

Hermetic Packaging for MEMS

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Hermetic Packaging For MEMS

2003. 4. 9

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Gyro Project

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2003-4-9



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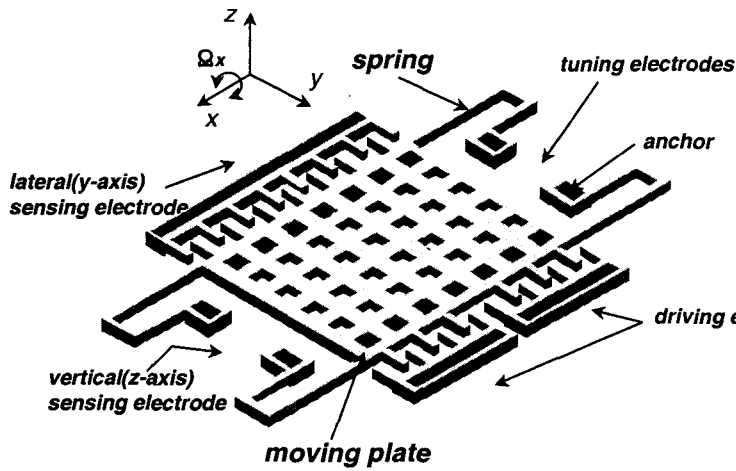
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MEMS Gyroscope Overview

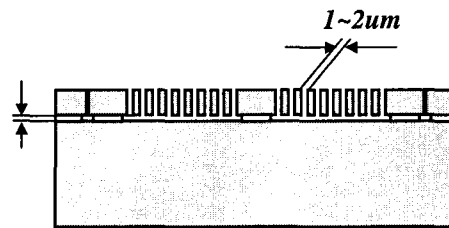


- Gyro Applications**
- Camcorder
 - 3D Mouse
 - Car navigation
 - Input Device
 - Virtual Reality
 - Military (MAV)

Critical Packaging Issues

- Vacuum Ambient
- Small Size
- Low Cost

2~3um



Cross-Section of The Gyroscope

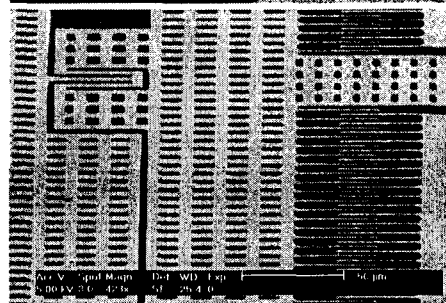
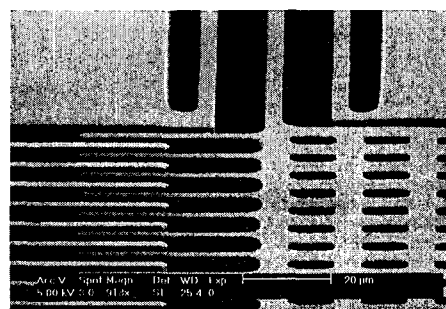
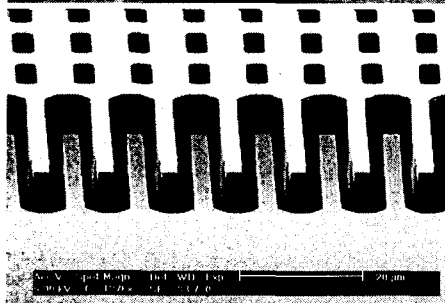
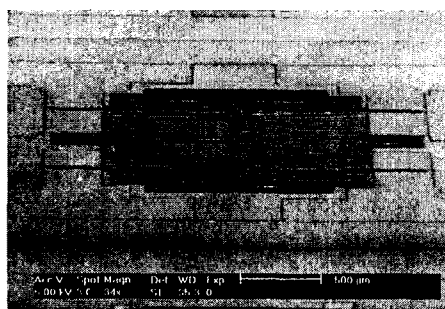
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MEMS Gyroscope Fab. Result



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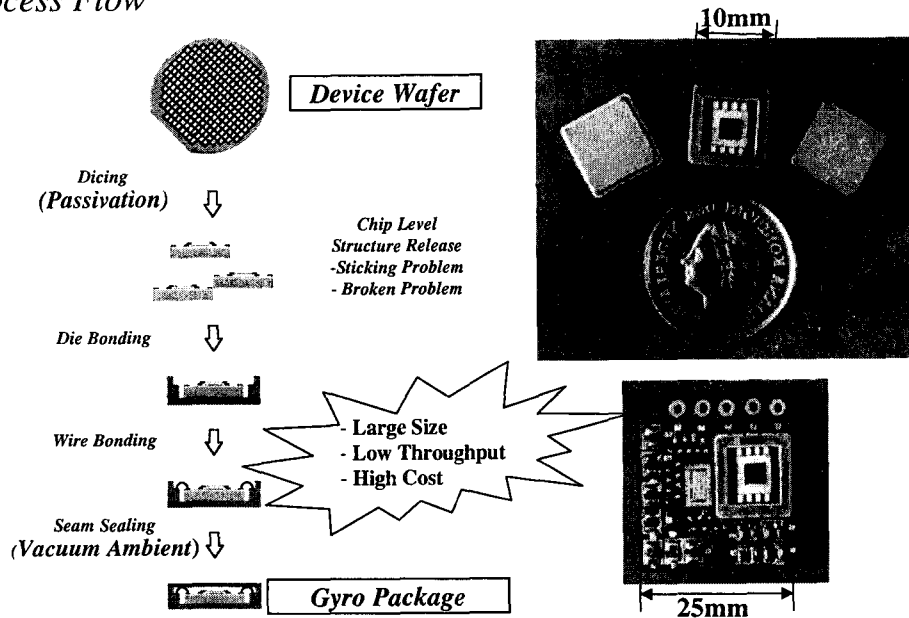
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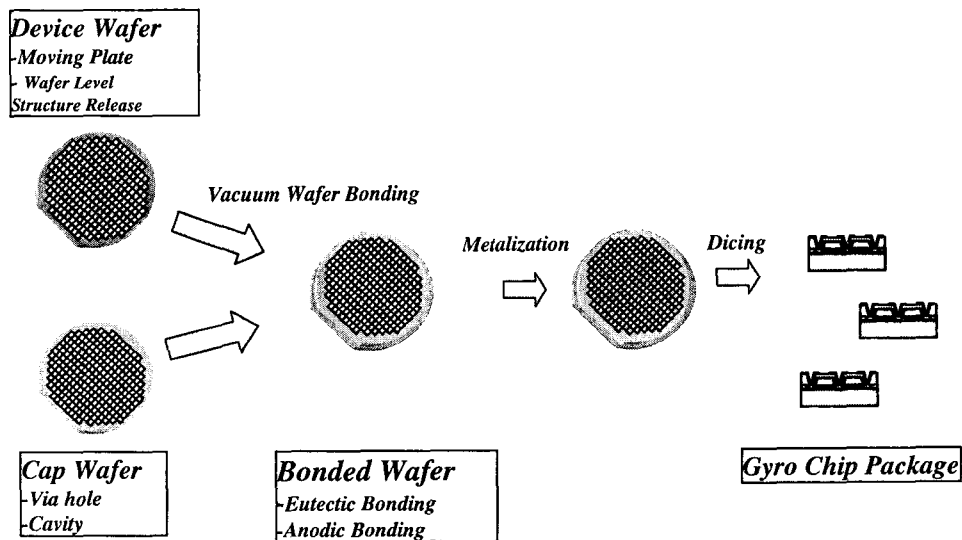
Ceramic Packaged Gyroscope



