Wafer-Level MEMS Packaging

Suk-Jin Ham*, Yoon-Chul Sohn**,

Woon-Bae Kim, and Chang-Youl Moon (Director Of Center)

Packaging Center

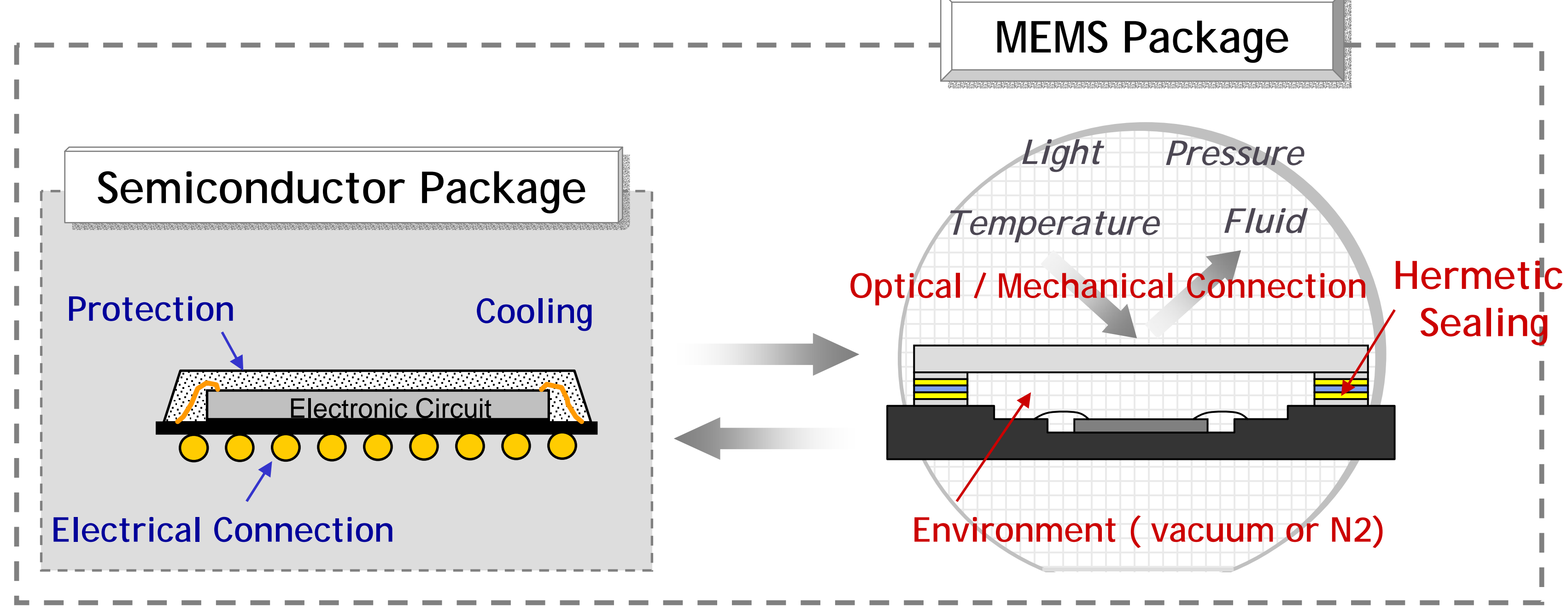
Samsung Advanced Institute of Technology

E-mail* : sj.ham@samsung.com

E-mail** : yoonchul.son@samsung.com

MEMS vs. IC Packaging

- Semiconductor Packaging :
  Electrical Connection, Heat dissipation, Mechanical Protection
- MEMS Package :
  Electrical, Optical and Mechanical Connection
  Hermetic or Vacuum Cavity for moving structure

