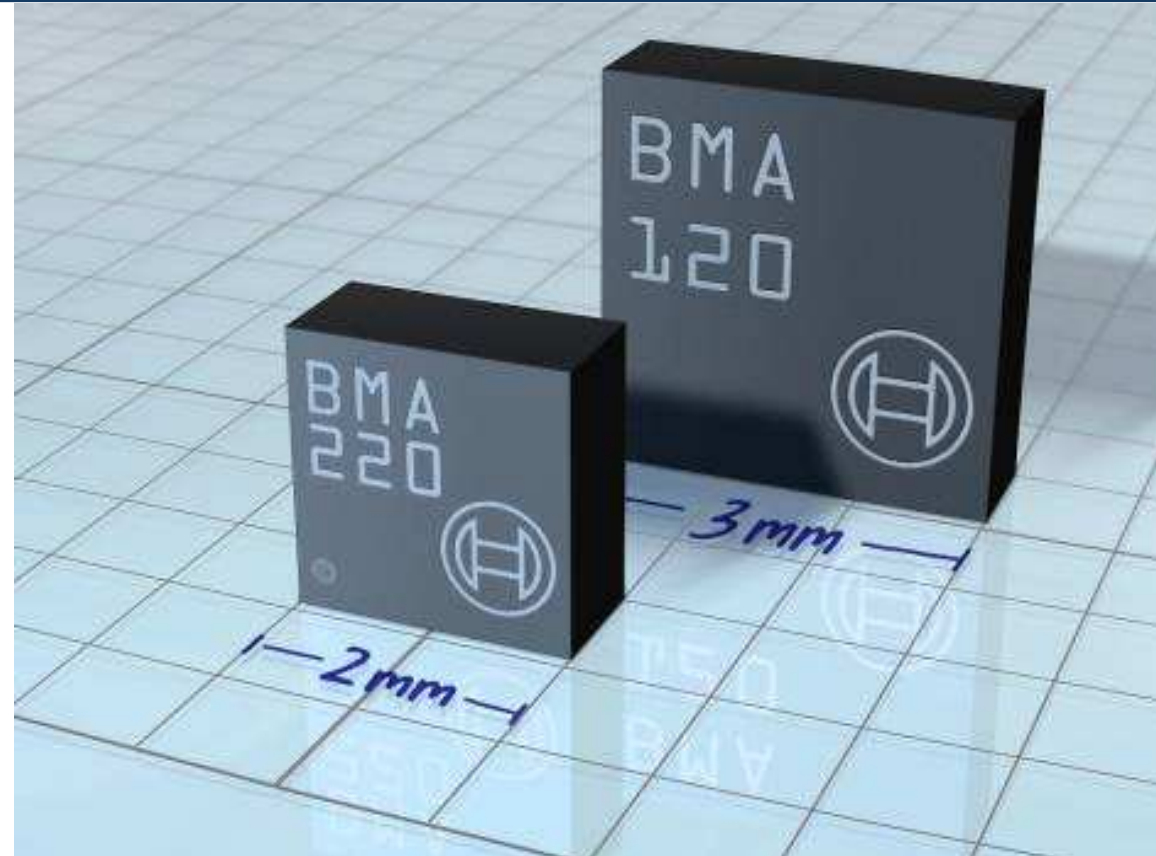


MEMS Sensors: From Automotive to CE Applications



**MicroNanoTec
Forum “Innovations for Industry”
2010 April 19th Hannover, Germany
Oliver Schatz, CTO Bosch Sensortec**

Bosch Sensortec
MEMS sensors
for the mobile world



Bosch Sensortec



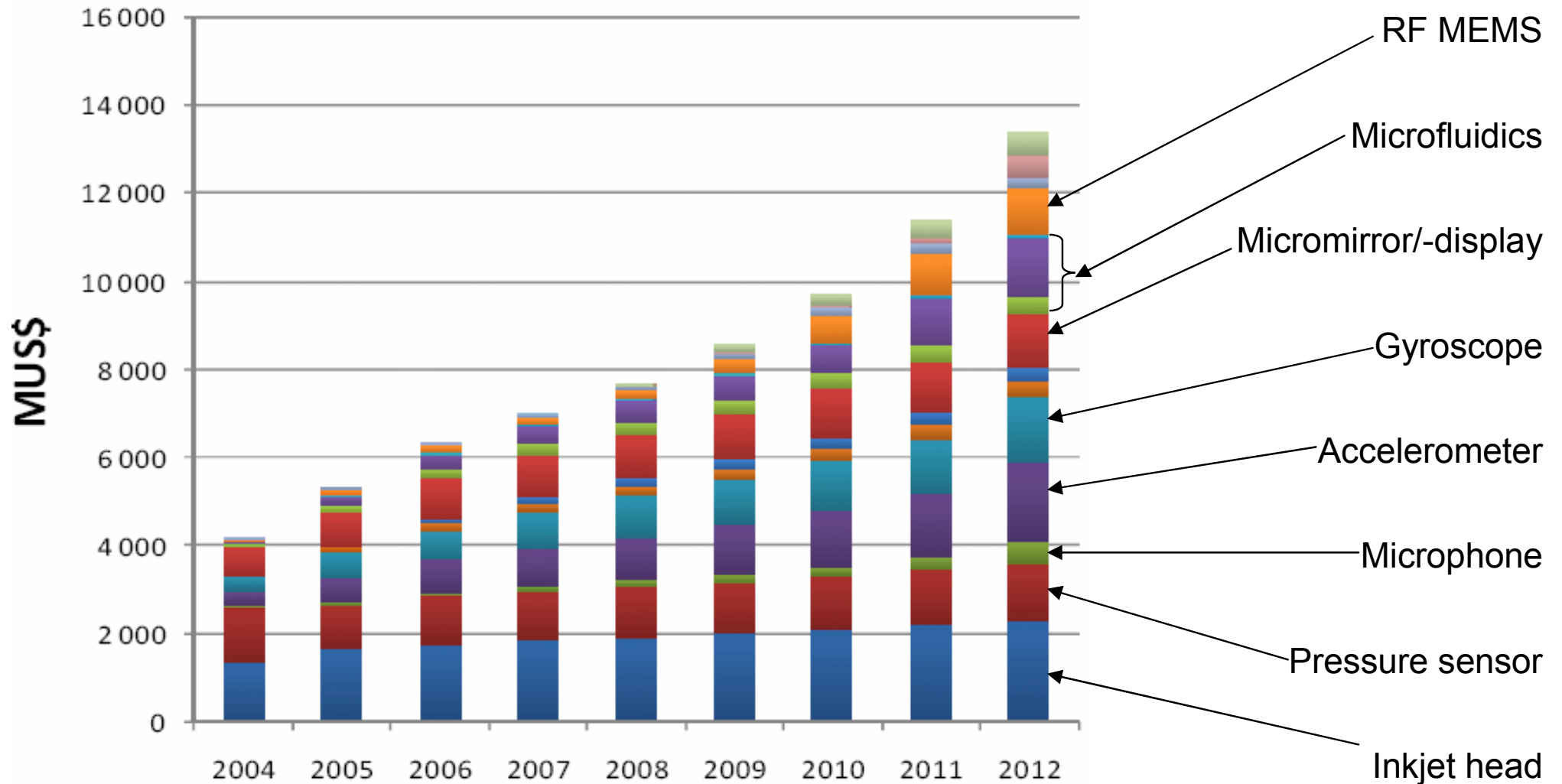
BOSCH

MEMS Sensors: From Automotive to Consumer Electronic Applications

→ Introduction

- Overview technologies
- Function principle and applications of MEMS sensors
- Future trends and applications in Consumer Electronics
- Outlook and summary

MEMS Sensor Market



Source: Yole Développement 2008

Challenges of MEMS (1/2)

