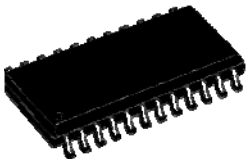

RELIABILITY CHALLENGES FOR MEMS INTEGRATION

EDN 2003 Innovator/Innovation of the Year Award Winner for Components
STMicroelectronics LIS3L02 three-axis low-g accelerometer March 29, 2004

Milano, 28th November 2006

Benedetto Vigna
MEMS Business Unit Director
Benedetto.Vigna@st.com

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Outline

- **MEMS Products:**
  - Technology Competition
  - Market Acceptance
- **MEMS Oxymoron**
- **MEMS ST approach to:**
  - Manufacturing Processes
  - Reliability Assessment Methodologies
- **Conclusions**

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MEMS Competition in a Nutshell

Mems family	Compete with	price	performances
ACCELEROMETER			
GYROSCOPE	QUARTZ/PIEZO	x	x
INERTIAL MODULE	HYBRID	x	x
BAW FILTER	SAW		x
PRESSURE			
BIO CHIP	HYBRID	x	x
ATOMIC STORAGE	ELECTRICAL MEMORY		x
RF MEMS	RADIO ARCHITECTURE		x
OPTICAL	OEO SOLUTIONS	x	x
INKJET			
DLP	LCD		x
MICROPHONE	ELECTRET		x

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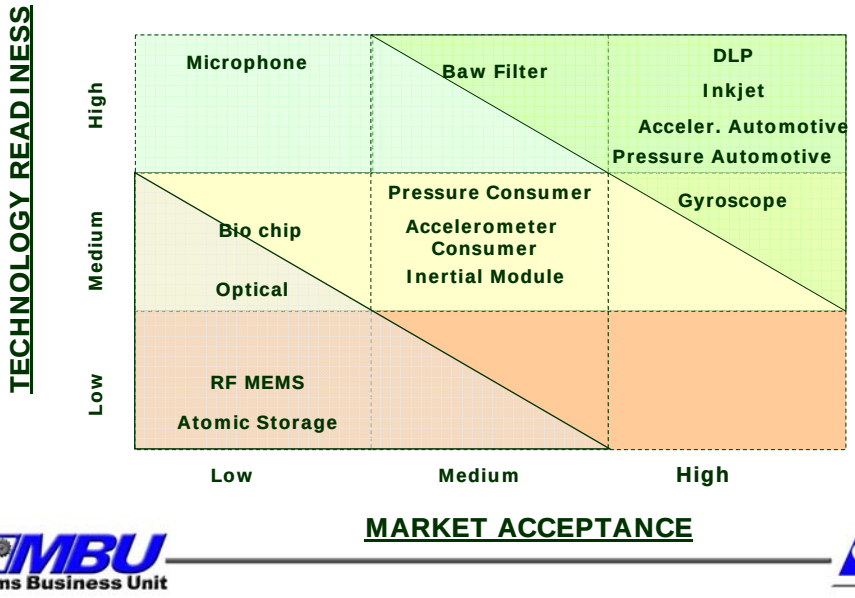
MEMS Market acceptance



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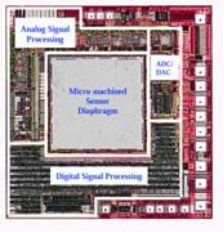
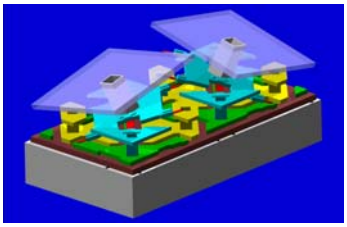
Most Successful Microsystems



Pressure Sensor

Accelerometer



MicroMirror

Printer Cartriges

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IC and uMachining Technologies

