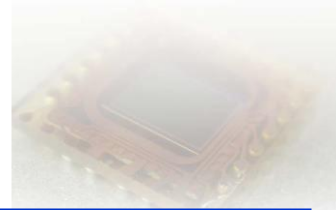


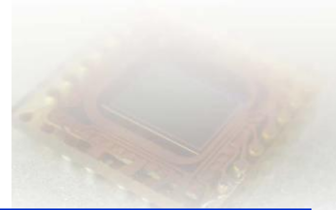
Flip Chip for Image Sensor Packaging

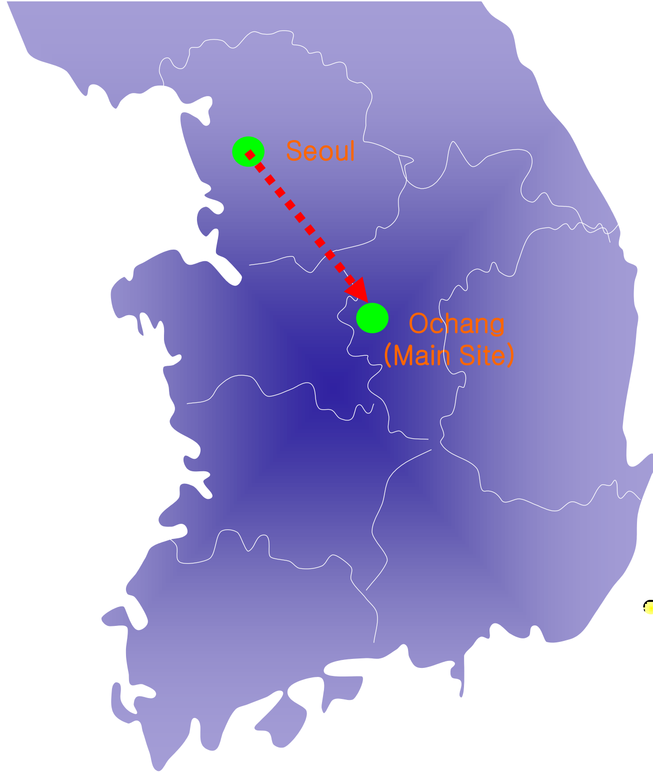
Peter Elenius

MEPTEC April 2011

OPTOPAC

OptoPAC Location and Overview





- Located in Ochang Scientific Industrial Complex
- 2.5 hours from Incheon Airport,
- 1.5 hours from Seoul
- 10 minutes by car from Jung-bu Hwy Ochang IC

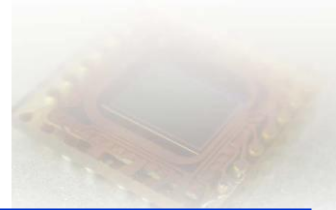
- **Land size** - 6,344m²
- **Building size** - 3,462m²