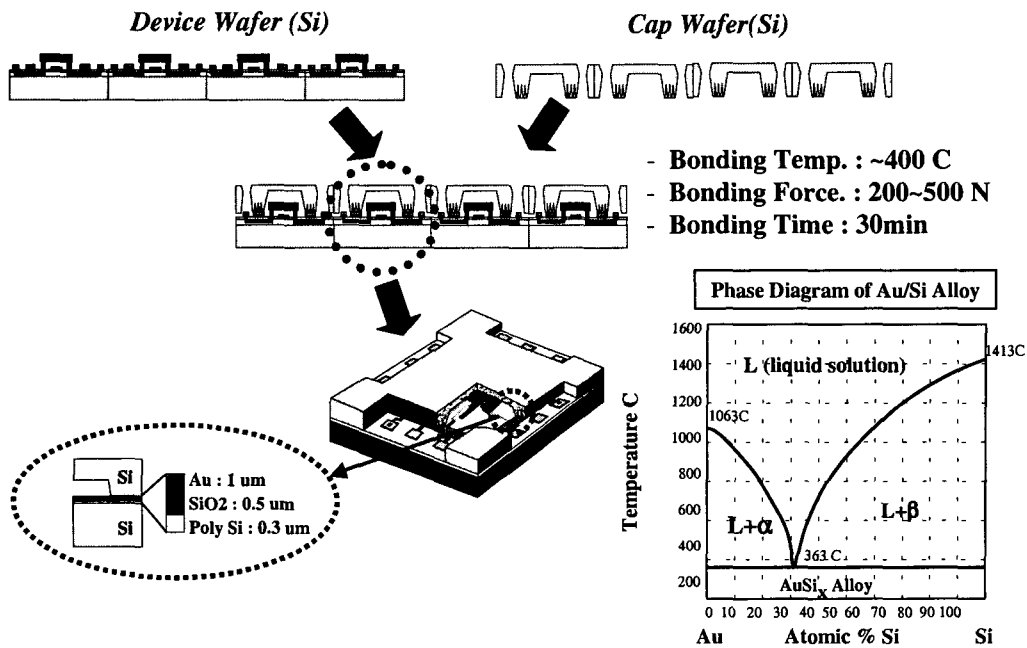
Process Flow



Wafer Level Vacuum Packaging



WLVP_1: Eutectic Bonding



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WLVP_2: Glass Frit Bonding



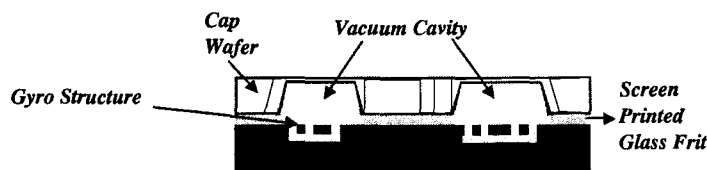
- Glass Frit Composition: Glass powder(B₂O₃·PbO·ZnO) + Binder
- Glass Powder Size: 5 ~ 10 μm



- Glass Depo. Method: Screen printing
- Glass Frit thick: <50 μm



- Bonding Temp.: 500 ~ 600 °C
- Bonding Time : 30 min



Gyro Project

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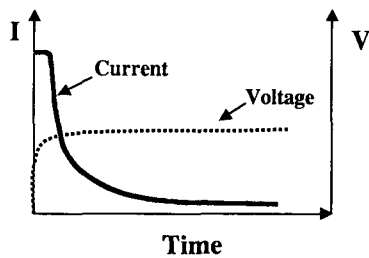
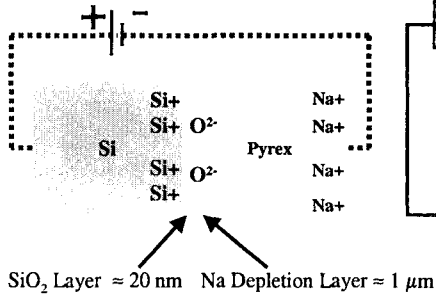
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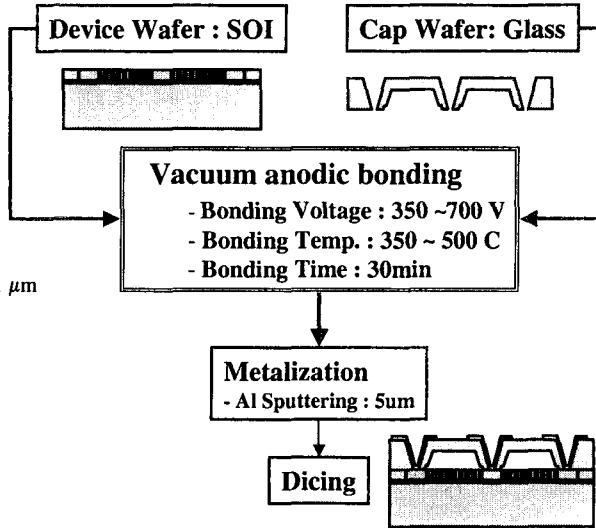
WLVP_3: Anodic Bonding



