Chip on Glass Technologies for High-Performance LCD Applications

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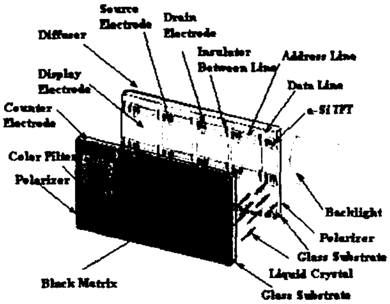
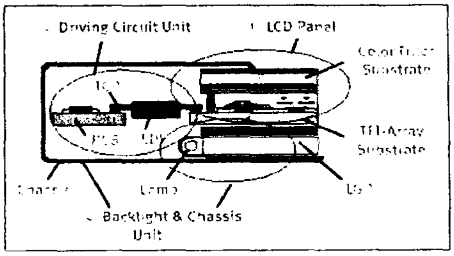
Contents

- ☑ **Introduction**
  - **Requirements and Trend in LCD driver IC packaging technology**
  - **Chip on Glass (COG) Technology**
  - **Approach**
- ☑ **Process development**
- ☑ **Electrical characterization of ultrasmall solder joints**
- ☑ **Summary**

TFT-LCD Display

☑ Structure of TFT-LCD Display





(Sourced by Samsung Electronics)

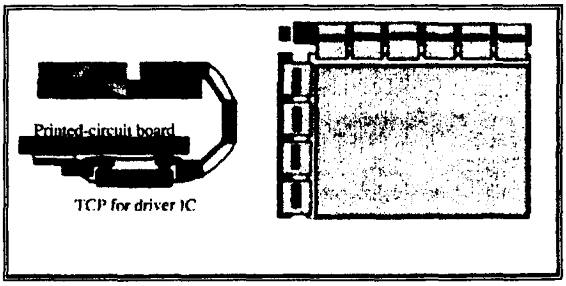
☑ Key requirements of driver IC packaging

- Higher density connection to the panel
- Lower packaging cost
- Lower product profile
- Acceptable joint resistance
- Lower temperature process
- Reworkability

Trend in TFT-LCD Driver IC Packaging Technology

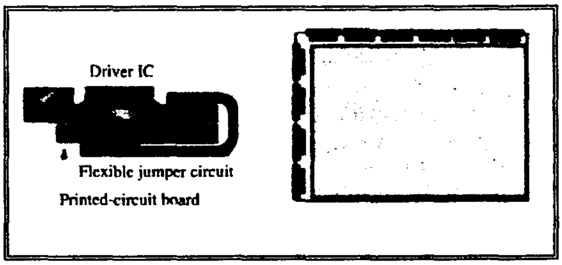
☑ TAB (Tape Automated Bonding)

- Widely used
- Applied to large display
- Minimum pitch ≈ 55 ㎛



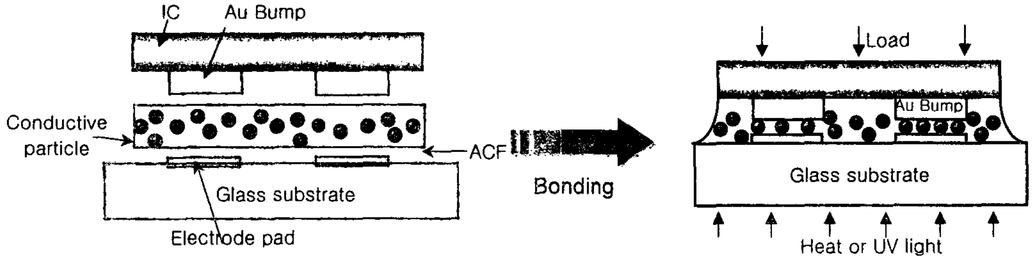
☑ COG (Chip on Glass)

- Slim and simple construction
- High reliability
- Applied to small display



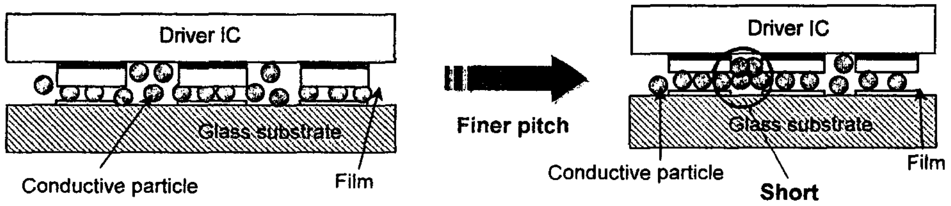
Chip on Glass (COG) Technology

- ✓ **Au bump formation on driver IC**
- ✓ **Bonding using Anisotropic Conductive Film (ACF)**
- ✓ **Conventional flip chip bonding using ACF**



