Short-cycle Industrialisation of MEMS inertial sensors

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Outline

- Introduction
- Itzehoe site
- Partners at Itzehoe site
- Research and Production at one Location
- Production Process Platform PSM-X2
- Available products
- Summary

Introduction

- MEMS has reached an excellent state within technology development and economic utilization.
- This success based on a good cooperation between research institutes and producing companies.
- At Itzehoe site a close network has been established between a research institute and producing companies.

Itzehoe site

- Built 1995
- Initial Investment: 125 Mio. €
- Investment till 2010: >270 Mio. €

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Itzehoe site

Wafer-Fab at Itzehoe site

- 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 for 200 mm wafer on 500 m² Clean Room Area
- Chemical Mechanical Polishing (CMP) on 200 m² Clean Room Area
- Different Research Laboratories on 1500 m²
- Pilot Production Line for Lithium Polymer Accumulators

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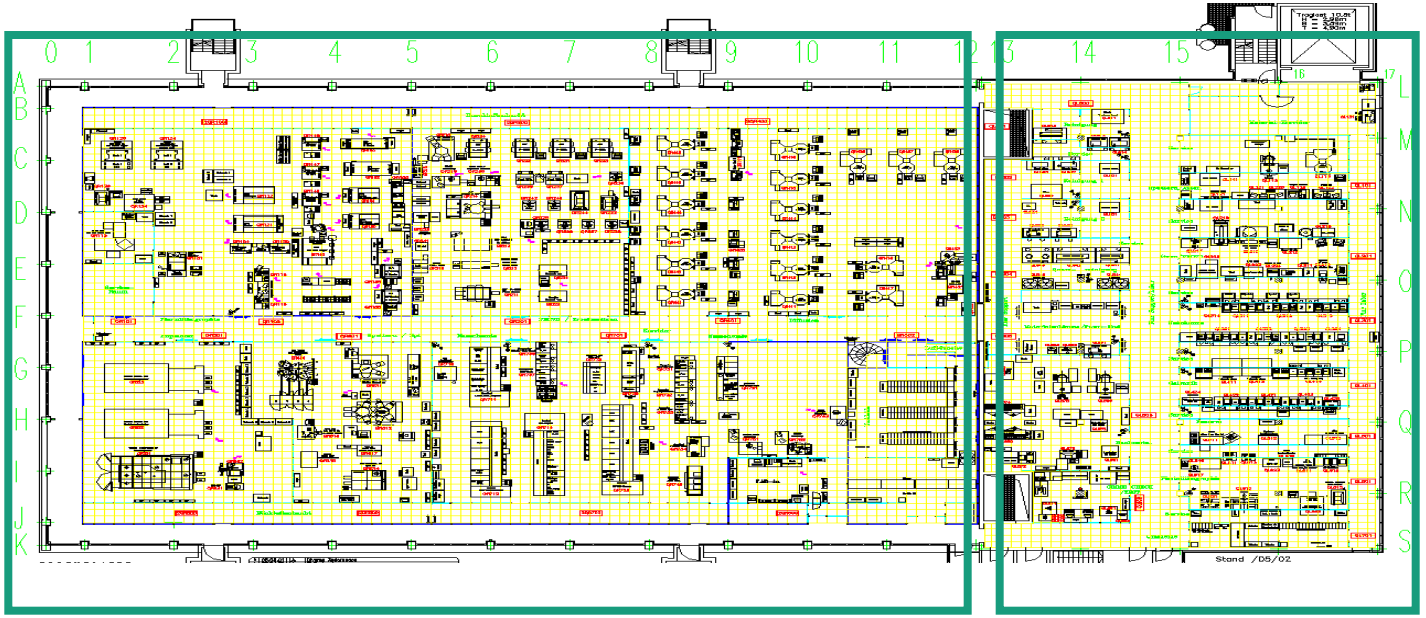
Itzehoe site

Facilities and Equipment Fab Layout / Dual Use Concept

- IC+ MEMS cleanroom
  - Production of Power and MEMS Devices (VSIG)
  - Development of MEMS Devices (ISIT)
- MEMS cleanroom
  - Production of MEMS Devices (SD + MFI)
  - Development of MEMS Devices (ISIT)



IC + MEMS cleanroom **MEMS cleamroom**

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Itzehoe site

Manufacturing control system

- Lot tracking by a Production Monitoring and Information System (PROMIS)
- PROMIS has extensive functionality
  - Complete process flow control
  - Traceability according to customer requirements
  - Automatic generation of lot holds if spec limits are violated
  - Task management for maintenance and service
  - Material Handling
  - SPC
  - Dispatching and WIP
  - Real-Time Data Collection and Data Analysis (Process Control Charts)

Itzehoe site

MEMS Process capabilities

Lithography
0,8 µm Widefield Stepper, Proximity Exposure
Front-to-Backside Alignment
Spin Coating, Spray Coating
Positive, Negative Dry Film, Thick Resist