Principle

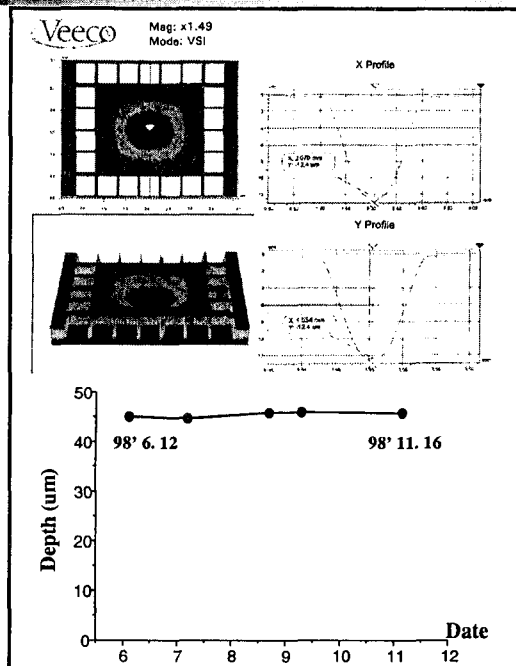
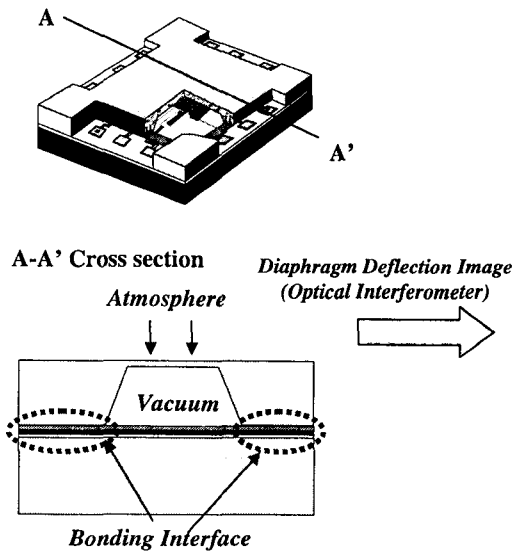


Process Flow

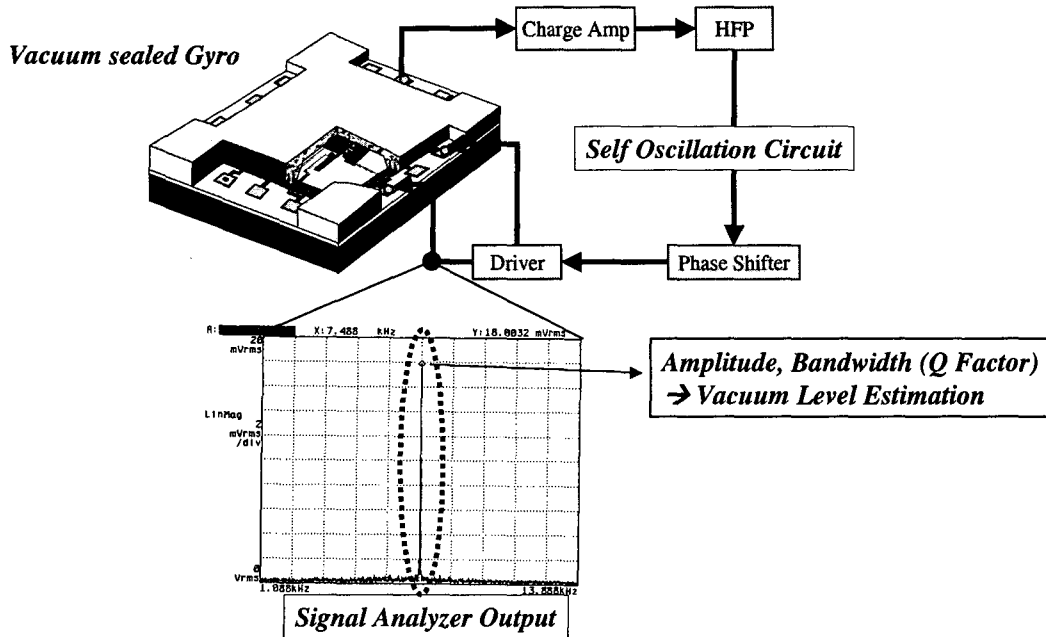


Pyrex Borosilicate glass has 3.5% Na2O

Hermeticity Monitoring #1



Hermeticity Monitoring #2



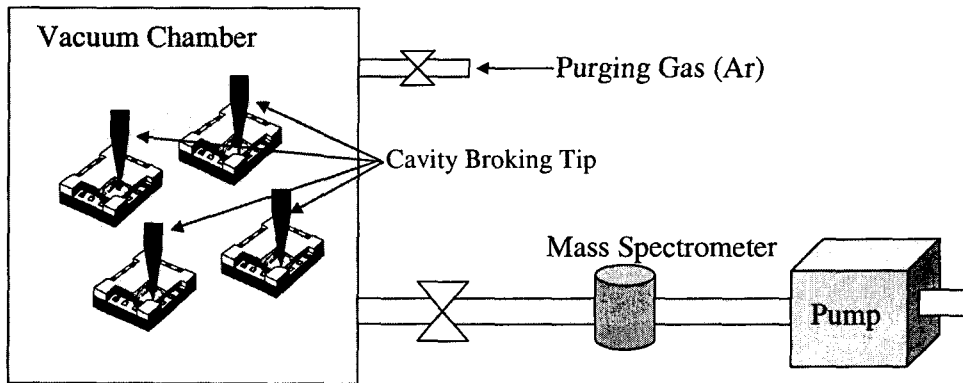
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Residual Gas Analysis