→ Dedicated processes and equipment

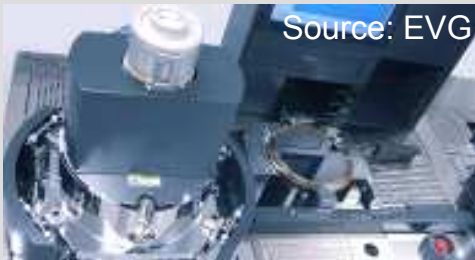


HF vapor etch

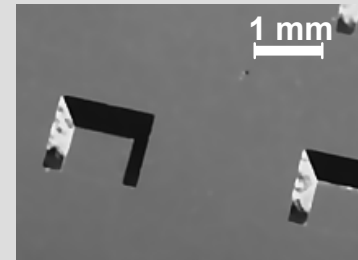


DRIE

→ Processes with contamination risks to ICs

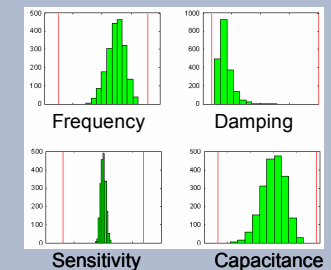
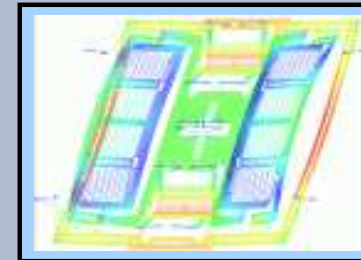
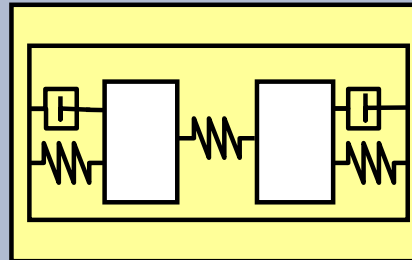
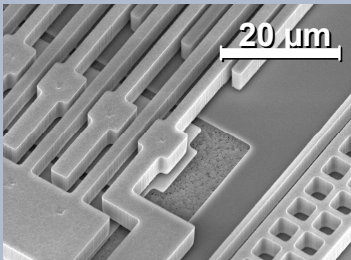


Anodic wafer bonding



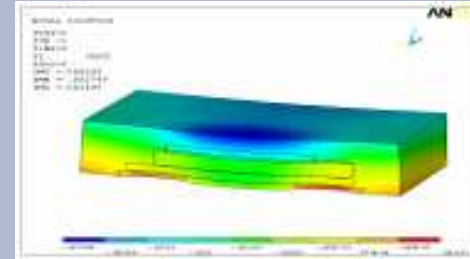
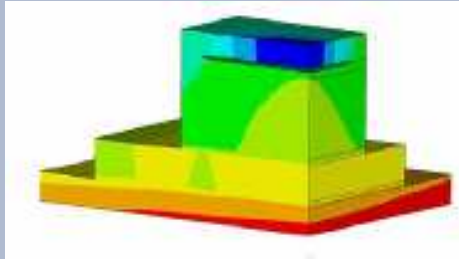
Anisotropic etching (KOH)

→ Combined design and control of mechanical and electrical parameters



Challenges of MEMS (2/2)

→ Controlling the influence of mechanical stress in the package



→ Testing of physical parameters



→ Robustness and media compatibility (e.g. for pressure or flow sensors)



air mass sensor



pressure sensor

Market drivers for MEMS sensors

Automotive applications

1. high functional requirements
(high accuracy, self test, advanced safety concepts)
2. high reliability/quality
(15 years, < 1 ppm, extreme environmental conditions)
3. low price
(< 3 EUR)

Consumer applications

1. small size
(~ 3 x 3 x 0,9 mm³)
2. ultra-low power consumption
(≤ 200 μA)
3. low price
(< 1 EUR)

MEMS Sensors: From Automotive to Consumer Electronic Applications

→ Introduction

→ **Overview technologies**

→ Function principle and applications of MEMS sensors

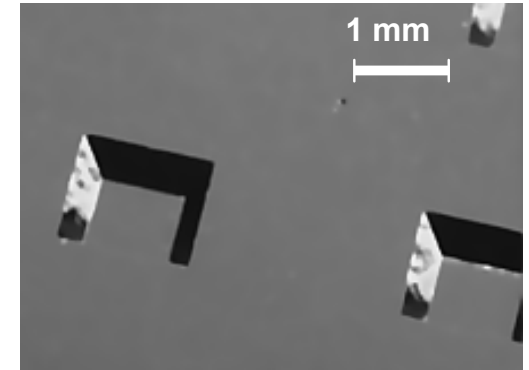
→ Future trends and applications in Consumer Electronics

→ Outlook and summary

Two fundamental ways doing micromachining

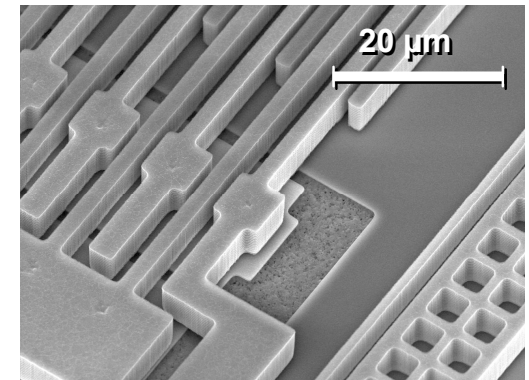
Volume Micromachining

- Building structures through wafer etching
- Structures from mono-crystalline silicon
- Sensor size reduction limited



Surface Micromachining

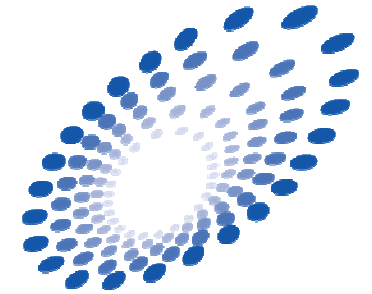
- Structures generated by applying different layers of polysilicon
- Good alignment with standardized semiconductor processes
- Sensor size can be reduced significantly



Surface Micromachining opens up a new world for sensors.

Bosch-team wins German Future Prize of the Federal President 2008

„Smart Sensors for Consumer Electronics, Industrial
and Medical Technologies“



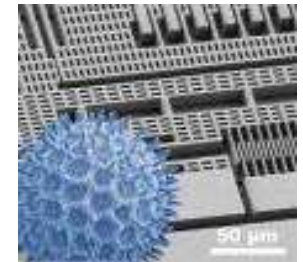
DEUTSCHER ZUKUNFTSPREIS
Preis des Bundespräsidenten
für Technik und Innovation



Surface micromachining – the key

Surface micromachining: Bosch-team develops five new key technologies for series-production.