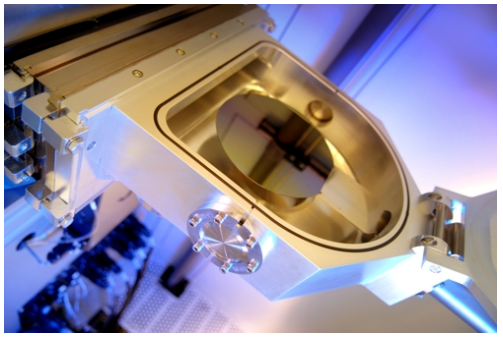
Wafer Level Packaging
Eutectic, Solder Alloy, Anodic Bonding
Glass Frit, Fusion Bonding
High Capacity Getter Films for Vacuum WLP
Optical WLP, Glass Micromachining

Film Deposition
SiO2 and LPCVD Si3N4
PECVD SiO2 and Si3N4, α-Si, up to 550 °C
Thick Epi Poly Silicon (10 – 100 µm), SiGe
Piezoelectric Layers: AlN, PZT
Sputter Metal: Al, Mo, Ti, TiN, Cr, Au, Ta, Cu
Evaporation Metal: Ti, Ta, Au, Pt, Ir, Ag
Electroplating: Au, Sn, Cu, Ni

Etching
RIE: Si, SiO2, SiN, AlN, PZT
DRIE: High Precision, High Rate
Wet Etch: Si, SiO2, SiN
Metal Etch: Al, Cu, Au, Cr, Ti, Mo
Al-compatible anisotropic Si-Etch
Single Wafer Spin Etching: Cu, Au, Ti, SiO2
Vapour Phase Etch: HF, XeF2

Surface Functionality
Chemical Mechanical Polishing
Organic and Anorganic Anti-Stiction Coatings
Surface Hardening
Anti Reflective Coatings

Postprocessing & Analysis
Dicing, Grinding, DBG, Wafertest
Reliability Device Qualification (AEC-Q100)
Shock&Vibration, High-g CA, Fatigue Testing
Failure Analysis, SEM, XRay, SAM, ...



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Partners at Itzehoe site

Fraunhofer Institute für Siliziumtechnolohgie (ISIT)

- Research and Development-Center for Microelectronics and Microsystems Technology
- Non profit organisation
- In Itzehoe since 1995
- Employees: 150
- Certified: ISO 9001:2000

- Managing Director:

  Prof. Wolfgang Benecke

  Deputy Directors: Dr. Wolfgang Windbrake / Dr. Bernd Wagner

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Partners at Itzehoe site

Vishay Siliconix Itzehoe GmbH (VSIG)

- Production of so-called PowerMOS transistors. These are special power transistors which are required in computers, mobile phones, automobiles, fixed network telecommunications, and in many other applications in industry electronics.
- Production: About 200.000 8-inch wafers per year in conti shifts
- Head count: about 180
- Founding year: 1996 as TEMIC Semiconductor Itzehoe GmbH,
  since 1998 part of the business division of Vishay Siliconix
- Director: Martin Schneider

Partners at Itzehoe site

SensorDynamics AG (SD)

- Company for automotive, industry & high-end consumer market
- Product Groups:
  - IMSS (Inertial MicroSensor Systems) - ESP, GPS, Toys,..
  - WISE (WIreless SEnsors) - Keyless Go, Energy Harvesting,...
  - ISIF (Intelligent Sensor InterFaces) – I/O for Macro Sensors
- Start of Operation: 2003
- Manpower: 120
- Locations: Graz/Austria, Pisa/Italy, Itzehoe/Germany

- CEO: Hubertus Christ

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Partners at Itzehoe site

MEMS Foundry Itzehoe GmbH (MFI)

- Foundry for Microsystems Technology Production
- Founded in 2009
- Spin-Off Enterprise of Fraunhofer
- Head Count End 2010: 10
- SOP 01.05.2010
- Est. Wafer Volume 2010: 6000 Wafer
- ISO 9001-2008 Certification by 09/2010

- CEO: Dr. Peter Merz

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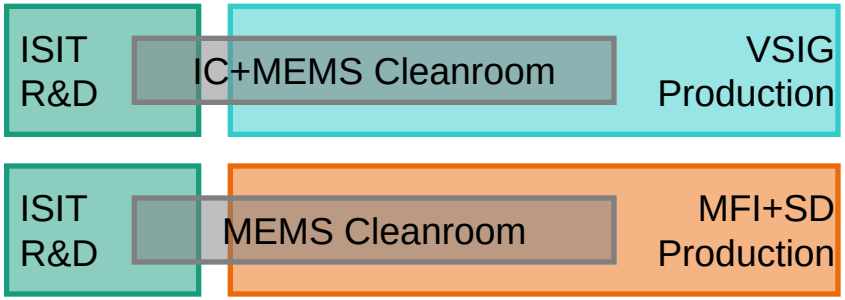
Research and Production at one Location

