Anisotropic Conductive Adhesives(ACAs) Flip Chip Technology :

Low Cost and Reliable Flip Chip Alternative

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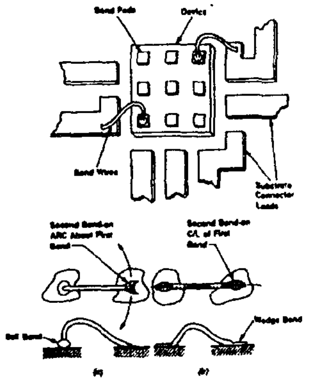
ASEM Hall

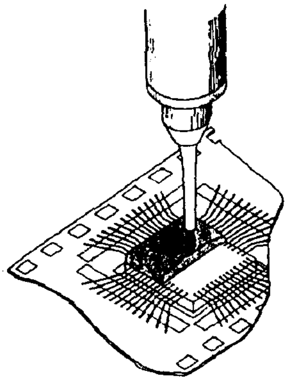
Outline

Reliability – Thermal Cycle
High Frequency Characteristics
Current Handling Capability

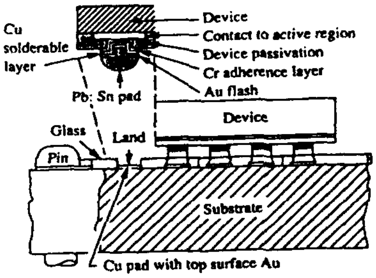
Chip Interconnection Technologies



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

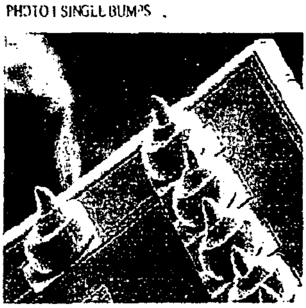
1. Solder Bumps – Solder Reflowing

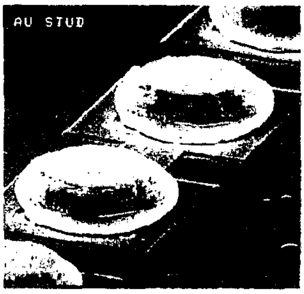
  - Evaporated solder bumps
  - Electroplated solder bumps
  - Screen printed solder bumps
- All joints made simultaneously by reflowing the solder

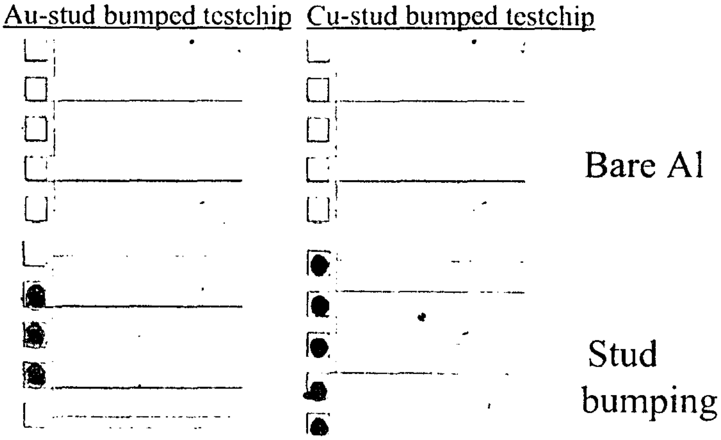
2. Non-Solder Bumps – ICAs or ACAs

  - Gold bumps
  - Au stud bumps
  - Electroless Ni/Au plated bumps
- Electrical interconnection medium such as ICAs and ACAs needed.

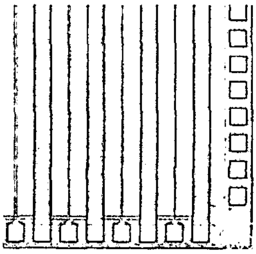
Gold and Copper Stud Bumps

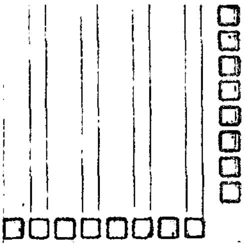


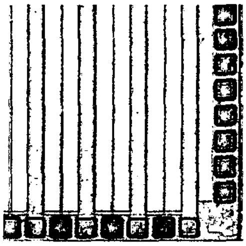




Electroless-Deposited Ni Bumps


Al Pads


Ni coated bumps


Au coated Ni bumps

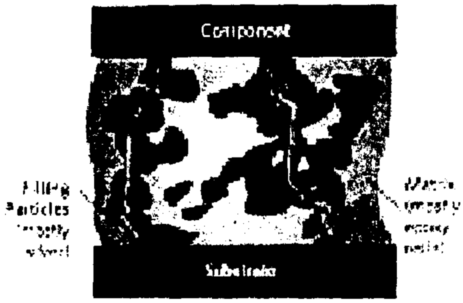

Electroless Ni Bumps


3-D shape of a bump

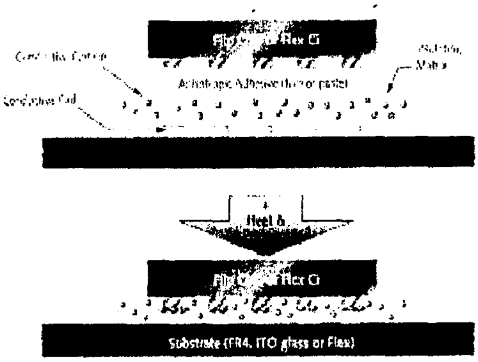
Electroless Ni Bumps Characteristics

Characteristic	Measurement	Characteristic	Measurement
Resistivity	70 $\mu\Omega$-cm	Material analysis	P wt10%
Thickness	20 μm	Hardness	500±50 HV
Pad size	100×100 μm^2	Pitch	150 μm

Non-Solder Bumps need interconnection materials

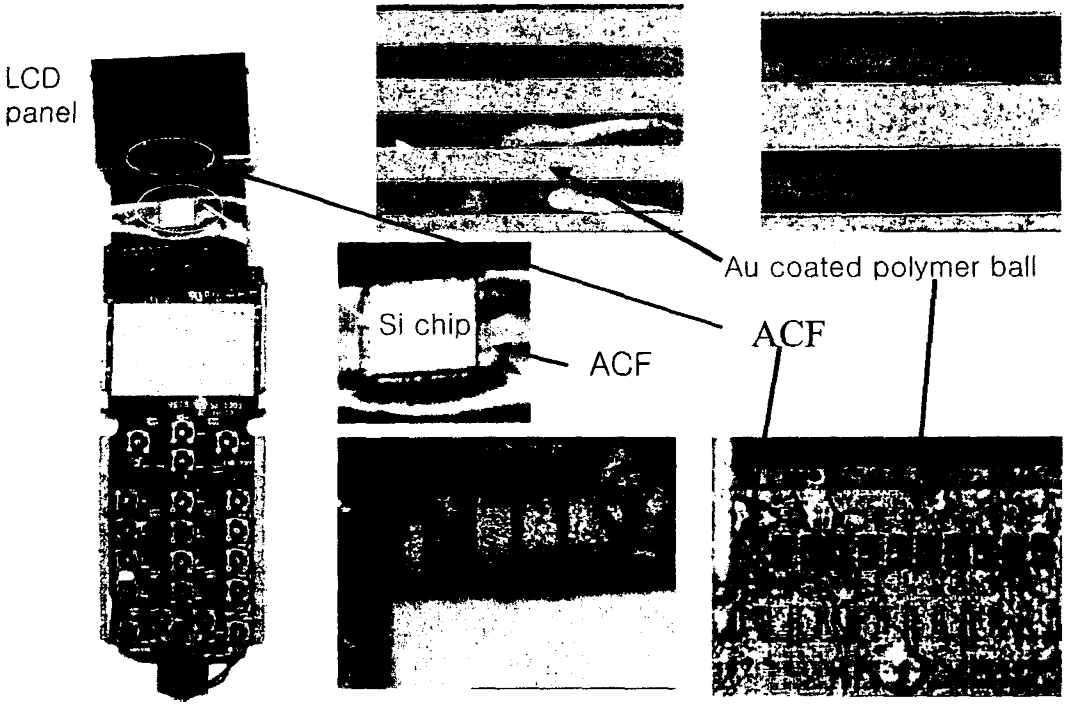


Isotropic Conductive Adhesive (ICA)