Cleanroom Inside View

Class 10,000 zone 858m²

Class 100 zone 528m²

Smart Phone Trends

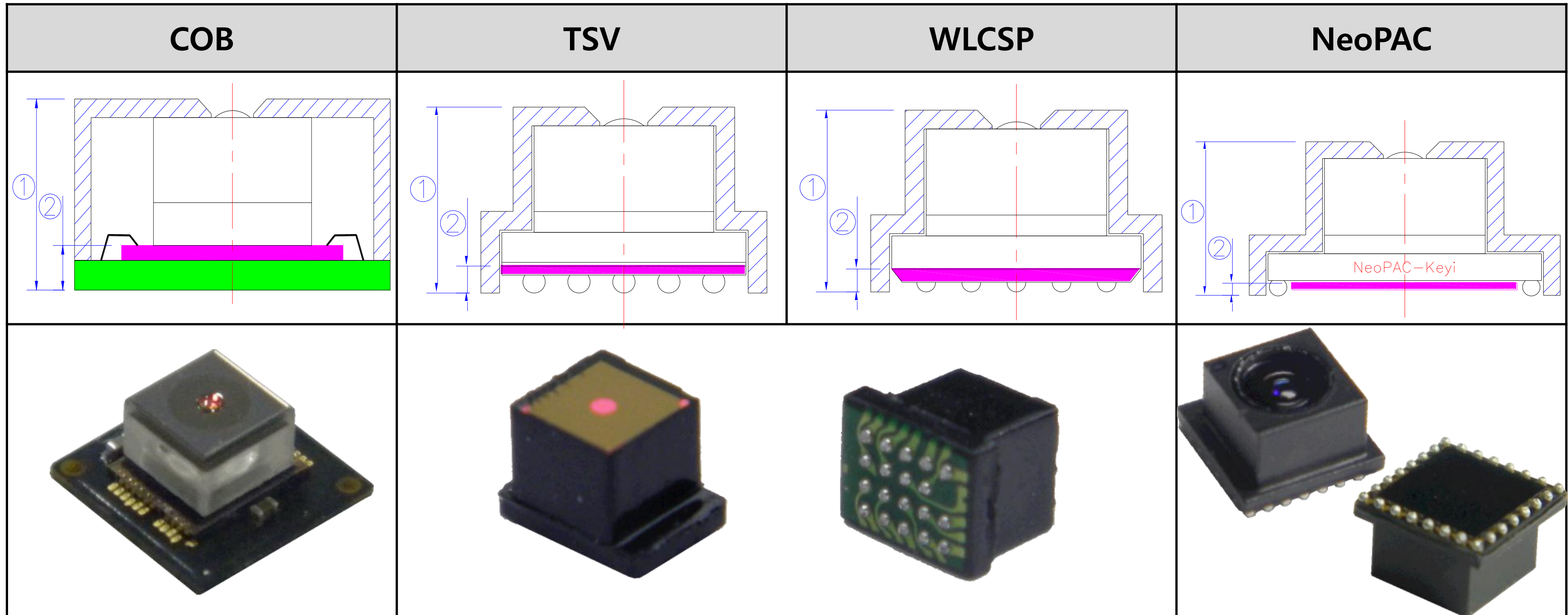


Attribute	Galaxy A	iPhone 3G	Galaxy S	iPhone 4G
Size	119.5 x 59.8	115.5 x 62.1	122.4 x 64.2	115.2 x 58.6
Thickness	12.5	12.3	**9.9**	**9.3**
Main	5M	3M	**5M**	**5M**
VT	VGA	N/A	**VGA**	**VGA**
LCD	3.7"(480X800)	3.5"(320X480)	**4"(480X800)**	**3.5"(640X960)**

Principal CIS Packaging Challenges

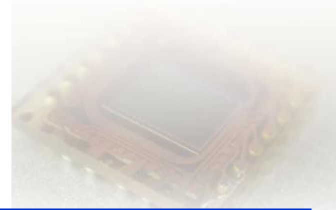
- Thin package,
- No contamination during assembly process,
- Seal ring to prevent future contamination,
- Seal ring structure that can pass preconditioning requirements,
- Reliability in thermal cycle, bend & drop testing

1/10" Reflowable Camera Modules

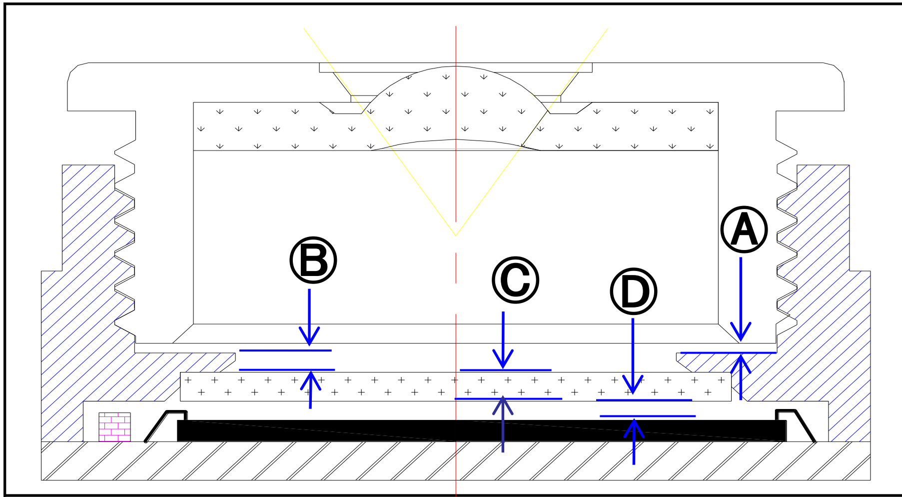


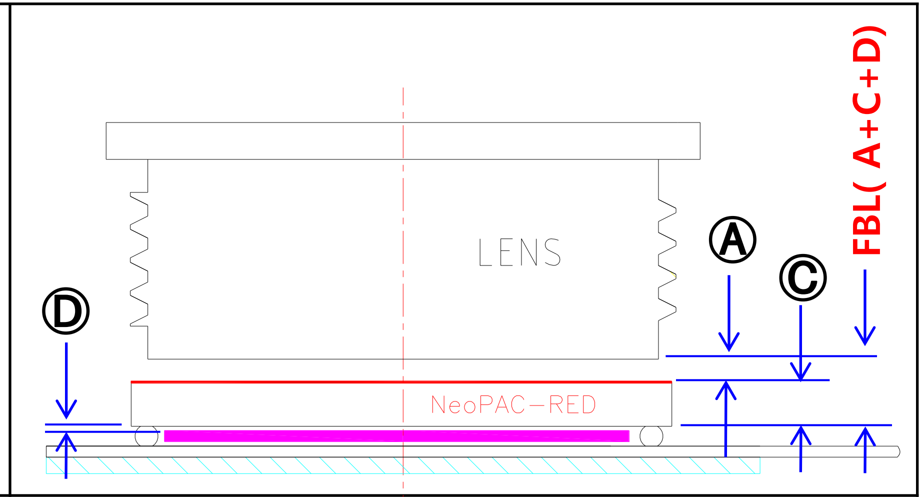
No	Item	COB	TSV	WLCSP	NeoPAC
①	Module T	2.570 mm	2.481 mm	2.416 mm	2.291 mm
②	Sensor Height	0.60 mm	0.36 mm	0.305 mm	0.18 mm