Common Clean room usage



Benefit

- Qualified production processes available for R&D

Common Equipment usage

Benefit

- Efficient usage of equipments
- No process transfer to external equipment for transfer to production

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Research and Production at one Location

Common Equipment Ownership

Benefit

- No risk for buying unproved equipment by production partners
- Parallel equipment makes R&D cycletime more confident

Using production processes in R&D process flows

Benefit

- Shortens turn around time for R&D flows due to operator processing

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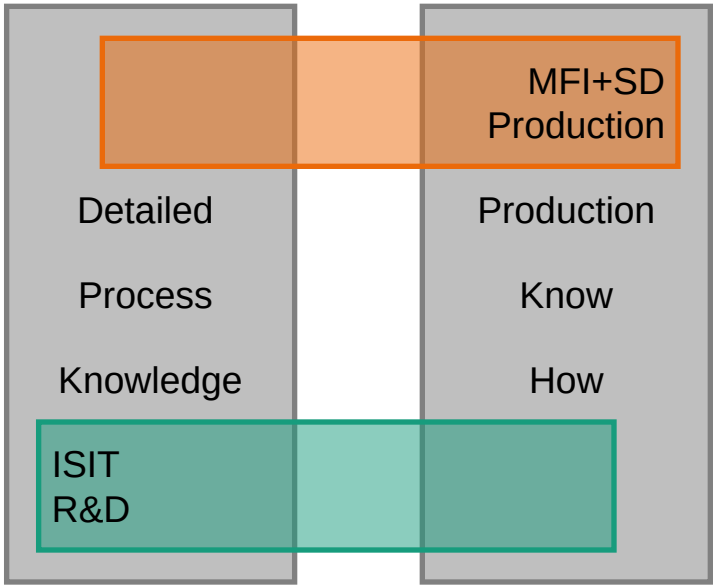
Research and Production at one Location

Close neighborhood of R&D team and production team



Benefit

- FARs* are done with deep process know how of R&D people

  *Failure Analysis Request

- Process development done already regarding production aspects

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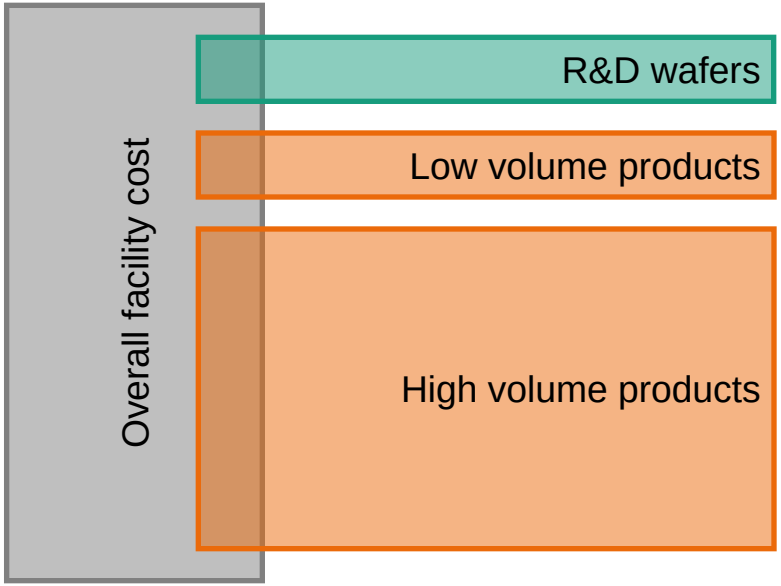
Research and Production at one Location

Cost of ownership of a state of the art process line



Benefit

- Low cost for R&D lots using a state of the art process line
- Low cost for low volume products for niche markets

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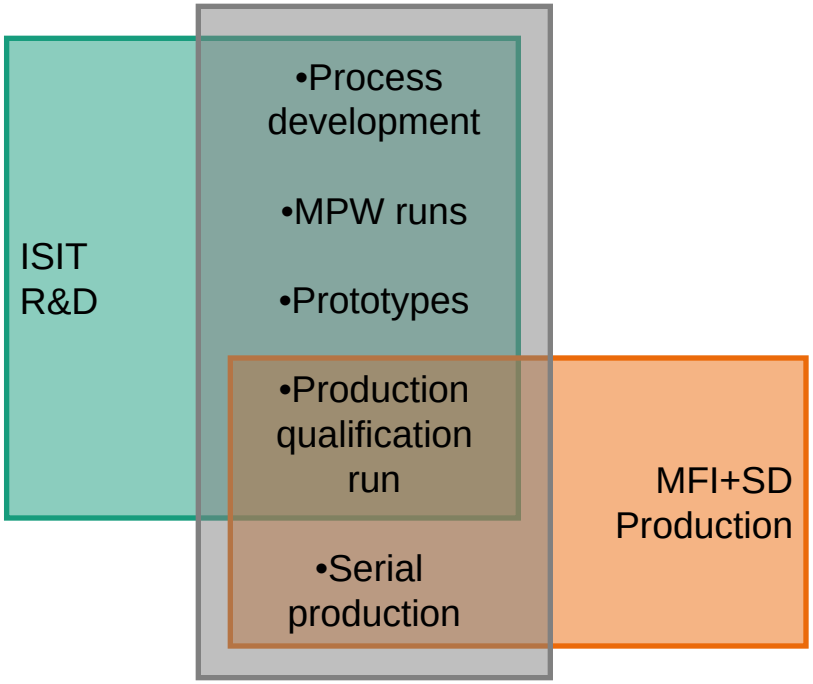
Research and Production at one Location