Anisotropic Conductive Adhesive(ACA)

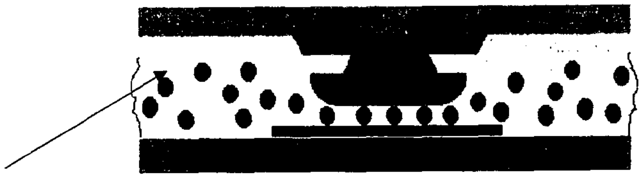
ACFs for LCD Applications



ACAs Interconnection Materials

1. Conductive Fillers

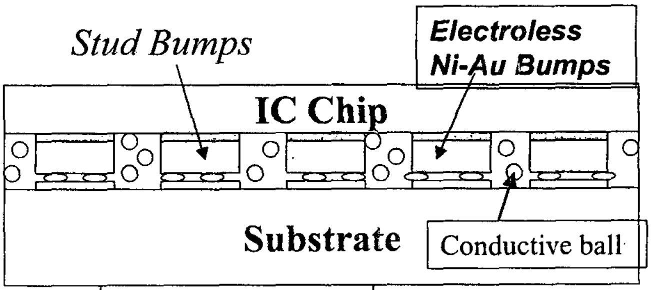
- Filler Types : metal particles (Ni, Ni/Au, solder) or
  – metal coated polymer particles
- Number, Diameter, Hardness, Conductivity
- ACFs/ACAs Design Parameters optimization



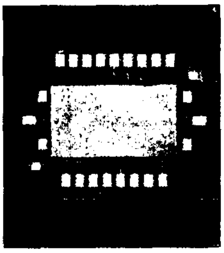
2. Polymer Resin

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

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

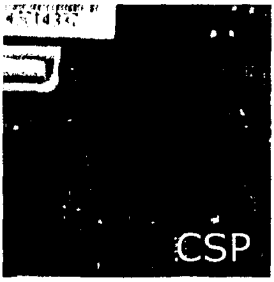
- CSP (Chip Size/Scale Package)

  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)

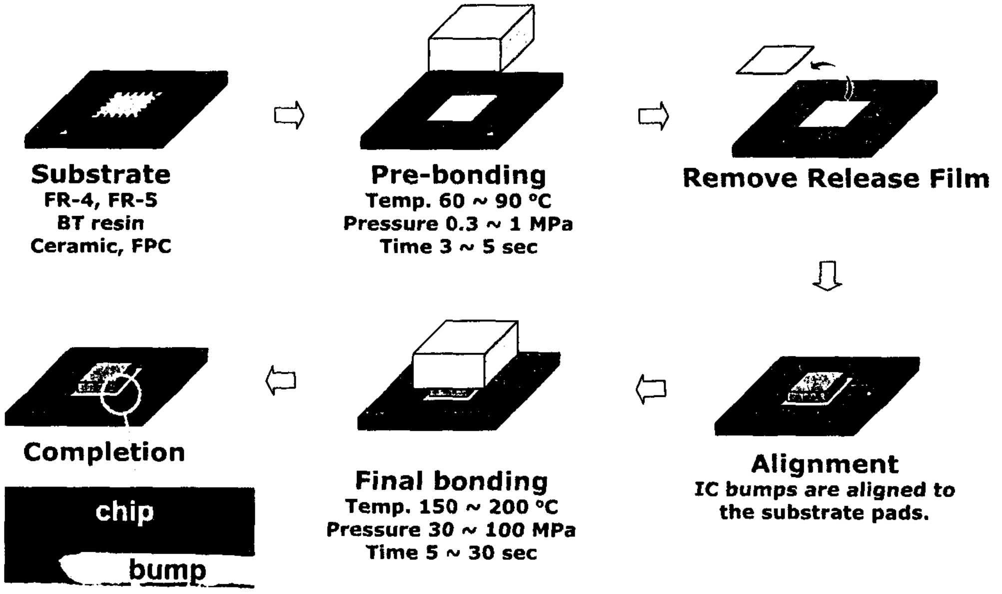
  Bare chip bonding on TAB, FPC, Smart card, RF Tag, Rigid/Flex hybrids and other flexible substrates.


MCM


CSP


COF

Flip chip Assembly using ACFs



Substrate
FR-4, FR-5
BT resin
Ceramic, FPC

Pre-bonding
Temp. 60 ~ 90 °C
Pressure 0.3 ~ 1 MPa
Time 3 ~ 5 sec

Remove Release Film

Alignment
IC bumps are aligned to the substrate pads.

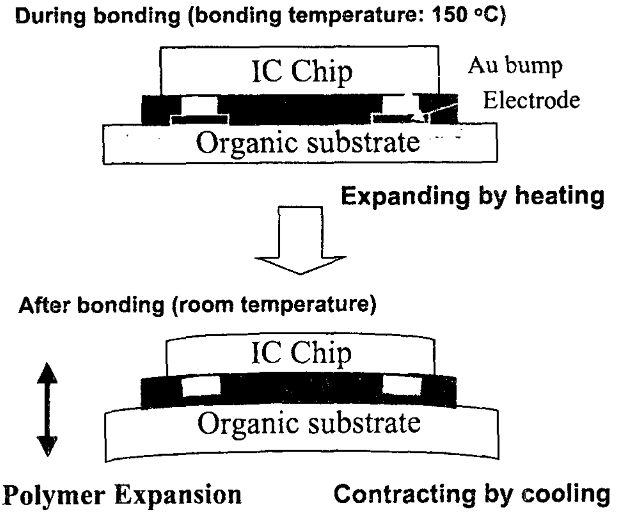
Final bonding
Temp. 150 ~ 200 °C
Pressure 30 ~ 100 MPa
Time 5 ~ 30 sec

Completion

substrate

Cross-section

ACA Flip Chip on Organic Substrates Problem



During bonding (bonding temperature: 150 °C)

Expanding by heating

After bonding (room temperature)

Polymer Expansion

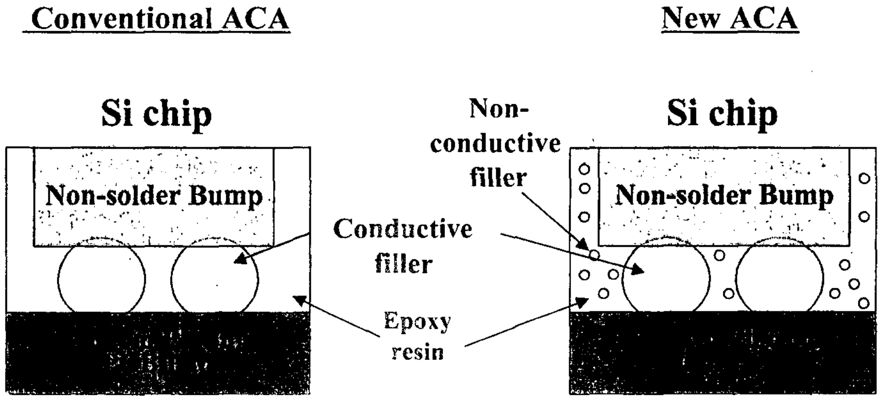
Contracting by cooling

Si : 3 ppm/°C
PWB : 14 - 17 ppm/°C
ACA : 70 - 90 ppm/°C

X-Y Directional
Thermo-mechanical
stress and strain
&
Z-Directional
Expansion and Shrink