Lens FBL – COB vs. NeoPAC



➢ Lens FBL (Flange Back Length) comparison - COB vs. NeoPAC-RED





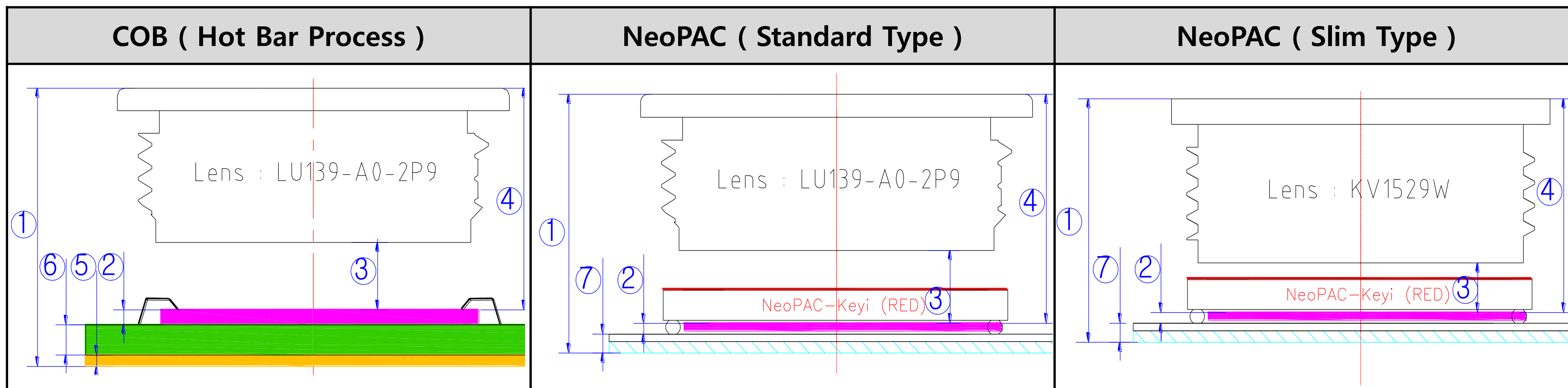
Item	Description	COB (mm)
Ⓐ	Barrel / holder Gap	0.15
Ⓑ	Min. holder injection	0.2
Ⓒ	Filter Thickness	0.3
Ⓓ	Sensor / filter Gap	0.25
Total		0.9 ~ 1.0

Item	Description	NeoPAC (mm)
Ⓐ	Lens / Filter Gap	0.1
Ⓒ	Glass/Filter Thickness	0.4
Ⓓ	Sensor / filter Gap	0.04
Total		0.54

✓ NeoPAC-RED Enables a Slim Lens Design

Module Height - COB vs. NeoPAC Slim

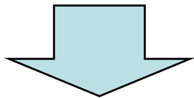
➢1/6” 1.3M Lens with TTL 3.00 mm versus Slim’s TTL of 2.80 mm



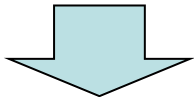
No	Item	COB (Hot bar Type)	NeoPAC (Standard Type)	NeoPAC (Slim Type)
1	Module T	3.75 mm	3.48 mm	3.19 mm
2	Sensor Height	0.20 mm	0.18 mm	0.14 mm
3	FBL	0.95 mm	0.95 mm	0.65 mm
4	TTL Mechanical	3.00 mm	3.00 mm	2.80 mm
5	Flex PCB	0.15 mm	0.30 mm	0.25 mm
6	PCB	0.40 mm	-	-