Problems of COG Technique Using ACF Due to Ultrafine Pitch Application

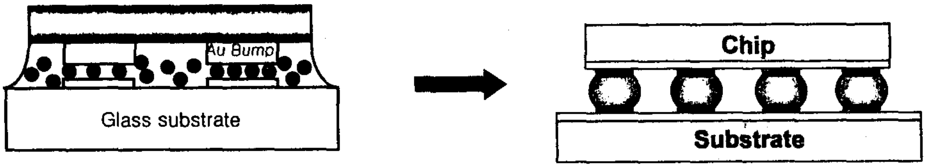
- ✓ **Increased possibility of electrical short**



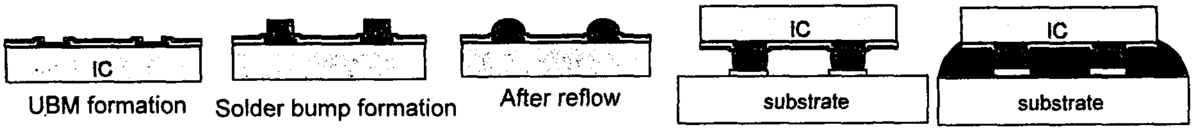
- ✓ **Increasing contact resistance due to reduced conducting particles in a bump**

COG Process Using Solder Bumps

- **Conventional method**
  - **Using anisotropic conductive film (ACF)**
- **New method**
  - **Using flip chip solder joining**



✓ **Flip chip solder joining process**



UBM formation　Solder bump formation　After reflow　Solder joining　Underfill

Flip Chip Solder Joining for LCD Driver IC Packaging

✓ **Advantages**

- **Finer pitch capability**
- **Self-alignment due to the surface tension of liquid solder**
- **Good electrical performance**
- **Easy reworkability**

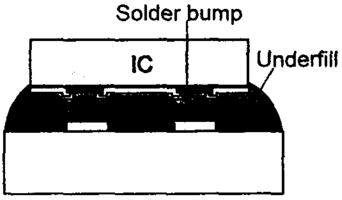
✓ **Problems**

- **High temperature process (T > 200℃)**

ex) 37Pb-63Sn　T_{mp} = 183℃

95Pb-5Sn　T_{mp} = 304 - 312℃

- **Liquid crystal or color filter can be degraded.**



✓ **Approach**

- **Using low mp solder**
- **58%Bi-42%Sn(138℃), 97%In-3%Ag(141℃)**

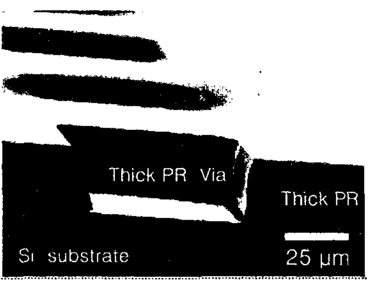
➡ **Flip chip solder joining should be processed below 160℃.**

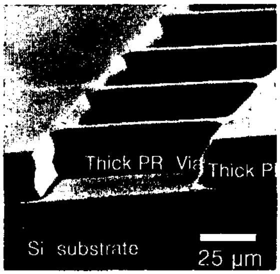
Ultrasmall Solder Bump Formation Using Lift-off Process

