Reliable Anisotropic Conductive Adhesives(ACAs) Flip Chip Technology

Kyung W. Paik

KAIST
Dept. of Materials Science and Engineering

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Nano Packaging & Interconnect Lab. (NPIL) KAIST

Outline

Reliability – Thermal Cycle
High Frequency Characteristics
Current Handling Capability

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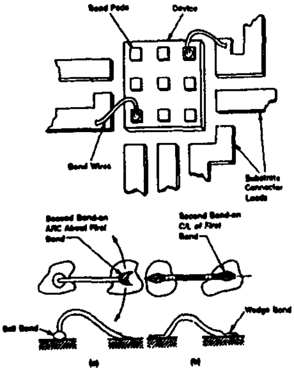
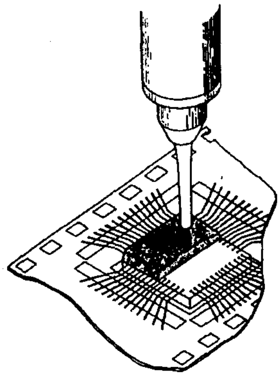
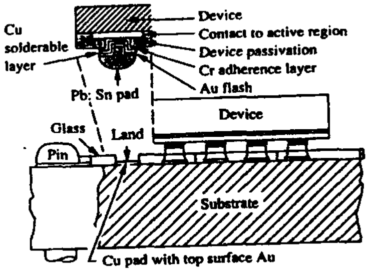
Chip Interconnection Technologies



Wire Bonding



Tape Automated Bonding (TAB)



Flip Chip

1. *Low Inductance, Capacitance*
2. *High I/O Density*
3. *Small Package Size*
4. *Self Alignment*

Flip Chip Interconnection Methods

1. Solder Bumps – Solder Reflowing

- Evaporated solder bumps
- Electroplated solder bumps
- Screen printed solder bumps

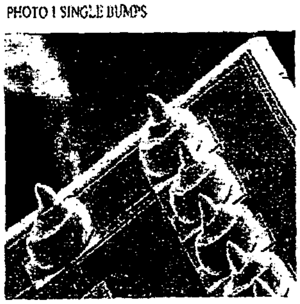
- All joints made simultaneously by reflowing the solder

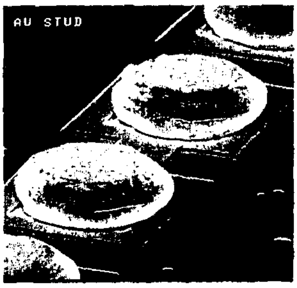
2. Non-Solder Bumps – ICAs or ACAs

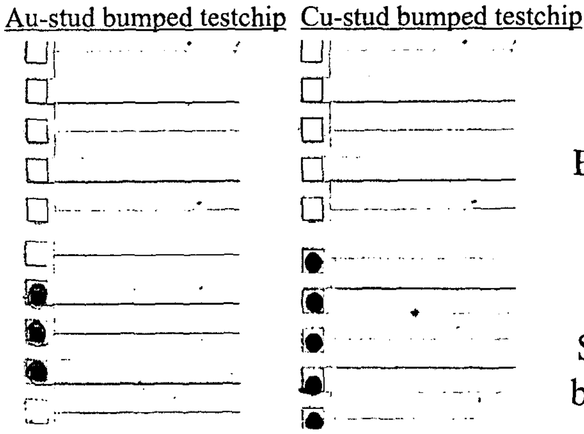
- Gold bumps
- Au stud bumps
- Electroless Ni/Au plated bumps

- Electrical interconnection medium such as ICAs and ACAs needed.

Gold and Copper Stud Bumps







Bare Al

Stud bumping

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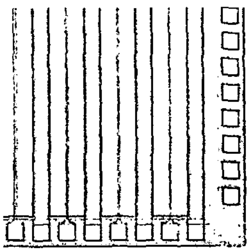
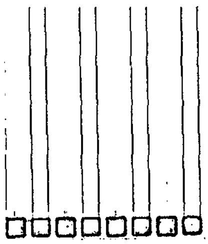
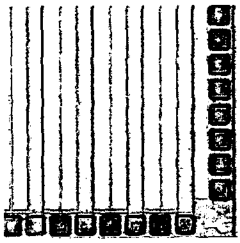
Electroless-Deposited Ni Bumps



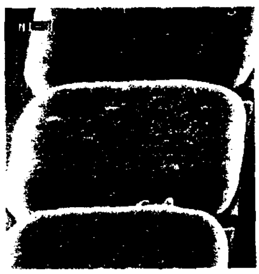
Al Pads



Ni coated bumps



Au coated Ni bumps



Electroless Ni Bumps

3-D shape of a bump

Electroless Ni Bumps Characteristics

Characteristic	Measurement	Characteristic	Measurement
Resistivity	70 μΩ-cm	Material analysis	P wt10%
Thickness	20 μm	Hardness	500±50 HV
Pad size	100×100 μm²	Pitch	150 μm

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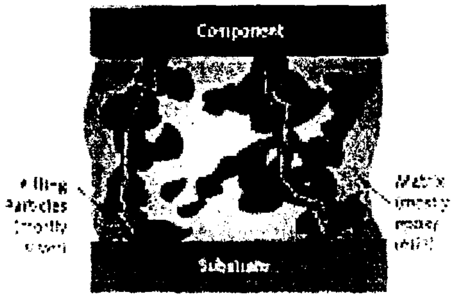
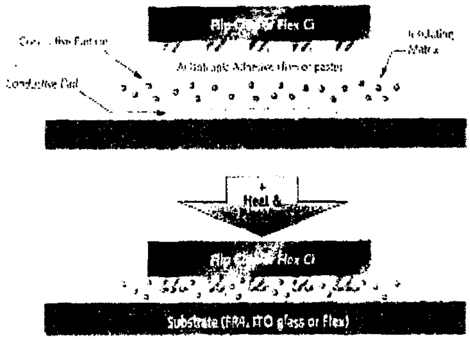
Non-Solder Bumps need interconnection materials