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

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

ACA Material Systems

1. Fillers

- Conductive fillers : 5 micron-sized Ni particles

- Non-conductive fillers : 1 micron-sized SiO2 particles

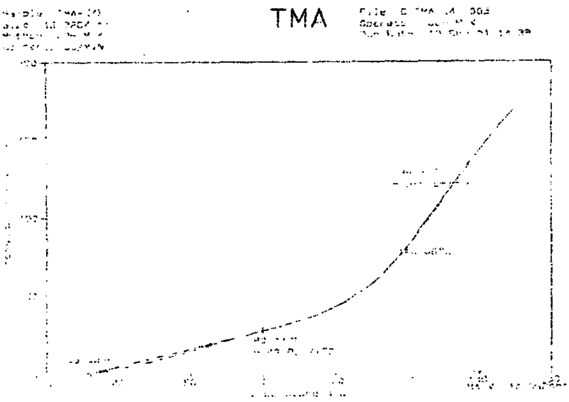
  Both type of fillers need surface modification to be uniformly dispersed in polymer matrix

2. Polymer Matrix

- Thermoset Epoxy: Bisphenol A type liquid epoxy

- Curing agent: imidazole type curing agent

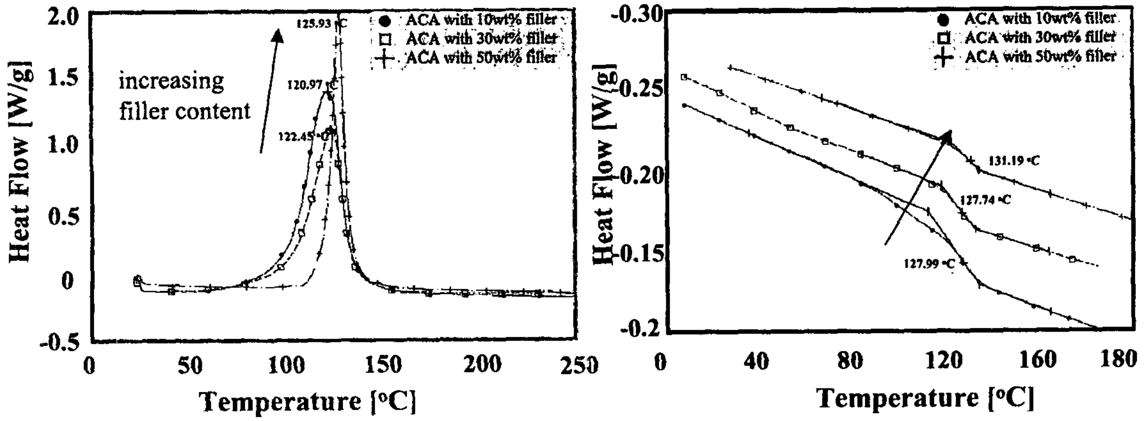
Material Characterization : TMA and TGA Results



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**

Material Characterization : DSC Results

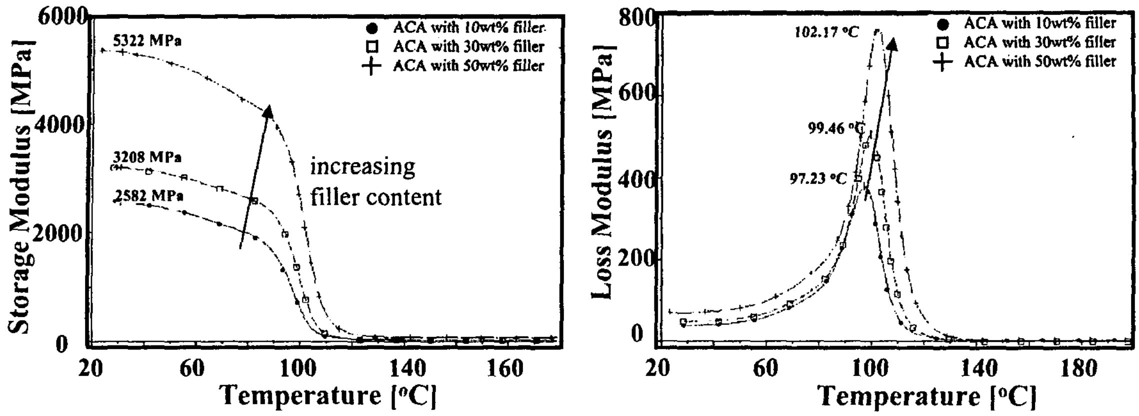
Differential Scanning Calorimeter



As Filler content ↑, Tg ↑ (Δ 4 °C)

Material Characterization : DMA Results

Dynamic Mechanical Analysis



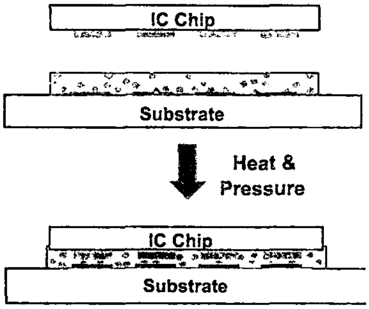
As Filler content ↑, Storage modulus and Tg ↑

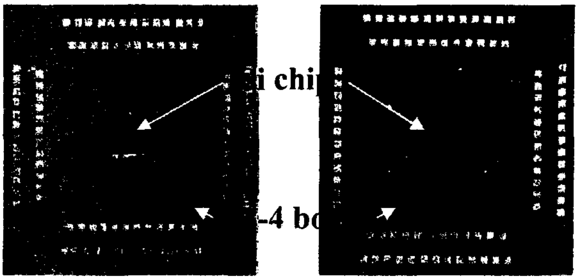
Summary of New ACA Material Properties

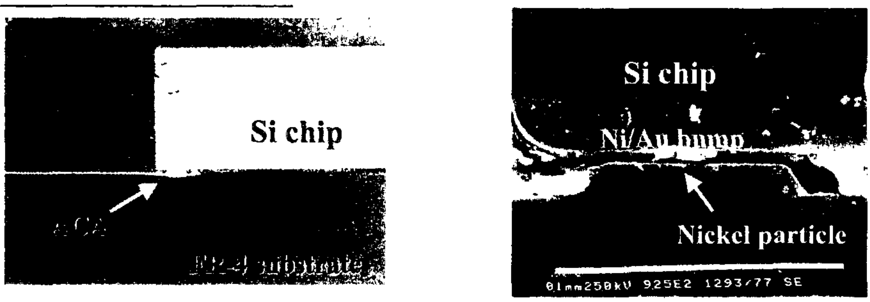
As the content of non-conductive fillers increased,