RGA Result For Anodic Bonded Gyro Sample

Detected Gas (ul)	H ₂ O	0.042052	0.163977	0.068000	0.092708
	O ₂	0.000012	0.008141	0.012764	0.010476

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Design of Experiment (Full Factorial)

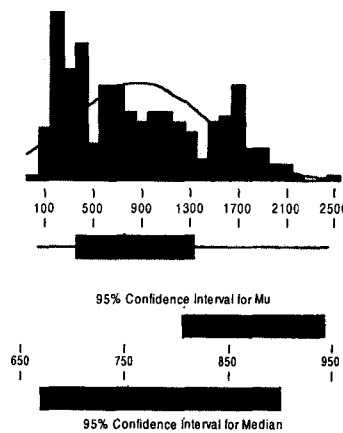
- Object : To Optimize the bonding conditions
- Factor : Voltage, Temp.
- Level : 2

Result

DOE #	Wafer ID	Bonding voltage (V)	Bonding temp. (° C)	Q factor (Mean)	Q factor stdev.
1	S24	350	400	874	574
2	S25	500	400	1030	533
3	S15	350	520	2782	1441
4	S19	500	520	1216	415
5	S26	425	460	3137	854



Descriptive Statistics



Variable: Qx_S24

Anderson-Darling Normality Test

A-Squared: 5.749
P-Value: 0.000

Mean: 874.119
StDev: 574.565
Variance: 330125
Skewness: 0.485138
Kurtosis: -9.0E-01
N: 268

Minimum: 46.00
1st Quartile: 363.75
Median: 753.50
3rd Quartile: 1332.00
Maximum: 2451.00

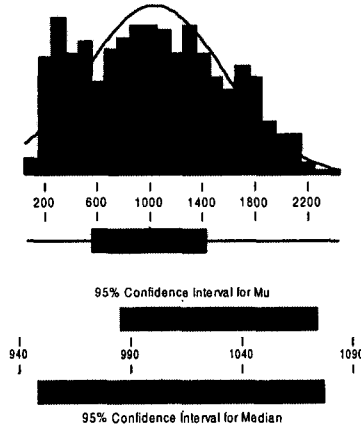
95% Confidence Interval for Mu
805.02 943.22

95% Confidence Interval for Sigma
529.69 627.61

95% Confidence Interval for Median
666.00 900.18



Descriptive Statistics



Variable: Qx_S25

Anderson-Darling Normality Test

A-Squared: 3.377
P-Value: 0.000

Mean 1029.79
StDev 533.17
Variance 284268
Skewness 0.192266
Kurtosis -8.8E-01
N 564

Minimum 70.00
1st Quartile 565.25
Median 1004.00
3rd Quartile 1429.50
Maximum 2443.00

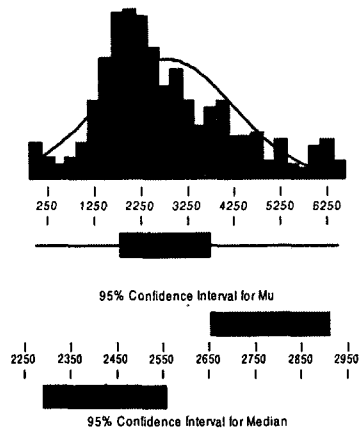
95% Confidence Interval for Mu
985.69 1073.89

95% Confidence Interval for Sigma
503.76 566.25

95% Confidence Interval for Median
948.24 1077.04



Descriptive Statistics



Variable: Qx_S15

Anderson-Darling Normality Test

A-Squared: 7.714
P-Value: 0.000

Mean 2782.29
StDev 1441.08
Variance 2076722
Skewness 0.651668
Kurtosis 2.53E-02
N 491

Minimum 0.00
1st Quartile 1806.00
Median 2427.00
3rd Quartile 3729.00
Maximum 6481.00

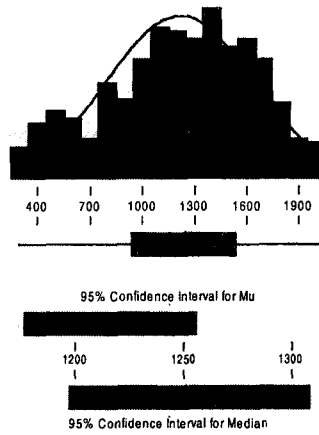
95% Confidence Interval for Mu
2654.50 2910.07

95% Confidence Interval for Sigma
1356.23 1537.35

95% Confidence Interval for Median
2289.64 2557.27



Descriptive Statistics



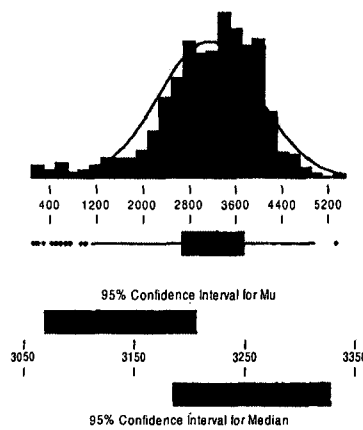
Variable: Qx_S19

Anderson-Darling Normality Test

A-Squared:	2.141
P-Value:	0.000
Mean	1216.10
StDev	415.51
Variance	172649
Skewness	-3.0E-01
Kurtosis	-6.5E-01
N	427
Minimum	291.00
1st Quartile	937.00
Median	1251.00
3rd Quartile	1536.00
Maximum	2047.00
95% Confidence Interval for Mu	1176.58 1255.63
95% Confidence Interval for Sigma	389.39 445.42
95% Confidence Interval for Median	1196.77 1308.23



