Dual pressure chip capping technology

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Session 10: MEMS Packaging

Outline

- Introduction
- PSM-X2 Process Platform
- Dual Pressure Wafer Level Package
- Getter Sorption Capacity and Rate
- Application of Dual Pressure WLP
- Summary

Introduction

- Micro Electro Mechanical Systems (MEMS) have achieved outstanding performance concerning device size, production cost and reliability.
- Innovative product trends lead to decreased chip size and cost but also to enhanced feature functionality.
- Multi axis sensor systems integrated into a single chip full inertial measurement unit is the final goal.
- The sensor combination of accelerometers and gyrometer in one chip is difficult due to different operating conditions
- The technical challenge is to handle the pressure differences between accelerometer cavity and gyrometer cavity within a one step wafer level packaging process.

PSM-X2 Process Platform

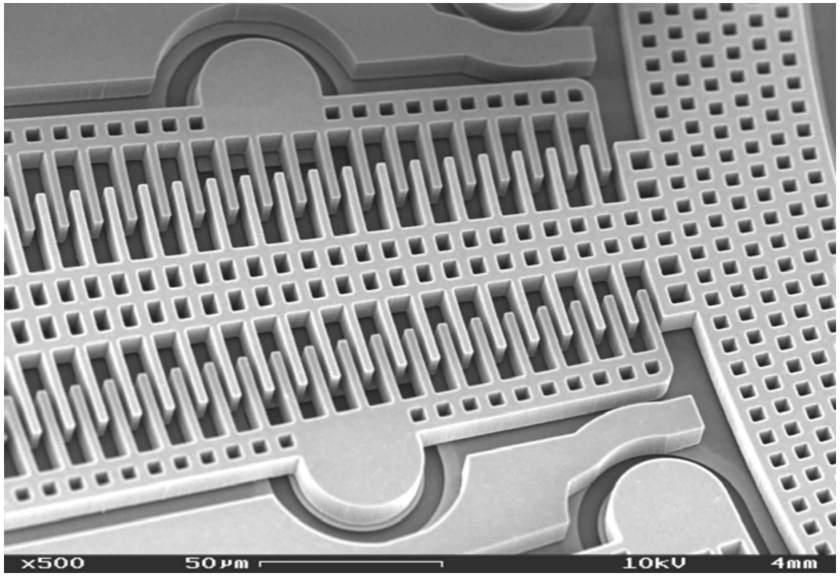
Fraunhofer Wafer-Fab in Itzehoe

- Research and Production at one Location
- Professional Semiconductor Production Line for 200 mm wafer on 2500 m² Clean Room Area Capacity: 250 000 wafer/year
- Technology Line for MEMS-Processes Development and Production on 500 m² Clean Room Area

PSM-X2 Process Platform

Motivation

- thick and robust active MEMS layer
- in-plane actuation and detection mode
- out-of plane actuation and detection mode
- defined, inert cavity pressure
- leak rate below 10^{-14} mbar l/s
- device lifetime > 17 years