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

Flip-chip Processes Using ACAs

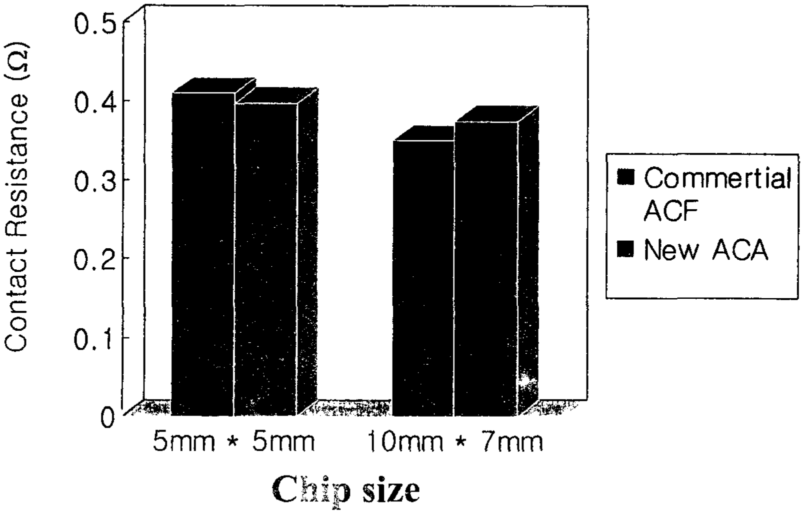






Cross-section image of ACA Flip-chip joint

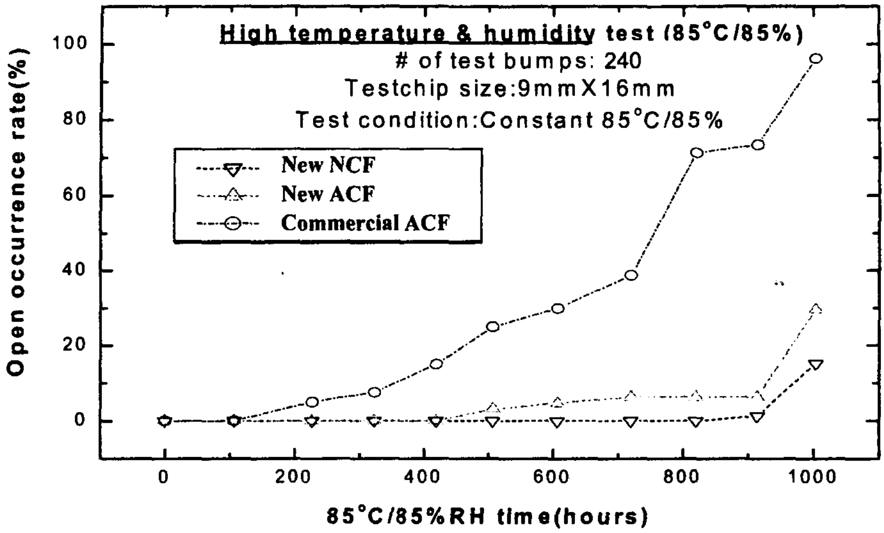
Contact Resistances of New ACA Interconnections



Electrical Conductivity of New ACA and Commercial ACF

Reliability 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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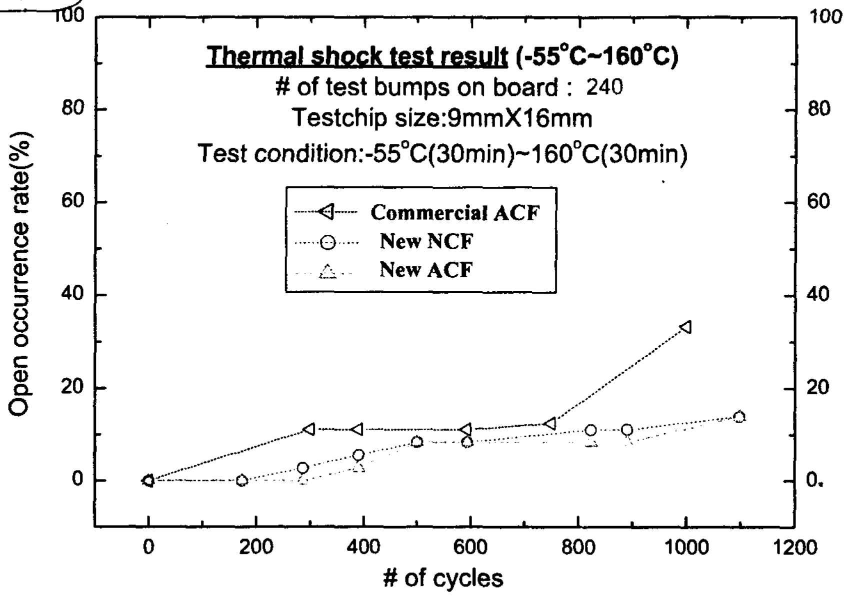
Reliability of New ACF/NCF

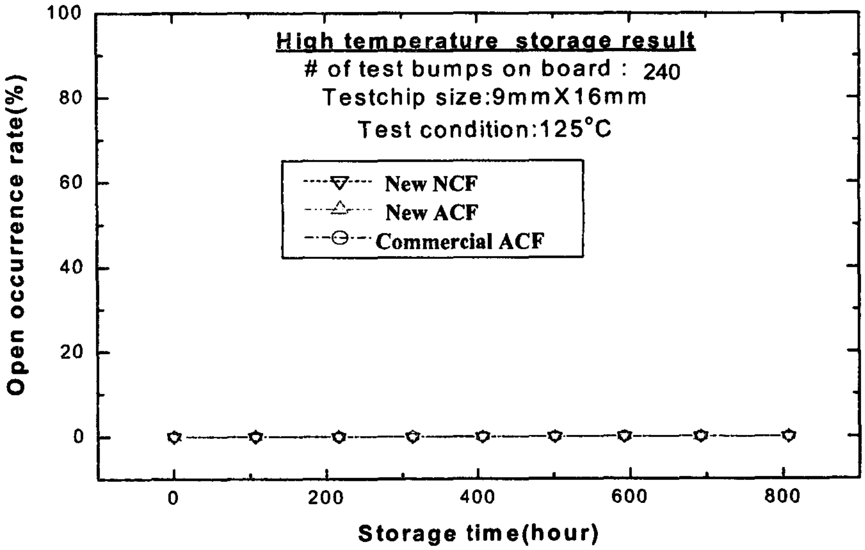
After IR Reflow (2 Times)

Thermal Shock Test (-65 ~150℃)

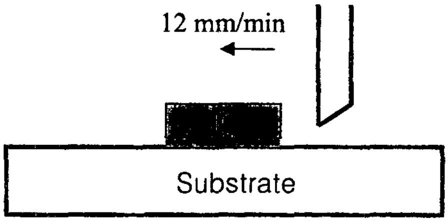


Reliability of New ACF/NCF

High Temp. Storage Test (125℃)



Adhesive Strength Test Method



ACF width : 4 mm

Bonding Condition : 180℃,40MPa, 20s

Substrate : FR-4 (40 mm * 40 mm)

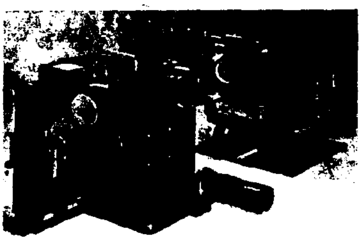
Test chip : 3 mm$^\square$, 0.4 mm^t, bumpless

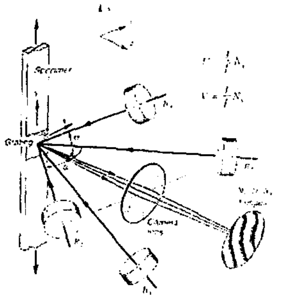
Pattern : Cu ½ ounce Ni, Au plating

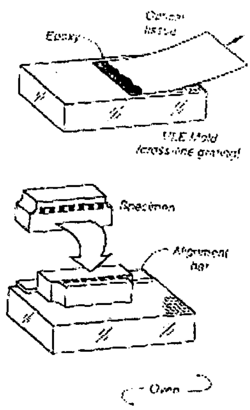
Sample	Initial	After 85°C/85%RH/500hrs
New ACF-1	IC fracture	IC fracture
New ACF-2	IC fracture	IC fracture