Category	IC	Surface	THELMA	Wet Bulk	DRIE Bulk	VENSEN
Lithography	Stepper	Stepper	Stepper	Contact	Stepper or Contact	Stepper
Structural Material	N/A	CVD Poly	Epi Poly	Mono Si	Mono Si	Mono Si
Sacrificial Material	N/A	Si Oxide	Si Oxide	Si Substrate	Si Substrate	Mono Si
Cleanroom Class	1 – 10	10 - 100	10 - 100	100- 1000	100 - 1000	10 – 100
Wafer Diameter	8" – 12"	4" - 6"	4" - 6"	4" - 6"	4" - 6"	6" – 8"
Photo Levels (#)	> 20	> 20	6 ; 8	2 ; 6	6 ; 8	10
Min. Linewidth	< 0.13 um	1 um	2 um	6um	3 um	1 um

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Many Different Materials can also be used!

MEMS Oxymoron

MEMS are built in Semiconductor fabs……

…..but they are not CMOS…….

a common process platform across the industry is missing and perhaps will never exist……..

<u>the MEMS silicon foundry is an oxymoron</u>

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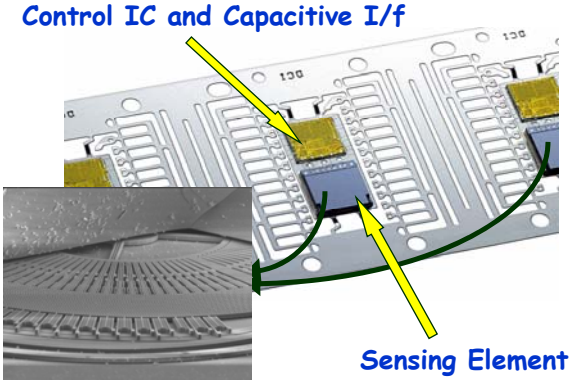
ST MEMS Accelerometers

<u>Hybrid Integration</u>

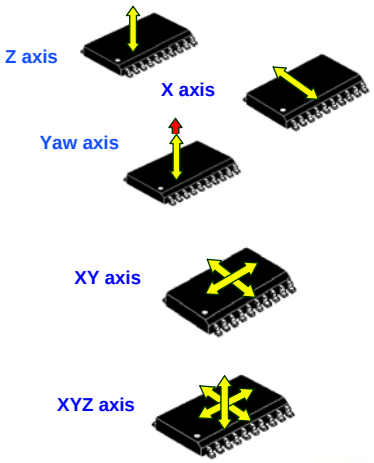
Control IC and Capacitive I/f



Sensing Element

THELMA15 Process

<u>LIS Sensitive axis</u>



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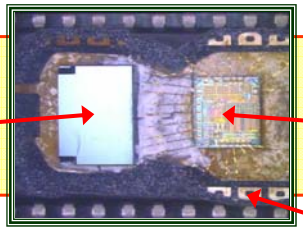
Two Dice – Single Package Approach: System Considerations

MEMS sensor chip translates acceleration into a differential capacitive change

Interface IC chip translates small capacitance changes into output signal, analog or digital

THELMA Sensor & Silicon Cap



High resolution Capacitive Interface IC in standard CMOS

leadframe

- ***Performance optimization***
- ***High modularity and flexibility***
- ***Custom additional integration on interface IC***
- ***Low cost solution (std plastic package)***

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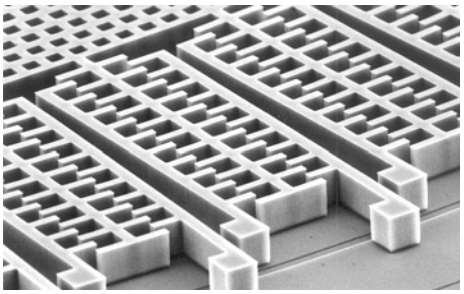
THELMA Process Highlights