Descriptive Statistics



Variable: Qx_26

Anderson-Darling Normality Test

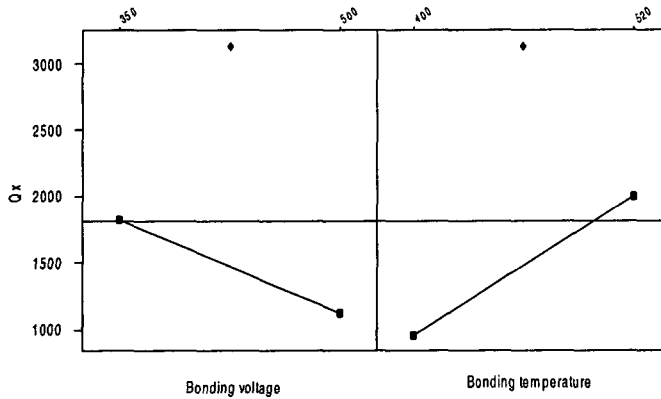
A-Squared:	6.525
P-Value:	0.000
Mean	3137.71
StDev	854.78
Variance	730645
Skewness	-9.2E-01
Kurtosis	1.31886
N	603
Minimum	112.00
1st Quartile	2681.00
Median	3279.00
3rd Quartile	3745.00
Maximum	5350.00
95% Confidence Interval for Mu	3069.35 3206.07
95% Confidence Interval for Sigma	809.10 905.96
95% Confidence Interval for Median	3184.88 3327.36

Main Effect Analysis



Main Effects Plot (data means) for Qx

• Centerpoint

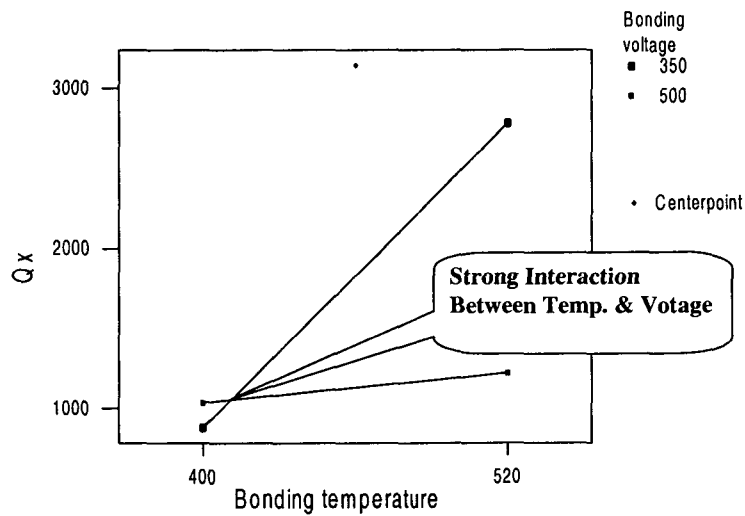


Term	Coef
Constant	-19243.3
Charge	39.3067
Temp	49.3833
Charge*Temp	-0.0956667
Ct Pt	1661.50

Interaction Factor Analysis

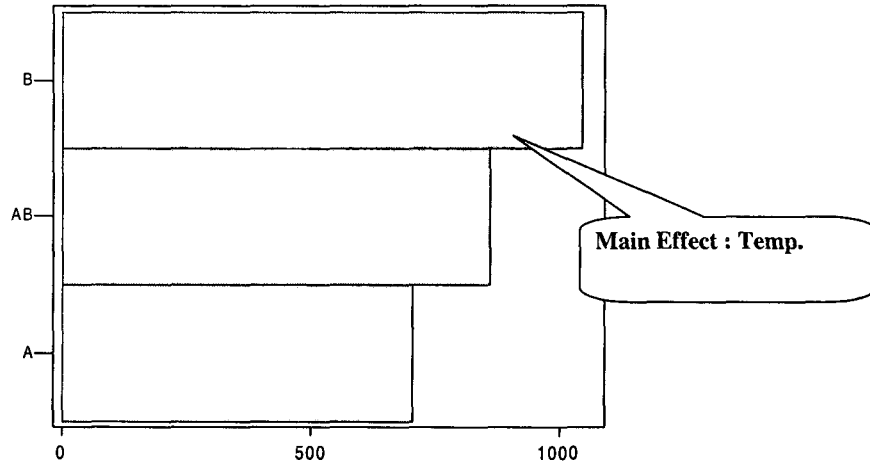


Interaction Plot (data means) for Qx





Qx Pareto Chart of the Effects

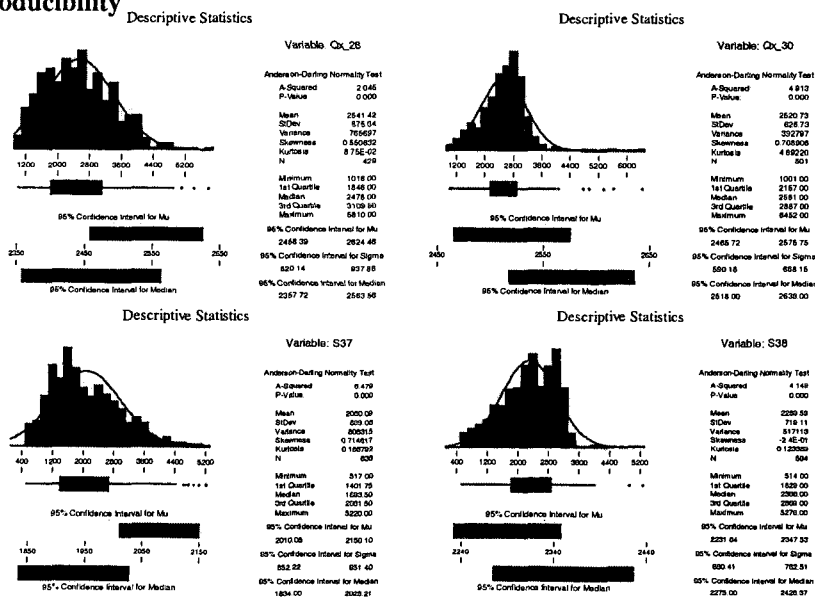


A: Bonding voltage
B: Bonding temp.