- Strong adhesion of New ACFs on organic substrate

Micro-Moire Fringe Analysis







Relationship between fringe order and displacement

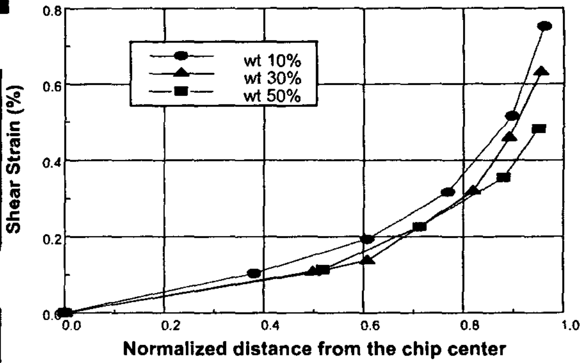
$$U_{(x,y)} = N_{x(x,y)}/f$$

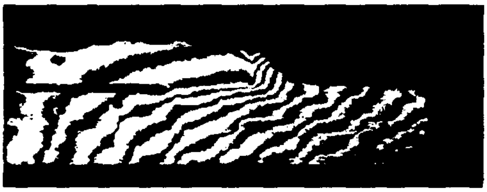
$$V_{(x,y)} = N_{y(x,y)}/f$$

U Field (x-direction) Deformation

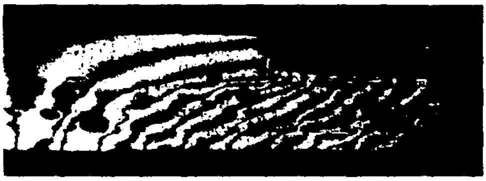
10 wt% SiO2

ΔT= 80 °C





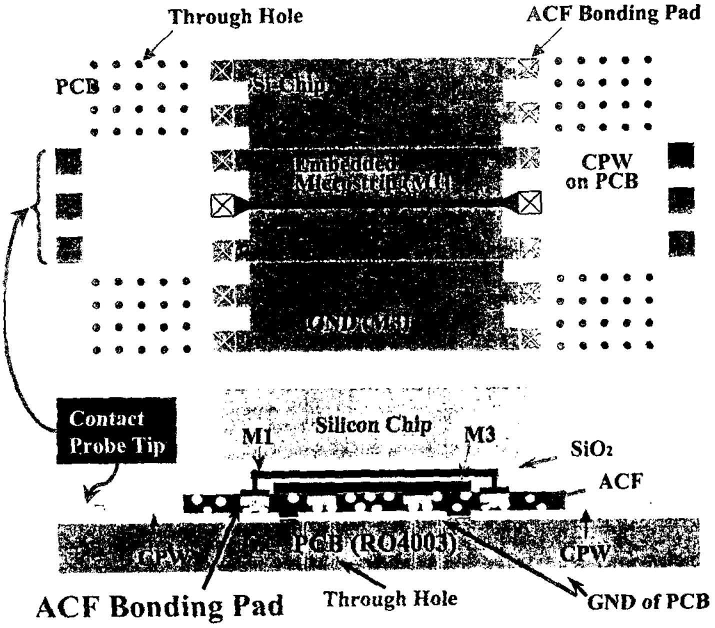
30 wt% SiO2

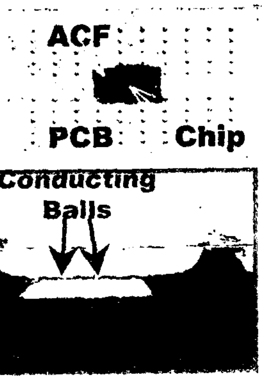


50 wt% SiO2

Reduced Shear Strain

Test Chip and PCB for High Frequency Measurement





CPW on PCB

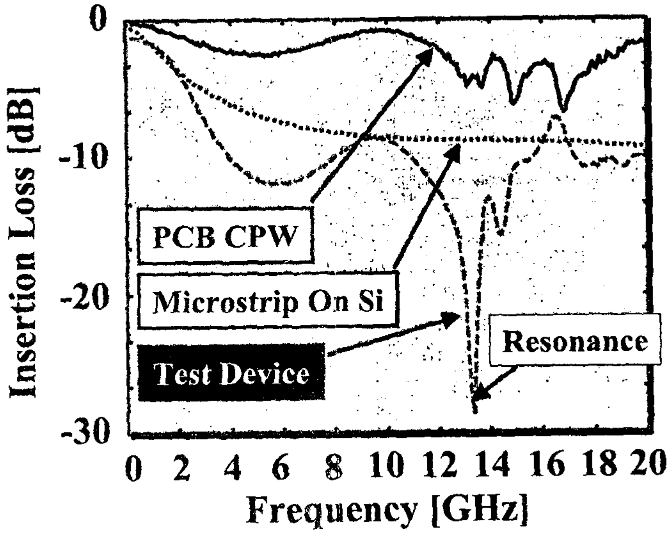
Microstrip on Silicon

Minimize the Parasitic and Silicon Effect

Multi-through Hole

Multi-via Hole for Low Impedance Ground

Measured Insertion Loss of Conventional ACFs



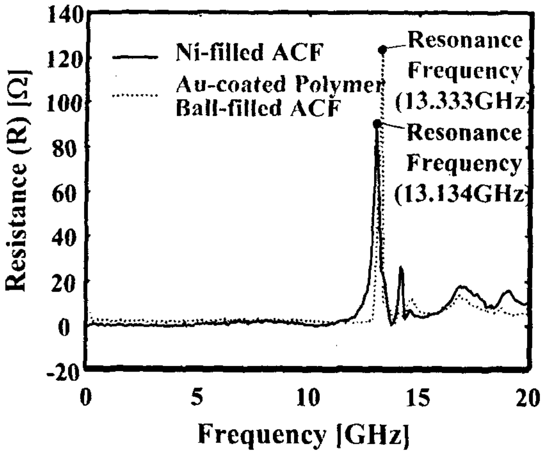
Measured Insertion Loss Using a Network Analyzer from 200 MHz to 20 GHz

Resonance Frequencies around 13 GHz.

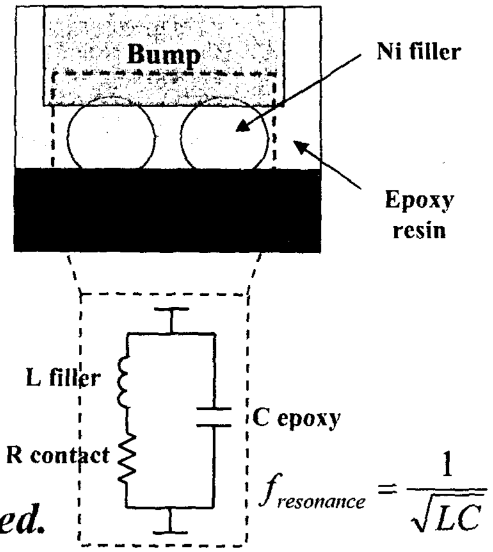
Parallel LC Resonance

High Frequency Properties of Flip Chip ACAs

High frequency characteristics of ACA interconnection



Equivalent circuit and resonance frequency

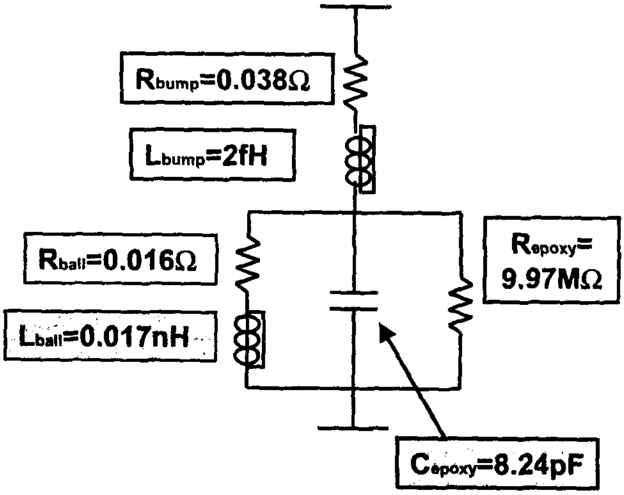


$$f_{resonance} = \frac{1}{\sqrt{LC}}$$

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

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

Final Equivalent Circuit of Conventional ACF Interconnect

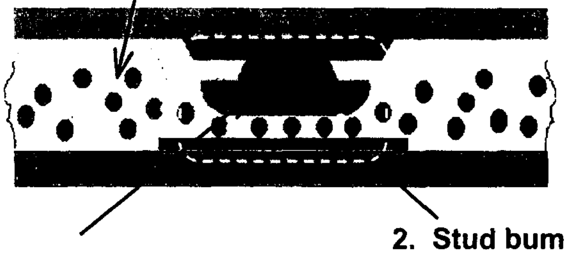


Extracted Equivalent Circuit Model of the 100μm×100μm Flip-chip Interconnection using Au-coated polymer ball-filled ACF