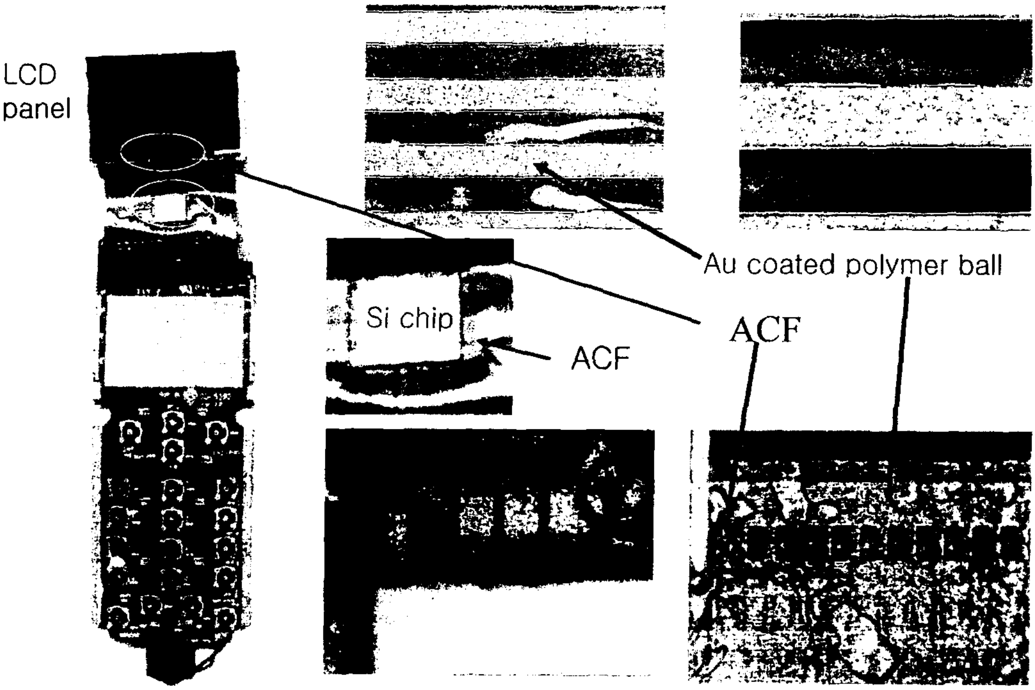


Isotropic Conductive Adhesive (ICA)



Anisotropic Conductive Adhesive(ACA)

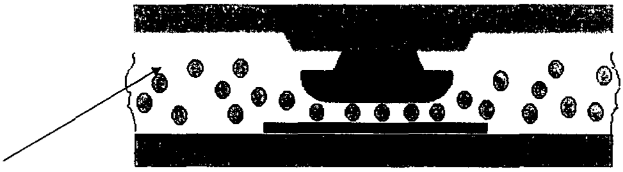
ACFs for LCD Applications



ACAs Interconnection Materials

1. Conductive Fillers

- Filler Types : metal particles (Ni, Ni/Au, solder) or
  – metal coated polymer particles
- Number, Diameter, Hardness, Conductivity
- ACFs/ACAs Design Parameters optimization



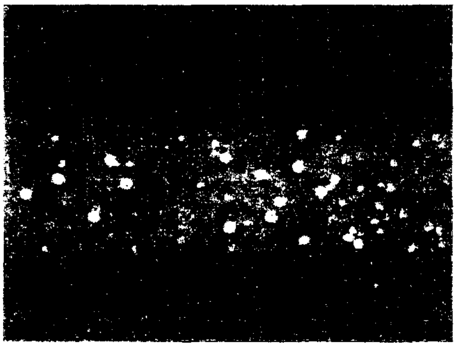
2. Polymer Resin

- Polymer types:
  thermosetting(epoxy) & thermoplastics
- Curing kinetics of epoxy resin

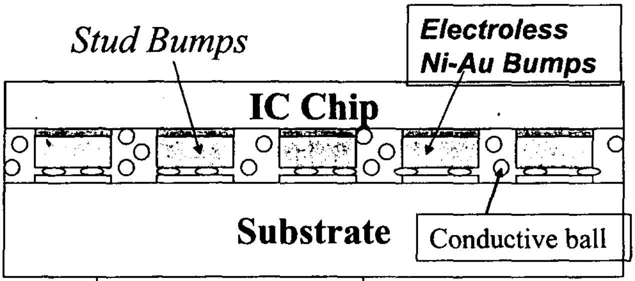
Photo of ACFs for FCP

Plain view ×500

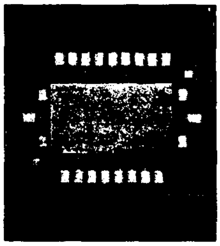
Cross-section view ×500



ACA Flip Chip Interconnect of Electroless Ni or Au stud Bumps



< ACA modeling >



Electroless Ni flip chip on a PCB using ACA

- ***Fine pitch interconnection capability (40 μm)***
- ***Cost-effective packaging method***
  (No UBMs, easy & reduced no. of processing)
- ***Low Temperature process (<180 C)***
- ***Good Mechanical and Electrical properties***
- ***Green Processes (No flux, No solvents, No Pb)***

ACF for FCP Applications

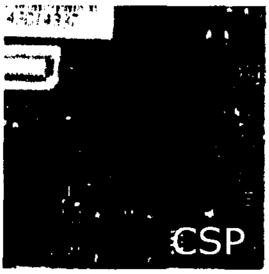
- CSP (Chip Size/Scale Package)

  Bare Chip bonding on ceramic, BT-resin, FR-4, FPC, etc
- MCM (Multi-Chip Module)

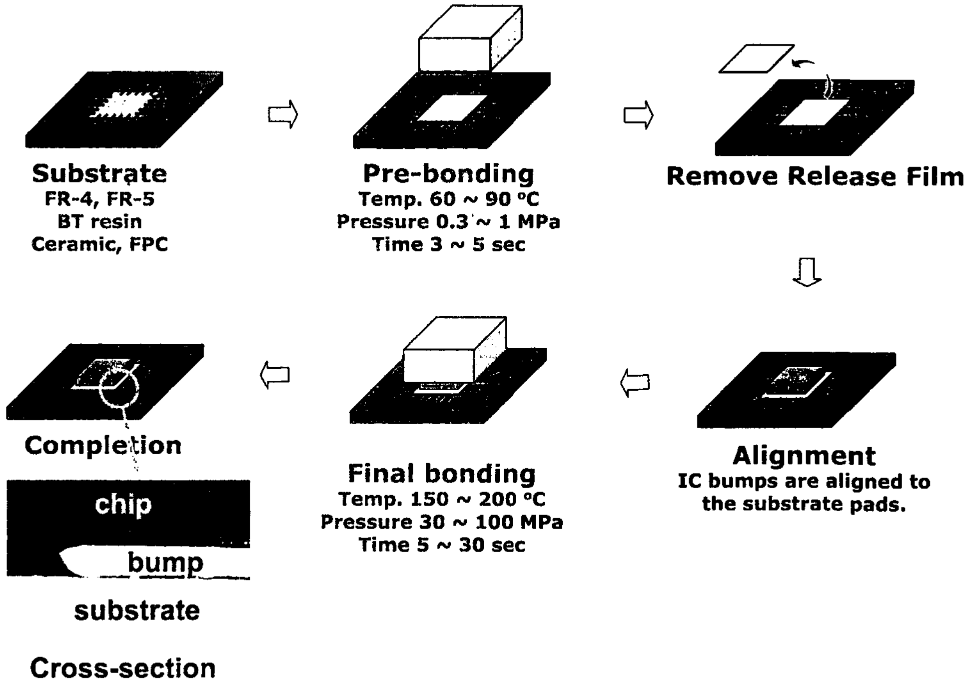
  Bare chip mounting as well as other electronic components.
- COF (Chip on Flex/Film)

  Bare chip bonding on TAB, FPC, Smart card, RF Tag, Rigid/Flex hybrids and other flexible substrates.