Introduction of a new product



Benefit

- Short cycling time from first product idea to serial production

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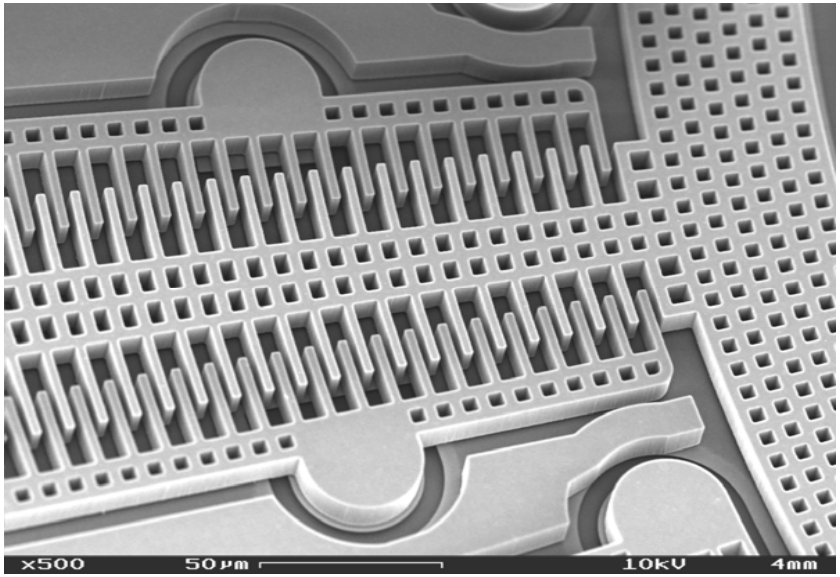
Production Process Platform PSM-X2

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

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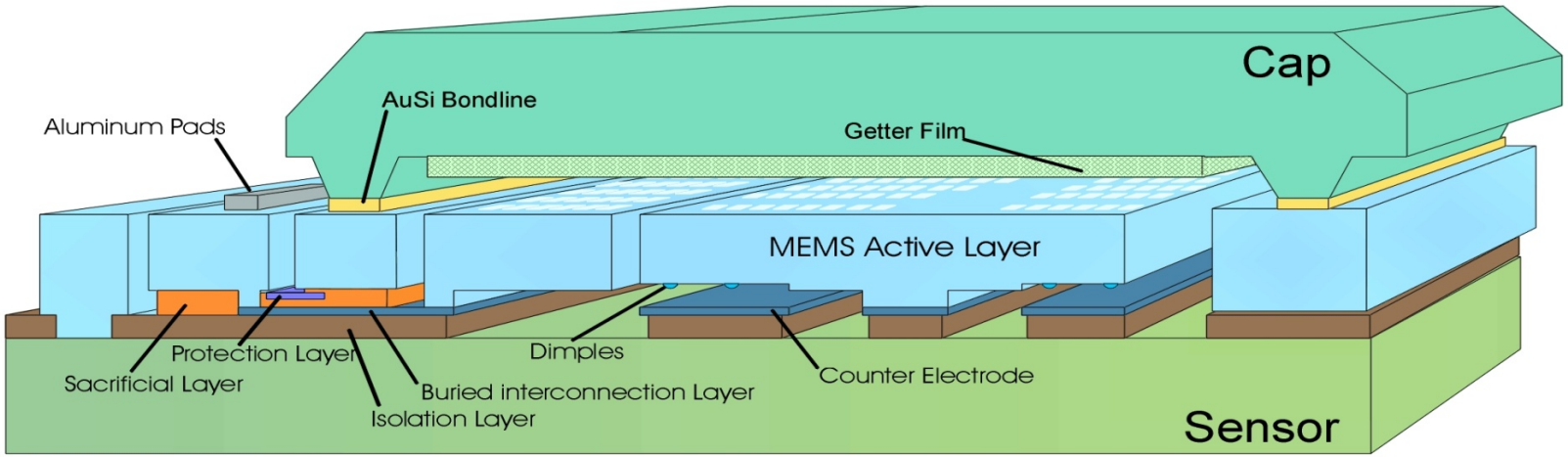
Production Process Platform PSM-X2