NeoPAC Fabrication Process

Sensor Wafer Bumping and Seal Ring Formation

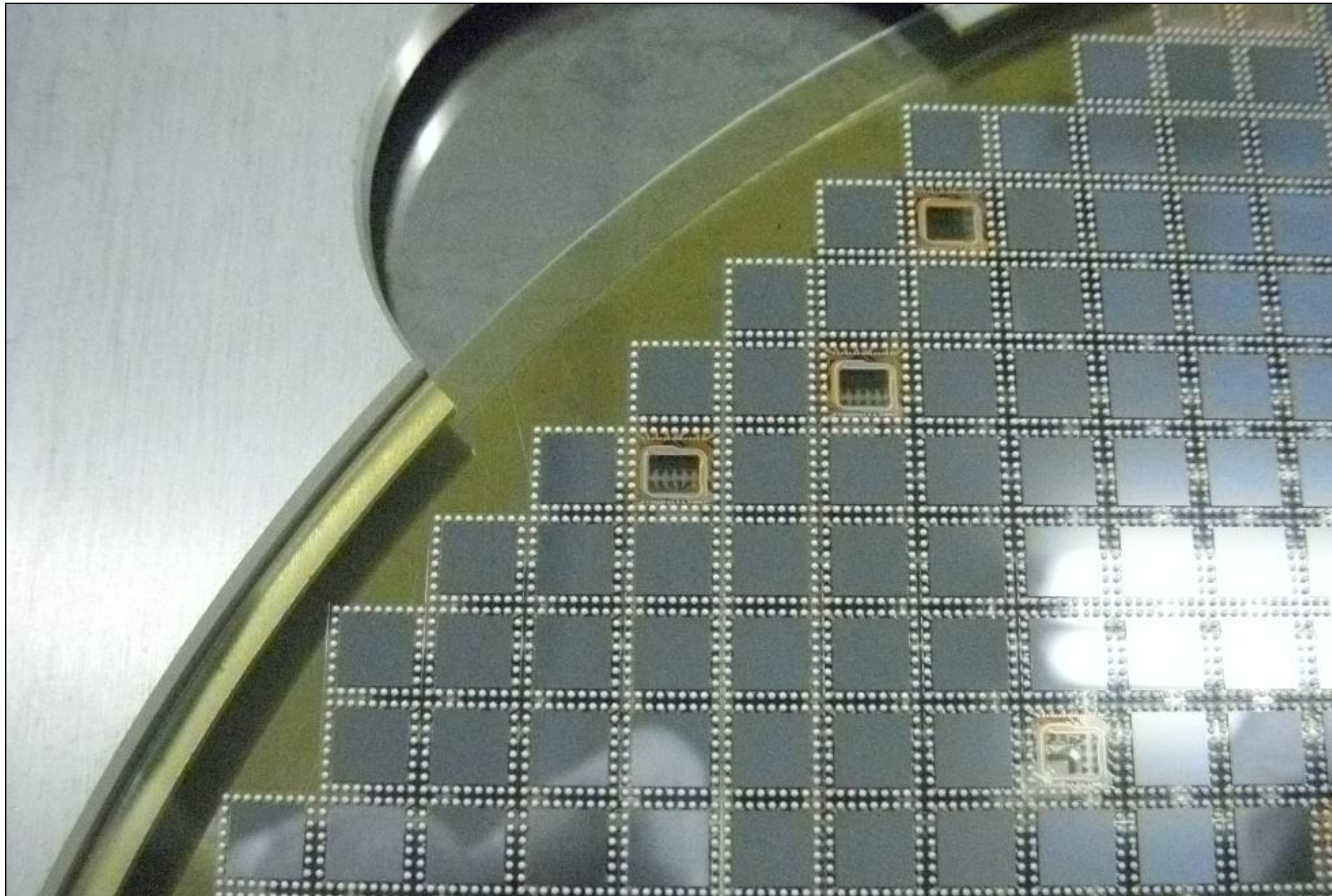


Glass Substrate Fabrication



Flip Chip Assembly

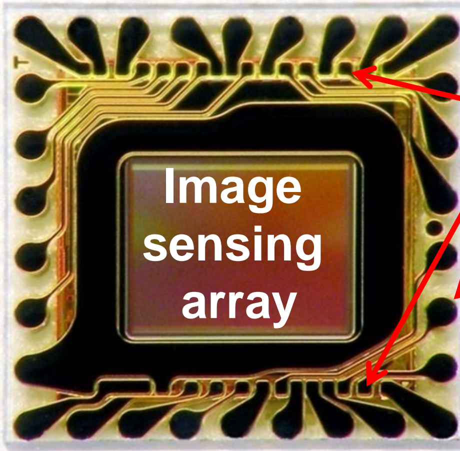
Assembled CISs on Glass Substrate



Automated O/S and Image Testing

OptoPAC NeoPAC Construction

Top View

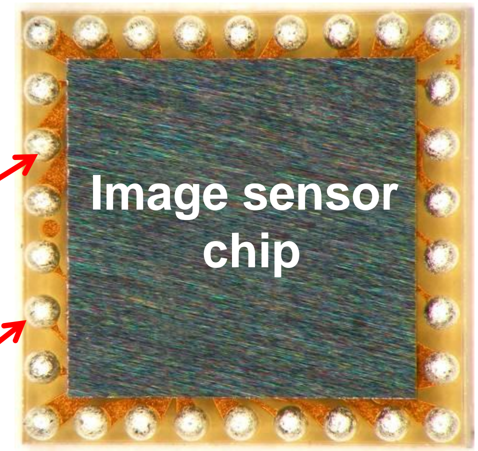


Flip chip solder joints

Glass substrate with metal and passivation layers

Solder balls on perimeter

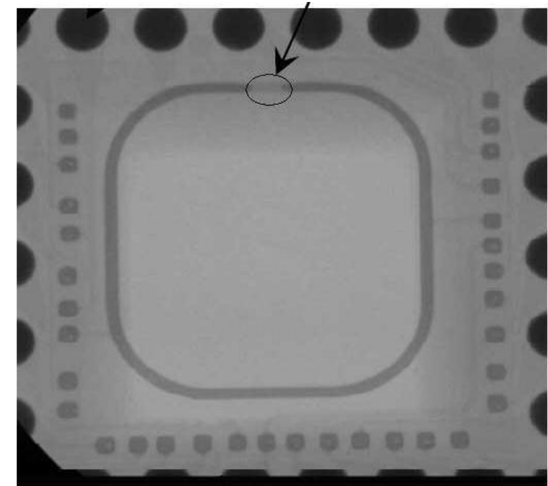
Bottom View

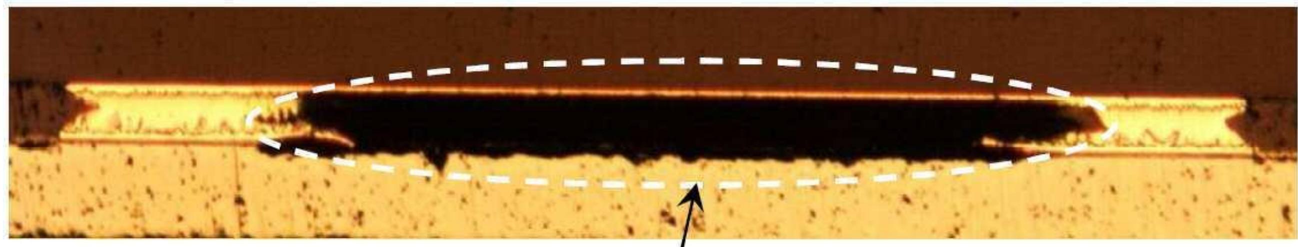


- Solder balls are decoupled from CIS
  - No distortion of image sensor plane, 100µm Si thickness
  - Large balls, require no underfilling
  - Thin package, 0.6mm total height