- Optimum Condition: Voltage : 425 V, Temp. : 460 C

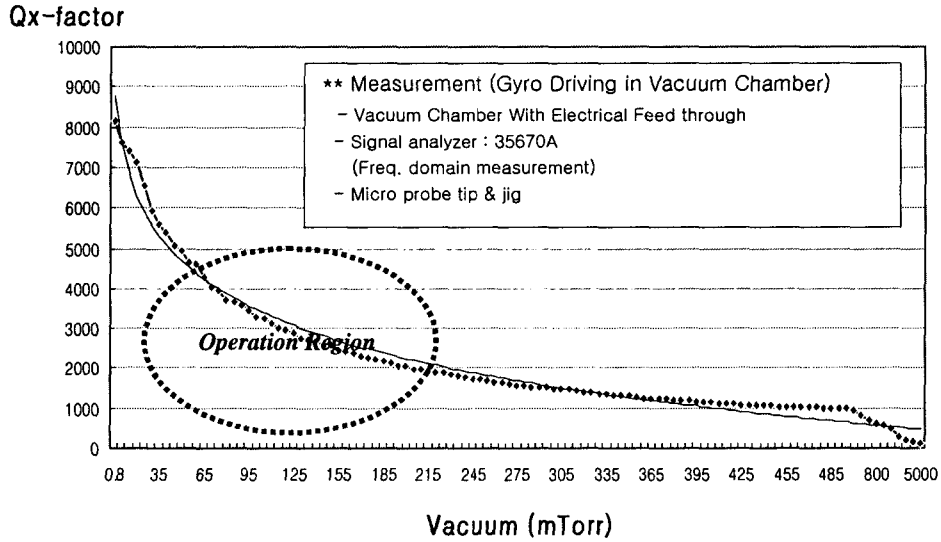
- Reproducibility



Vacuum Level vs. Q Factor



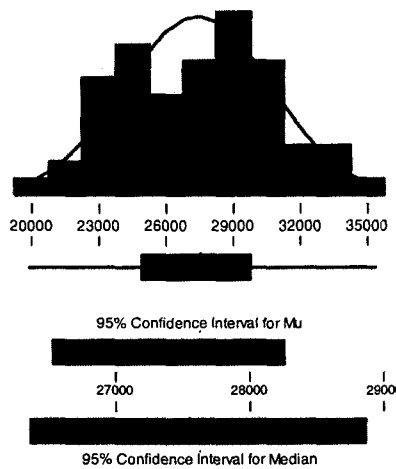
Qx factor vs. Vacuum level



Cavity Vacuum Level (Q) Control



Descriptive Statistics



Variable: SA10

Anderson-Darling Normality Test

A-Squared: 0.343
P-Value: 0.479

Mean: 27395.7
StDev: 3312.6
Variance: 10973605
Skewness: 6.03E-03
Kurtosis: -5.1E-01
N: 59

Minimum: 19889.0
1st Quartile: 24900.0
Median: 27548.0
3rd Quartile: 29780.0
Maximum: 35311.0

95% Confidence Interval for Mu
26532.4 28259.0

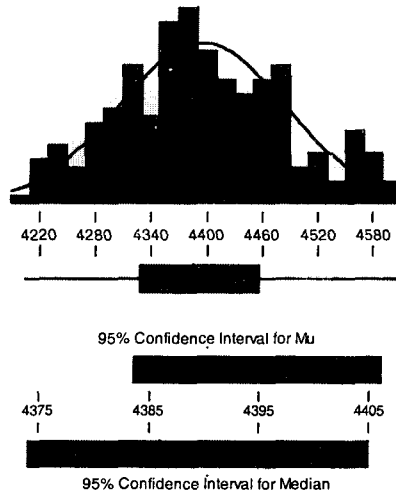
95% Confidence Interval for Sigma
2804.3 4047.9

95% Confidence Interval for Median
26358.5 28863.1





Descriptive Statistics



Variable: SA07

Anderson-Darling Normality Test

A-Squared: 0.539
P-Value: 0.165

Mean 4394.91
StDev 90.44
Variance 8180.05
Skewness 0.183871
Kurtosis -4.7E-01
N 251

Minimum 4205.00
1st Quartile 4329.00
Median 4386.00
3rd Quartile 4456.00
Maximum 4604.00

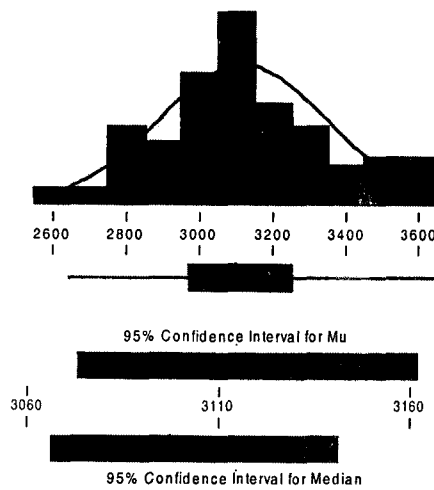
95% Confidence Interval for Mu
4383.67 4406.16

95% Confidence Interval for Sigma
83.16 99.13

95% Confidence Interval for Median
4374.00 4405.00



Descriptive Statistics



Variable: SA20

Anderson-Darling Normality Test

A-Squared: 0.522
P-Value: 0.180

Mean 3117.42
StDev 228.65
Variance 52279.5
Skewness 0.285706
Kurtosis -2.8E-01
N 104

Minimum 2643.00
1st Quartile 2972.25
Median 3097.00
3rd Quartile 3252.50
Maximum 3639.00

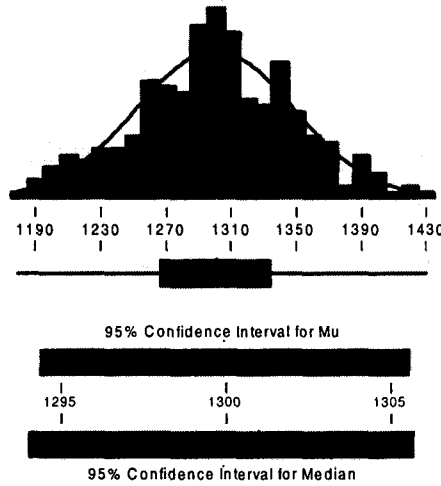
95% Confidence Interval for Mu
3072.96 3161.89