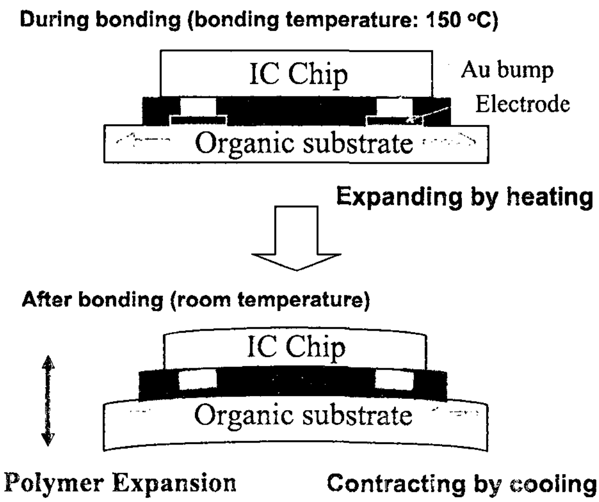
MCM

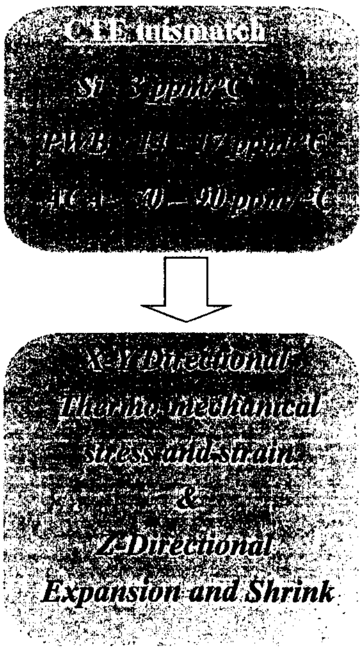


Flip chip Assembly using ACFs



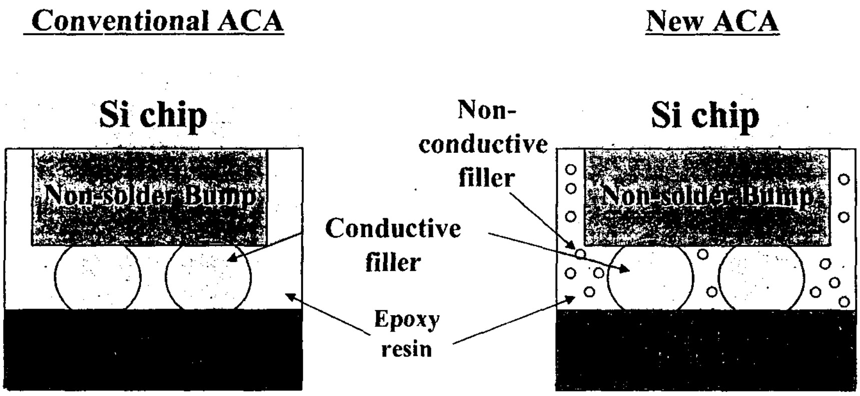
ACA Flip Chip on Organic Substrates Problem





Low CTE adhesives with underfill functions

Newly Modified ACAs



- Modification of adhesive resin, mixed concept of ACA and underfill : CTE, modulus and dielectric constant

U.S. patent 6,238,597 issued, Japan and Korea patent pending : 03/99

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Understanding of the effect of non-conductive fillers on the ACA formulation

- The thermo-mechanical properties of cured ACA materials
  → Reliability enhancement of ACA flip chip assembly on organic substrates
- The dielectric properties of cured ACA materials
  → High frequency electrical properties enhancement of ACA materials for High Frequency Applications
- Current Handling Capability of ACA materials

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ACA Material Systems

1. Fillers

- Conductive fillers : 5 micron-sized Ni particles

- Non-conductive fillers : 1 micron-sized SiO2 particles
  Both type of fillers need surface modification to be uniformly dispersed in polymer matrix

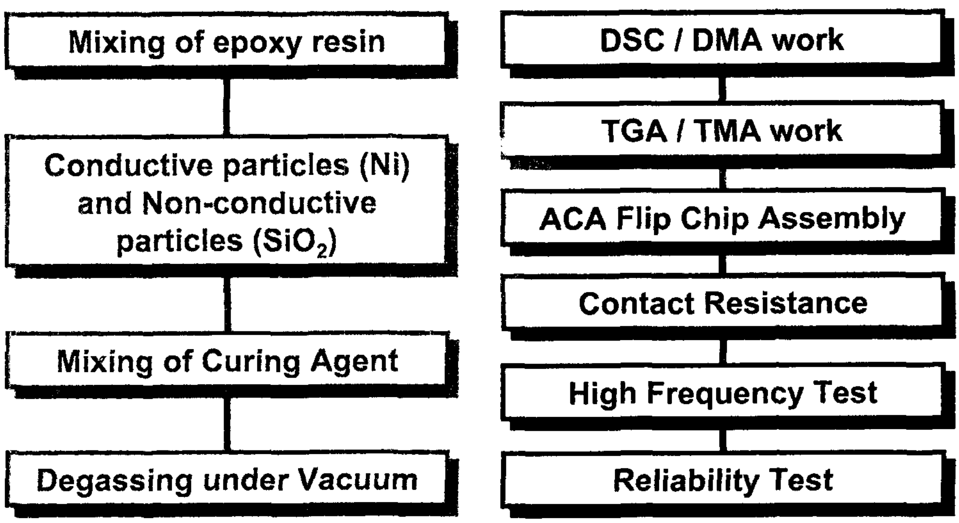
2. Polymer Matrix

- Thermoset Epoxy: Bisphenol A type liquid epoxy

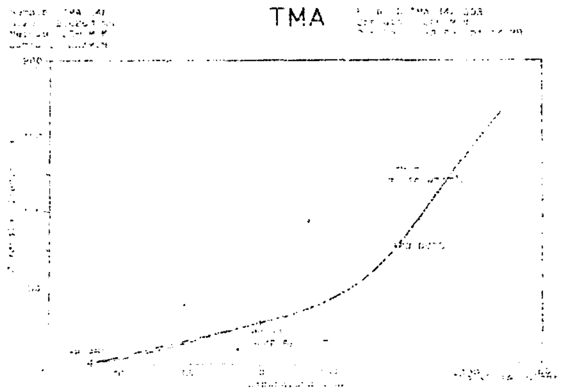
- Curing agent: imidazole type curing agent

Experimental Procedures

Preparation of modified ACA | **Characterization**



Material Characterization : TMA and TGA Results



ACA composite	*α1 (ppm/°C)*	α2 (ppm/°C)
ACA with 0 wt% filler	*58.4*	**3450**
ACA with 10 wt% filler	*51.3*	**1740**
ACA with 30 wt% filler with A epoxy resin	*43.4*	**445**
ACA with 30 wt% filler with B epoxy resin	*42.8*	**245**