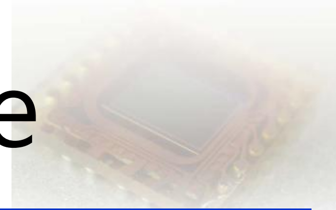
Closed Solder Seal Ring Structure

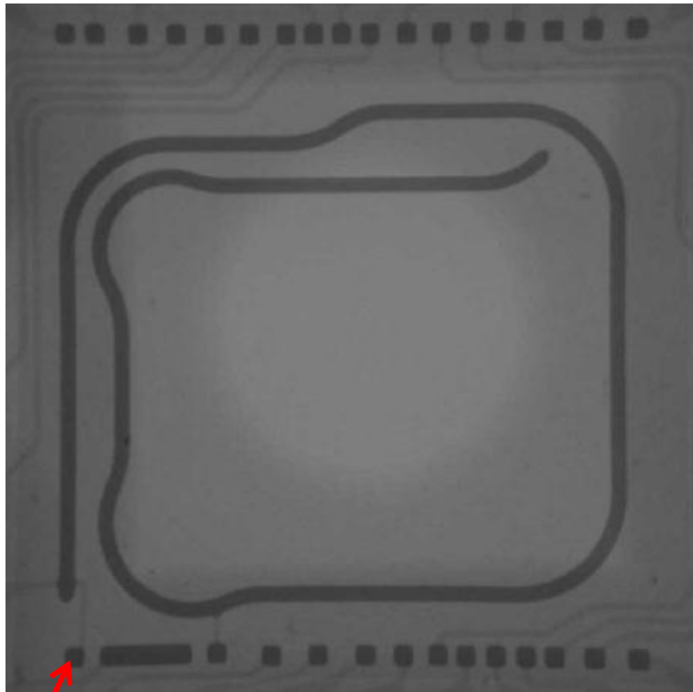
- 30µm SnAg solder on CIS joined to 8µm Cu on glass
  - Typical flip chip solder joint structure
- Fluxless joining process
- Seal ring blows out during SMT reflow
  - Color Filter outgassing
  - Microlens (µLens) outgassing
  - Gas & H_2O diffusion thru µLens layer
- Not used by OptoPAC





Vented Seal Ring Structure

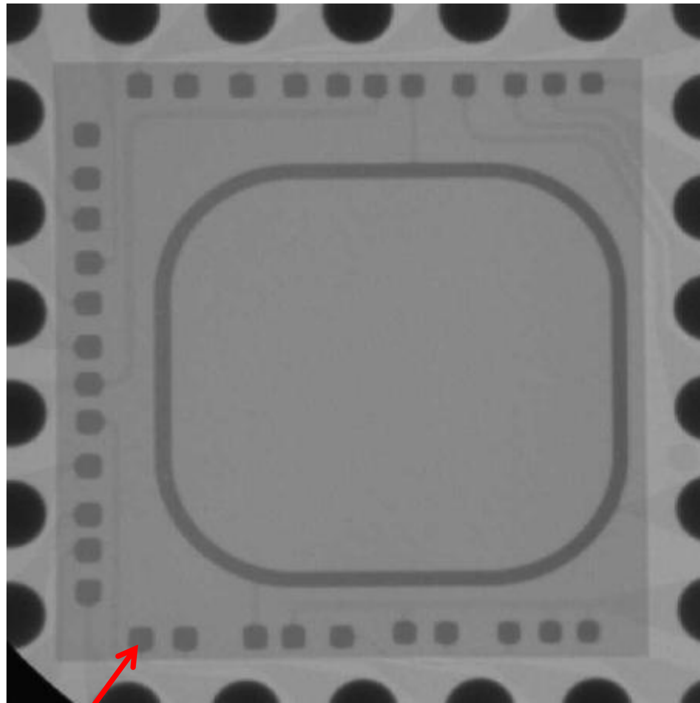




Flip chip solder joints

- 30µm SnAg solder on CIS joined to 8µm Cu on glass
- Fluxless joining process
- Vented structure required due to:
  - Color Filter outgassing
  - Microlens (µLens) outgassing
  - Gas & H_2O diffusion thru µLens layer
- Potential for liquid ingress in some assembly processes
- Original production technology

Closed TLP Seal Ring Structure



Flip chip solder joints

- 30µm Cu and 8µm SnAg solder on CIS joined to 8µm Cu on glass
  - Transient Liquid Phase (TLP) bonding
  - Resulting joint melting temp is >450C
- Fluxless joining process
  - 250C max temperature
- No seal ring failure due to:
  - Color Filter outgassing
  - Microlens outgassing
  - Gas & H_2O diffusion thru µLens layer

What is Transient Liquid Phase Bonding?