- Growth of extremely thick layers of polysilicon
- High-precision and fast deep etching - „Bosch process“
- Gas phase etching for release of the structures
- Encapsulation for hermetical sealing
- APSM process – exact vacuum cavities in silicon



Sensors fulfill requirements of consumer electronics

- Sensors considerably smaller and less expensive
- Sensors with less power consumption



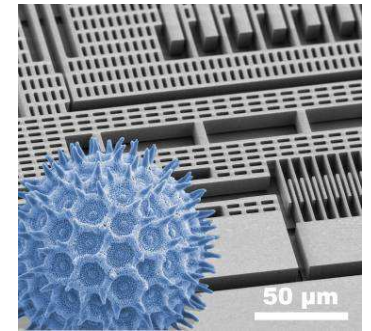
Automotive electronics  Consumer electronics



Surface Micromachining

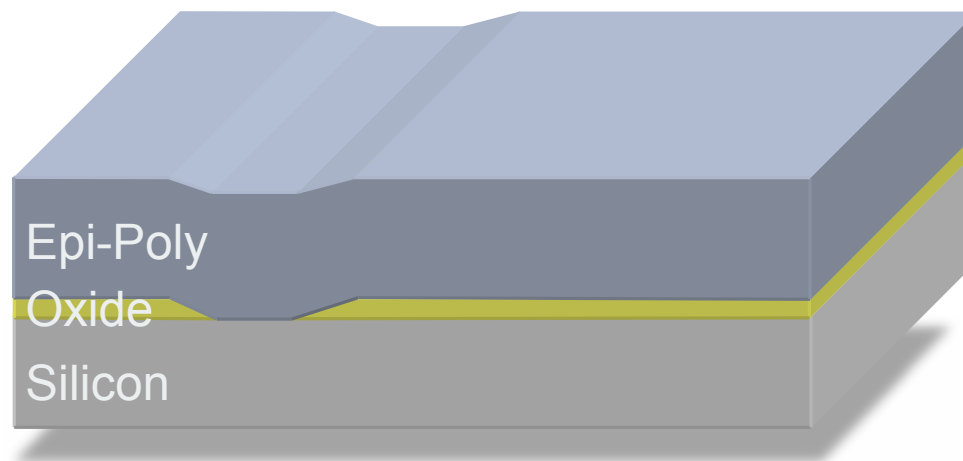
Surface micromachining: Bosch-team develops five new key technologies for series-production

→ Growth of extremely thick layers of polysilicon.



Five Key processes (1/5)

→ Growth of extremely thick layers of polysilicon.

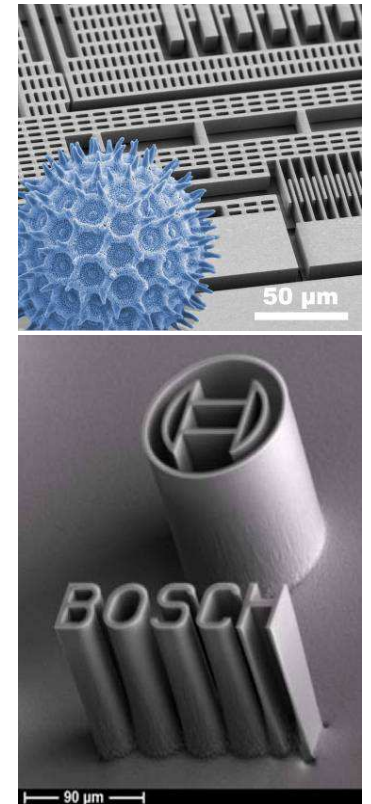


Thickness of structures tailor-made.

Surface Micromachining

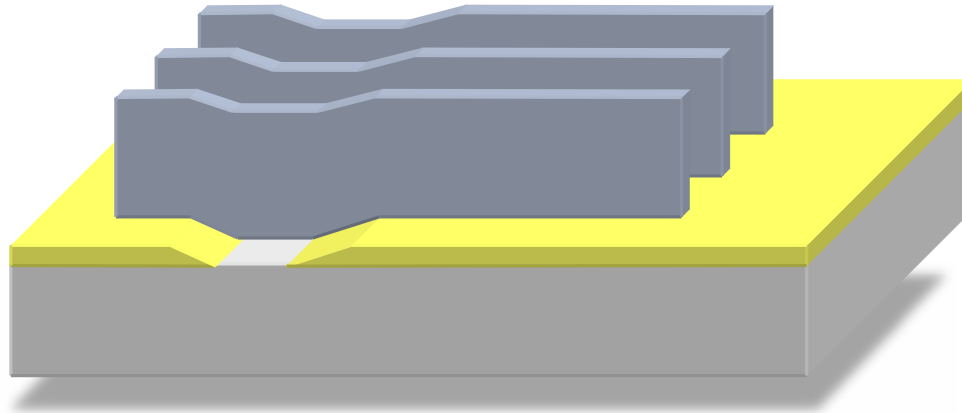
Surface micromachining: Bosch-team develops five new key technologies for series-production

- Growth of extremely thick layers of polysilicon.
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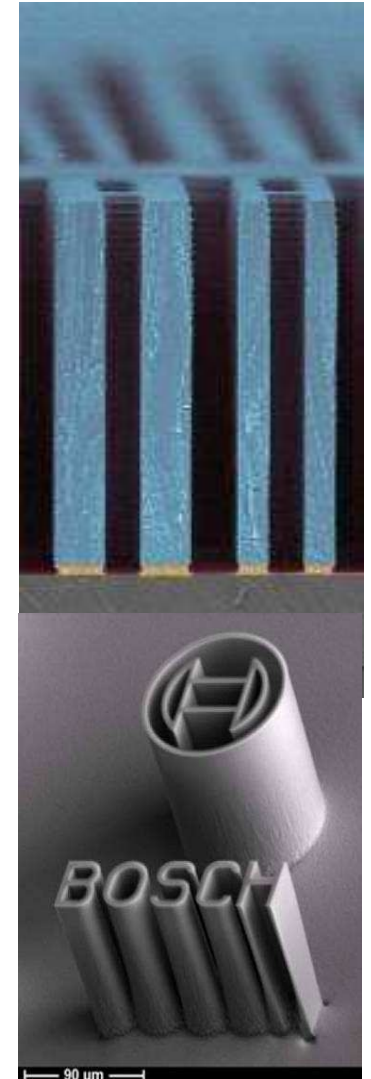


Five key processes (2/5)

- High-precision and fast deep etching („Bosch process“).