Useful up to 15GHz

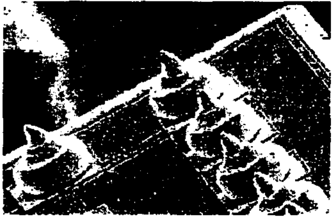
Low Loss and Dielectric Constant of the Epoxy Resin

Extracted Result 1- SiO_2 Filler Addition Effects

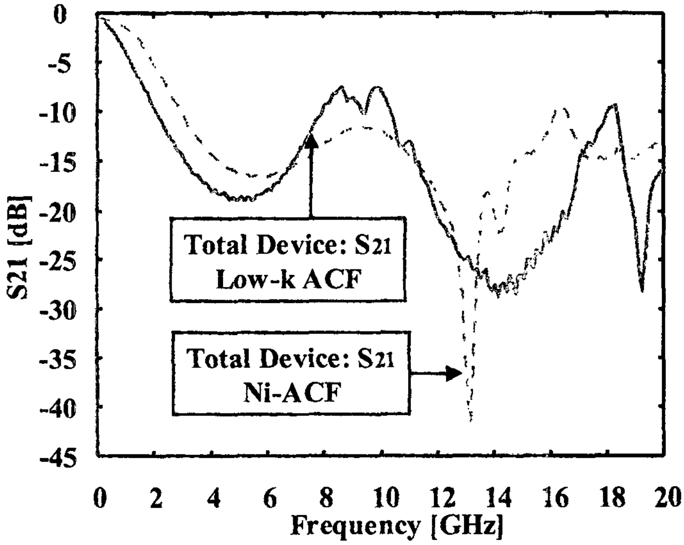


1. Low-k SiO_2 filler addition effects
(C_{epoxy} reduction)

2. Stud bump characterization

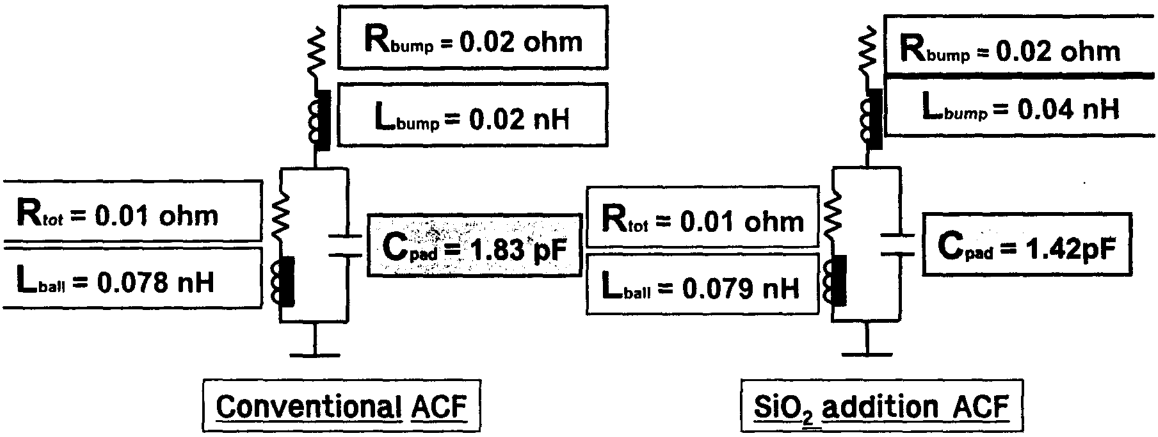


Measured insertion loss(S_{21}) : SiO2 filler added ACF with Electroless Ni Bumps



- ☐ SiO_2-added ACF have resonance at 15GHz
- ☐ Resonance is shifted to higher frequency
- ☐ Resonance shift is caused by added SiO_2
- ☐ From the s-parameter, impedance parameter was extracted

SiO_2 Particle Addition Effects on Capacitance



R_{bump} = 0.02 ohm

L_{bump} = 0.02 nH

R_{tot} = 0.01 ohm

L_{ball} = 0.078 nH

C_{pad} = 1.83 pF

Conventional ACF

R_{bump} = 0.02 ohm

L_{bump} = 0.04 nH

R_{tot} = 0.01 ohm

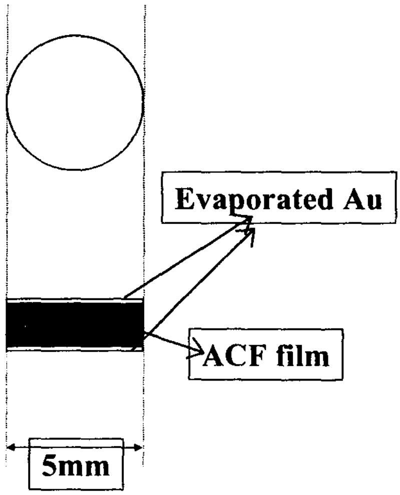
L_{ball} = 0.079 nH

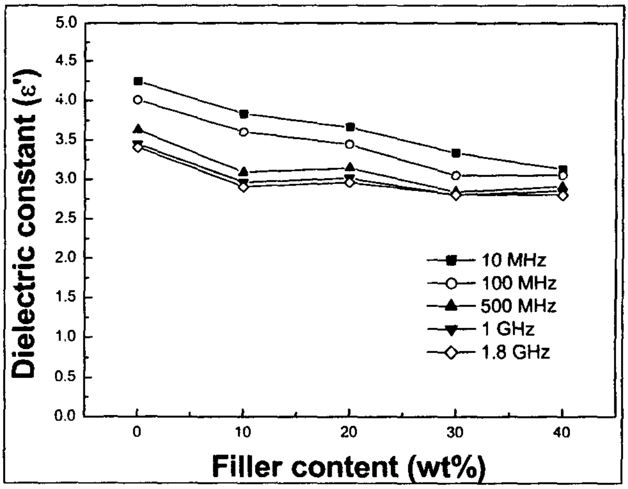
C_{pad} = 1.42pF

SiO_2 addition ACF

- ☐ Epoxy capacitance is reduced due to low-k SiO_2 particle
- ☐ Reduced epoxy capacitance caused shift of resonant freq.

Experimental evidence of C_{epoxy} reduction

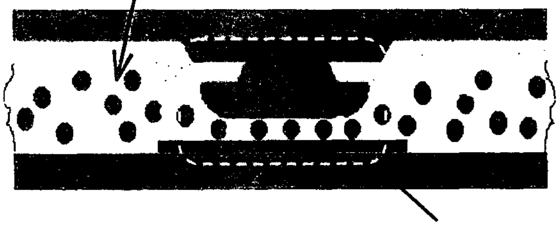




✓ Fabricated with M-I-M structure for ε_{epoxy} measurement

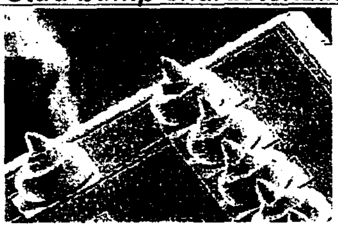
SiO_2 filler amount ↑ ⇨ ε_{epoxy}↓ ⇨ C_{epoxy} ↓ ⇨ resonant freq. ↑