95% Confidence Interval for Sigma
201.23 264.78

95% Confidence Interval for Median
3065.89 3141.00



Descriptive Statistics



Variable: SA12

Anderson-Darling Normality Test

A-Squared:	0.422
P-Value:	0.320
Mean	1299.98
StDev	48.66
Variance	2367.94
Skewness	-1.2E-02
Kurtosis	-1.3E-01
N	291
Minimum	1179.00
1st Quartile	1267.00
Median	1301.00
3rd Quartile	1334.00
Maximum	1430.00
95% Confidence Interval for Mu	1294.36 1305.59
95% Confidence Interval for Sigma	45.00 52.97
95% Confidence Interval for Median	1294.00 1305.69

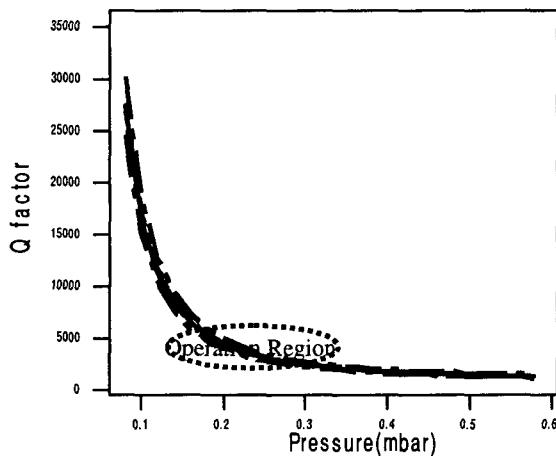


Regression Analysis

Regression Plot

$$\log(Q \text{ factor}) = 3.05 + 0.081 \log(\text{Pressure}) + 1.51 \log(\text{Pressure})^2 + 0.258 \log(\text{Pressure})^3$$

S = 0.0228153 R-Sq = 99.6 % R-Sq(adj) = 99.6 %



Predictor	Coef	SE Coef	T	P
VIF				
Constant	3.05197	0.02676	114.03	0.000
log p	0.0811	0.1759	0.46	0.645
3074.5				
(log p) ²	1.5055	0.3049	4.94	0.000
13024.9				
(log p) ³	0.2576	0.1523	1.69	0.091
3823.6				

Analysis of Variance

Source	DF	SS	MS	F
P				
Regression	3	99.394	33.131	63648.31
0.000				
Residual Error	701	0.365	0.001	
Total	704	99.759		

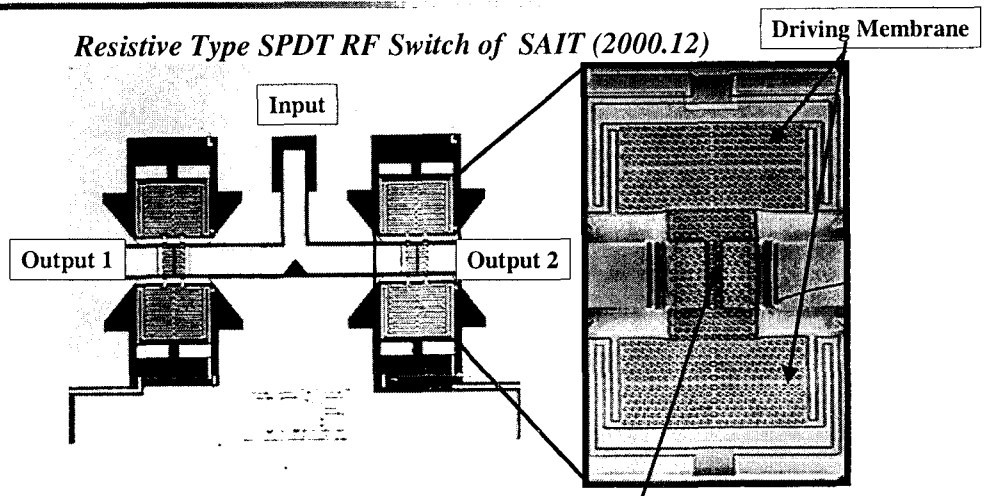
— Regression
- - - 95% CI
— 95% PI

$$\log Q = 3.05 + 0.081 \log p + 1.51 (\log p)^2 + 0.258 (\log p)^3$$

RF MEMS Switch



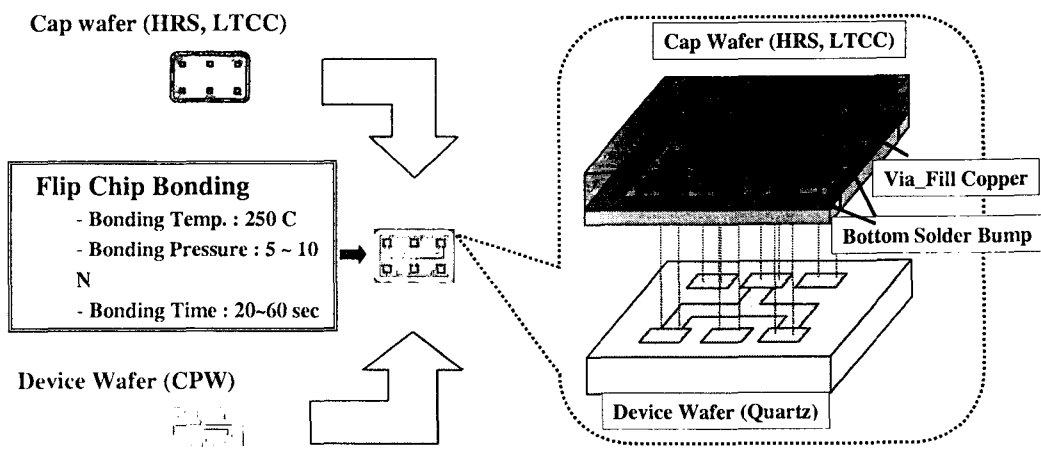
Resistive Type SPDT RF Switch of SAIT (2000.12)