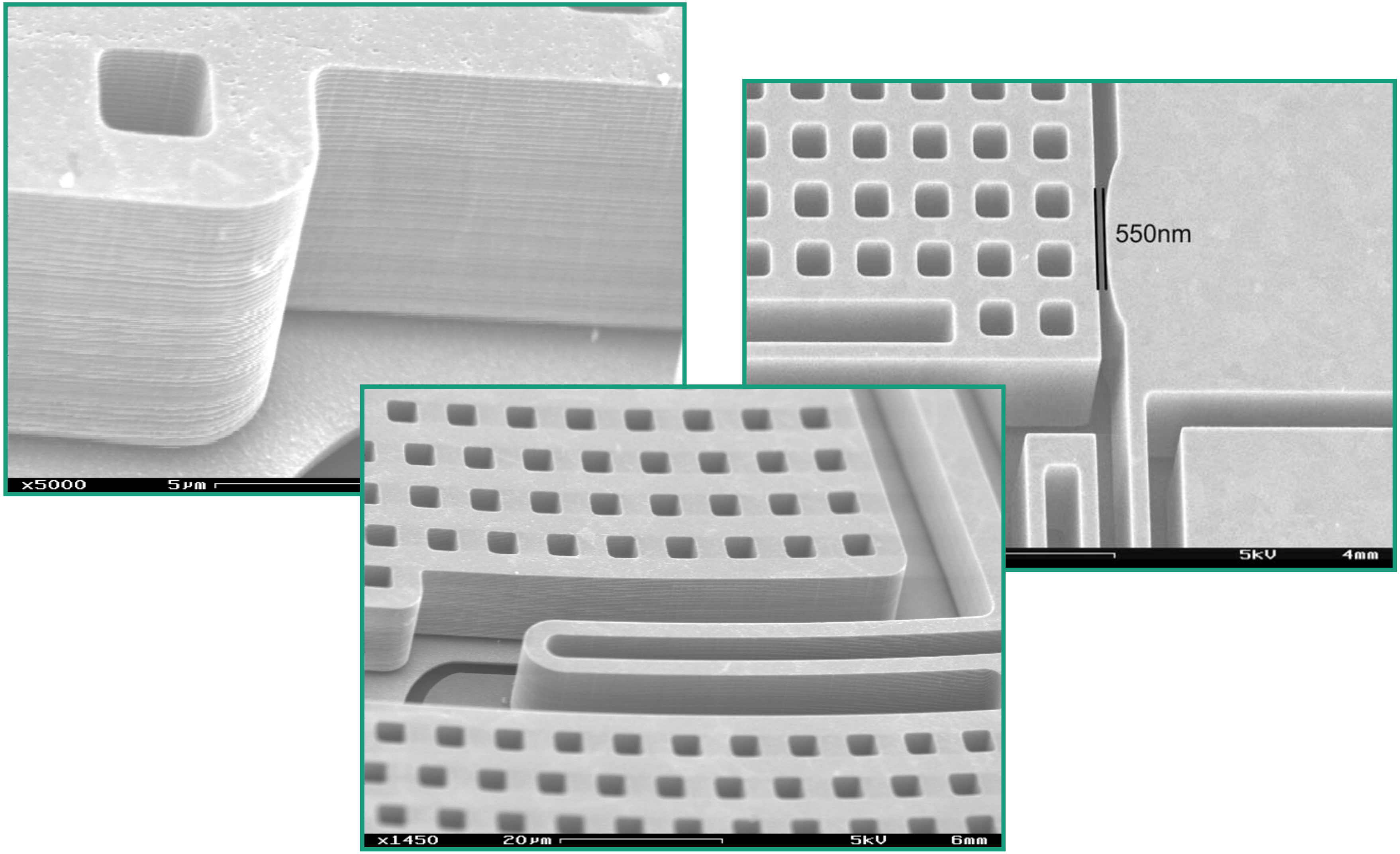


Technology

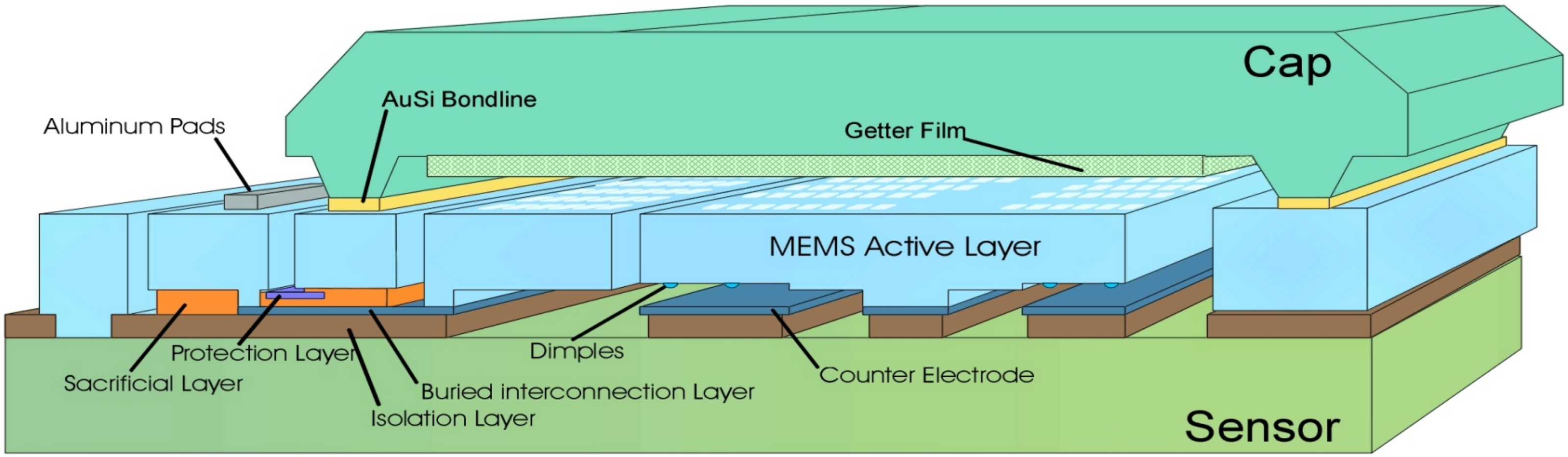
- 11 micron thick epi poly layer
- good temperature stability
- high fracture and yield strength
- low stress and stress gradient
- DRIE vertical structuring (Bosch process)
- perforated membrane structure for large membrane area
- underneath 'buried' functional layers and structures
- wafer level packaging
- integrated getter film for broadband gas adsorption
- inert gas backfilling

- PSM-X2 process on 200 mm Wafer ready for production since end of 2009

PSM-X2 Process Platform



PSM-X2 Process Platform



- Thickness Sensor Wafer 675 µm
- Thickness Cap Wafer 508 µm
- Total Thickness 1.2 mm
- Grinding 0.6 mm

- MEMS Active Layer 10-30 µm
- Min. Structur Width 0.5 µm

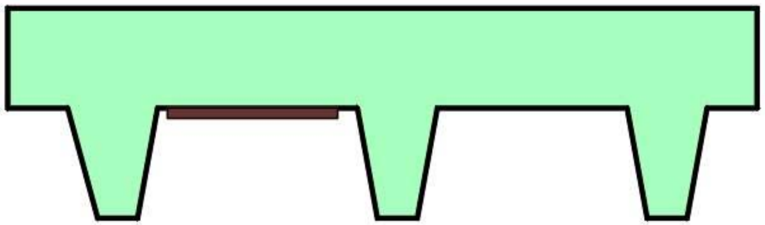
- Eutectic AuSi Bonding
- Bondline Width <100 µm
- Cavity Pressure Level <1 µbar ... 3 bar

- Integrated Getter Film (SAES Getters PaGe)