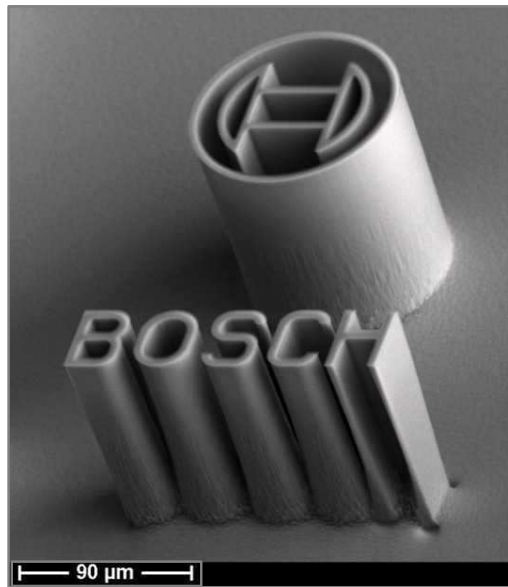


The base process of surface micromachining worldwide



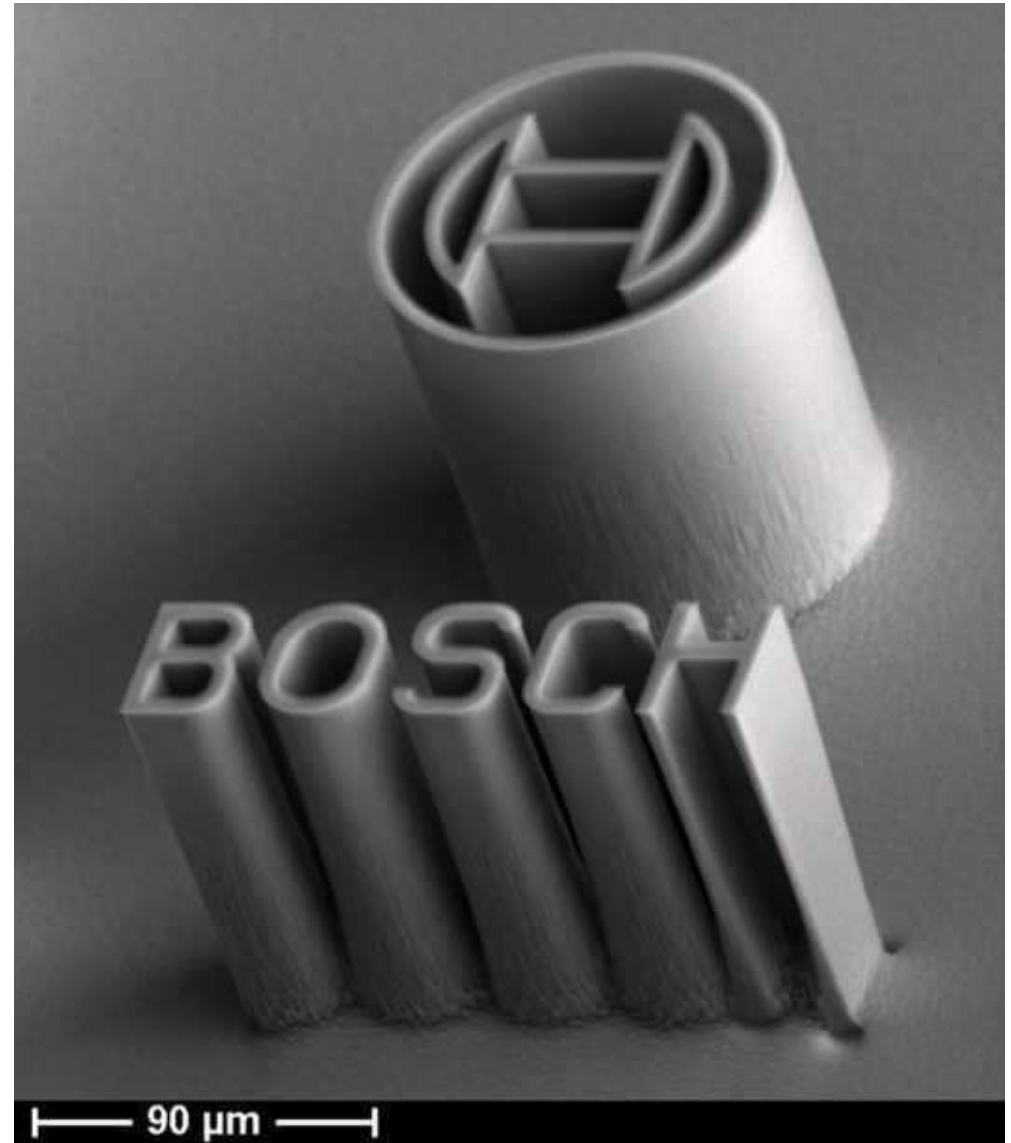
DRIE – The “BOSCH process”

- Deep RIE of silicon trenches
- Licensed to many companies worldwide
- “European Inventor of the Year 2007” Andrea Urban and Dr. Franz Lärmer



DRIE – the BOSCH process

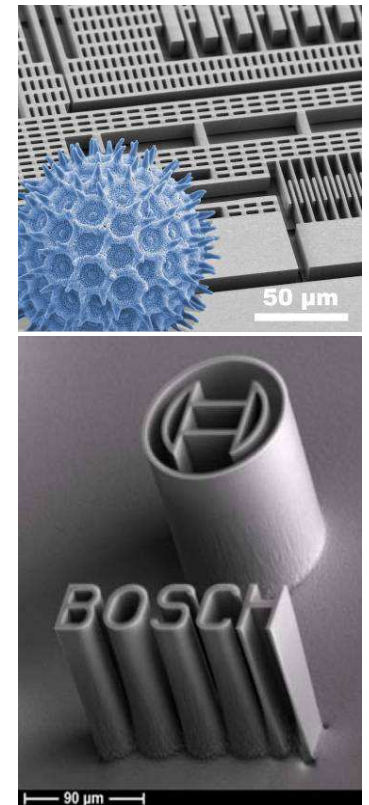
- Deep RIE of silicon trenches
- Alternating etch- (SF_6) and passivation cycles (C_4F_8)
- High aspect ratio ($\gg 10:1$)
- High anisotropy
(underetch $\ll 2\%$ of etch depth)
- High etch rate



Surface Micromachining

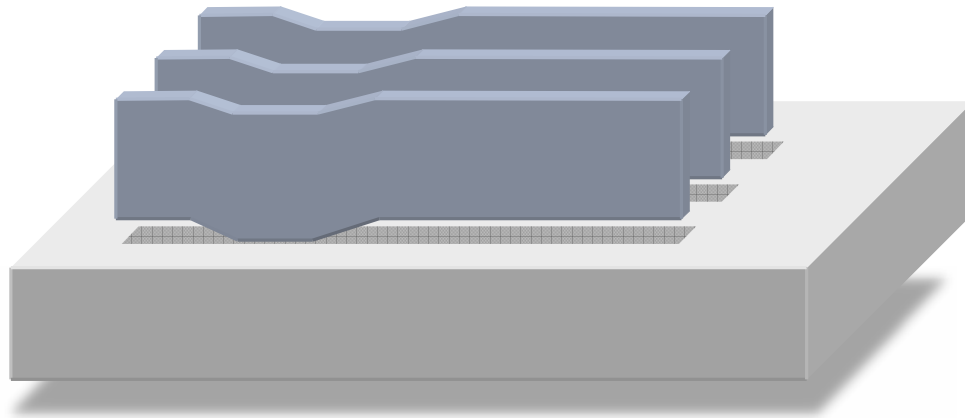
Surface micromachining: Bosch-team develops five new key technologies for series-production

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- Gas phase etching for release of the structures.



Five Key Processes (3/5)

→ Gas phase etching for release of the structures.

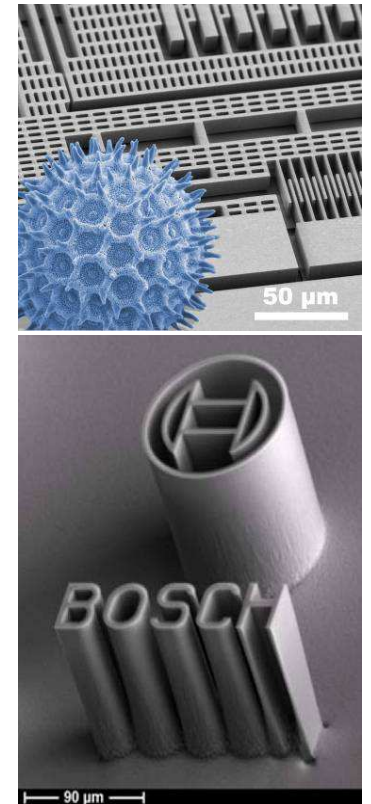


With this process the structures become movable.