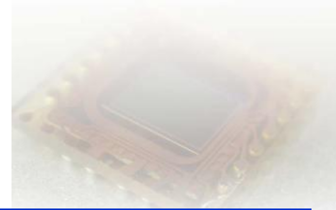
- Definition of transient from Webster's Dictionary
  - Passing especially quickly into and out of existence
  - Passing through or by a place with only a brief stay or sojourn
- For a solder system
  - The solder alloy is liquid for a short period of time and as it consumes one or more of the base metals the IMC formed is of a much higher melting temperature.
- Different TLP Bonding metal systems have been studied for multiple types of applications ranging from aircraft to semiconductor

Some TLP Bonding Metal Options

Material System	Bonding Process	Remelt Temperature
Copper – Tin	4 min at 280ºC	>415ºC
Silver – Tin	60 min at 250ºC	>600ºC
Silver – Indium	120 min at 175ºC	>880ºC
Gold – Tin	15 min at 260ºC	>278ºC
Gold – Indium	0.5 min at 200ºC	>495ºC
Nickel – Tin	6 min at 300ºC	>400ºC
Palladium – Indium	~1 min at 200ºC	>660ºC

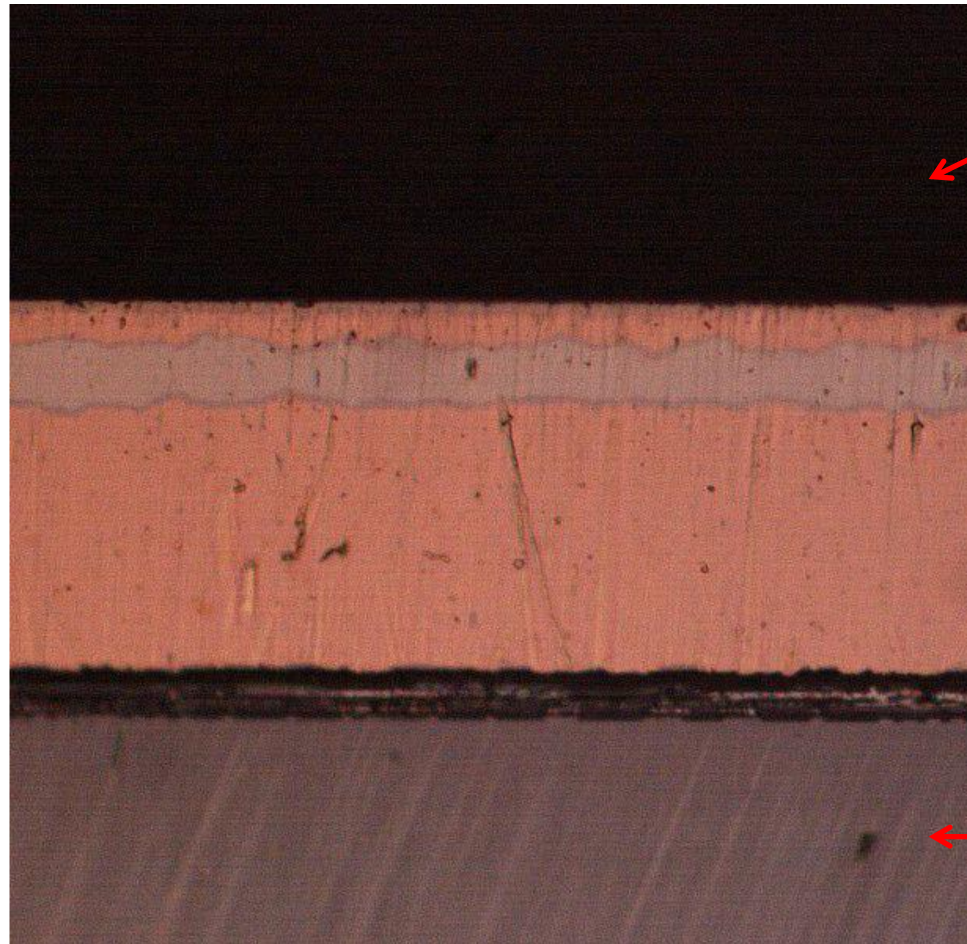
Table 1 (except for Pd-In system) from – W.C. Welch, Gold-Indium Transient Liquid Phase (TLP) Wafer Bonding for MEMS Vacuum Packaging, IEEE MEMS 2008, Tucson, AZ, USA, January 13-17, 2008 Which was adapted from - G. Humpston, Principles of Soldering. Materials Park, OH : ASM International, 2004, pp. xii, 271.