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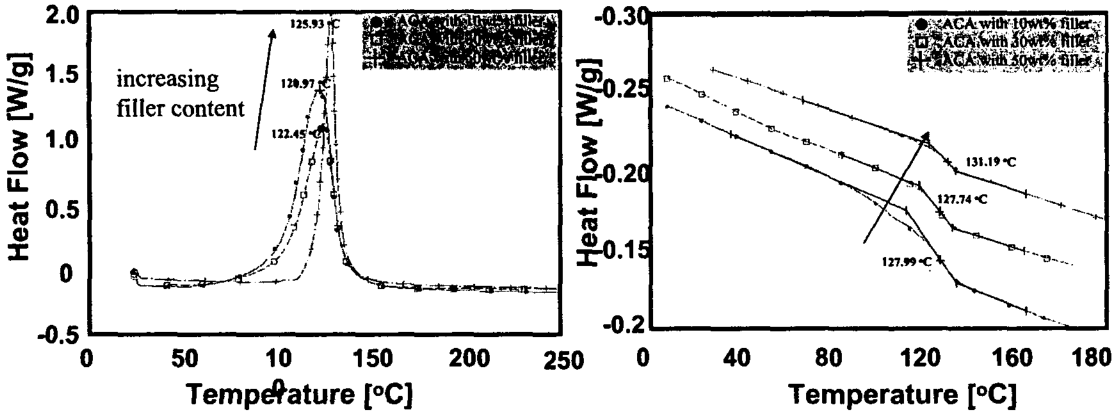
Material Characterization : DSC Results

Differential Scanning Calorimeter



As Filler content ↑, Tg ↑ (Δ 4 °C)

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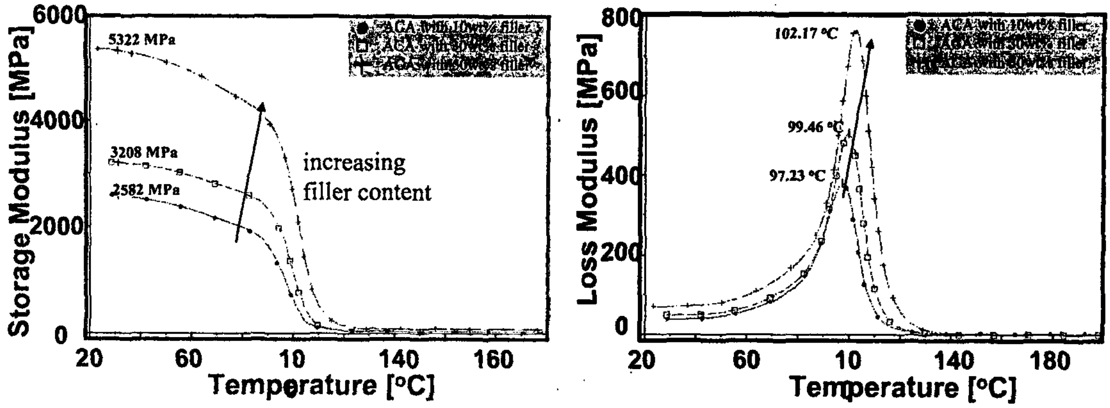
Material Characterization : DMA Results

<u>**Dynamic Mechanical Analysis**</u>



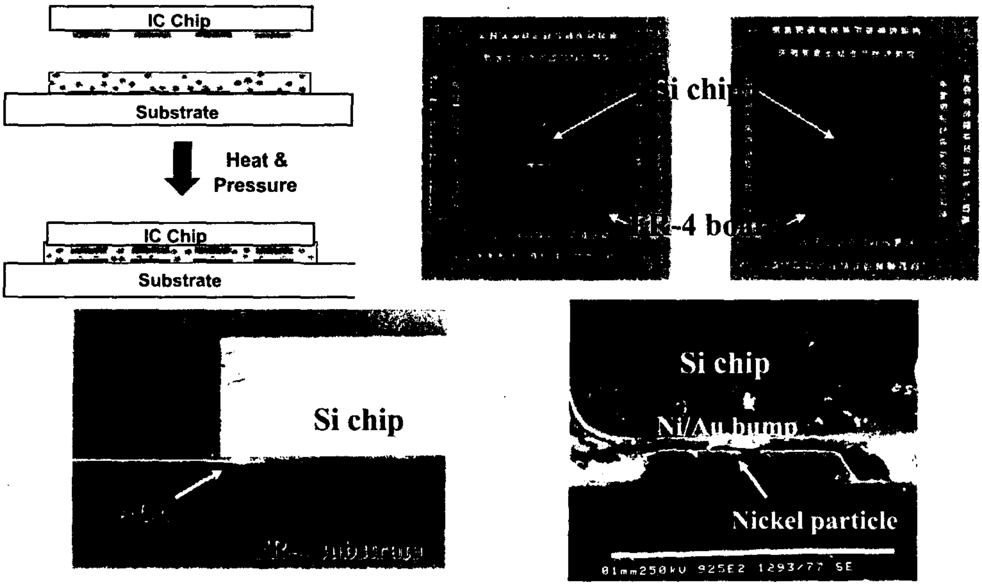
As Filler content ↑, Storage modulus and Tg ↑

Summary of New ACA Material Properties

As the content of non-conductive fillers increased,

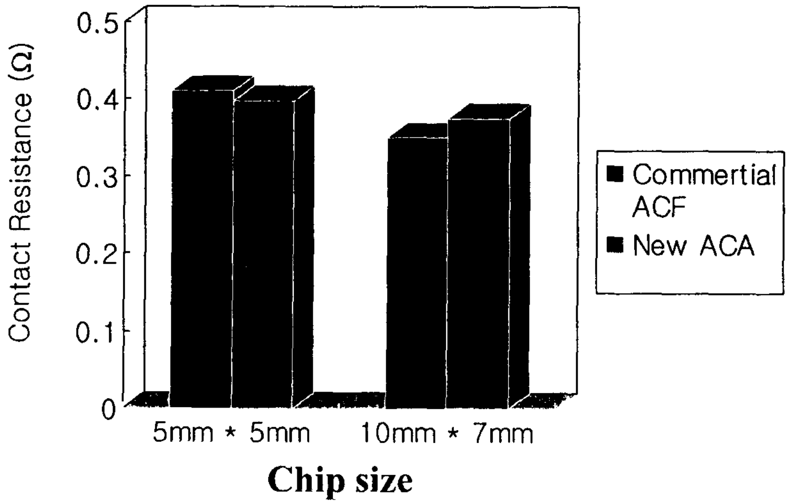
	Increase	Decrease
Storage modulus	✓	
Tg	✓	
Curing onset temperature Curing peak temperature	✓	
CTE below Tg		✓
Dielectric constant		✓

Flip-chip Processes Using ACAs



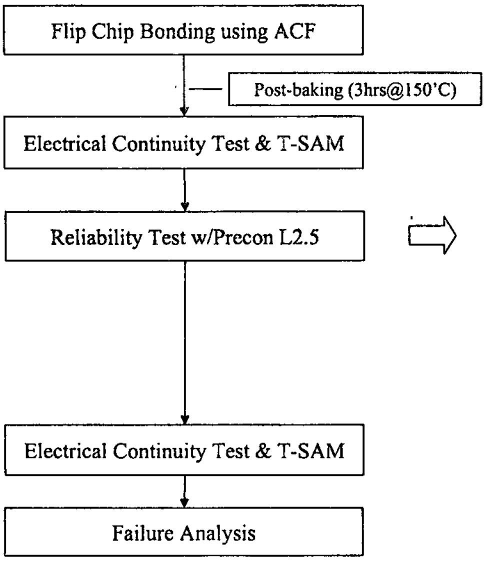
Cross-section image of ACA Flip-chip joint