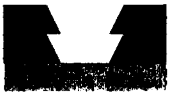
Conventional structure

Overhang structure

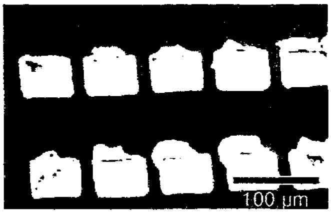
Thick PR mask

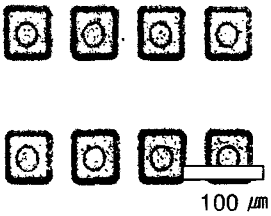






As-deposited solder bump

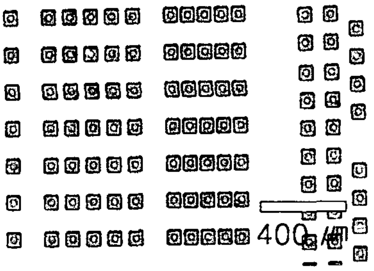


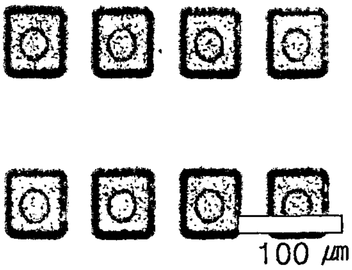


Overhang structure is more effective for perfect lift-off conventional one.
Perfect lift-off is important for ultrasmall solder bump formation.

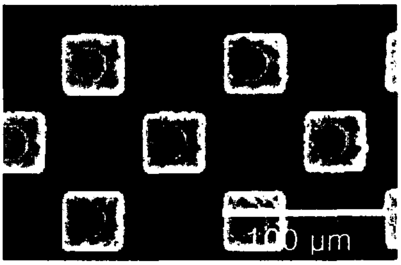
As-deposited Solder Bumps after Lift-off Process

✓ **Bi-Sn solder**



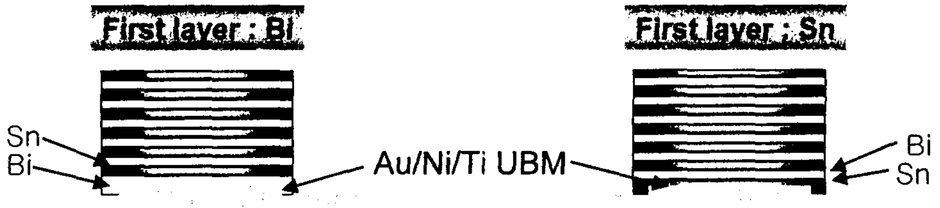


✓ **In solder**

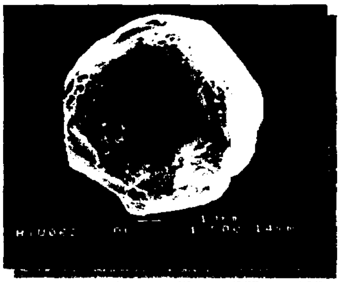


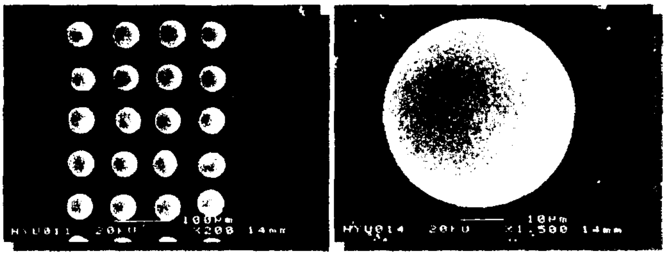
Wetting Characteristics of Bi-Sn Solder on Au/Ni/Ti UBM

- **Cross-sectional schematic view of as-deposited solder**



After reflow process



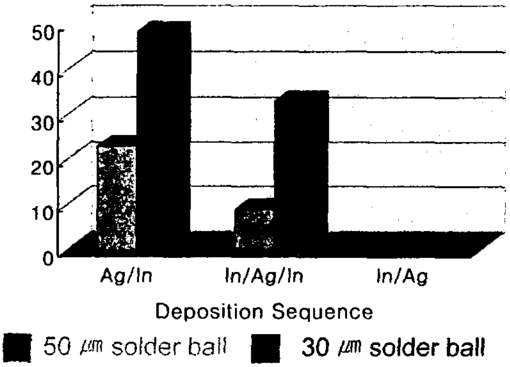


Ultrasmall Bump Formation of In-Ag Solder

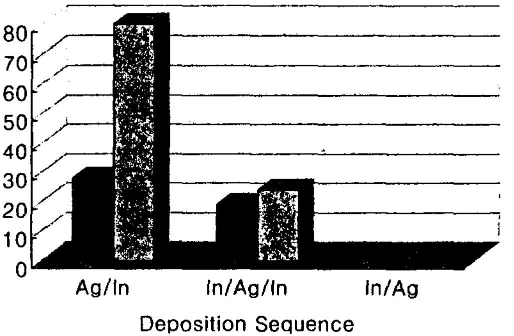
- **Cross-sectional schematic view of as-deposited solder**