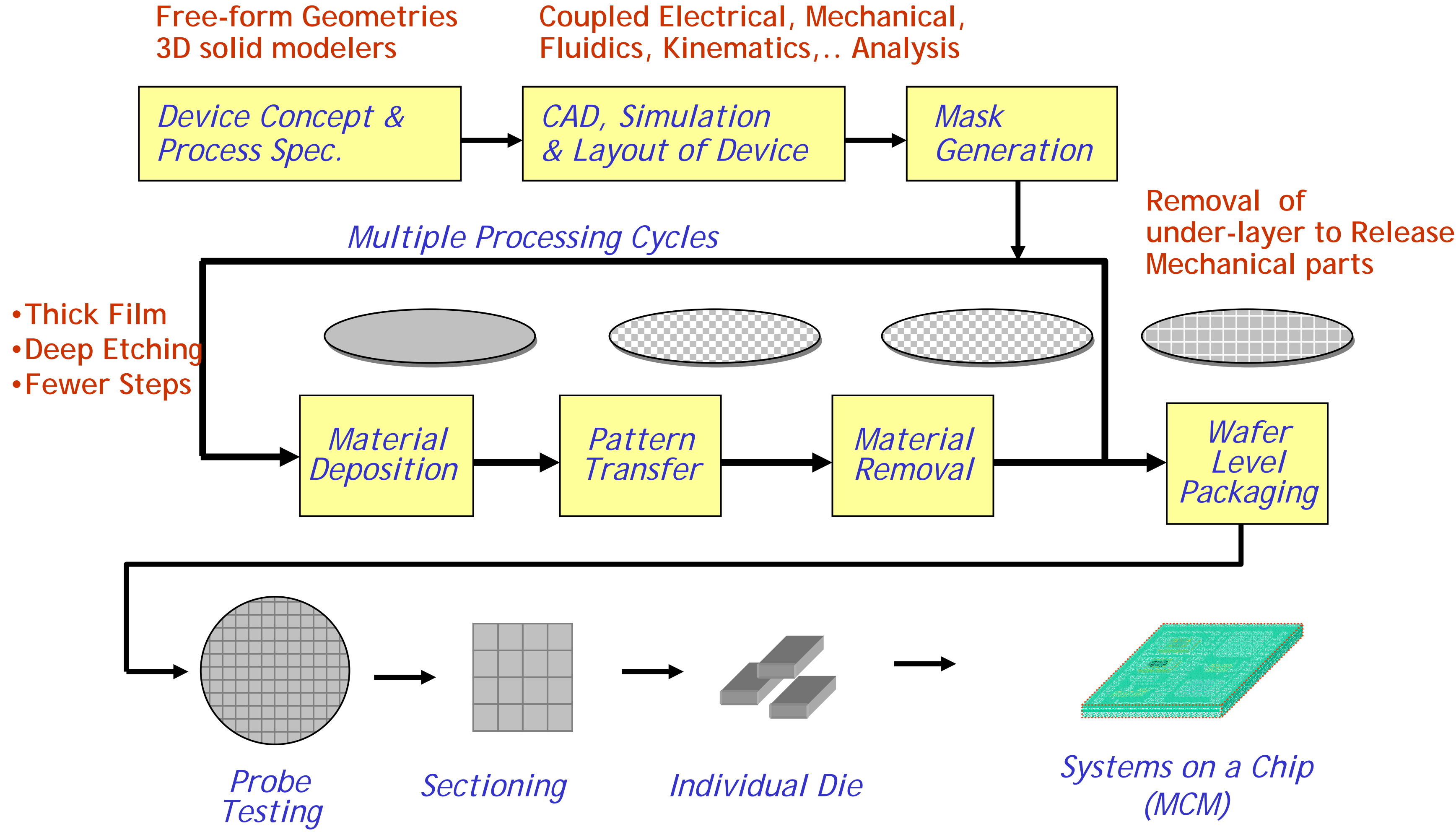


MEMS vs. IC Package

❑ MEMS PKG vs. Semiconductor PKG

		Semiconductor PKG	MEMS PKG
Applications		• High Volume : Telecommunications Consumer electronics	• Multiple application : Medical, Bio, Automobile Telecommunication, Display
Structure	Geometry	•2-Dimension •Quasi-hermetic	•3-Dimension •Hermetic /Vacuum Package
	Film Thickness CD Aspect Ratio Topology	• 1um • Sub micron • < 2:1 • < 1um	• 1 ~ several hundred um • > 1um • < 100:1 • < several hundred um
Technical Issue		• High speed • Small size • High density • Thermal dissipation • EMI	•Micro level Issue Stress-induced deformation, Stiction, Wear-out •Material Issue Chemical Reaction Biological Compatibility
Needs		• High Performance • Small Form-Factor • System Integration	▪ Low Cost ▪ Yield & Infrastructure ▪ Reliability ▪ Standardization

MEMS vs. IC Package



Key Technology of WL-μP

Wafer-Level Bonding

- Eutectic : AuSn(260℃),
  InSn (Below 200℃),
  SnAgCu(217℃)
- Al Anodic(280℃)

