (Av.):	1.05 W/m °K
		Blanket deposition helps conductivity result	
(3)	*NCA Materials:	Quoted:	0.02 - 0.03 W/m °K
		Measured (Av.):	0.92 W/m °K (good sample)
		Measured (Av.):	0.22 W/m °K (bad sample)
		Good bump-to-substrate contact helps result	

Evaluation Programme

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  - ***Assembly of Test Structures & Non-Des. Evaluation (NMRC)***
  - ***Reliability Performance Testing (NMRC)***

Reliability Test Plan

Test Sample Assembly
(5 Samples - Each Material)

Initial Characterisation
- Visual Inspection
- Electrical test
- Thermal Resistance
- Radiographic Inspection
- SAM Inspection

Control Samples
1 per material
WP 4

Monitored Thermal Cycling
(5 X 100 cycles – 55°C /+125°C)

Assessment Tests
- External Visual (each 100c)
- Thermal Res. (200 & 500)
- X-ray (200 & 500 cycles)
- SAM (200 & 500 cycles)

THB Test
(1,000 hrs / 85°C / 85% RH)

Assessment (168, 500, 1,000 h)
- Electrical Test
- External Visual
- Thermal Resistance
- X-ray & SAM

Analysis of Failures (WP5)
DPA of 1 sample – each material
DPA of any failures

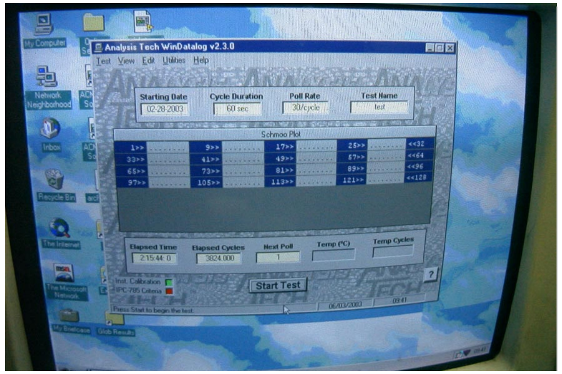
Reliability Testing

Monitored Thermal Cycling Test:

- Mil-Std-883E, Method 1010.7
- Upper Temp: +125° C
- Lower Temp: -55°C
- Dwell: 15 Min
- No. of Cycles: 500

Interim Tests (Every 100 cycles):

- Electrical Check
- Visual Inspection
- X-ray Inspection
- SAM Inspection
- Thermal Resistance



Anatech Event Detector
128-Channel Continuity Monitor

Reliability Testing

Monitored Thermal Cycling Test:

- JESD A-101 B
- Temperature: +85° C
- Humidity: 85% RH
- Bias: -10V / Gnd /+10V
- Duration: 1,000 hours

Interim Tests (168, 500 & 1,000 hrs):

- Electrical (Corrosion Monitors)
- Visual Inspection
- X-ray Inspection
- SAM Inspection
- Thermal Resistance

NMRC Weis-Technik
Temperature / Humidity Chamber

Reliability Testing

Proposed DPA Procedure:

- **Non-Destructive Tests:**
  - *Electrical – Continuity / Isolation*
  - *Optical Inspection*
  - *SEM Inspection*
  - *X-ray Imaging*
  - *SAM Imaging*
  - *Thermal Resistance Measurement*
- **Destructive Tests:**
  - *Shear Strength*
  - *Microsectioning*

Anticipated Failure Modes:

- **Thermo-mechanical:**
  - *Movement - open circuits*
  - *Bond failure / adhesion loss*
  - *Property changes - above Tg*
  - *CTE – intermittent opens*
  - *Possible increase $R\theta jc$*
- **Moisture-Induced:**
  - *Leakage currents / shorts*
  - *Corrosion / ionics*
  - *Silver migration (ICA)*
  - *Dendritic growths*
  - *Adhesion Loss*

Presentation Outline

- Introduction
- Flip-Chip Assembly Technologies
- Evaluation Programme:
  - *Approach*
  - *Materials Evaluation*
  - *Test Vehicle Details, Assembly & Verification*
  - *Reliability Testing*
  - *Results to Date*
- Conclusions / Summary / Acknowledgements

Conclusions To Date

- Adhesive will find difficulty meeting demands of harsh stress tests.
- Concern that Tg is much lower than + 125°C in many cases:
  - *Thermomechanical behaviour may be unpredictable.*
  - *Materials may soften at elevated temperatures.*
- ICA materials likely to be most reliable:
  - *Best electrical & thermal properties.*
  - *Selective deposition – lower risk.*
  - *Ag content may lead to migration / dendrite issues.*
- Corrosion filures likely to occur in THB test:
  - *Adhesives absorb moisture.*
  - *Non-hermetic protection.*
  - *Adhesives contain ionic elements.*
- ACA & NCA likley to exhibit intermittent failures due to movement.
- Bond strength v. extpected stress a concern in NCA case.

Summary

- 18-month programme (NMRC & Astrium)
- Selection of candidate adhesive materials – ACA, ICA, NCA
- Study factors affecting reliability:
  - *Material properties*
  - *Thermal issues*
  - *Assembly quality*
- Test chip & substrate design
- Test sample assembly / Process optimisation
- Reliability tests (Thermal cycling & THB)
  - *Interim performance assessments*
  - *Final DPA*

Acknowledgements

- ESA / ESTEC – Funding for Project
  - *Alberto Boetti – Technical Supervision & Guidance*
- Astrium, Velizy, France
  - *Jean-Claude Tual – Substrate Layout*
  - *Brigitte Braux – Astrium Project Manager*
- NMRC
  - *Gary Relihan – Materials Properties*
  - *Denis O' Mahoney – FE Modelling*
  - *Adrian Mulcahy – Assembly & Analysis Work*
  - *Eoin Sheehan – Chip and Substrate Test*