Fluxless TLP Joining Process



- Formic acid based process
  - Wafer level process
- No forces applied to chip during joining
- Flip chip and seal ring joints formed simultaneously
- Basic joining process steps
  - Oxide reduction step
  - Typical solder joining step at 225C to 230C
  - Conversion to CuSn IMCs at 250C max temperature
- Must also control time, pressure, formic acid concentration, and O_2 levels

Completed TLP Seal Ring Joint



Glass substrate

Cu layer on glass

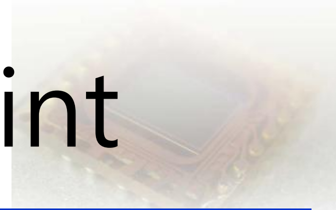
CuSn IMC

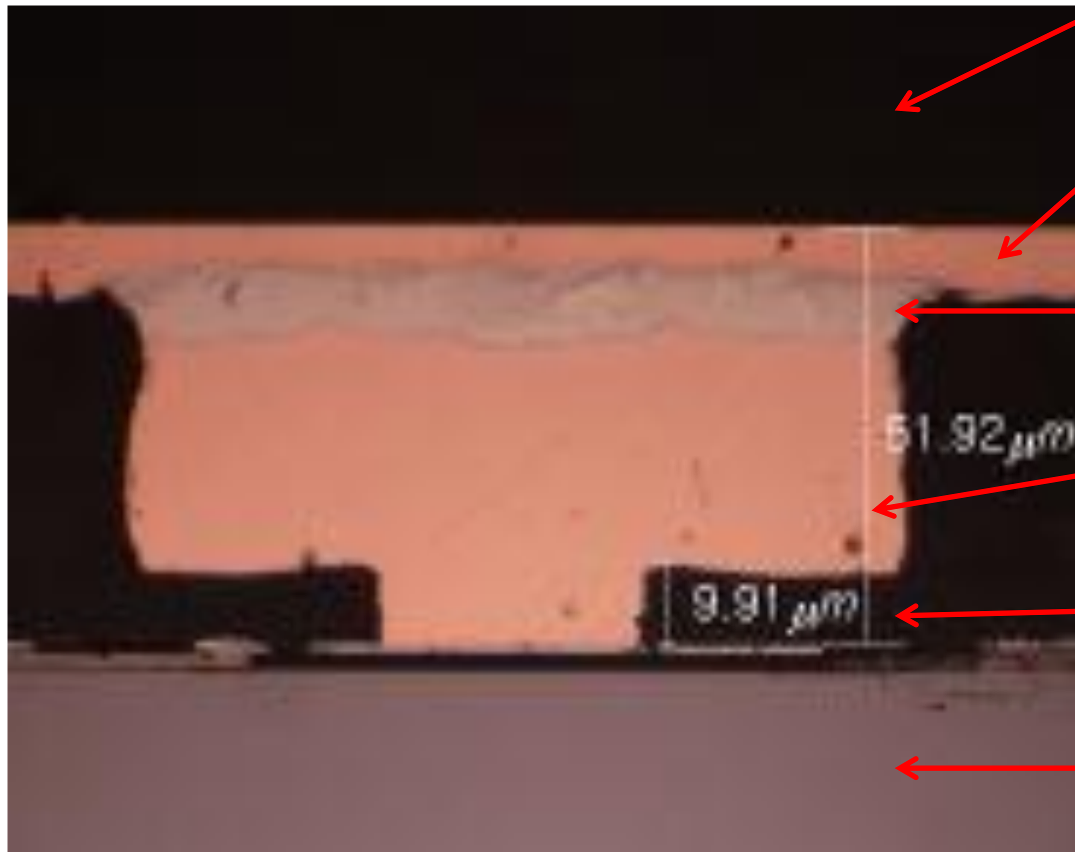
Plated Cu seal ring

Microlens layer

Silicon

Completed TLP Flip Chip Joint





Glass substrate

Cu layer on glass

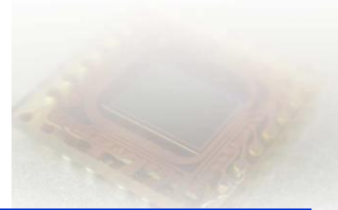
CuSn IMC

Plated Cu Pillar

Stress Buffer Layer

Silicon

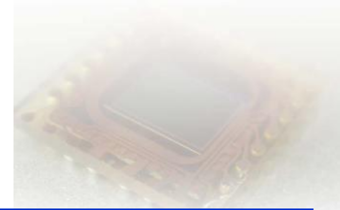
Package Level Reliability



- Large 6.7mm by 7.7mm CIS in a 9.8mm x 9.7mm package
  - Initial screening for AEC Q100 Grade 2 (-40C to 105C ambient)
- Many designs have already passed cell phone & note book quals
  - Tens of millions parts produced to date

Symbol	Test	Test Conditions	n	Results	Comment
RTSH	Resistance to Soldering Heat	125C /24hrs 85C/85% RH 168hrs IR Reflow Tc=260C, 3cycles	10	Pass	MSL1
TC	Temperature Cycle	-50C to 125C, 500cycles	45	Pass	-
HTSL	High Temperature Storage Life	125C, 500hrs	45	Pass	-
THS	Temperature Humidity Storage	85C/85% RH 500hrs	45	Pass	-
VI	External Visual Inspection	Microscope 40X	all	Pass	-
ET	Electrical Test	Room Temperature (RT)	75	Pass	-
IS	Internal Inspection	Internal Visual, Solder Ball Shear, Cross Section	3	Pass	-