Wafer Level Evaluation

- Wafer Level Testing
- Failure Mode Analysis
- Hermetic, Residual Gas Analysis
- Micro Bonding Strength Measurement

Through Wafer Interconnection

- Micro Via Etching : ICP RIE, Sand Blasting
- Micro Via Filling : Electro Plating, Solder Filling

Flip Chip Bonding

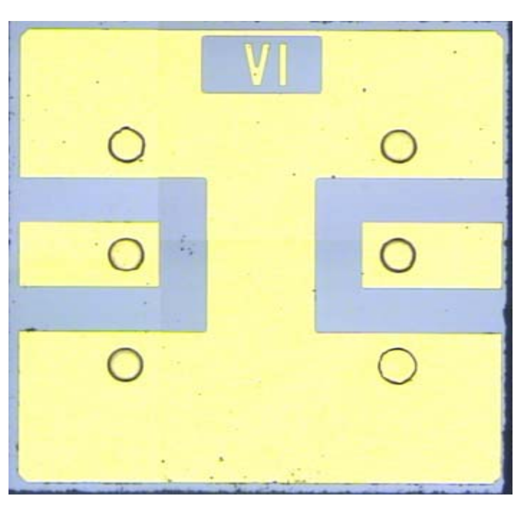
- Micro Via Interconnection
- Solder Bumping

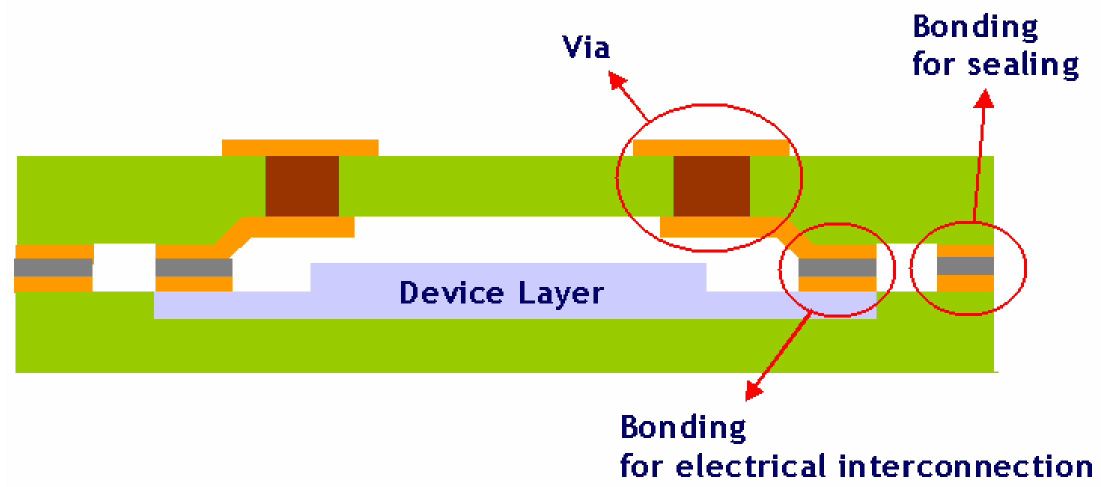
Wafer Bonding Technology

Bonding Techniques

Techniques without intermediate layer			Techniques with intermediate layer		
Seam/Laser Welding	**Silicon direct fusion bonding**	**Anodic bonding**	**Eutectic bonding**	**Adhesive bonding**	**Glass frit bonding**
Kovar @low temp	Fusion Bonding Si-Si @~1100°C Glass-glass @~650°C	Si-glass @300°C	Si-Au @~400°C PbSn @183°C InSn @118°C	polymer, PR, polyimide, epoxy @125°C~400°C	Glass @~400°C
-Partially low temp -Reliable,Hermetic -High cost	-Wafer level -High temp -Vacuum process	-Wafer level -High temp -Vacuum process	-Low cost -Hermetic -Oxidation	-Low cost -Non hermetic -Outgassing	-Wafer level -High temp -Outgassing