Surface Micromachining

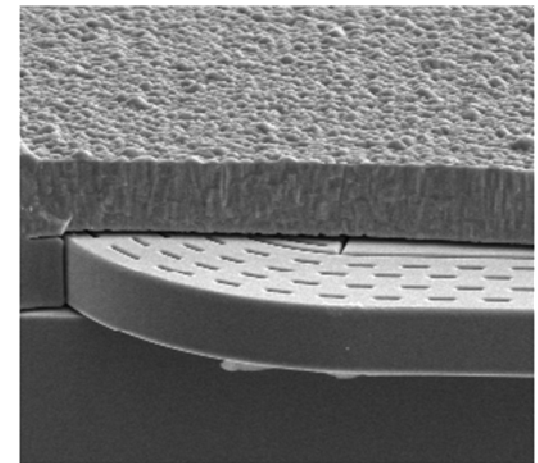
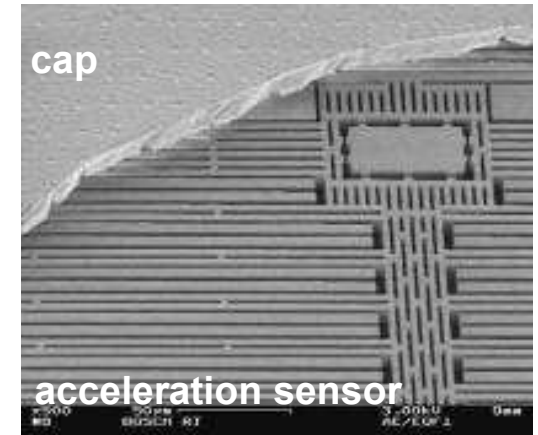
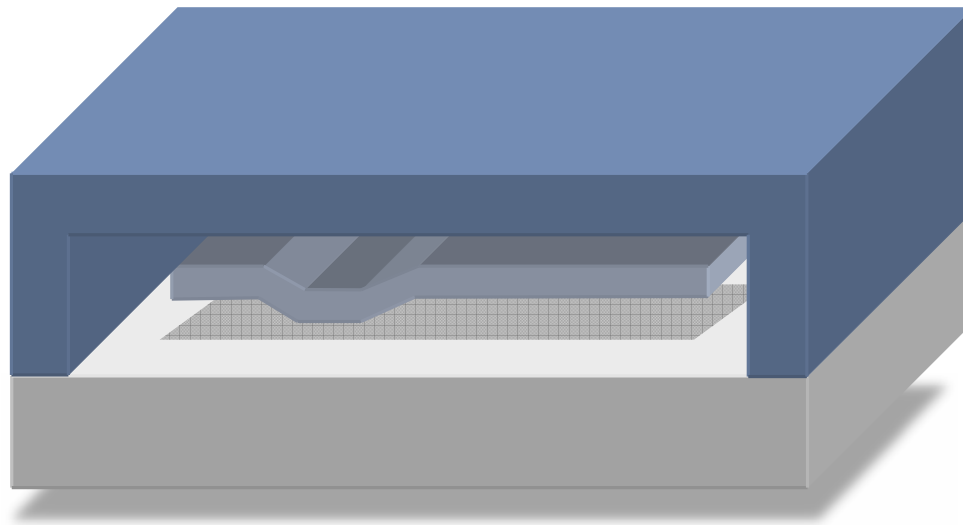
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Five Key Processes (4/5)

→ Encapsulation for hermetical sealing

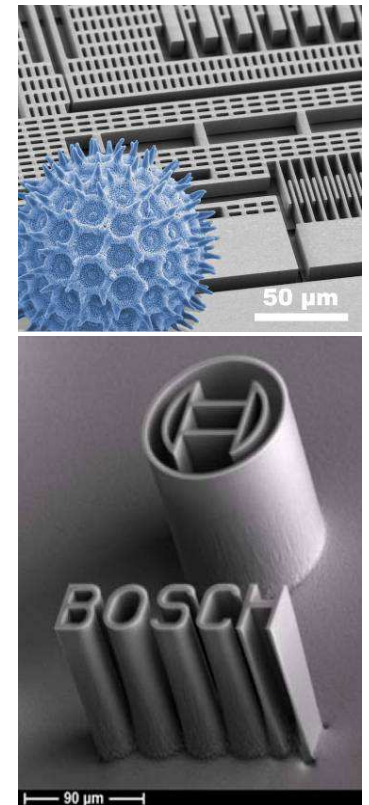


Construction of compact elements

Surface Micromachining

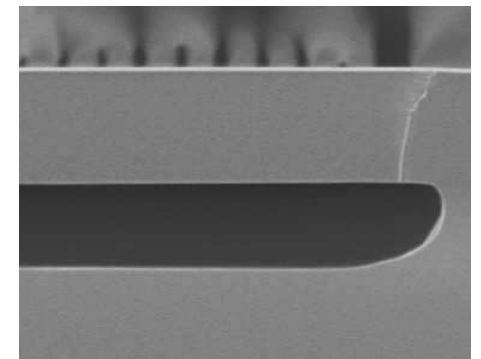
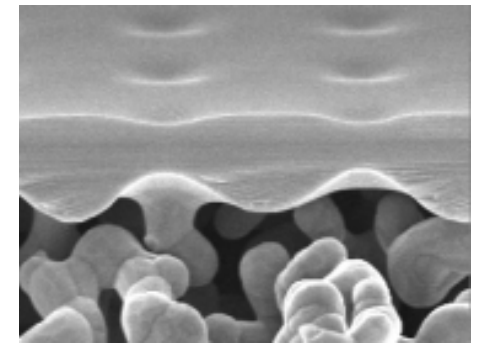
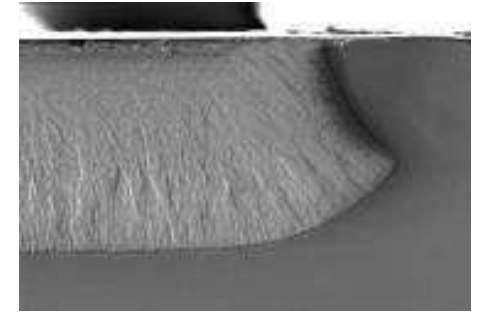
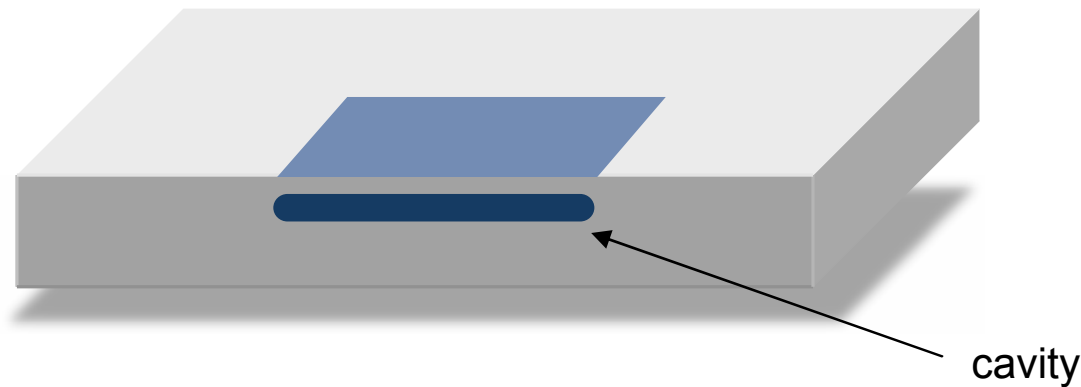
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Five Key Processes (5/5)

→ APSM process – exact vacuum cavities in silicon

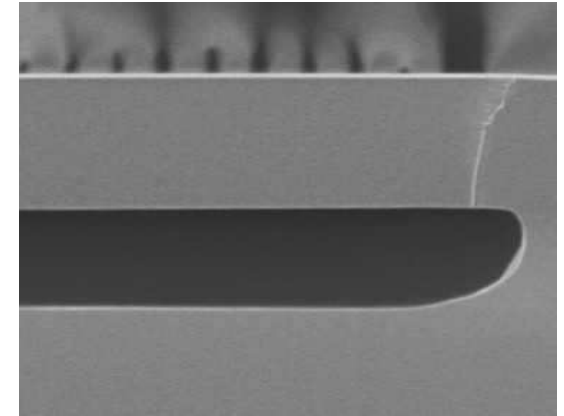


The core of „ASPM process“ is porous silicon

APSM technology advantages

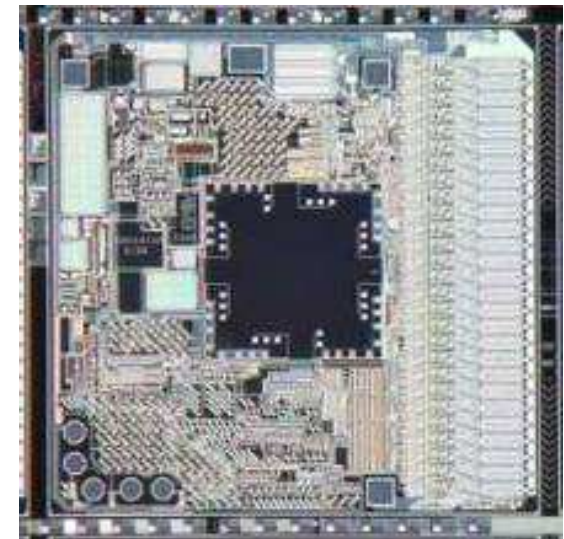
New surface micromachining technique

- Reduced size: bond frames not necessary
- Fabrication of monocrystalline Si membranes
- Full flexibility with size and shape of the membrane