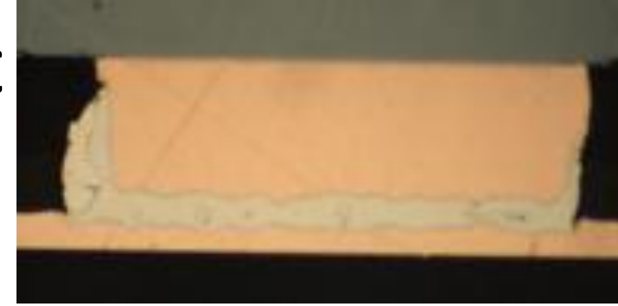
Board Level Testing



- Same 6.7mm by 7.7mm CIS in a 9.8mm x 9.7mm package
  - 0.65mm polymer core solder balls
  - Mounted to 1.6mm FR-4 board

Test Item	Test	Test Condition	n	Results
TC	Temperature Cycle	-40C to 125C, 500 cycles Dwell time 15min Cool-down time 15min Heat-up time 5min	25	Pass
VI	External Visual Inspection	Microscope 40X	25	Pass
ET	Electrical Test	Room Temperature	25	Pass

Extended Reliability Characterization



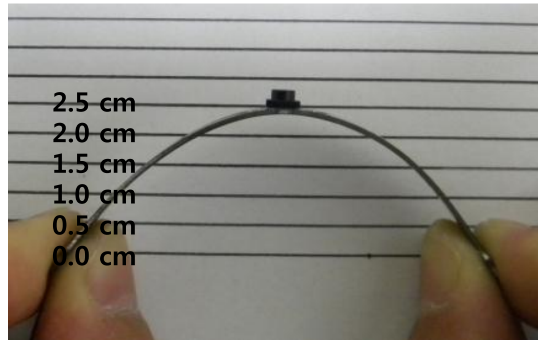
- Pkg level thermal cycling -50C to 125C
  - Four cells passed 1,950 cycles
  - Four cells passed 1,700 cycles
- Board level thermal cycling -40C to 125C (no underfilling)
  - Optimal cells passed 1,500 cycles
  - Failures occurred at 1,700 cycle read point
- Final qualification testing in process
  - Full qualification by customer to AEC-Q100 in process
    - Grade 2 (-40C to 105C ambient)
  - OptoPAC thermal cycle testing has passed 750 cycles to date

Notebook Camera Bending Test

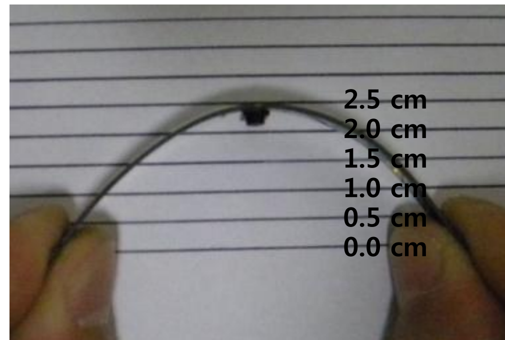
NeoPAC with 1.3M 1/6” sensor, no underfill

- Real time image monitoring during bending test
- SAC solder ball

PCB top direction bending



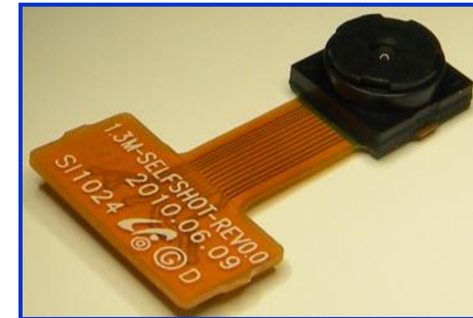
PCB bottom direction bending

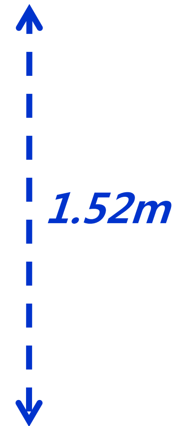


Sample	Bending Direction	
	Bottom	Top
#1	2.00	2.50
#2	1.75	2.00
#3	1.75	2.50
#4	1.75	3.00
#5	2.00	2.50
Avg.	**1.85**	**2.50**
Min.	1.75	2.00
Max.	2.00	3.00

NeoPAC Module Level Drop Test Method

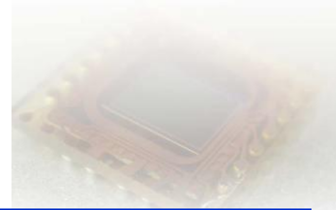
- Drop Test Method - Samsung Electronics' specification
  - Drop module onto steel plate
  - Drop height of 1.52m
  - Number of required drops is 30
  - Image check after each drop
  - Sensor : S5K6AAFX13 in NeoPAC : CC02SS130A





Condition	30 Times Drop	
	Failure / Test	Failure Rate
Underfill	0 / 10	0%
No Underfill	0 / 10	0%

Summary



- TLP bonding is being used for CIS packages
  - First known HVM semiconductor production use of TLP bonding
  - Mixed flip chip and seal ring application
- Package is MSL 1
- TLP bonded structure, has passed:
  - Automotive reliability requirements for thermal cycling
  - Notebook camera bending requirements w/o underfill
  - Mobile phone drop test requirements w/o underfill
- Plan is to extend the technology to MEMS applications