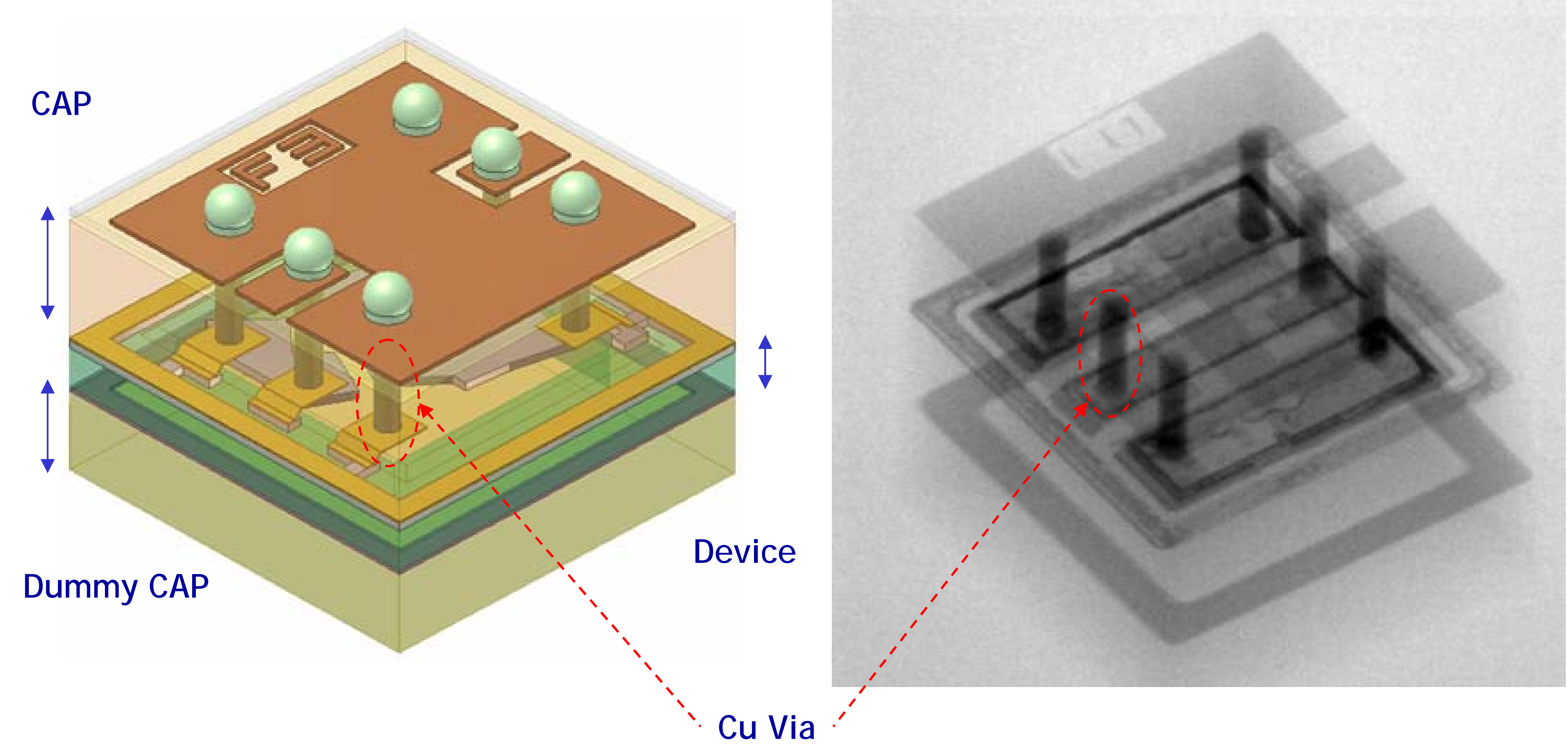
Representative SAIT RF-Device WLP



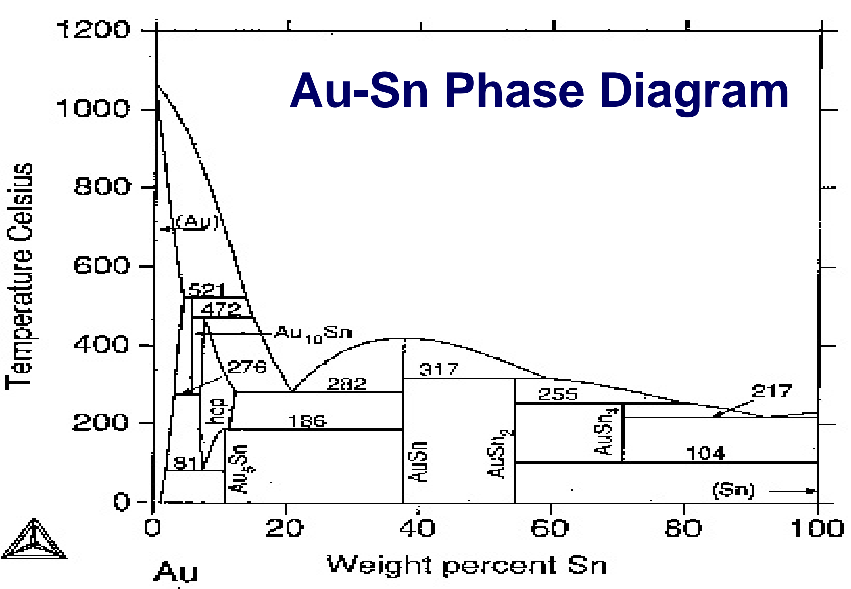


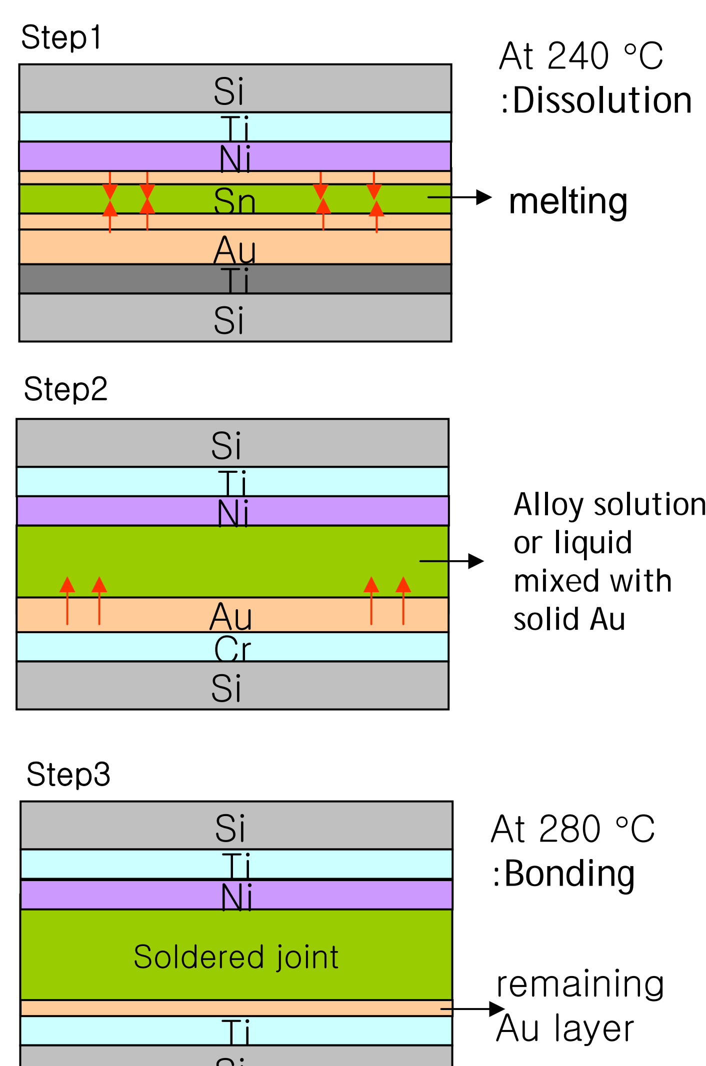
- Package size : 1 x 1 x 1 mm, 2.5 x 2.5 x 1 mm
- The number of via : 6 ~ 20
- Via diameter : 40 ~ 80 um
- Wafer bonding : 2 or 3 wafers using Au/Sn Metal Layers