Contact Resistances of New ACA Interconnections



Electrical Conductivity of New ACA and Commercial ACF

Reliability Test of ACF for FCP



Failure Criteria : TBD

MRT L2, 85'C/60%RH 168hrs
TC(-40~+60'C) 5x & Reflow 3x@240'C
Precon. L3, 30'C/60%RH 192hrs
TC(-40~+60'C) 5x & Reflow 3x@240'C
Precon. L2.5, 85'C/85%RH 24hrs, 125'C/24hrs
Reflow 3x@240'C
Temp Cycle w/precon
Cond. "C" -65'C ~ + 150'C
monitored at 500 and 1000cycles
PCT w/precon 121'C, 100%RH, 15psig
monitored at 168hrs, 240hrs and 336hrs
85/85 w/precon, 85°C, 85%RH,
monitored at 500hrs and 1000hrs
HTS w/o precon, 150'C,
monitored at 500 and 1000 hrs

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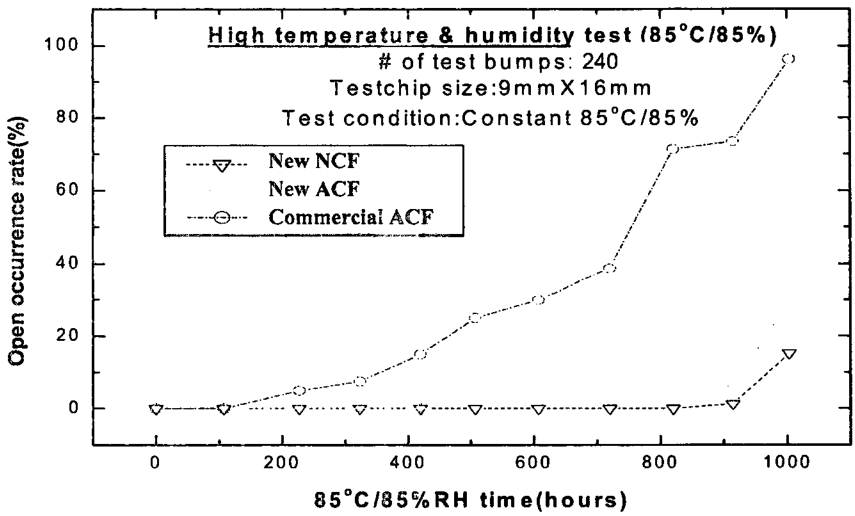
Reliability of New ACF/NCF

85℃/ 85% RH Test



Bonding Condition : 180 °C, 30 sec, 40 MPa, substrate heating, hot bar 125℃
Open occurrence rate : # of failed interconnects / total # of bumps tested
Definition of failed bump : 100 % increase of initial contact resistance

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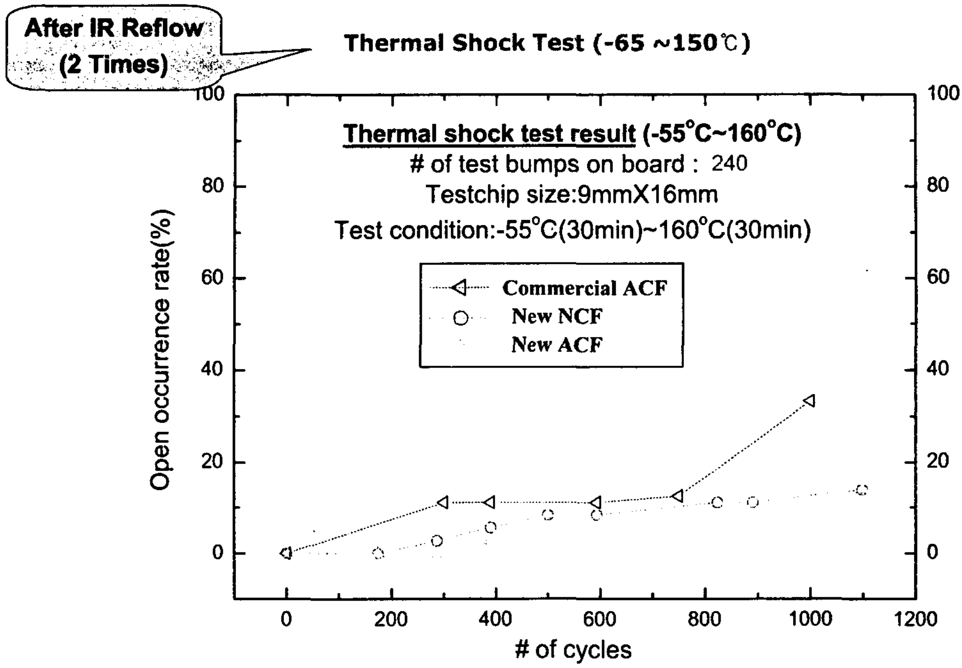
Reliability of New ACF/NCF



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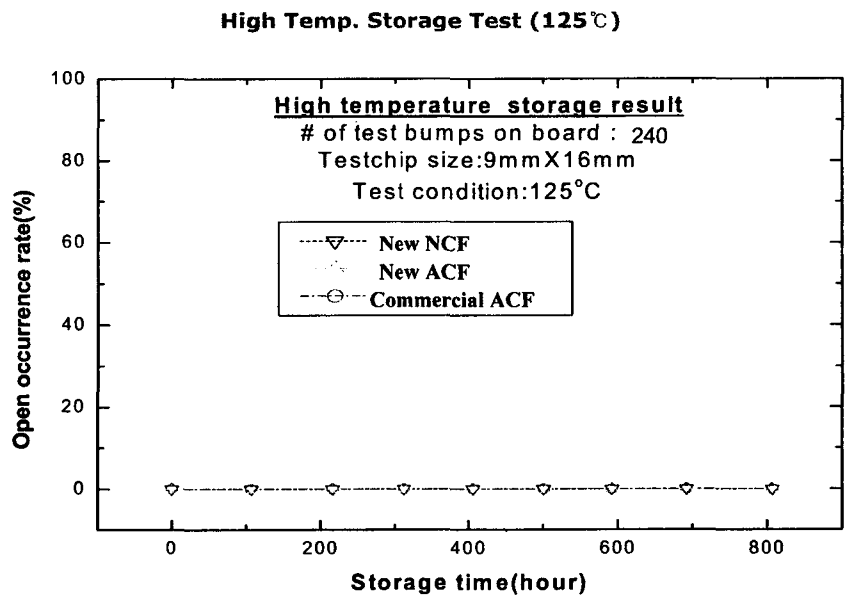
Reliability of New ACF/NCF



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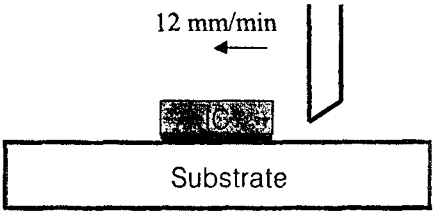
Adhesive Strength Test Method