Dual Pressure Wafer Level Package

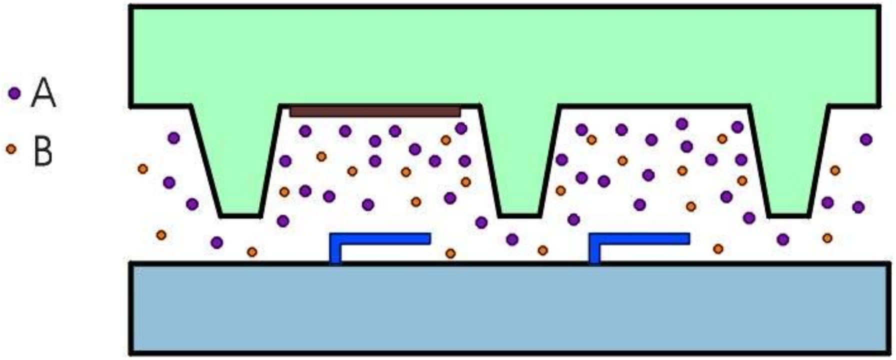
1. Preparation of Cap Wafer

- Left cavity with getter film
- Right cavity without getter film

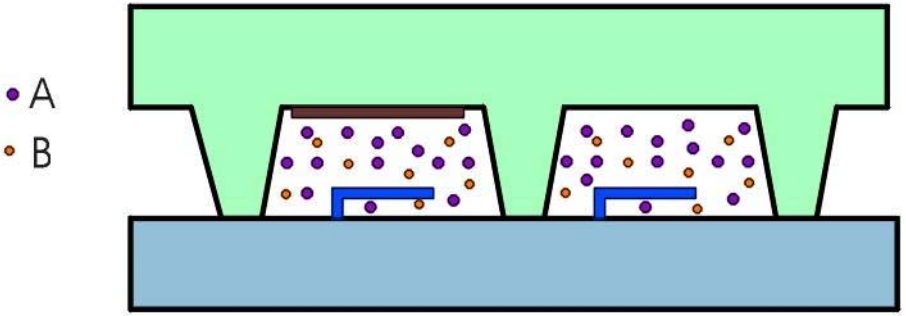


2. Preparation for Wafer Level Bonding

- Alinment of cap- and scensor-wafer
- Backfill of gas mixture
  - A = Getterable gas
  - B = Noble gas

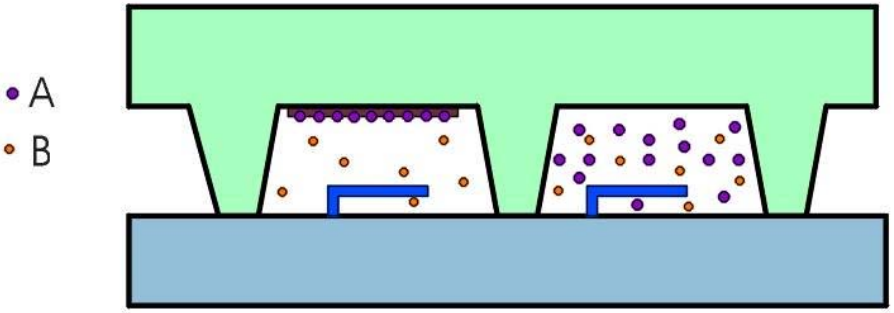


Dual Pressure Wafer Level Package



3. Wafer Bonding

- Hermetic seal of cavities
- Eutectic Au-Si bond process



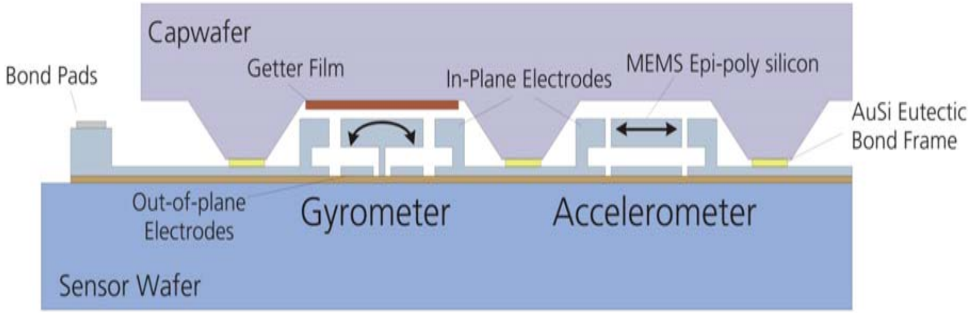
4. Getter Activation

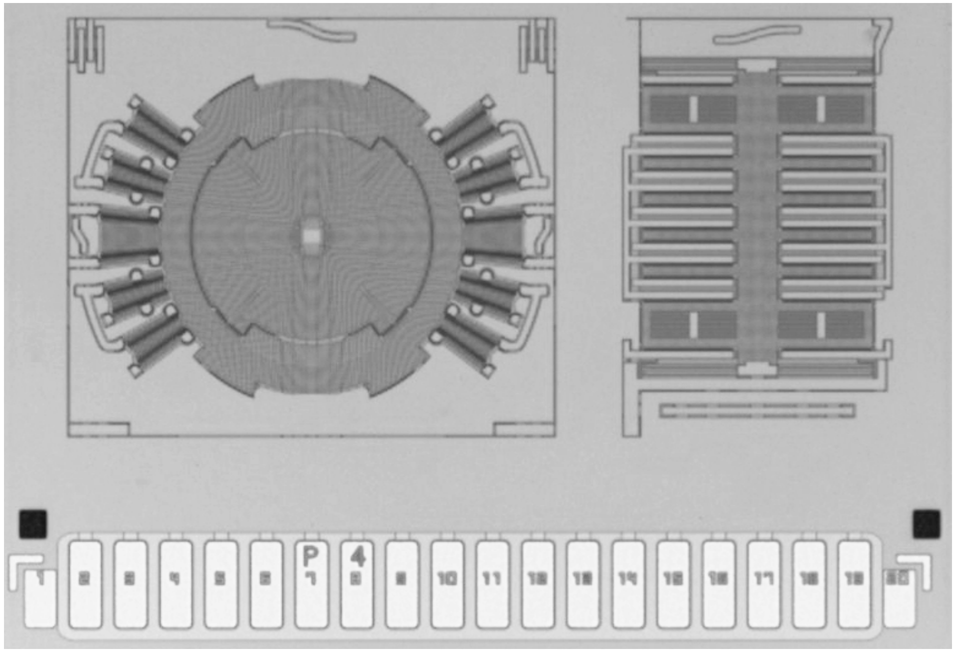
- Post bond getter activation at 250-400 °C, 1-40 h
- Left cavity: Only noble gas remains
- Right cavity: Complete backfill gas mixture remains