- 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)

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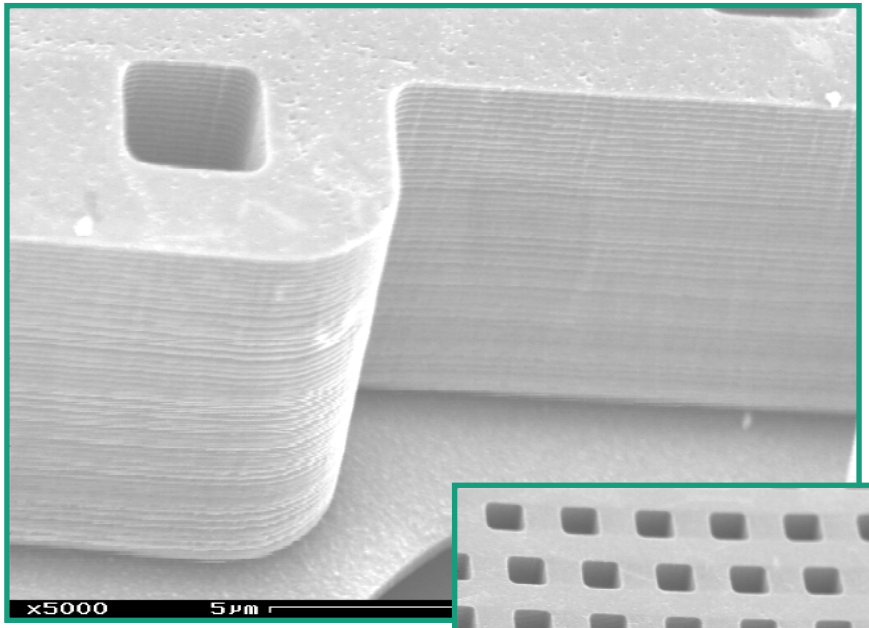
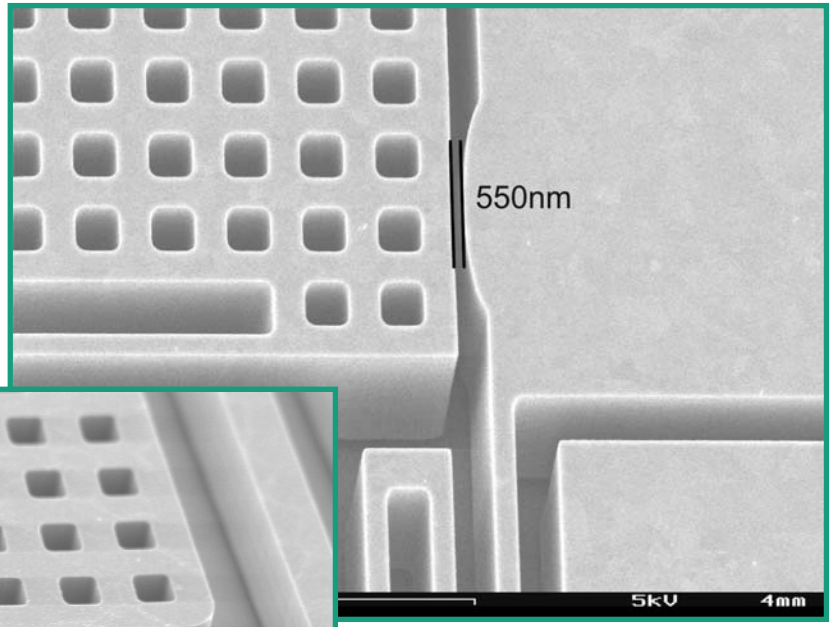
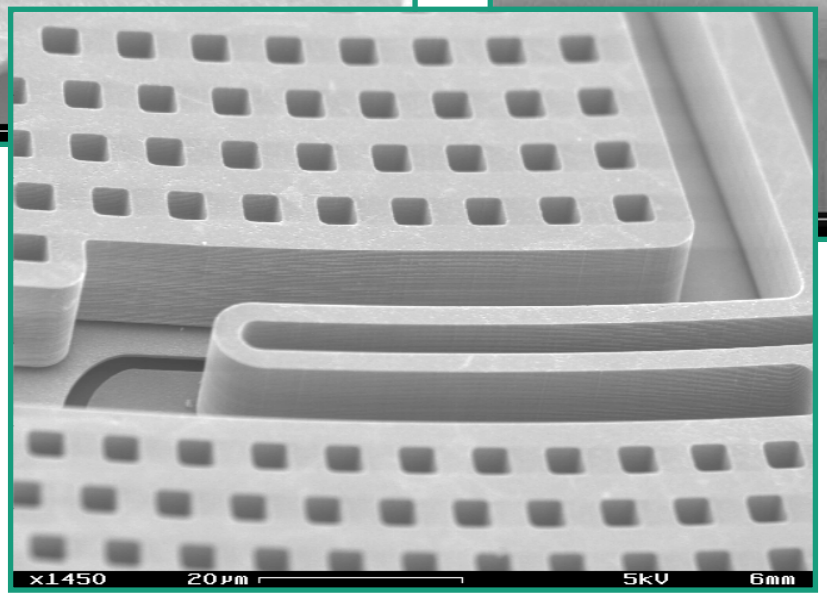
Production Process Platform PSM-X2