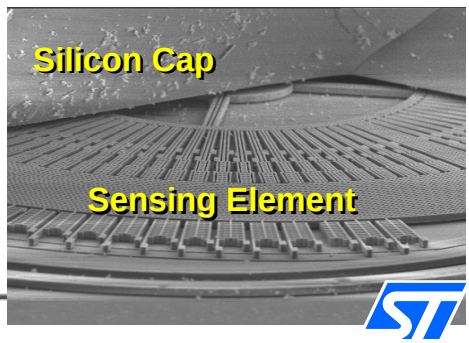
Thelma

- **Epitaxial Poly Growth**
  - From few µm up to 50µm
- **Mechanical Polishing**
  - Smooth Surface - Stress Reduction
- **Deep Silicon Etching**
  - High Aspect Ratio – Vertical Sidewall
  - Low Cross-Talk – High Resolution
- **HF Dry Etching**
  - No Stiction – Free Structures



Wafer Level Protection with Silicon Cap

- **Wafer to Wafer Bonding**
  - Structure Protection in wafer sawing
  - Wafer scale Package



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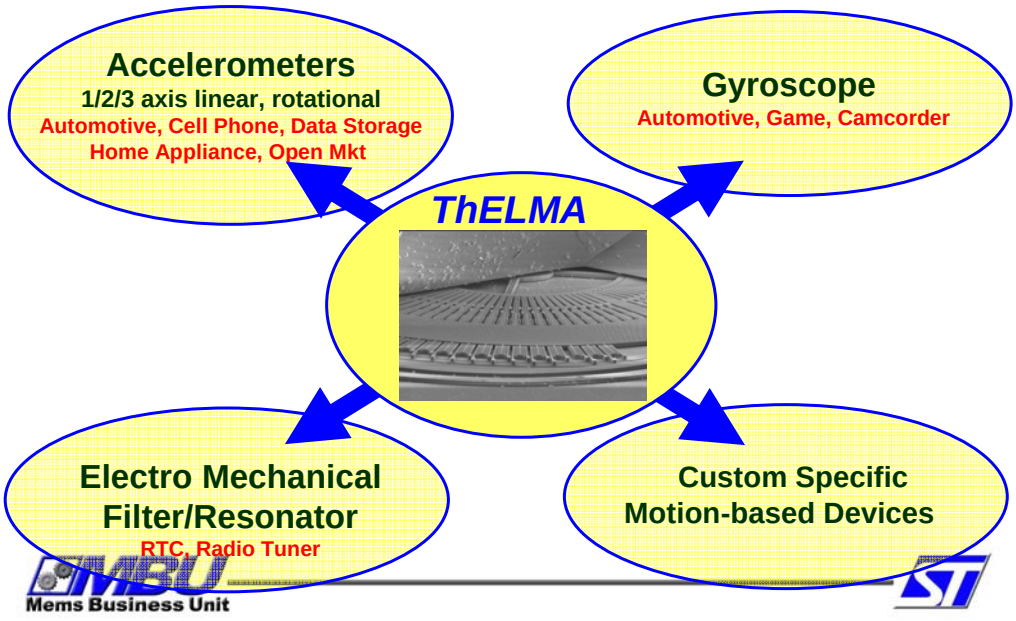
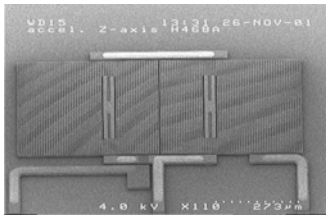
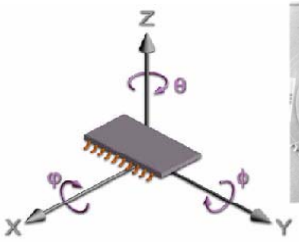
ThELMA Process Platform