Schematics & X-Ray Inspection Image



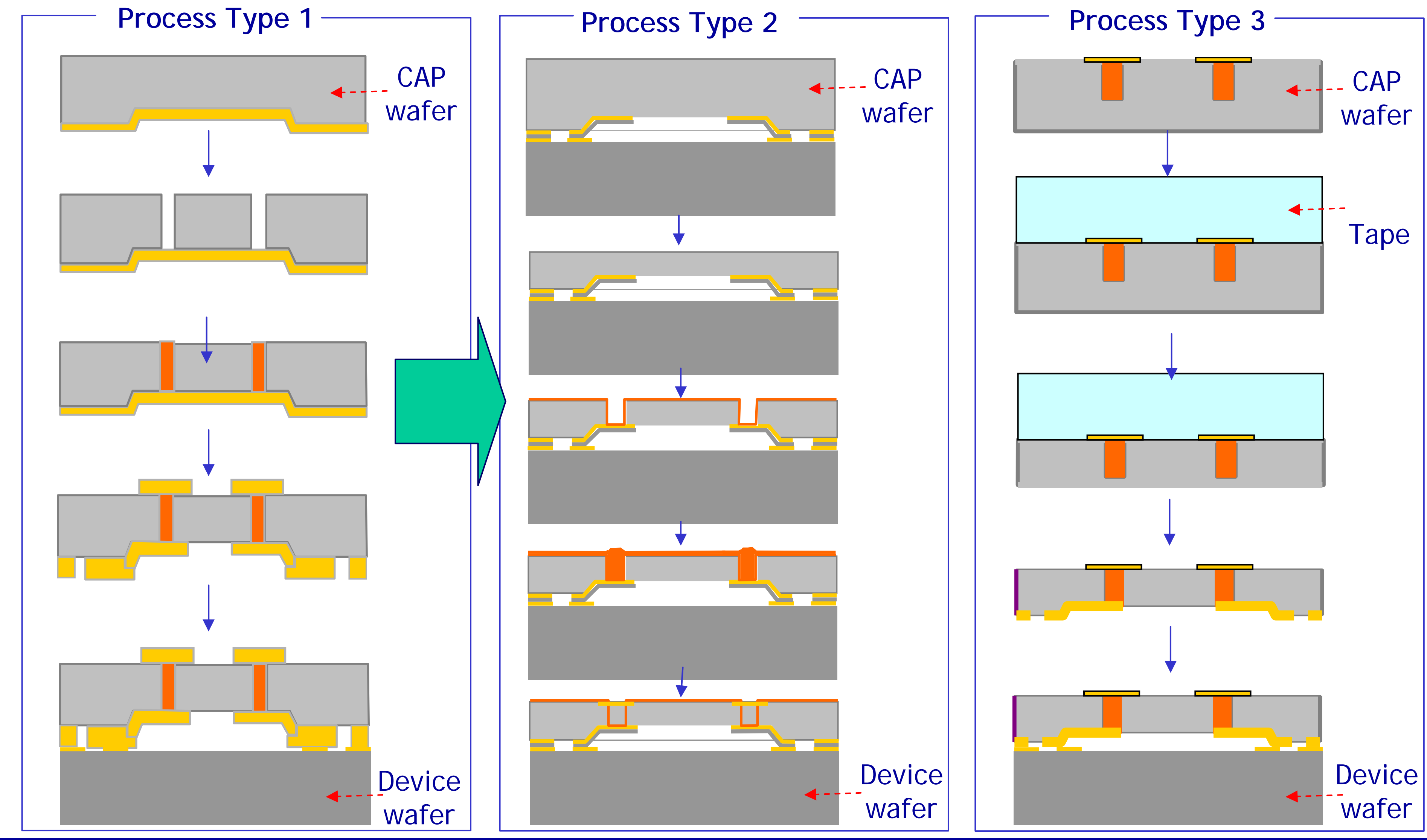
Stable Flux-free Au-Sn Eutectic Bonding





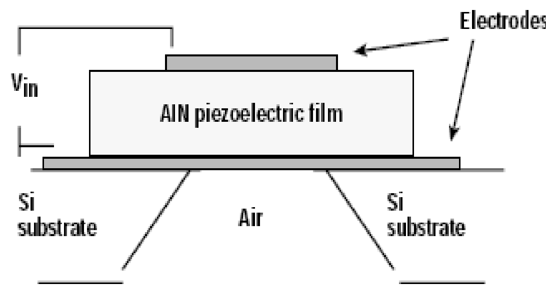
- Au-Sn Eutectic bonding
- Solid Liquid Interface Diffusion
  - Uniform bonding
    - Solder formation using e-beam
  - Remelting temp. above 280C
    - Stable bonding
    - Merit for process design