Details of
thick epi layer
after
DRIE and HF release

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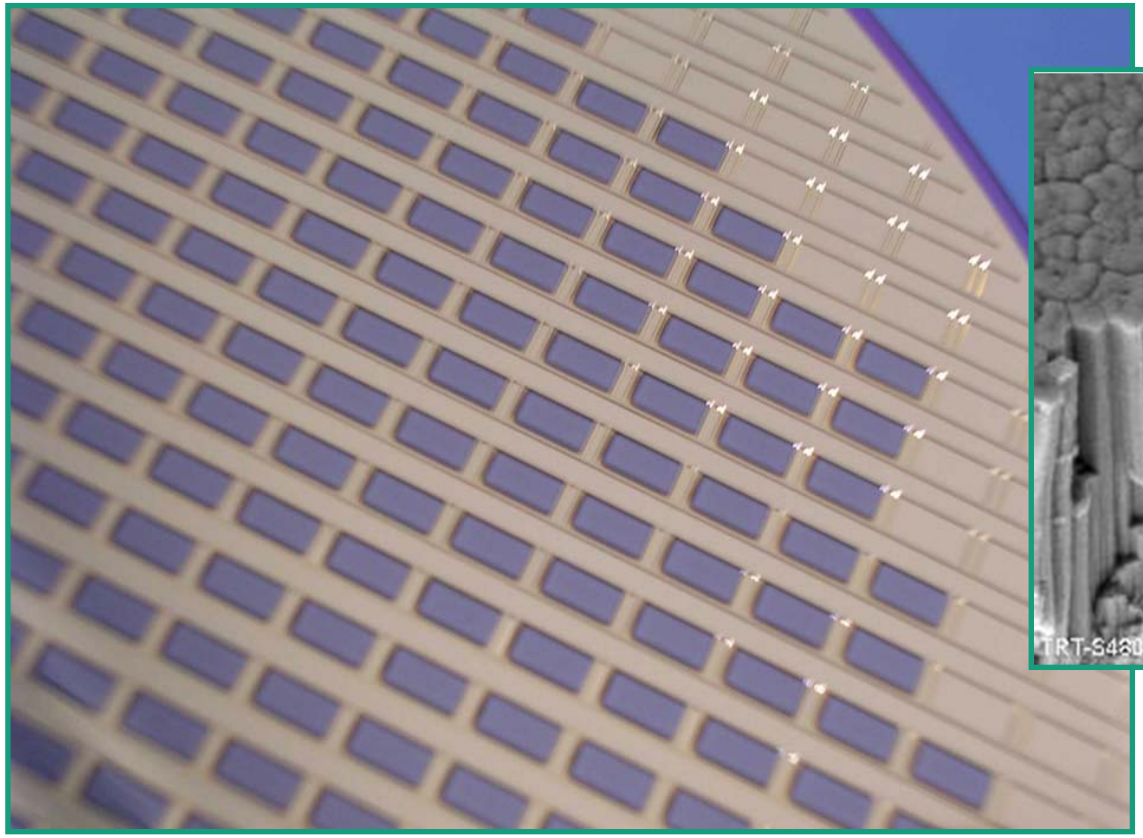
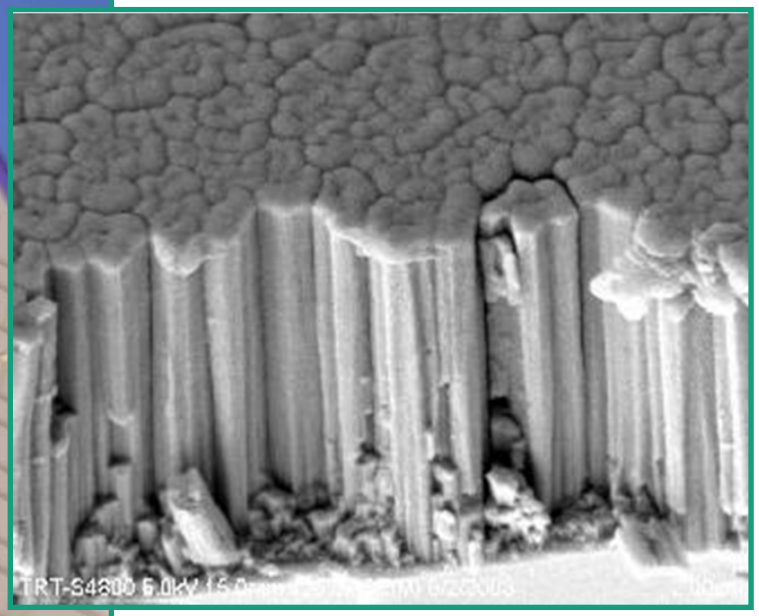
Production Process Platform PSM-X2