CMOS compatible process

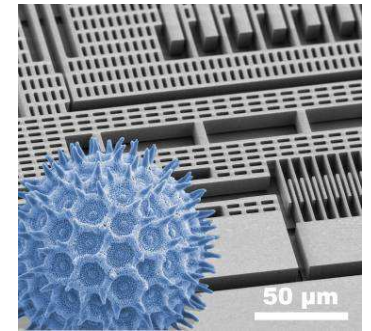
- High synergy between MEMS and ASIC
- No process media that are difficult for a CMOS fab
- Fully integrated process flow in a CMOS wafer fab
- Integrated pressure sensor



Surface Micromachining

Surface micromachining: Bosch-team develops five new key technologies for series-production

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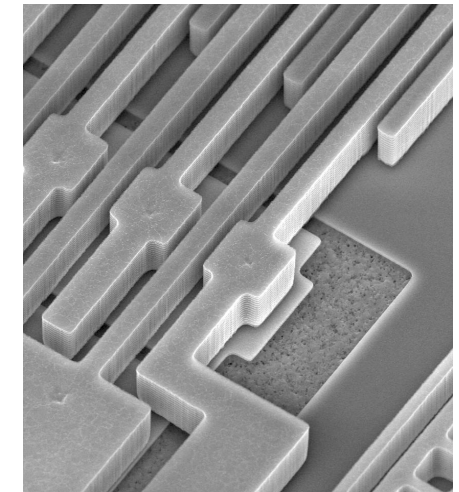
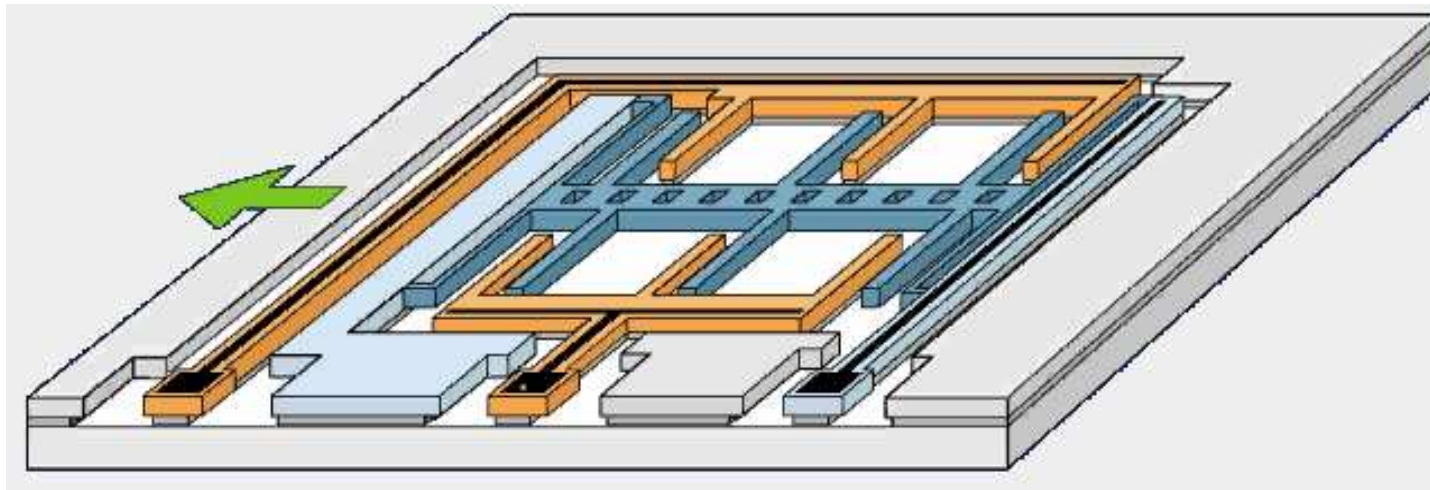


MEMS Sensors: From Automotive to Consumer Electronic Applications

- Introduction
- Overview technologies
- **Function principle and applications of MEMS sensors**
- Future trends and applications in Consumer Electronics
- Outlook and summary

Movable structures...

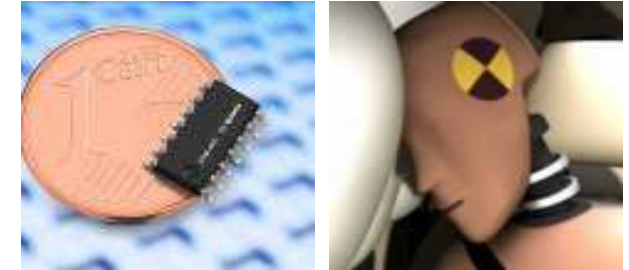
→ ... to measure acceleration and tilt



MEMS sensors – automotive applications

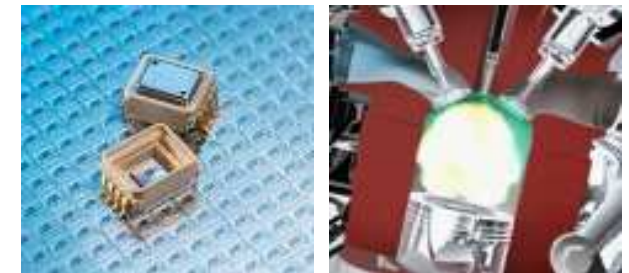
→ Airbag Systems

- Acceleration sensors for occupant protection



→ Engine Management

- Pressure sensors for engine management



→ Vehicle Dynamics Control (VDC)