Design Change

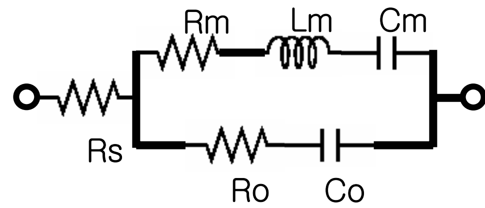


RF-Resonator for Reliability Test

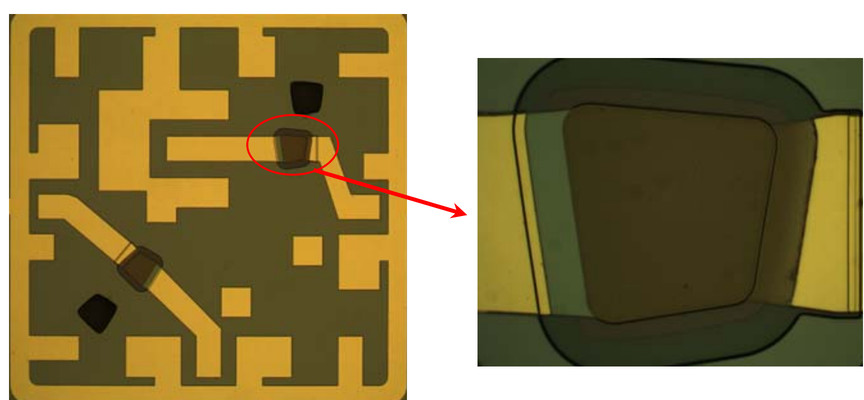
❑ Film Bulk Acoustic Resonator (FBAR)