PMS-X2 Cap Wafer



SAES PaGeWafer Getter Film

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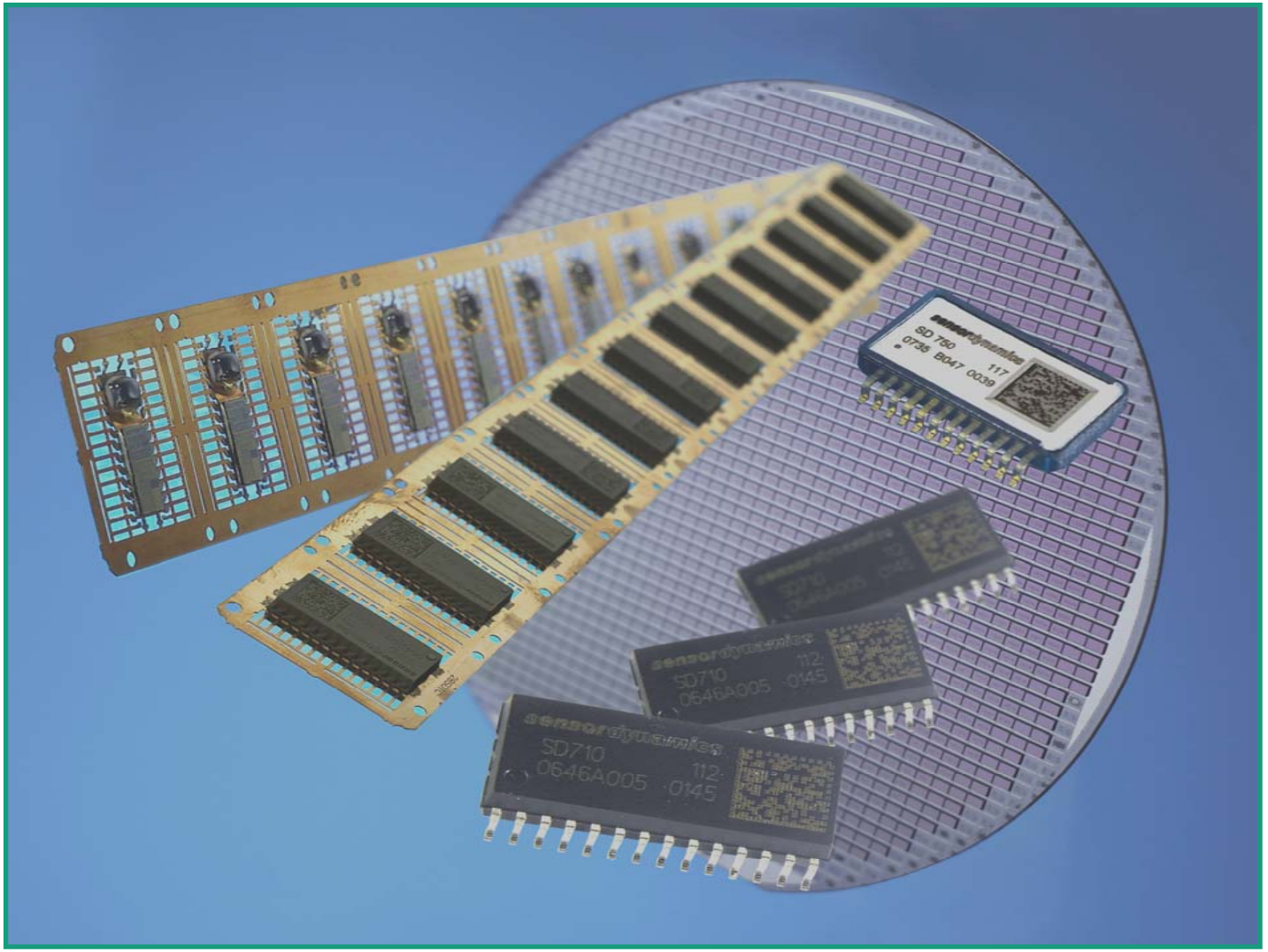
Production Process Platform PSM-X2



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Production Process Platform PSM-X2

AEC Q100 Qualification

Detailed overview of AEC-Q100 stress tests along with sample size, test conditions, reference to applicable standards and read-out points for performance tests, which were applied and relevant for the qualification.