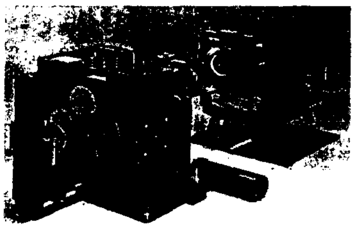


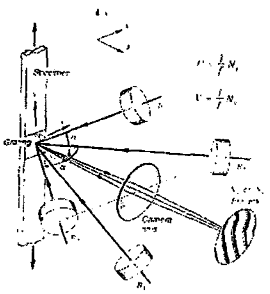
ACF width : 4 mm
Bonding Condition : 180℃,40MPa, 20s
Substrate : FR-4 (40 mm * 40 mm)
Test chip : 3 mm$^{\square}$, 0.4 mm^{t}, bumpless
Pattern : Cu ½ ounce Ni, Au plating

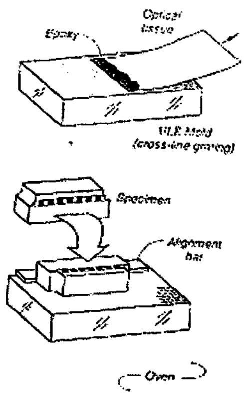
Sample	Initial	After 85°C/85%RH/500hrs
New ACF-1	IC fracture	IC fracture
New ACF-2	IC fracture	IC fracture

- Strong adhesion of New ACFs on organic substrate

Micro-Moire Fringe Analysis







Relationship between fringe order and displacement

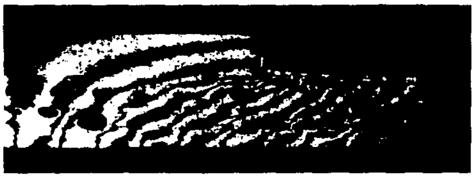
$$U_{(x,y)} = N_{x(x,y)}/f$$

$$V_{(x,y)} = N_{y(x,y)}/f$$

U Field (x-direction) Deformation

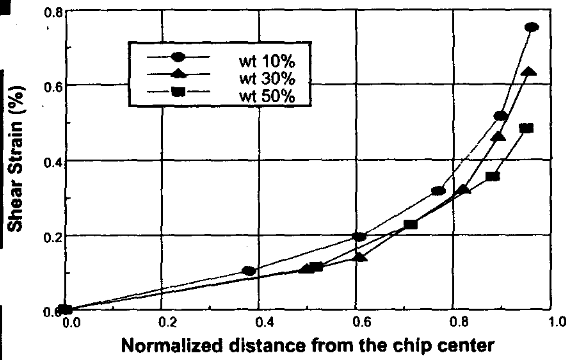
10 wt% SiO2

30 wt% SiO2



50 wt% SiO2

Δ T= 80 °C



Reduced Shear Strain

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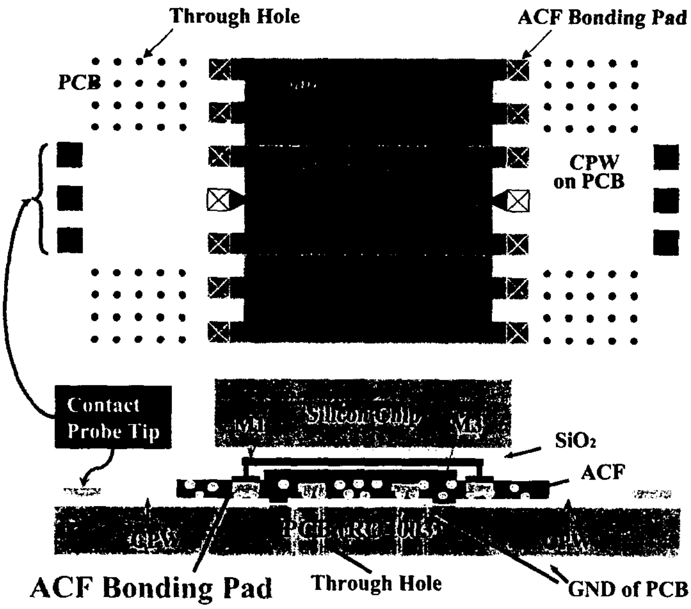
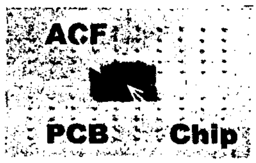
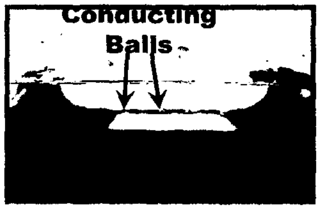
Test Chip and PCB for High Frequency Measurement







CPW on PCB

Microstrip on Silicon

Minimize the Parasitic and Silicon Effect

Multi-through Hole

Multi-via Hole for Low Impedance Ground

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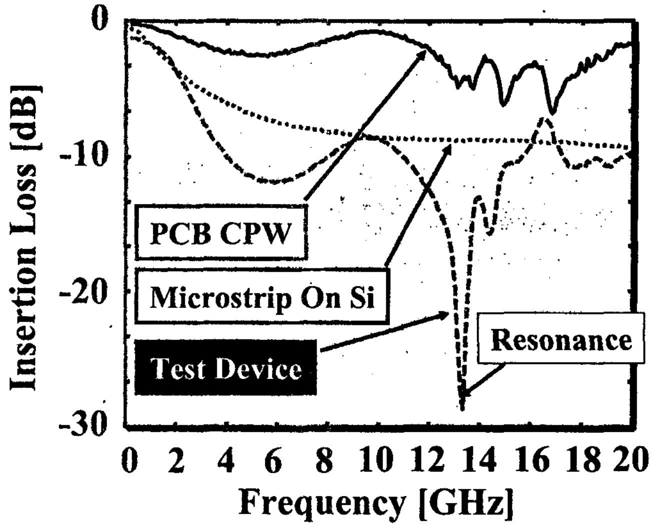
Measured Insertion Loss of Conventional ACFs

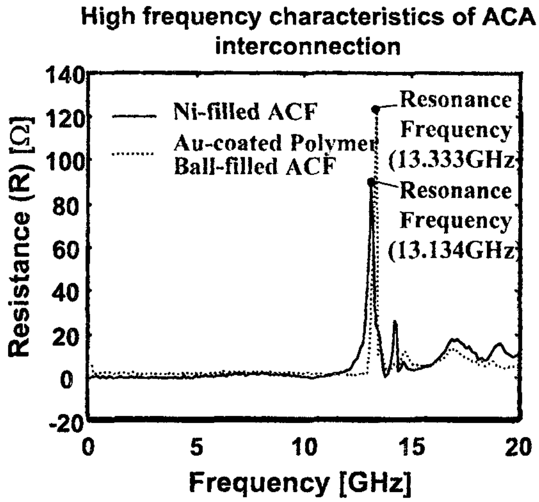


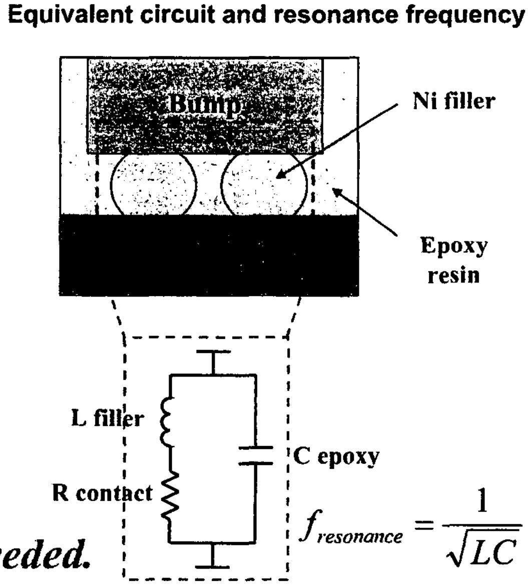
Measured Insertion Loss Using a Network Analyzer from 200 MHz to 20 GHz

Resonance Frequencies around 13 GHz.