- Acceleration and angular rate sensors for VDC

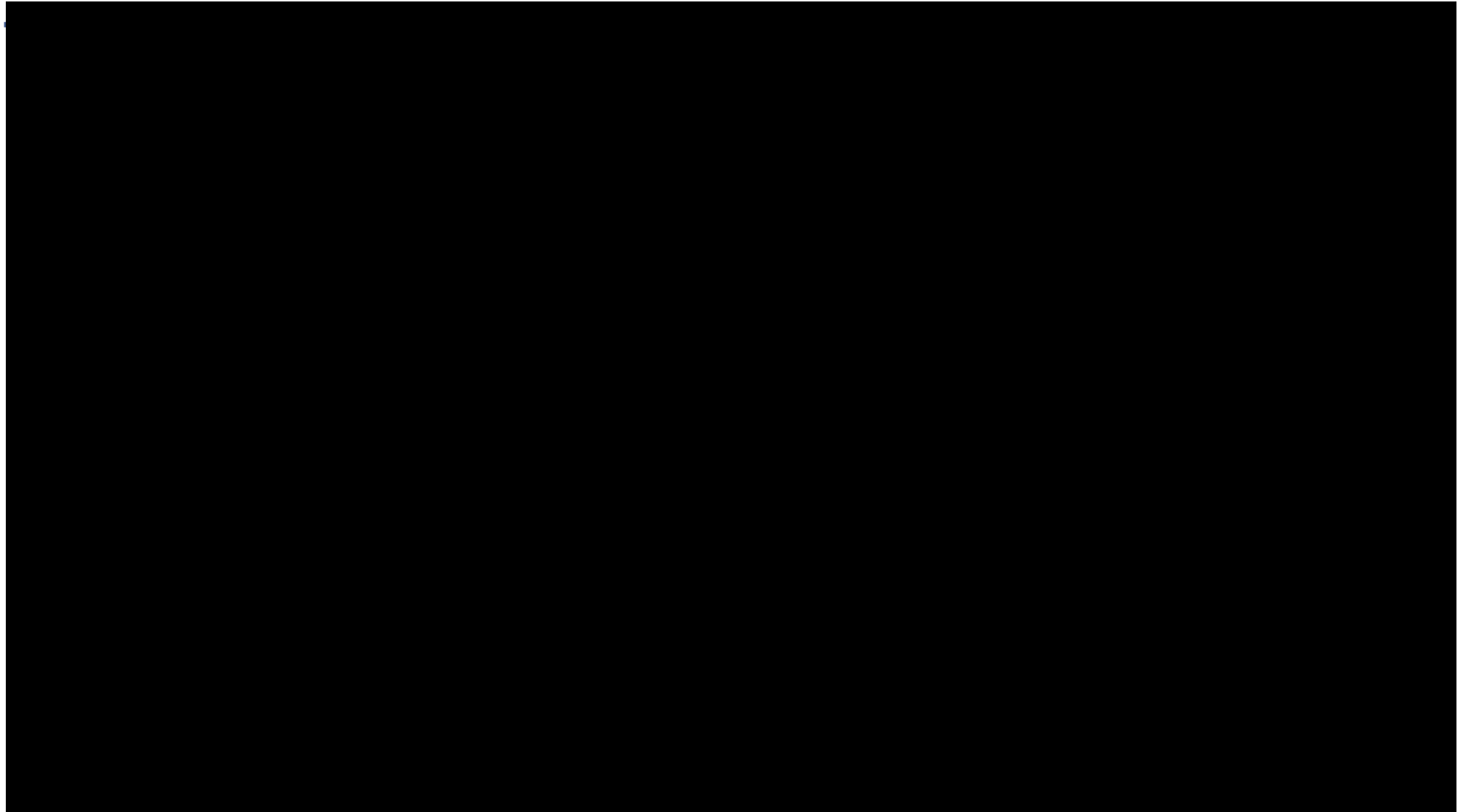


→ Driver Information

- Angular rate sensor for navigation systems

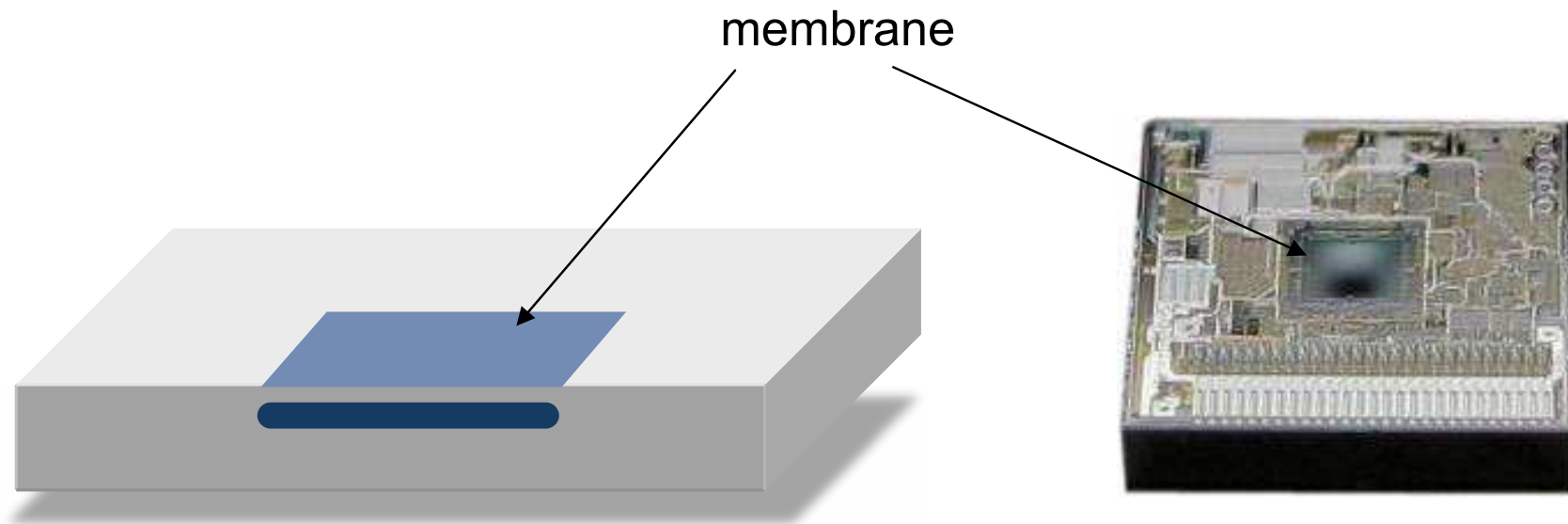


Movable structures...

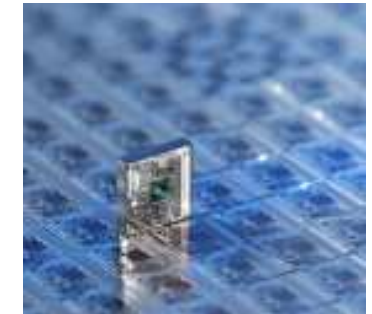
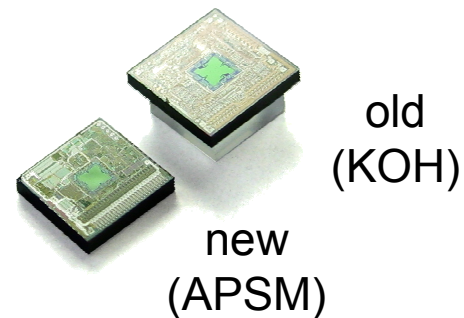
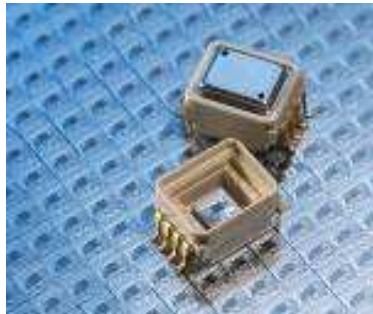


Movable structures...

→ ... to measure pressure



Pressure sensors for automotive and CE applications



Automobile applications

e.g. Motor management

- Highest accuracy over temperature and lifetime
- Integrated, single chip solution
- stable single-crystalline membrane
- Diagnosis capability
- Small SMD package

Consumer electronics applications

e.g. Altitude measurement

- High absolute accuracy
- Extremely high precision
- Very small, robust LCC8 ceramic package
- Ultra-low current consumption
- Digital I2C interface

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Surface Micromachining...