→ All tests are passed

Stress Test	ABV	#	Sample size	Sample type	Method / Conditions	Readout Points
TEST GROUP A						
Temperature-Humidity-Bias	THB	A2	60	Sensor	JESD22-A101 / +85°C, 85% RH, biased (shirp)	@ 500 hrs, end of test (1000 hrs)
Autoclave	AC	A3	77	Sensor	JESD22-A102 / +121°C, 2bar, 100% RH, unbiased	end of test (96 hrs)
Temperature Cycling	TC	A4	77	Sensor	JESD22-A104 & App. 3, Grade 1 / -50°C to +150°C, unbiased	@ 500 cycles, end of test (1000 cycles)
High Temperature Storage Life	HTSL	A6	1	Wafer	JESD22-A103, Grade 1 / +150°C, unbiased	@ 500 hrs, end of test (1000 hrs)
TEST GROUP B						
Neon Bombing Test after stress of THB	NBT2		45	Sensor	Ne, 3bar	end of test (96 hrs)
Cap Shear Test after Stress	CAPS2	DS	45	Sensor		none
TEST GROUP C						
Neon Bombing Test	NBT		2	Wafer	Ne, 3bar	end of test (96 hrs)
Cap Shear Test	CAPS1	DS	50	Sensor		none
Ball Shear Test	BALLS	C5	10	Sensor	AEC Q100-010	none
Physical Dimensions	PD	C4	10		JESD22-B100 / B108	none
TEST GROUP E						
Pre- and Post-Stress Function/Parameter Test on Sensor Level	TEST1	E1	Acc. test		to supplier data sheet or user specification	@ all stress test readout points
Pre- and Post-Stress Function/Parameter Test on Wafer Level	TEST2	E8	Acc. test		to supplier data sheet or user specification	@ all stress test readout points
Electrical Distributions	ED	E5	all		AEC Q100-009	None
Characterization	CHAR	E7	all		Acc. Limits	None
TEST GROUP F						
Process Average Testing	PAT	F1	all		Reject units outside limits with +/- 6 sigma	None
Statistical Bin/Yield Analysis	SBA	F2	all		Reject units outside criteria	None
TEST GROUP G						
Constant Acceleration	CA	G3	10	Sensor	30.000g / 1min / -Z direction	end of test
Die Strength Test	DST		20	Sensor	90 bar oil pressure / RT / 1h	None

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Available products of sensordynamics

PRODUCT NAME	SD70x	SD721	SD755	SD77x/ 78x	6DoF
	1D gyroscope	1D gyroscope	1D gyroscope+ 1D accelerometer	1D gyroscope+ 3Daccelerometer	IMU
Special features	const. self diagnosis	fail-safe, automotive	fail-safe, automotive	fail-safe, automotive	6DoF IMU on PCB
Temperature operating range [°C]	-40 / +85	-40 / +125	-40 / +125	-40 / +125	-40 / +85
Package	QFN40	SOIC28	OC24	OC24	n.a.
Interface	SPI	SPI	SPI	SPI	
Supply voltage [V]	3.3 or 5.0	5.0	5.0	3.3 or 5.0	
Gyroscope axes	X or Z	X	X	X or Z	X,Y,Z
Dual gyroscope measurement ranges	yes	yes	yes	yes	yes
Gyroscope calibrated measurement range(s)	±100 & ±300	±100 & ±300	±100 & ±300	±100 & ±300	±100 & ±300
Gyroscope measurement range(s)	±128 & ±512	±128 & ±512	±128 & ±512	±128 & ±512	±128 & ±512
Gyroscope maximum RMS noise [°/s]	0.3 & 0.8	0.3 & 0.8	0.13 & 0.2	0.1 & 0.2	0.1 & 0.2
Gyrocope total error including temperature drift & aging [°/s]	±5	±2	±2	±2	±2
Gyroscope default b&width [Hz]	10 & 75	40 & 75	40 & 75	40 & 75	40 & 75
Dual accelerometer measurement ranges	-	-	yes	no	no
Accelerometer axes	-	-	Y	X, Y, Z	X, Y, Z
Accelerometer calibrated measurement range(s) [g]	-	-	±2 & ±5	±2	±2
Accelerometer measurement range(s)	-	-	±6.8 & ±13.6	±6.8	±6.8
Accelerometer maximum RMS noise [mg]	-	-	2 & 3	0.75	0.75
Accelerometer total error incl. temperature drift & aging [g]	-	-	±0.1	±0.1	±0.1
Accelerometer default b&width [Hz]	-	-	40 & 100	40	40

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Summary

- At Itzehoe site a close network has been established between a research institute and producing companies.

- Benefits of Research and Production at one Location
  - Qualified production processes available for R&D
  - No process transfer to external equipment for transfer to production
  - Shortens turn around time for R&D flows due to operator processing
  - Process development done already regarding production aspects
  - Low cost for R&D lots using a state of the art process line
  - Low cost for low volume products for niche markets
  - Short cycling time from first product idea to serial production

- PSM-X2 production process passed all tests of AEC Q100 qualification

- First products are available from Itzehoe site