Parallel LC Resonance

High Frequency Properties of Flip Chip ACAs



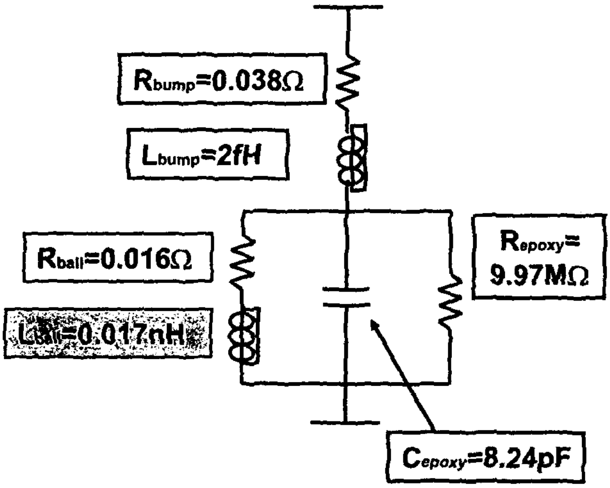


$$f_{resonance} = \frac{1}{\sqrt{LC}}$$

- ***Low dielectric adhesive is needed.***

Ref. IEEE Trans. On CPT Vol. 22, No.4, pp.575-581

Final Equivalent Circuit of Conventional ACF Interconnect



Extracted Equivalent Circuit Model of the 100μm×100μm Flip-chip Interconnection using Au-coated polymer ball-filled ACF

Useful up to 15GHz

Low Loss and Dielectric Constant of the Epoxy Resin

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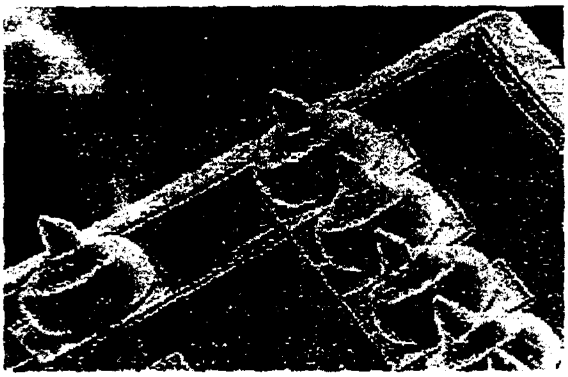
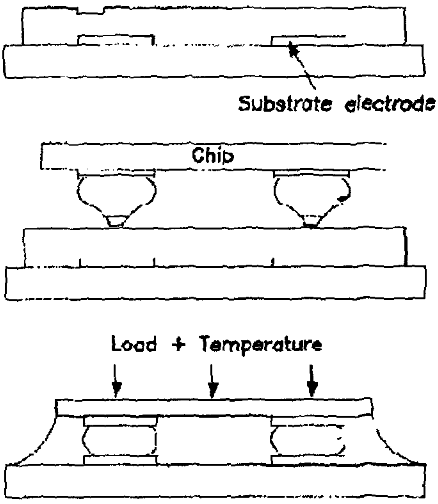
High frequency behavior of gold stud bump ACF flip chip





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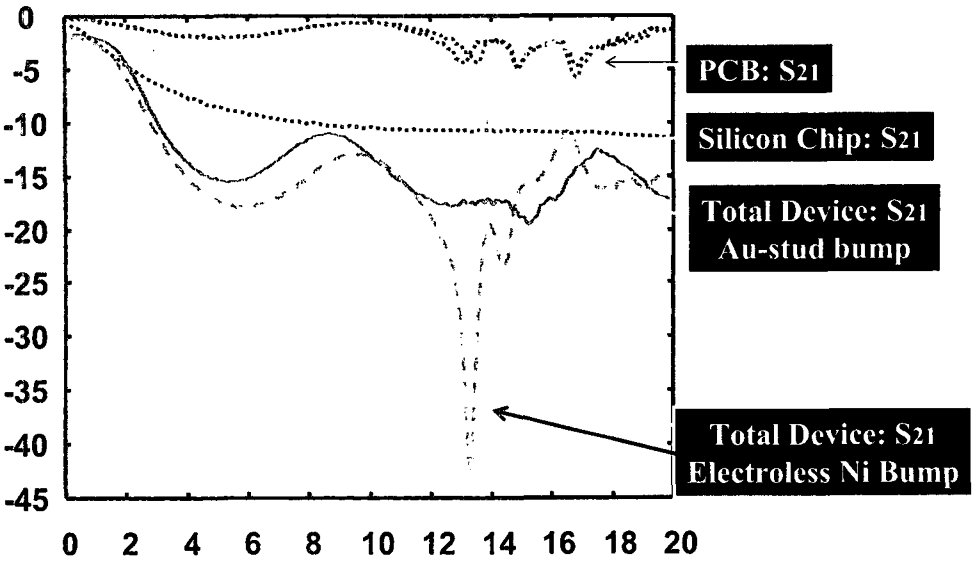
High frequency behavior of Au stud bump with Conventional ACFs



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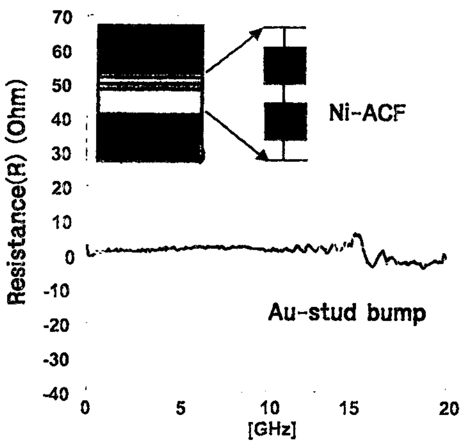
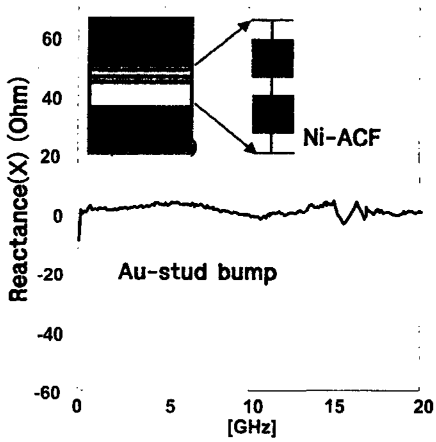
Impedance parameter extraction : Au-stud bump





- ✓ Resonance phenomena was not occurred
- ✓ At microwave frequency, impedance is constantly maintained (Good high frequency characteristics)
- ✓ Packaging of microwave device within 20GHz operation freq.