Dual Pressure Wafer Level Package

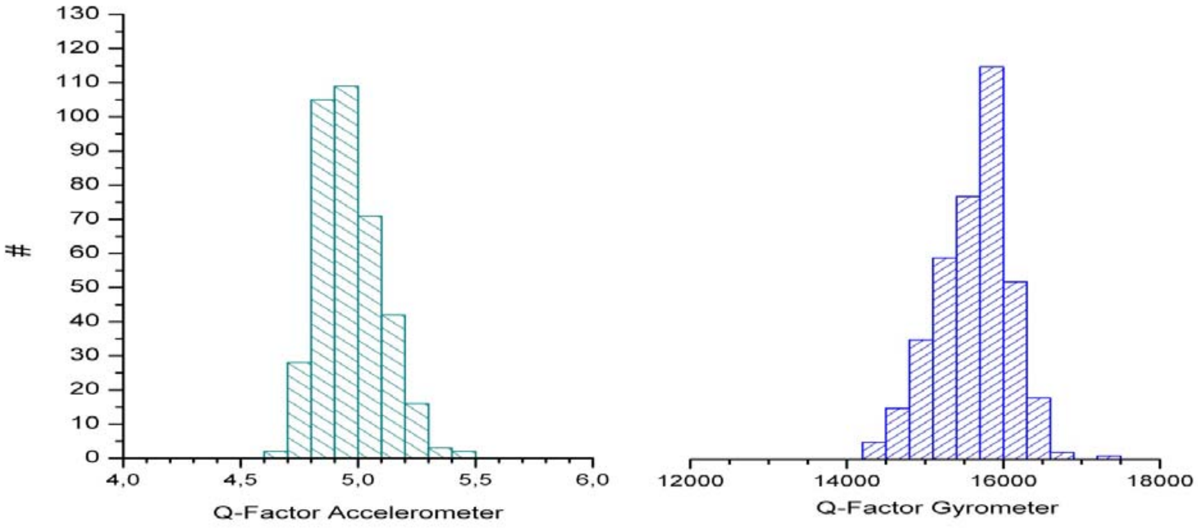
<ins>Example</ins>

- Combine gyrometer and accelerometer
- Gyrometer:
    - Mode = Vibrating mass
    - Pressure = 250 µbar
- Accelerometer
    - Mode = Static mass
    - Pressure = 100 mbar
- Extracting of pressure level by Quality-Factor measurement (air damping is main damping effect)





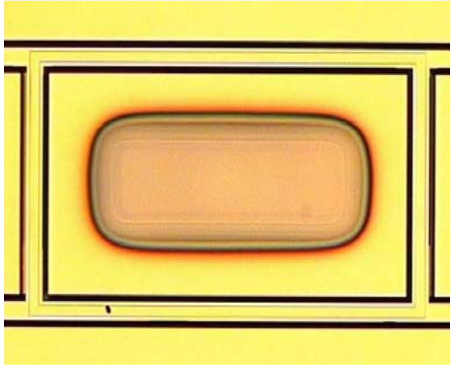
Dual Pressure Wafer Level Package

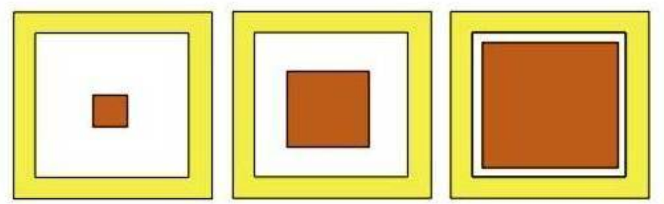


	Accelerometer	Gyrometer
Frequency w_0	2.2 kHz	11.5 kHz
Measured Q- Factor	5	15800
Attenuation $\alpha = w_0/2Q$	230 s^{-1}	0.37 s^{-1}
Calculated Pressure	100 mbar	0.25 mbar
Pressure Ratio	400 :	1
Noble Gas Content	0.25%	100%