Ag/In/UBM **In/Ag/UBM** **In/Ag/In/UBM**

Ball Formation Ratio with Solder Size

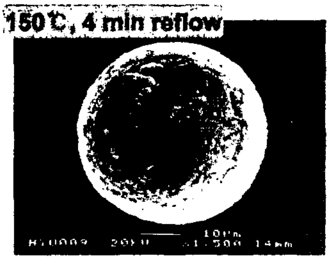


Ball Formation Ratio with Solder Density

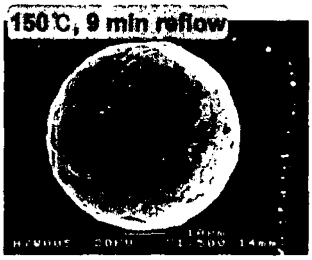


Surface Morphology of Bi-Sn Solder Bumps

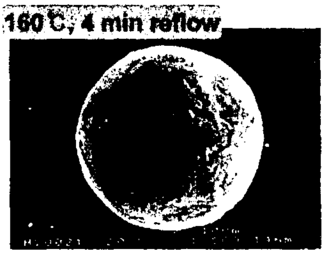
- Au/Cu(1 ㎛)/Cr UBM
- Intermediate cooling rate (10℃/min)



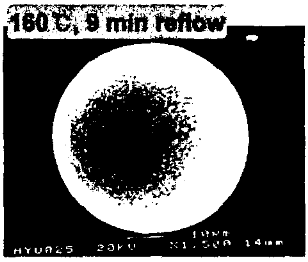
150℃, 4 min reflow



150℃, 9 min reflow



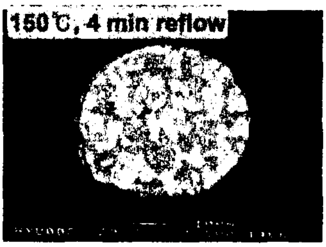
160℃, 4 min reflow



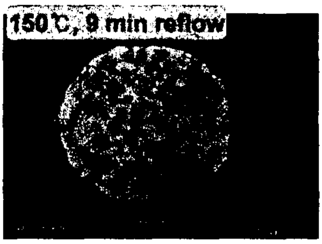
160℃, 9 min reflow

Cross-sectional Images of Bi-Sn Solder Bumps

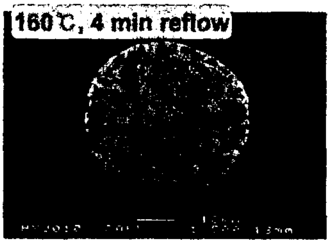
- Au/Cu(1 ㎛)/Cr UBM
- Intermediate cooling rate (10℃/min)



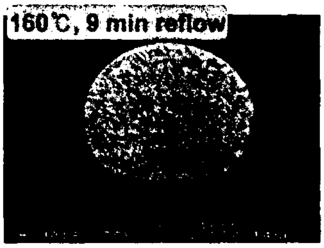
150℃, 4 min reflow



150℃, 9 min reflow



160℃, 4 min reflow



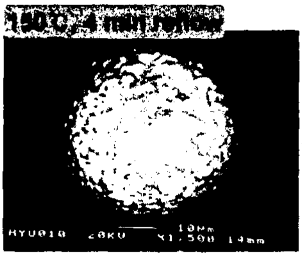
160℃, 9 min reflow

Finer microstructure makes smoother surface and more spherical shape

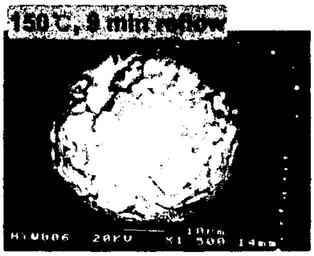
Backscattered Electron Images of Bi-Sn Solder Bumps

- Au/Cu(1 µm)/Cr UBM
- Intermediate cooling rate (10℃/min)