Extracted Result 2 – Stud Bumps Effects

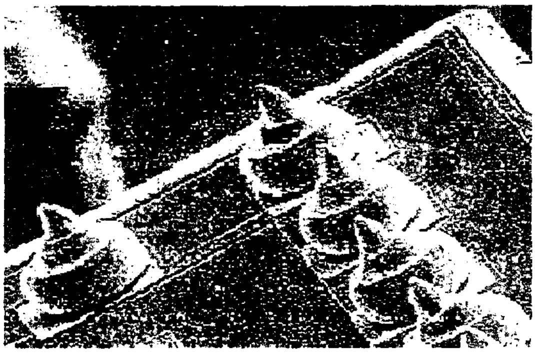


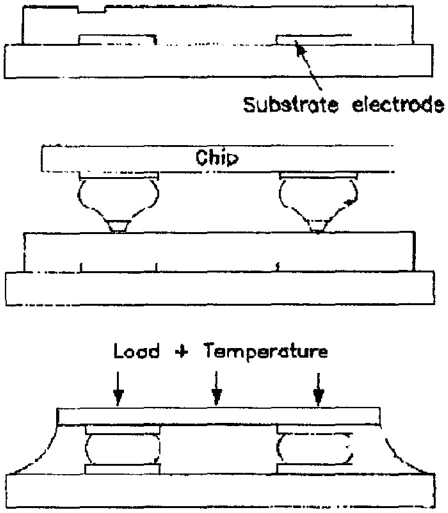
1. Low-k SiO_2 filler addition effects (C_{epoxy} reduction)

2. *Stud bump characterization*

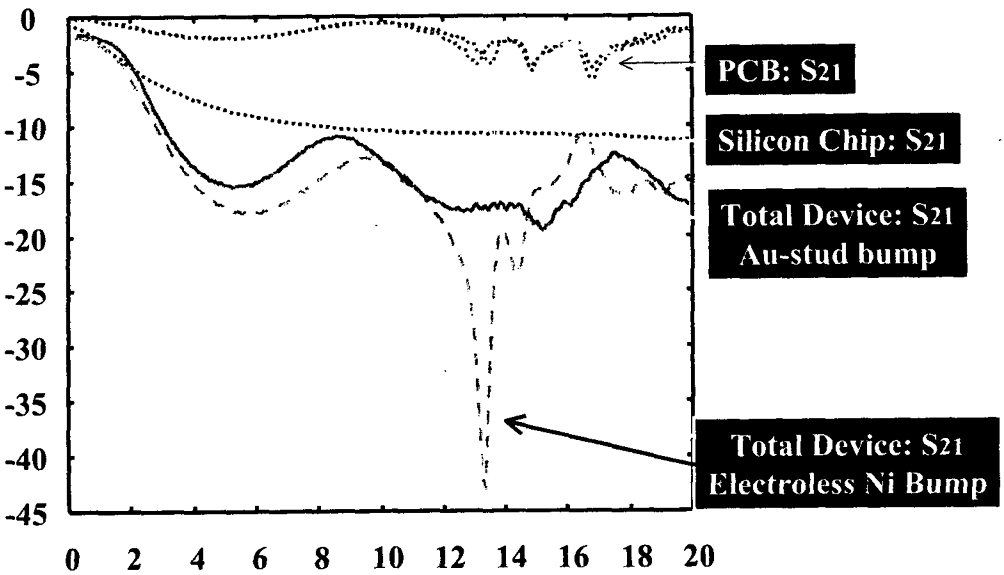


Experiment III : High frequency behavior of stud bump

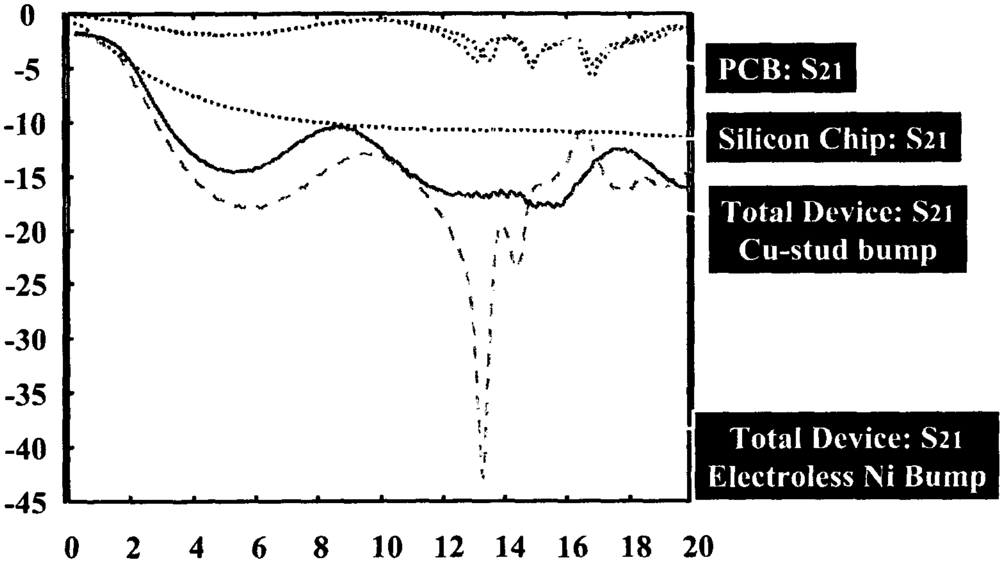




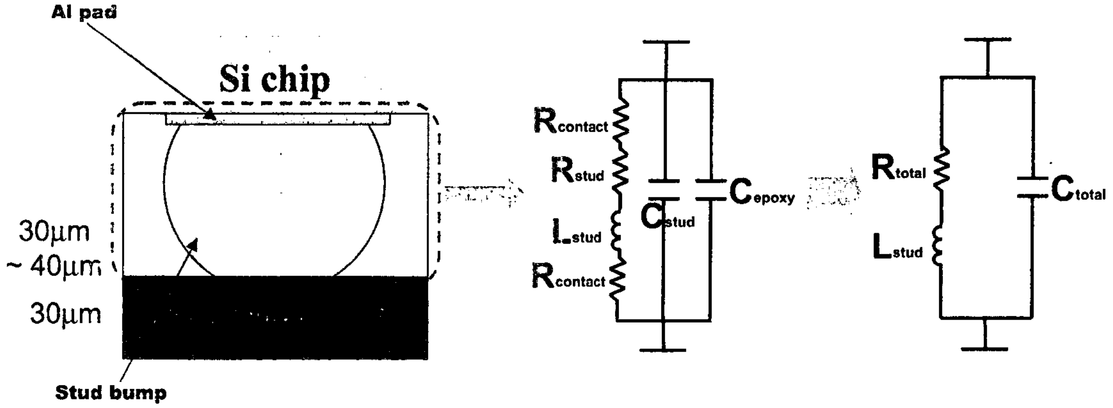
High frequency behavior of Au stud bump with Conventional ACFs



High frequency behavior of Cu stud bump

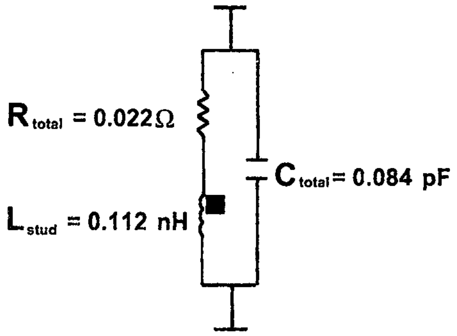


Stud bumps model

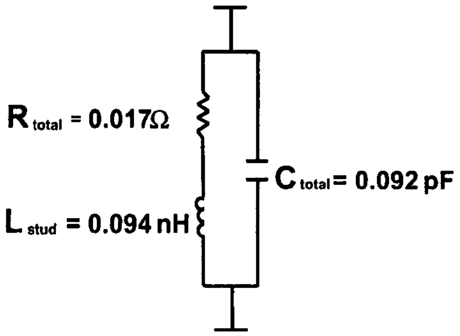


- ✓ Modeling for equivalent circuit extraction
- ✓ Modeling system
  = stud bump system + insulating epoxy system