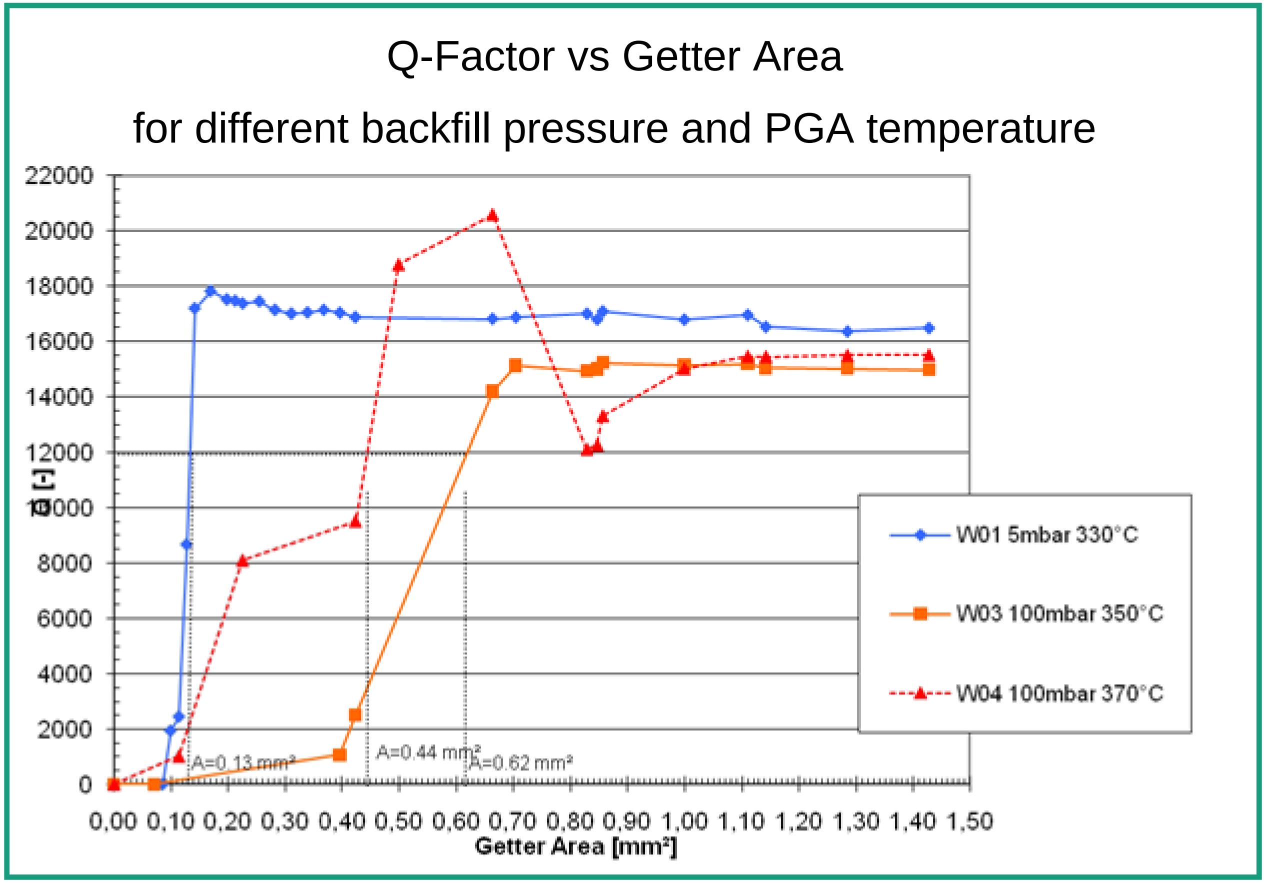
Getter Sorption Capacity and Rate

- For Getter Capacity calculation: $C = n / A_{min}$
- Gas amount: $n=PV/RT$
- Variation of Getter Area to evaluate A_{min}