150℃, 4 min reflow

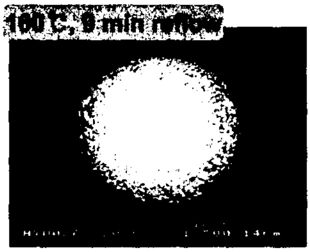


150℃, 9 min reflow



160℃, 4 min reflow

160℃, 9 min reflow



The surface morphology is controlled by the microstructure of Bi-Sn solder

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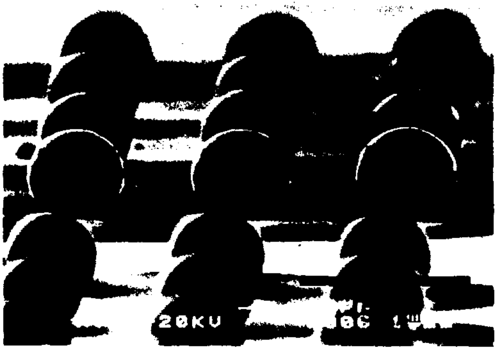
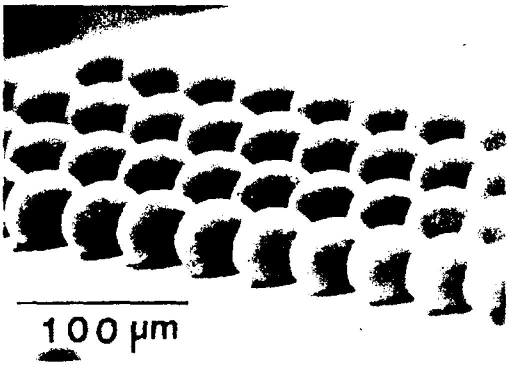
Solder Bumps after Reflow Process

- **Peak temperature : 160℃**

50 µm pitch Bi-Sn solder bumps



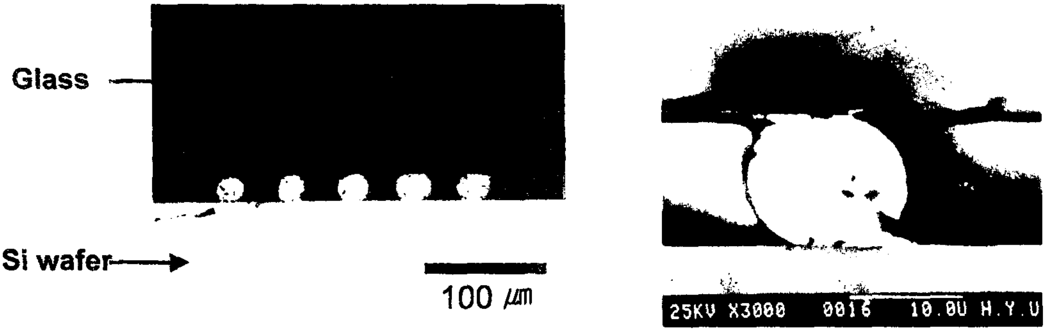
80 µm pitch Bi-Sn solder bumps



Ultra-small and spherical solder bumps can be uniformly fabricated.
Uniform and smooth solder bumps are suitable for flip chip bonding.

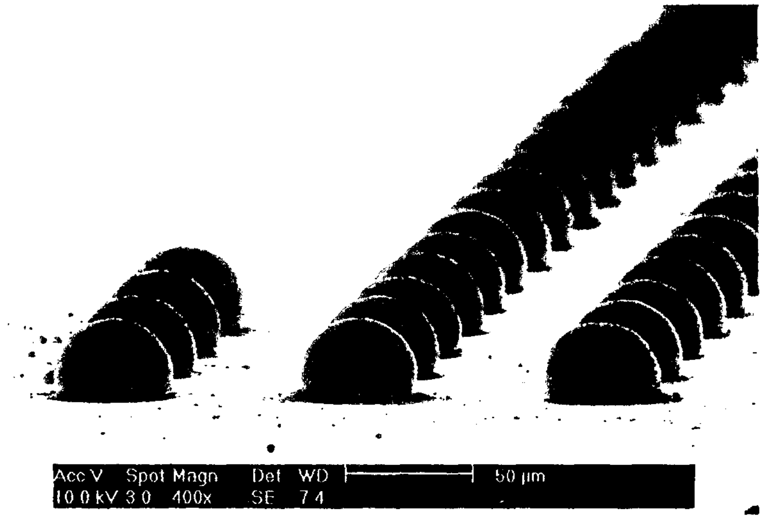
Cross-Sectional SEM Images of Solder Joints