Equivalent CKT modeling of stud bumps



Au-stud bump

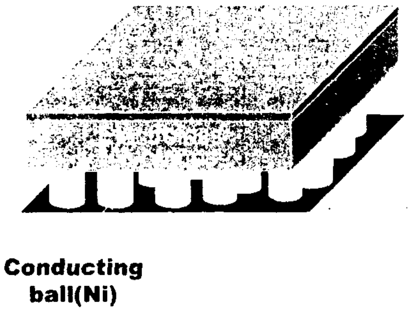


Cu-stud bump

- ✓ 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

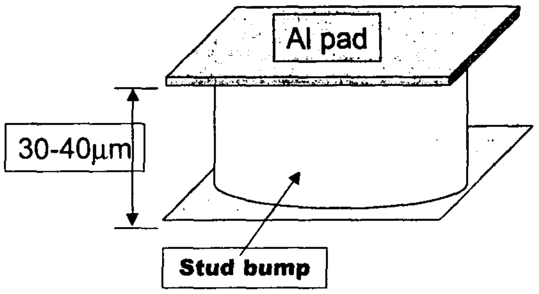
Origin of reduced capacitive coupling

Electroless Nu Bump



ACF interconnect structure

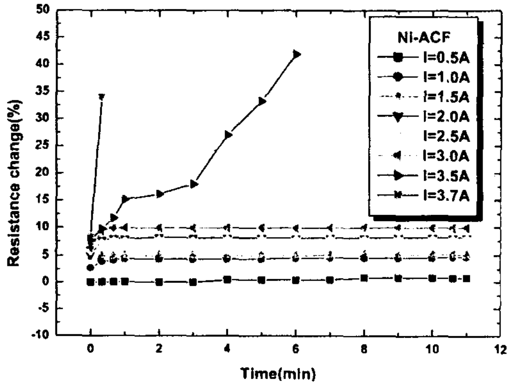
Stud Bump



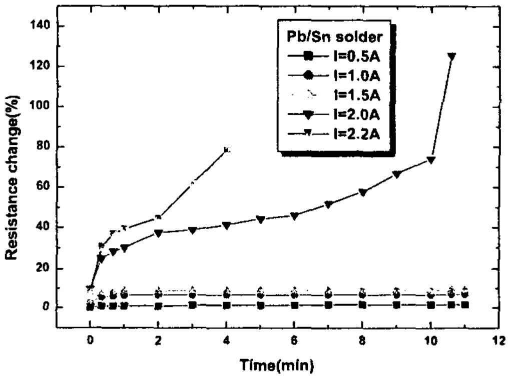
Stud bumps interconnect structure

- ✓ 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

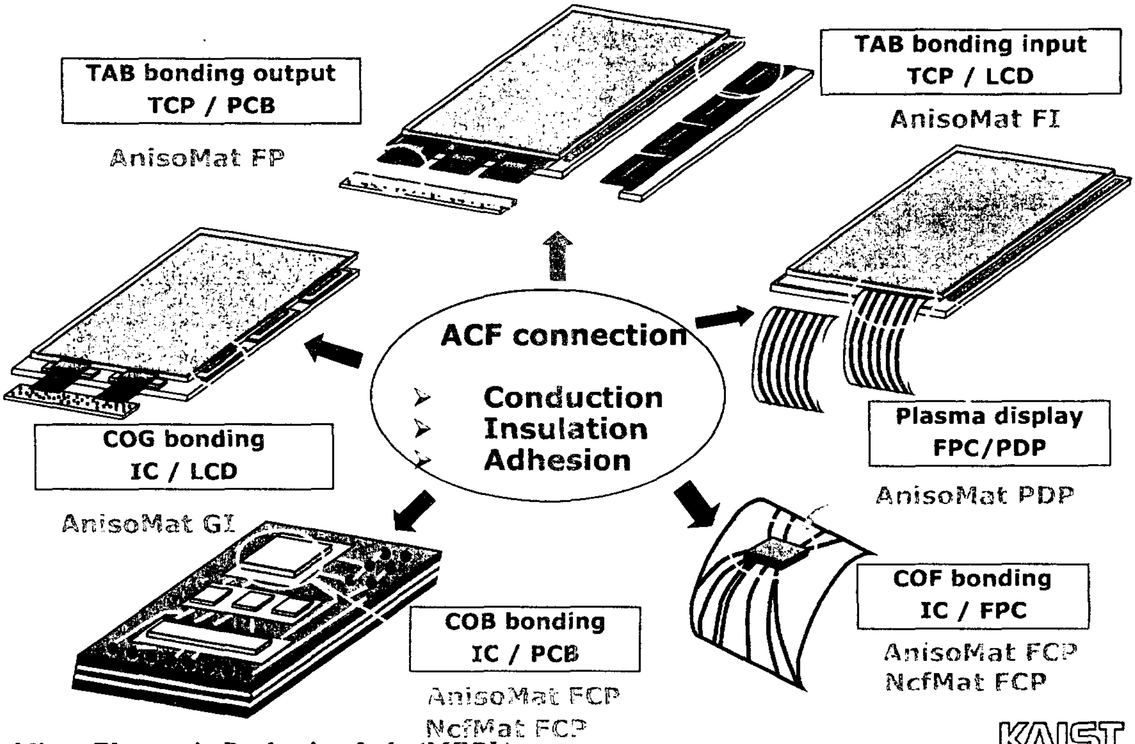


Ni ACF(pad 500 μm)



Solder (bump 750 μm dia.)

Telephus ACF Applications



TAB bonding output
TCP / PCB
AnisoMat FP

TAB bonding input
TCP / LCD
AnisoMat FI

ACF connection

- Conduction
- Insulation
- Adhesion

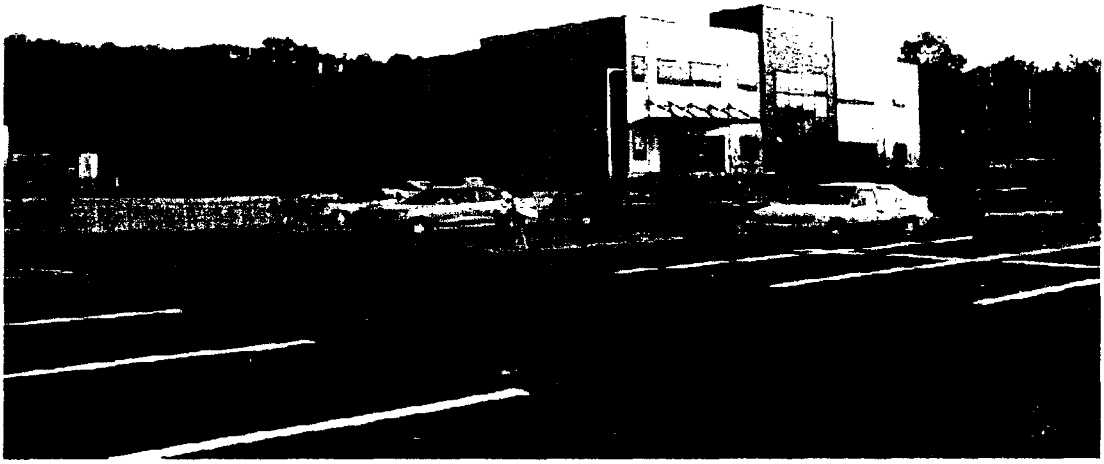
COG bonding
IC / LCD
AnisoMat GI

Plasma display
FPC/PDP
AnisoMat PDP

COB bonding
IC / PCB
AnisoMat FCP
NcfMat FCP

COF bonding
IC / FPC
AnisoMat FCP
NcfMat FCP

Telephus Fab. Overview



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.