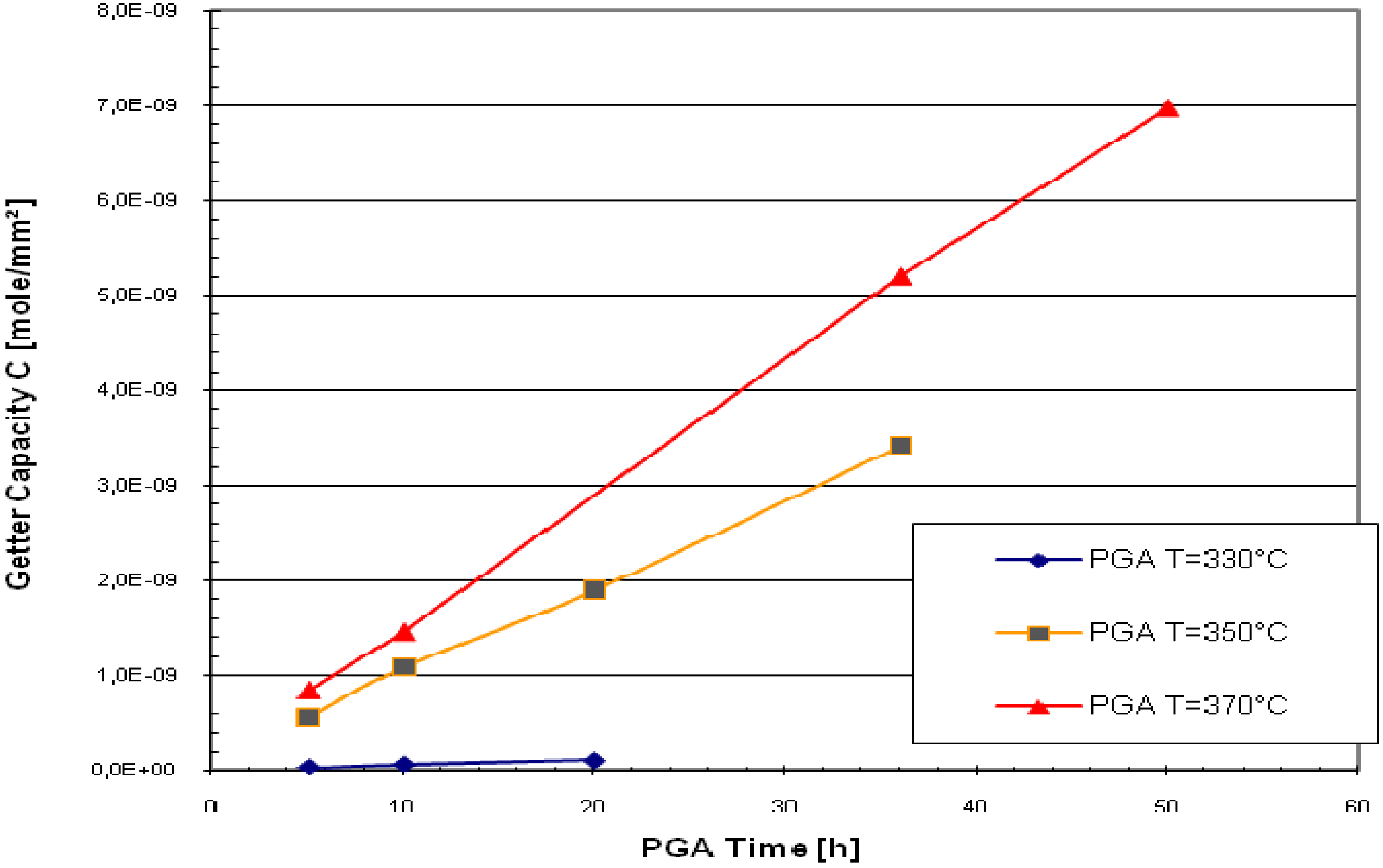
Getter Sorption Capacity and Rate



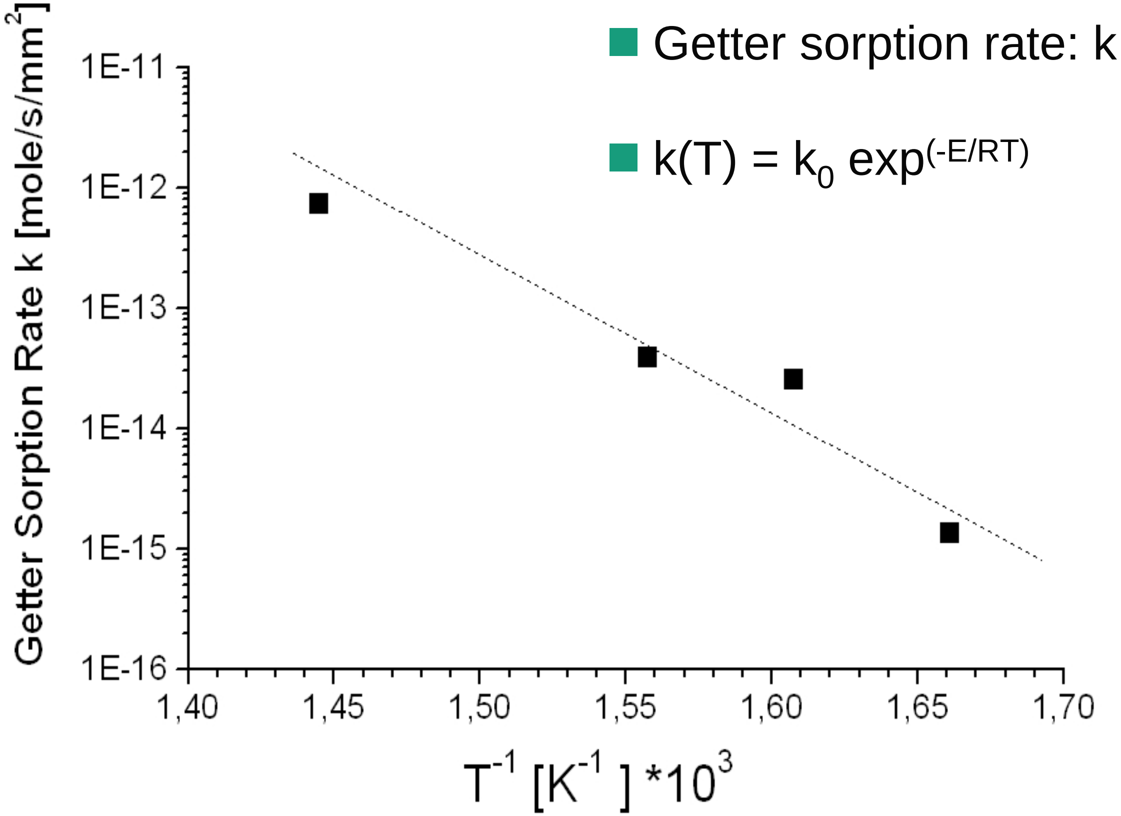
- Backfill pressure = 5 mbar / PGA temp = 330°C → A_{min} = 0.13 mm^2
- Backfill pressure = 100 mbar / PGA temp = 350°C → A_{min} = 0.62 mm^2
- Backfill pressure = 100 mbar / PGA temp = 370°C → A_{min} = 0.44 mm^2