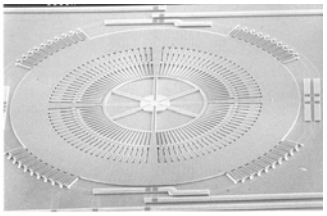
ST Accelerometer Product Family

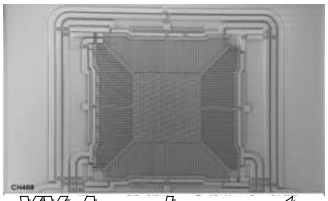


Z Accelerometer



Accelerometer





XY Accelerometer

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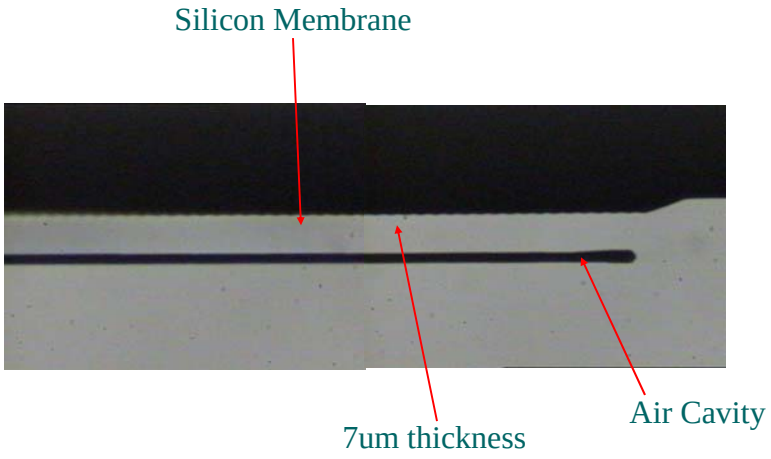
Venezia Process platform



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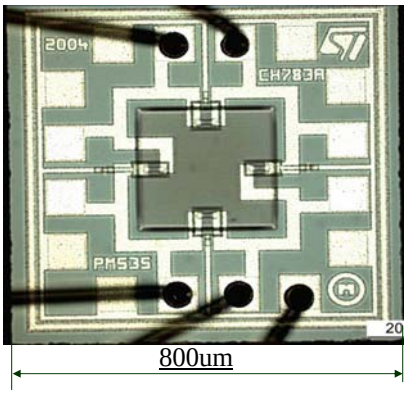
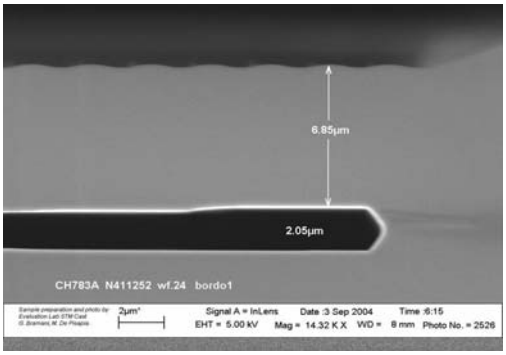
Micromachining Process for Pressure and Force Sensors





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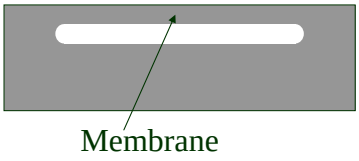
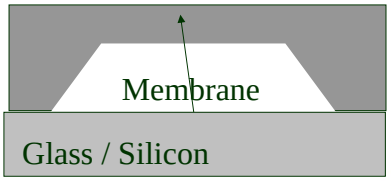
ST solution advantages

- Very small footprint and thickness
- Vertical Stoppers to avoid breakage
- Hermetic cavity; no need of wafer bonding
- Higher Sensitivity to Pressure
- Lower Sensitivity to Spurious Accelerations

ST Technology



Current Technology



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MACRO to MICRO: a big transition

MECHANICAL PROPERTIES:

μ ρ Y_s H_v σ

THERMAL PROPERTIES :

K α C_p

ELECTRICAL PROPERTIES :

BV ρ I_{max}

CHEMICAL PROPERTIES :

CORROSION

DIFFUSION

HOW TO OBTAIN THESE?