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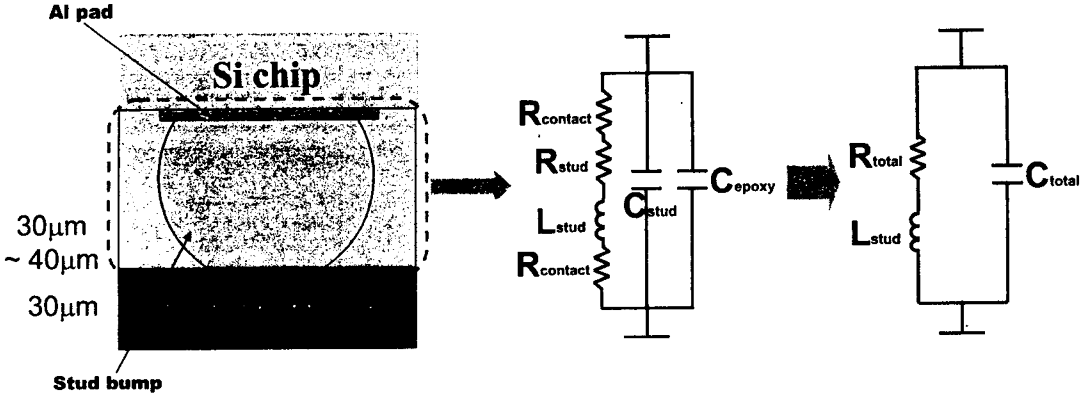
Stud bumps model



- ✓ Modeling for equivalent circuit extraction
- ✓ Modeling system
  = stud bump system + insulating epoxy system

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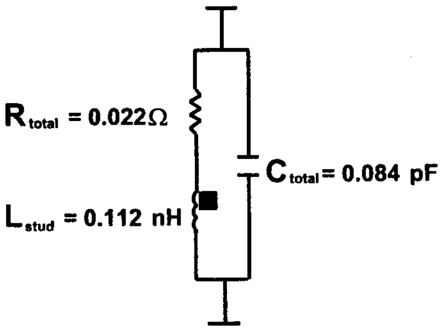
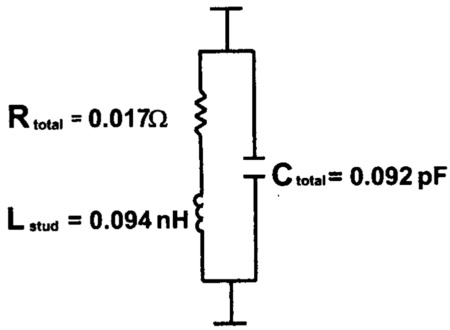
Equivalent CKT modeling of stud bumps



Au-stud bump



Cu-stud bump

- ✓ C_{total} was greatly reduced when compared with ACF(2 order smaller)
- ✓ This reduction is originated from the structural difference of interconnection
- ✓ Availability of this equivalent circuit was verified

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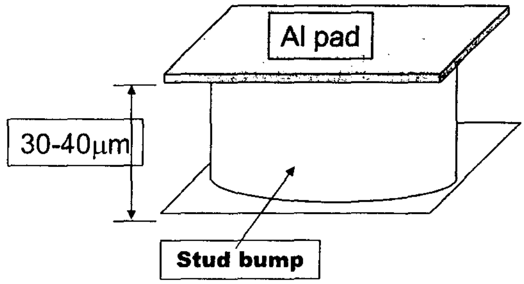
Origin of reduced capacitive coupling

Electroless Nu Bump

Conducting ball(Ni)

ACF interconnect structure

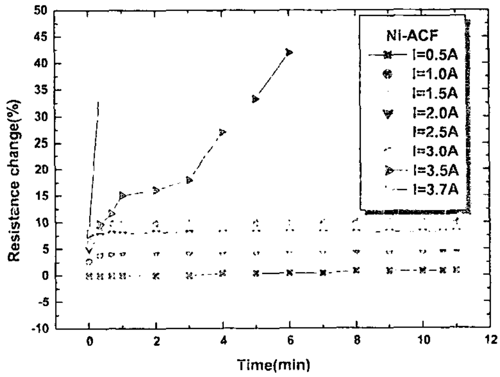
Stud Bump



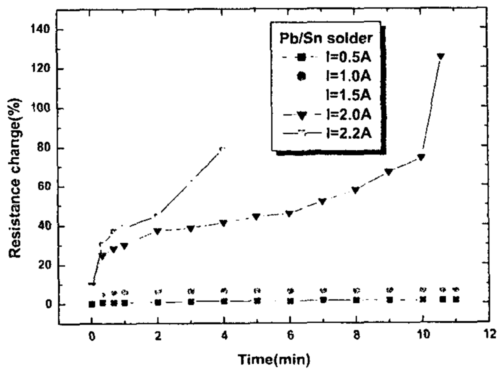
Stud bumps interconnect structure

- ✓ Capacitive coupling is originated from E-field interaction
- ✓ Capacitive coupling (~$1/L^2$)
  = (1)chip-substrate proximity effect + (2)inter-conducting system effect
- ✓ Therefore, capacitive coupling of ACF is larger than that of stud bumps

ACF Current Handling Capability: Resistance Changes vs. Current and Times

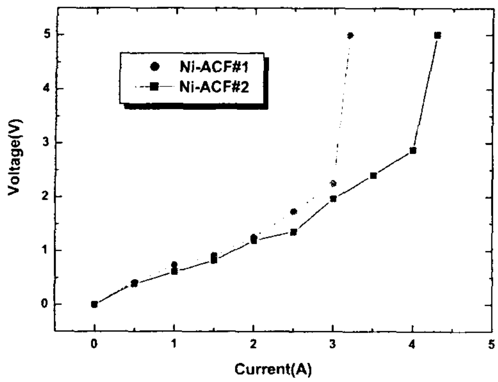


Ni ACF(pad 500 μm)

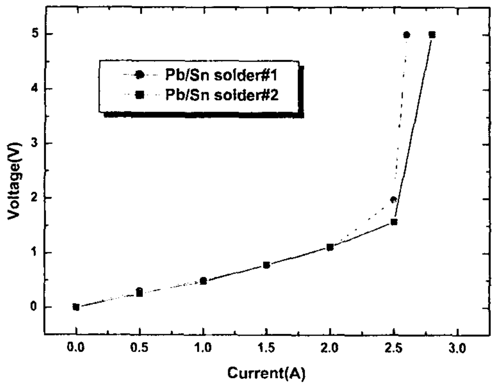


Solder (bump 750 μm dia.)

Current Handling Capability of ACF and Solder Flip Chip



Ni ACF(pad 500 μm)



Solder (bump 750 μm dia.)

ACF Technology Conclusions

- ACF Technology – Mature Technology
  - Display packaging technology materials
  - Mechanism, formulation, manufacturing well understood
- ACF Materials innovation under progress
  - Low temperature, fast curing ACF
  - Fine pitch ACFs
  - Flip chip ACFs for organic boards
- ACF flip chip
  - Proven at high frequency applications
  - Cost competitive
  - Materials, equipment, bumping – infrastructure built
- The newly modified flip chip ACFs – reliability proven technology
- Applications – memory, telecommunication, appliances, etc.