Getter Sorption Capacity and Rate

Linear increase of Getter Capacity over PGA time



Getter Sorption Capacity and Rate



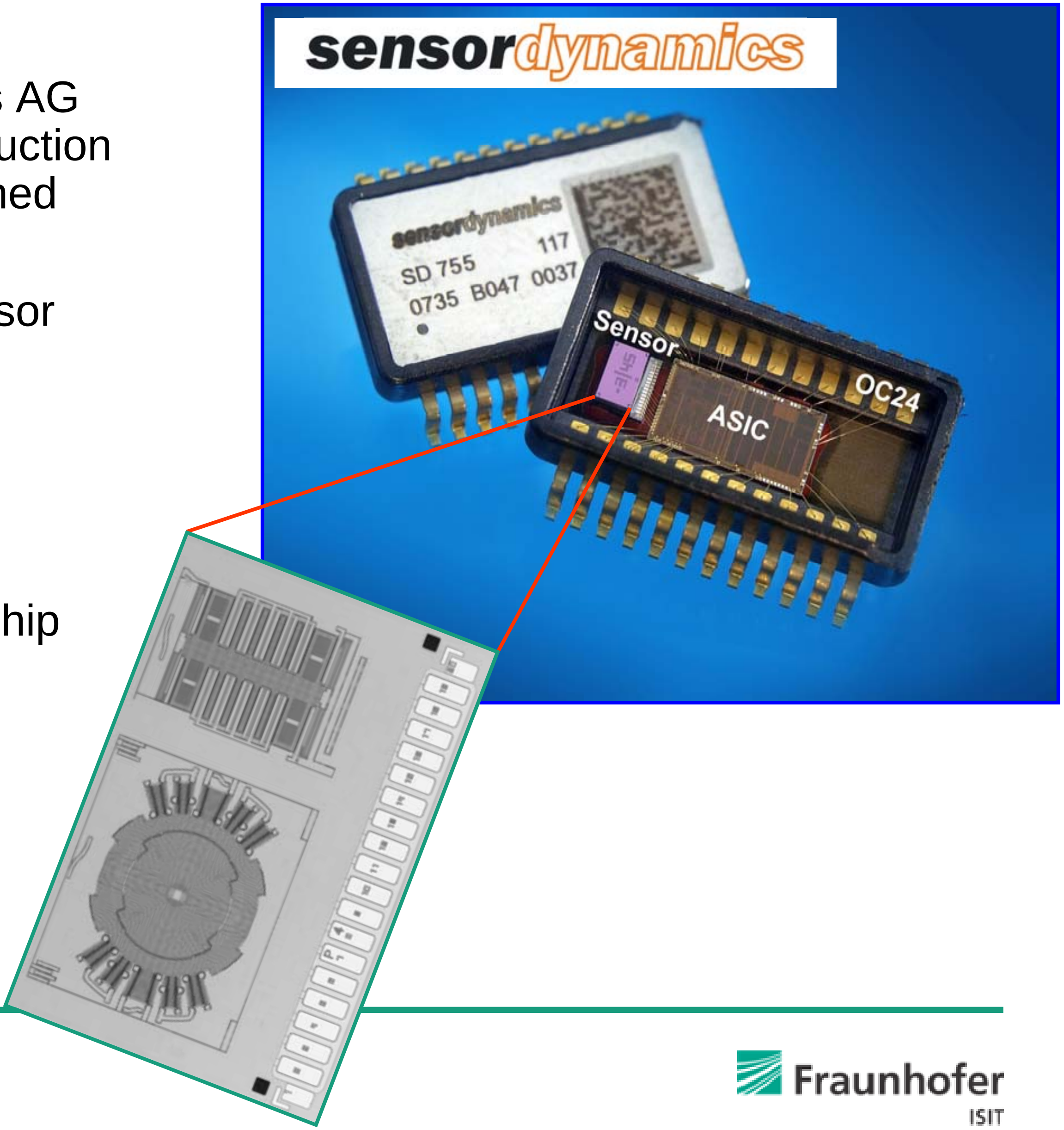
- Getter sorption rate: $k = C / t_{PGA}$ [mole/s/mm^2]
- $k(T) = k_0 \exp^{(-E/RT)}$

For SAES PaGe Film

- k_0= 92300 mole/s/mm^2
- E = 225’000 J/mole (Integral Sorption Activation Energy)

Application of Dual Pressure WLP

- Fraunhofer ISIT and the company SensorDynamics AG developed together a production ready solution for a combined MEMS sensor chip.
- The combined MEMS Sensor chip integrates one accelerometer and one gyrometer.
- The OC24 housing of the SD755 sensor includes a combined MEMS Sensor chip and an ASIC.



Application of Dual Pressure WLP

- Perforemance data of combi sensor SD755 from sensordynamics

Parameter	Gyrometer	Accelerometer
Measurement range 1	±100 °/s	±2 g
Measurement range 2	±300 °/s	±5 g
Resolution of range 1	0,0039 °/s/bit	207,15 µg/LSB
Resolution of range 2	0,0156 °/s/bit	414,2 µg/LSB
Signal to noise (R 1)	<0,1 °/s@25 Hz	<2 mg @40 Hz
Sensitivity error	±2 %	±2,5 %
Linearity error	±0,2 % FS	±0,2 % FS
Offset error @25°C incl. aging	0,5 °/s	0,03 g
Cross sensitivity against acceler.	0,1 °/s/g	2 %
Shock stability in use	1500 g	
Temperature range	-40 °C to +125 °C	
Interface	SPI	