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MEMS Reliability Approach

- **Basic studies on dedicated test structures**
  - Material characterization
  - Key failure mechanisms investigation
  - Design rules definition
- **Validation tests on sub-parts**
  - Technology oriented validation
  - Specific critical issues early investigation
- **Qualification exercise on final MEMS device**
  - Whole system design validation
  - Assembly stresses compatibility
  - Real field application simulation

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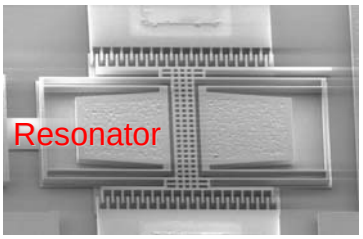
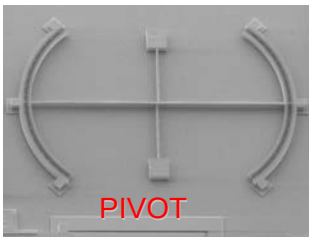
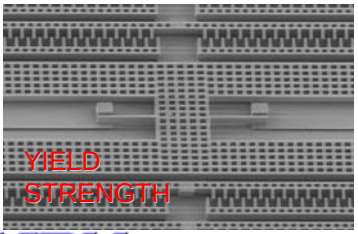
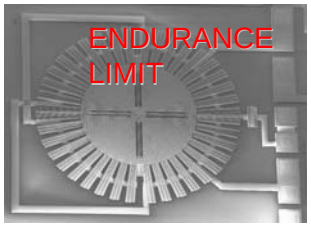
Test Structures for Wafer Level Reliability Program









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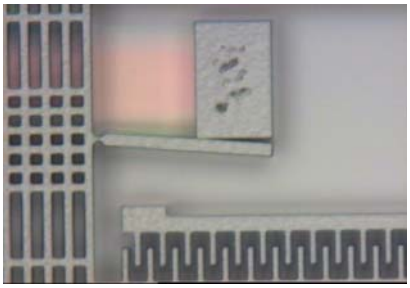
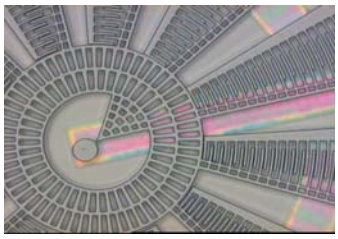
Yield Strength, Young Module Measurements





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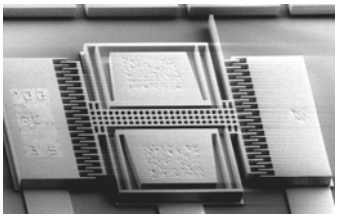
Quality Test for High Vacuum level

Quality factor test to ensure high vacuum level for vibrating MEMS devices.



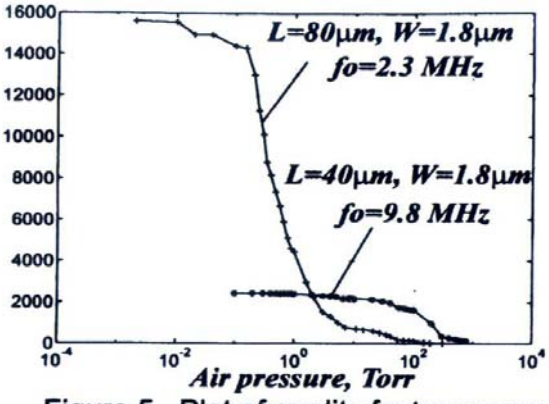


Figure 5. Plot of quality factor versus operating air pressure.

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Conclusions

- **MEMS Process Standardization inside a company** is a key step for the commercial success of MEMS
- ST is pursuing two processes platforms: **Thelma and Venezia** for different micro-machined product families. A big effort is currently on-going to port other MEMS design in these industrialized processes.
- Reliability assessment procedures are very **specific**. Although Silicon is the base material the **failure mechanisms** are new and depend on the market segment, application and product
- **Reliability** assessment procedure must be derived from other industries and implemented at **wafer level**.
- **MEMS Foundry is an oxymoron**: a common process platform doesn't exist. MEMS are different from CMOS where company alliances exist and work in the same fab.
- **Ideal Process doesn't exist**: Each company will use its own preferred and available manufacturing process to run the production at lowest possible cost to compete successfully on the market at highest quality standards.

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THANK YOU

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