✓ **In-Ag solder on Au/Cu/Cr (50 µm pitch)**
Reflow temperature : 160 ℃

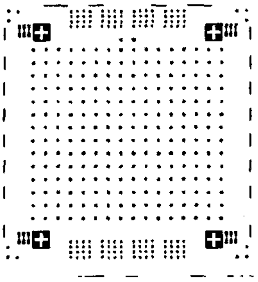


The ultrasmall solder joints having 50 µm pitches were assembled successfully.

SEM Image of Electroplated Bi-Sn Solder Bumps after Reflow

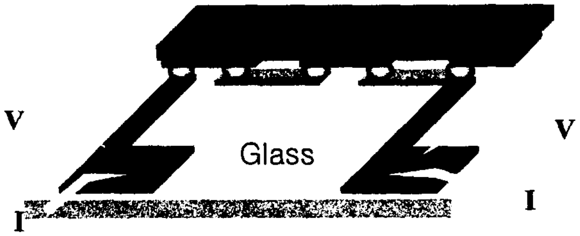


Electrical Test Using Daisy Chain Method

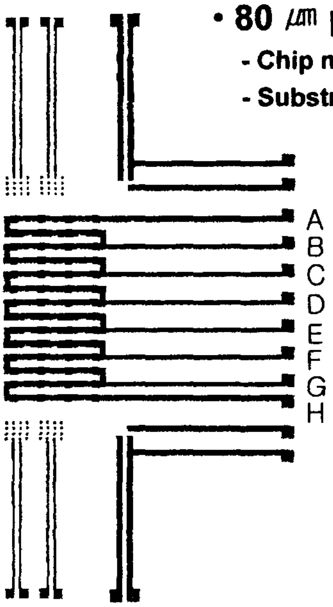


Schematic view of electrical test vehicle

- **Test vehicle**
  - **Pitch size : 80 ㎛, 200 ㎛**
  - **Maximum pad number of a daisy chain : 112**
  - **Solder material : Evaporated eutectic Bi-Sn**



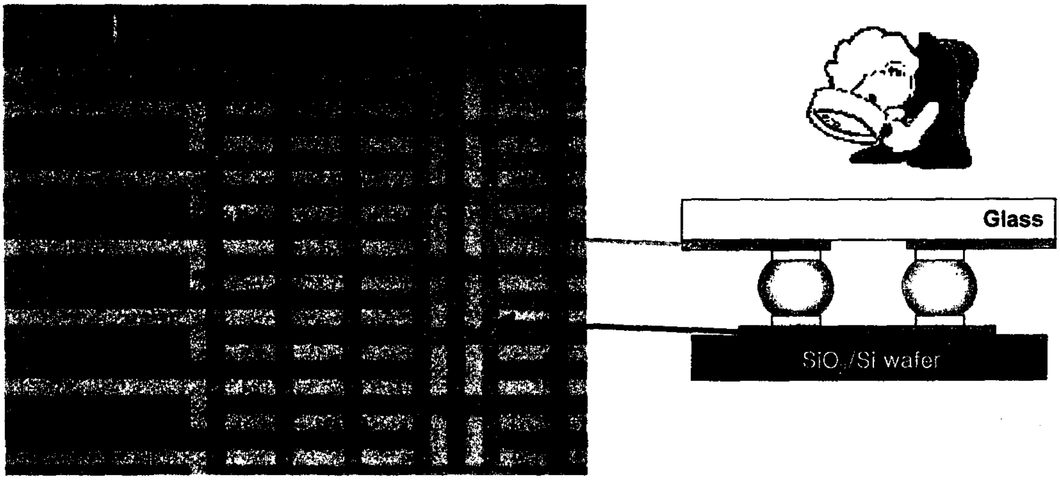
One Example of Contact Resistance Measurement Data



- **80 ㎛ pitch Bi-Sn solder joint**
  - **Chip metallization : Au/Cu/Ti**
  - **Substrate metallization : Au/Cu/Ti**