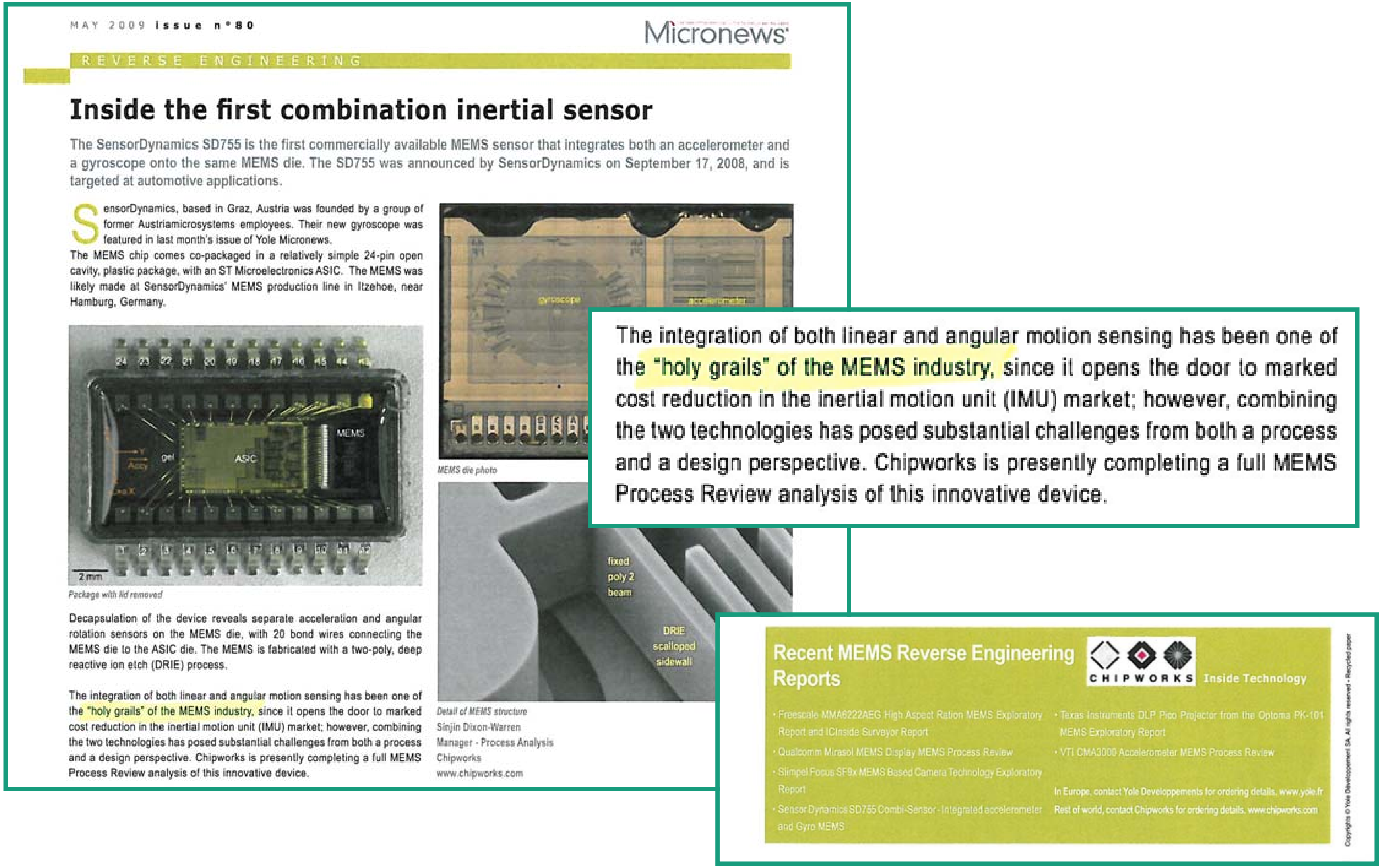
Application of Dual Pressure WLP

Next steps

- Monolithic 6 DOF IMU Sensor = 3x Accel. + 3x Gyro
- Monolithic 9 DOF IMU Sensor = 3x Accel. + 3x Gyro + 3x Magnetometer

- Different pressure levels may be used for the combination of several sensor and/or actuator types:
  - Accelerometer
  - Gyrometer
  - Magnetometer
  - Energy Harvester
  - Si-Clocks
  - Bolometer
  - RF MEMS
  - µMirror scanner

Summary



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Micronews

REVERSE ENGINEERING

Inside the first combination inertial sensor

The SensorDynamics SD755 is the first commercially available MEMS sensor that integrates both an accelerometer and a gyroscope onto the same MEMS die. The SD755 was announced by SensorDynamics on September 17, 2008, and is targeted at automotive applications.

SensorDynamics, based in Graz, Austria was founded by a group of former Austriamicrosystems employees. Their new gyroscope was featured in last month's issue of Yole Micronews.

The MEMS chip comes co-packaged in a relatively simple 24-pin open cavity, plastic package, with an ST Microelectronics ASIC. The MEMS was likely made at SensorDynamics' MEMS production line in Itzehoe, near Hamburg, Germany.

Package with lid removed

MEMS die photo

Decapsulation of the device reveals separate acceleration and angular rotation sensors on the MEMS die, with 20 bond wires connecting the MEMS die to the ASIC die. The MEMS is fabricated with a two-poly, deep reactive ion etch (DRIE) process.

Detail of MEMS structure

The integration of both linear and angular motion sensing has been one of the "holy grails" of the MEMS industry, since it opens the door to marked cost reduction in the inertial motion unit (IMU) market; however, combining the two technologies has posed substantial challenges from both a process and a design perspective. Chipworks is presently completing a full MEMS Process Review analysis of this innovative device.

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Manager - Process Analysis
Chipworks
www.chipworks.com

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Summary

- Introduction of a novel Multi Pressure Wafer Level Packaging Concept

- Feasability shown on PSM-X2 process platform
  - Combination of low pressure gyro and high pressure accelerometer
  - Cavity Pressure Ratio up to 1:400 achieved
  - Main limiting factor is total getter sorption capacity

- Getter Sorption Performance: Simple Test Method (Area Variation)
  - Extraction of Sorption Capacity, Rate and Activation Energy for SAES PaGe

- This process strategy results in a very compact chip size for dual pressure sensorelements

- First monolithic Inertial Combi Sensor using this technology is available on the market