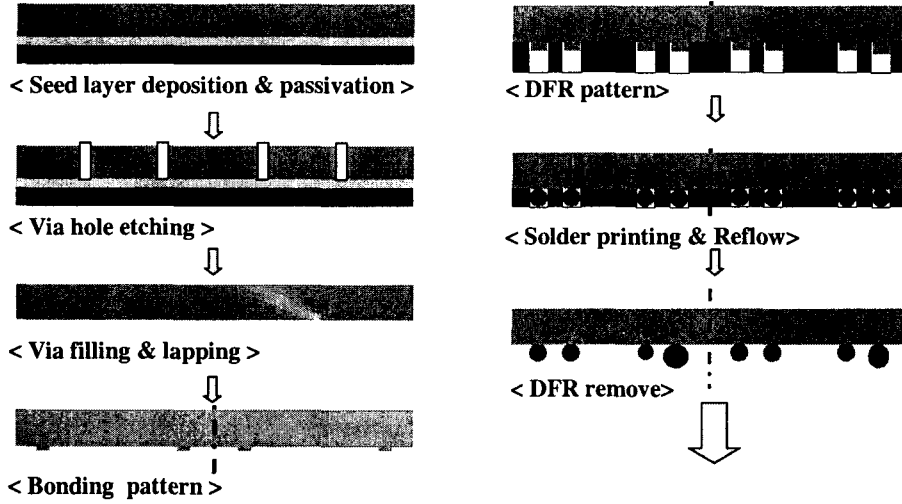


Critical Packaging Issues

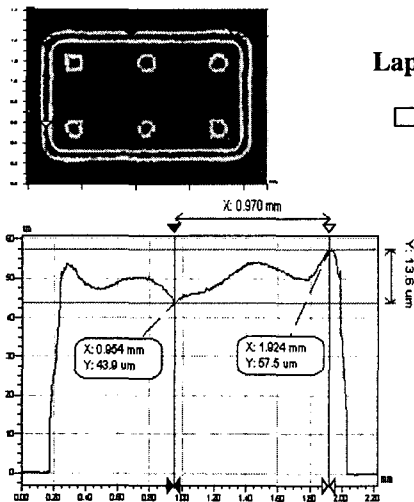
- Low cost
- Small size
- Hermetic sealing
- Low Insertion Loss

RF SW Packaging



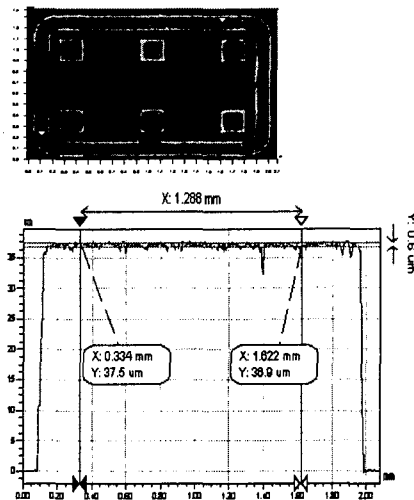


■ After Reflow
Thickness Variation :
13.6um



Lapping
➔

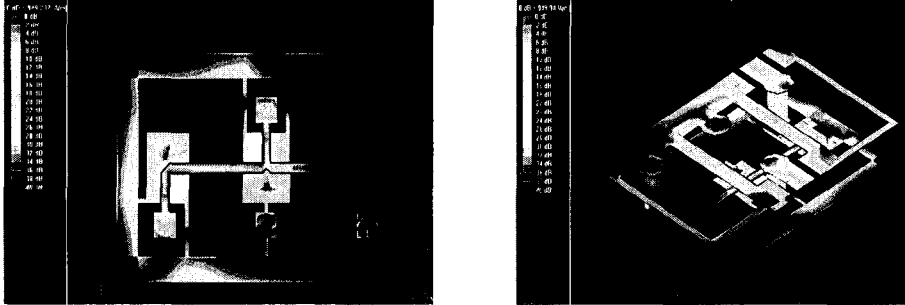
■ After Lapping
Thickness Variation :
0.6 um



Packaging Result



- Simulated Insertion Losses and Isolations by HFSS



- Experimental Result

Items	Spec.	Packaged SW (test sample : 128 EA)			Only CPW(ref)	Only Package
		Best	Average	σ		
Insertion Loss (dB)	0.1 @ 2GHz	0.06 @ 2GHz	0.08 @ 2GHz	0.020 @ 2GHz	0.05 @ 2GHz	<u>0.030 @ 2GHz</u>

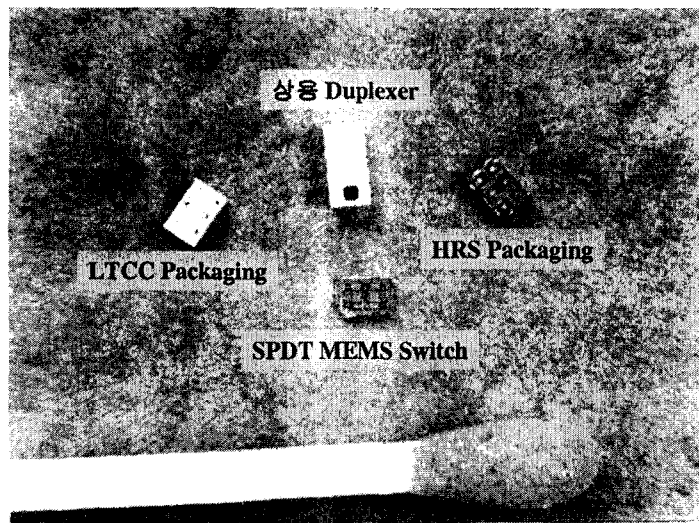
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Packaged RF Switch



Gyro Project

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- 1991. 2. : 경북대학교 전자공학과 졸업
- 1993. 2. : 동 대학원 전자공학과(반도체전공)석사
- 1993. 2 ~ 현재 : 삼성종합기술원 근무
 - 1993. 2 ~ 1995. 10 : Red Laser Diode 개발 (Packaging & Reliability)
 - 1995. 11. ~ 1999. 12 : MEMS Gyro 개발 (MEMS Fabrication & Packaging)
 - 2000. 1. ~ 2001. 7. : RF MEMS Switch 개발 (MEMS Fabrication & Packaging)
 - 2001. 8. ~ 현재 : MEMS Gyro 개발 (MEMS Fabrication & Packaging)

관심분야

- MEMS Fabrication & Packaging기술