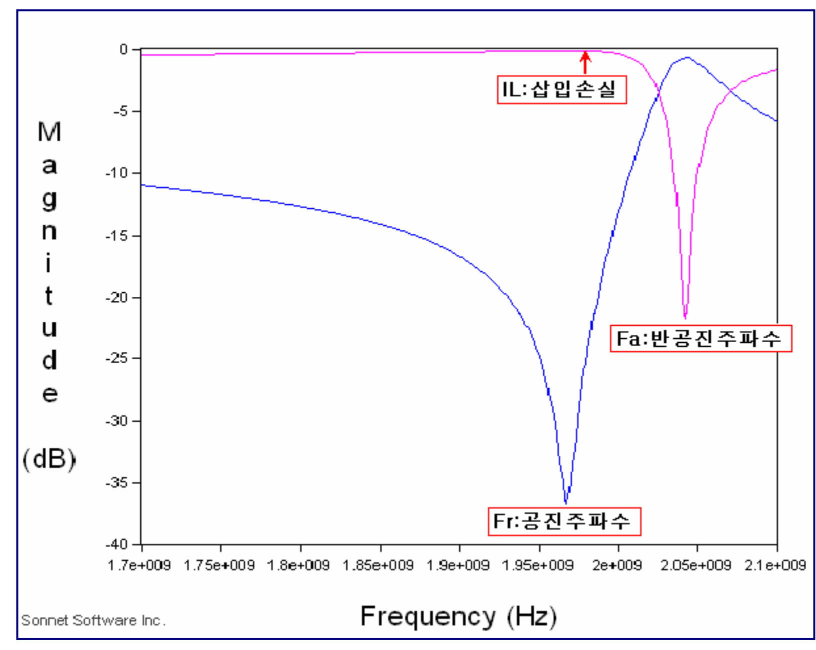


● Schematics

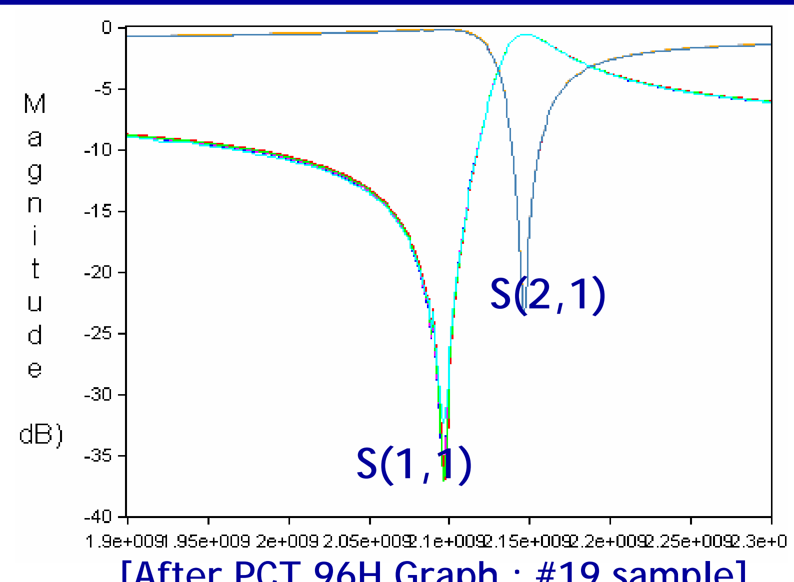


● Equivalent Circuit Model





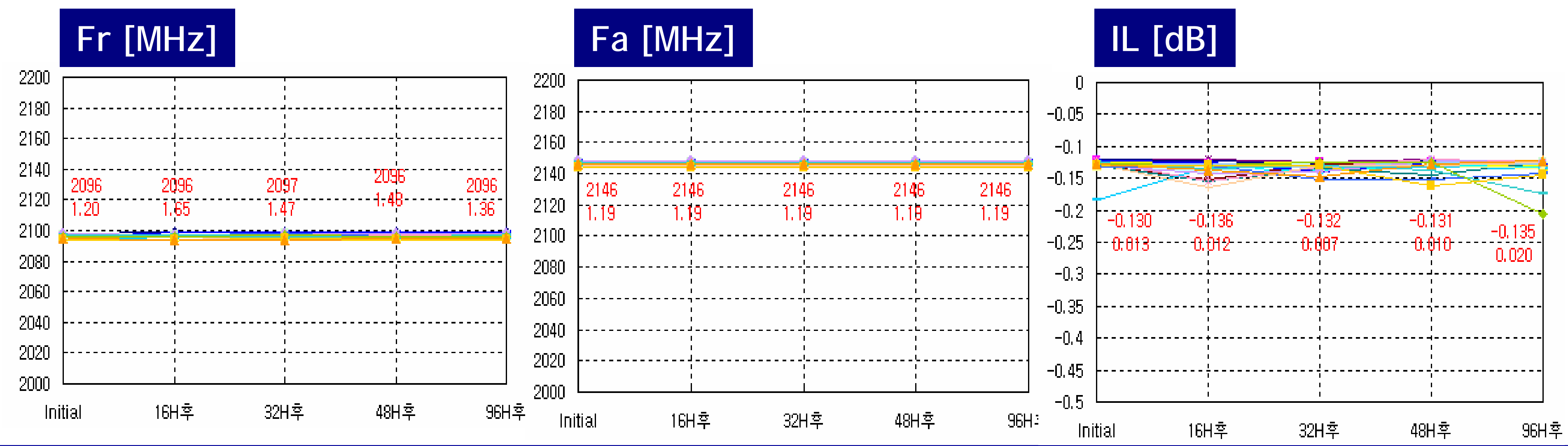
Pressure Cooker Test (121℃ / 100%RH / 2atm)



[After PCT 96H Graph : #19 sample]

[After PCT 96H]

	Fr(MHz)	Fa(MHz)	IL(dB)
Mean	0.57	0.00	-0.005
Stdev	1.08	0.00	0.024
Max	4	0.00	0.048
Min	-1	0.00	-0.080



Summary of Reliability Test

[Table1. NRES#03 Sample Reliability Test Result]

Item	Condition	Duration	RF-Performance			Result
			Fa (MHz)	Fr (MHz)	IL (dB)	
1. PCT	121℃/100%RH/2atm	96 Hours	0.57	0.00	-0.005	Pass
2. Humidity Test	85℃/85%RH	120 Hours	0.48	0.10	0.010	Pass
3. High Temp. storage	125℃	120 Hours	0.24	0.00	0.010	Pass
4. Temp. Cycle	-40℃/85℃ 2 Hours/Cycle	30 Cycles	0.38	0.05	0.010	Pass

Residual Gas Analysis

Gas	Gas detected after breaking the packages					
	Before the tests		After PCT 96 Hours		85/85 120 Hours	
	μl	%	μl	%	μl	%
H_2O	0.02	2.2	0.02	2.0	0.02	2.5
N_2	0.91	97.8	1.12	98.0	0.90	97.5
Total	0.93	100.0	1.14	100.0	0.93	100.0

Concluding Remarks

- Driven Technologies in MEMS Packaging – WLP
- Key Technology for WLP
  - Wafer-Level Bonding Technology
  - Through Wafer Interconnection Technology
  - Hermeticity Evaluation Technology
- Suitable for MEMS - Low Temperature Bonding