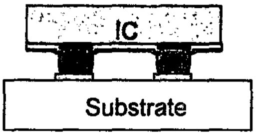
Probing pad	# of solder joints	Total resistance (Ω)	Resistance per section (Ω)	Contact resistace per solder joint (Ω)
A-B	16	0.620		
A-C	32	0.908	0.288	0.0180
A-D	48	1.152	0.244	0.0153
A-E	64	1.474	0.322	0.0201
A-F	80	1.824	0.350	0.0219
A-G	96	2.148	0.324	0.0203
A-H	112	2.484	0.336	0.0210
Average contact resistance per solder joint				0.0194

Optical Micrograph of Electrical Test Specimen



Contact Resistance of Ultrasmall Bi-Sn Solder Joints

- Before underfill process
- Average value in several specimens



Solder Joint	Chip Metallization	Substrate Metallization	Contact resistance (Measurement)		Contact resistance (Calculation)
			Average (Ω)	Standard deviation	Average (Ω)
80 ㎛ Pitch Bi-Sn Solder	Au/Cu/Ti	Au/Cu/Ti	0.019	0.003	0.008
		Au/Ni/Cu/Ti	0.035	0.006	0.012
50 ㎛ Pitch Bi-Sn Solder	Au/Cu/Ti	Au/Cu/Ti	0.060	0.019	0.042

The contact resistance of Bi-Sn solder joints is much lower than that of conventional ACF bonding for COG technique.

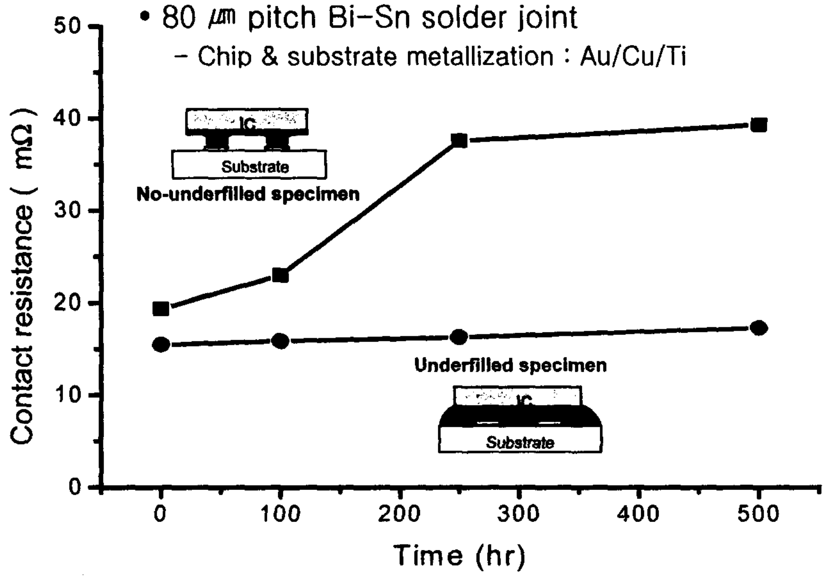
Contact Resistance of Solder Joints after Underfill

- **Underfill process**
  - **- Material : Epoxy (AMICON E 1355)**
  - **- Curing condition : 160℃, 5 min holding**

Solder Joint	Chip Metallization	Substrate Metallization	Underfill	Average contact resistance (Ω)	Standard deviation
80 ㎛ Pitch Bi-Sn Solder	Au/Cu/Ti	Au/Cu/Ti	Before Underfill	0.019	0.004
			After Underfill	0.023	0.007

Contact Resistance after 85 ℃/85% RH Storage

- 80 ㎛ pitch Bi-Sn solder joint
  - Chip & substrate metallization : Au/Cu/Ti



The contact resistances of Bi-Sn solder joints did not change even after hot humidity test.

Summary

- Using eutectic In-Ag and Bi-Sn solder materials, we developed the COG technique having a minimum pitch of 50 ㎛. The maximum temperature in this process is 160℃.

- We fabricated spherical and uniform solder bumps by controlling the microstructure of Bi-Sn solder bumps.

- The contact resistances of Bi-Sn solder joints were 19 mΩ at 80 ㎛ pitch and 60 mΩ at 50 ㎛ pitch, respectively. These values are much lower than the contact resistance of the conventional ACF bonding.

- The contact resistances of the solder joint are almost the same before and after the underfill process. The contact resistance of the underfilled Bi-Sn solder joint did not change even after reliability test.