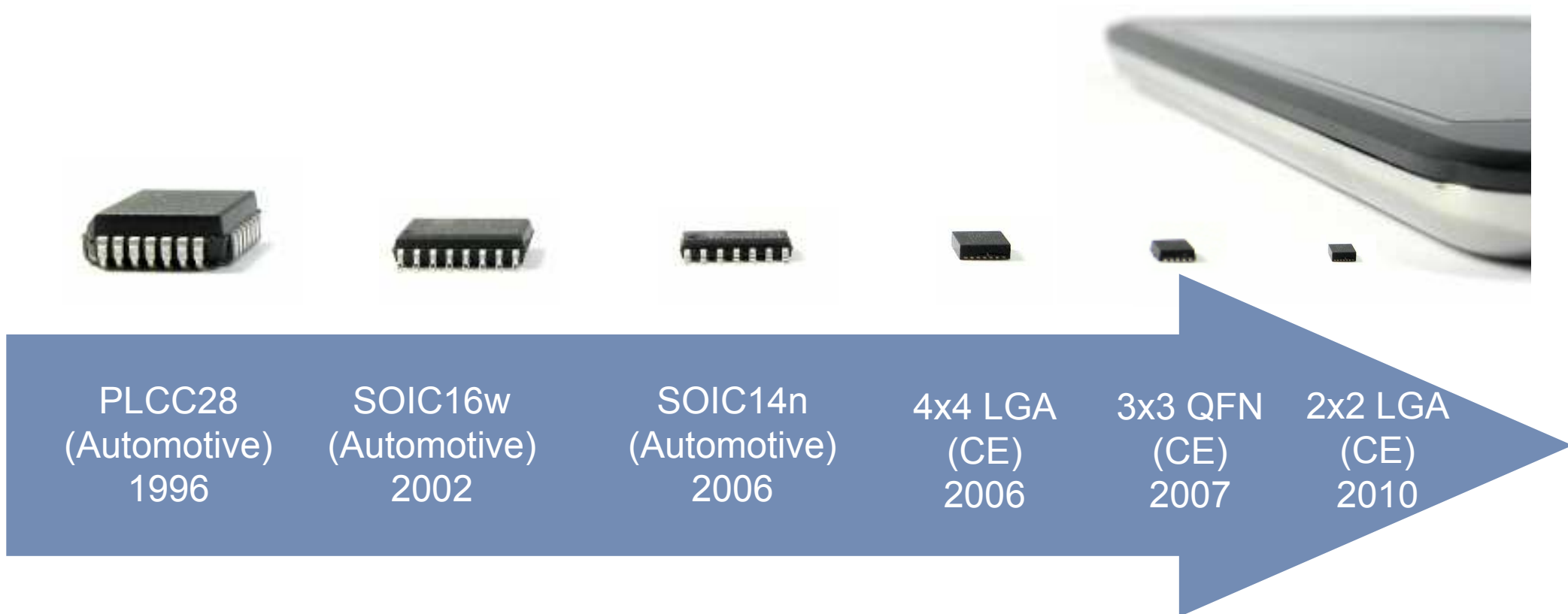
...the key for versatile new applications

- Sensors considerably smaller
- Sensors with much less power consumption
- Sensors less expensive
- Sensors fulfil the requirements of consumer electronics



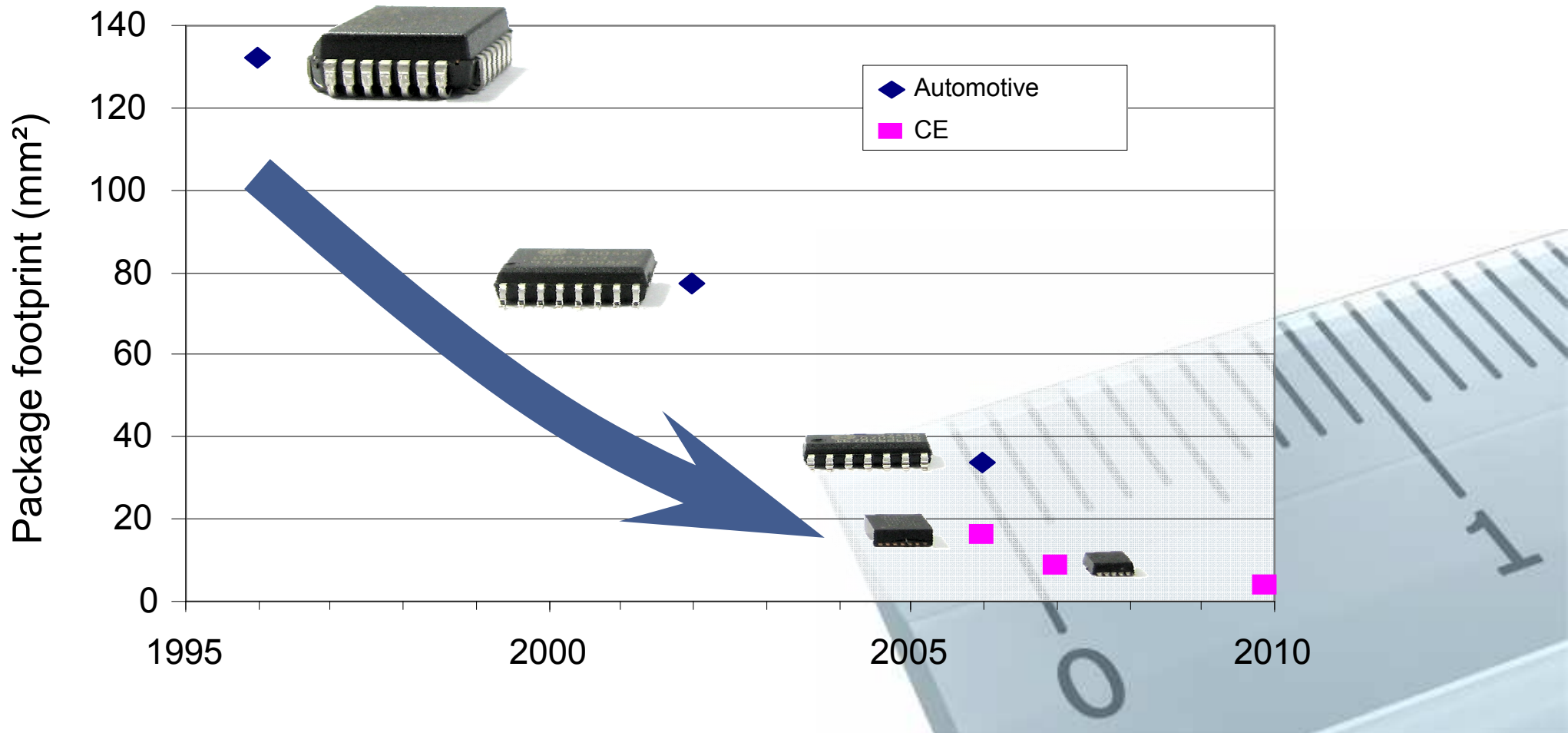
Evolution of requirements (1/2)

Packages of acceleration sensors



Evolution of requirements (2/2)

Packages acceleration sensors



MEMS sensors – the senses for mobile devices

- Mobile phones, PDAs
 - Intuitive menu input through motion and position change

- Gaming and toys
 - New gaming experience through motion interaction

- Mobile computing
 - Data protection by free-fall detection

- Sports and fitness
 - Monitoring through step-counting and altimetry



Use cases for MEMS sensors in mobile phones

User Interface

- Tap control
- Gaming input
- Menu navigation



Pedestrian navigation

- Speed & distance estimation
- Altitude detection
- Location based services



Position Detection

- Upside down
- Portrait / landscape



Motion Detection

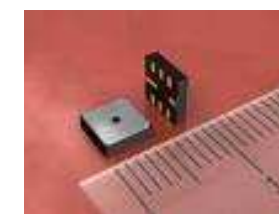
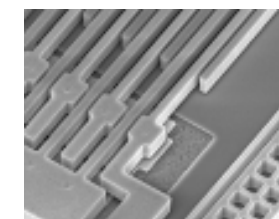
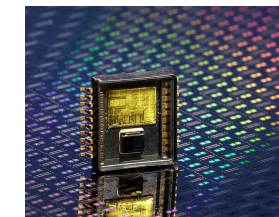
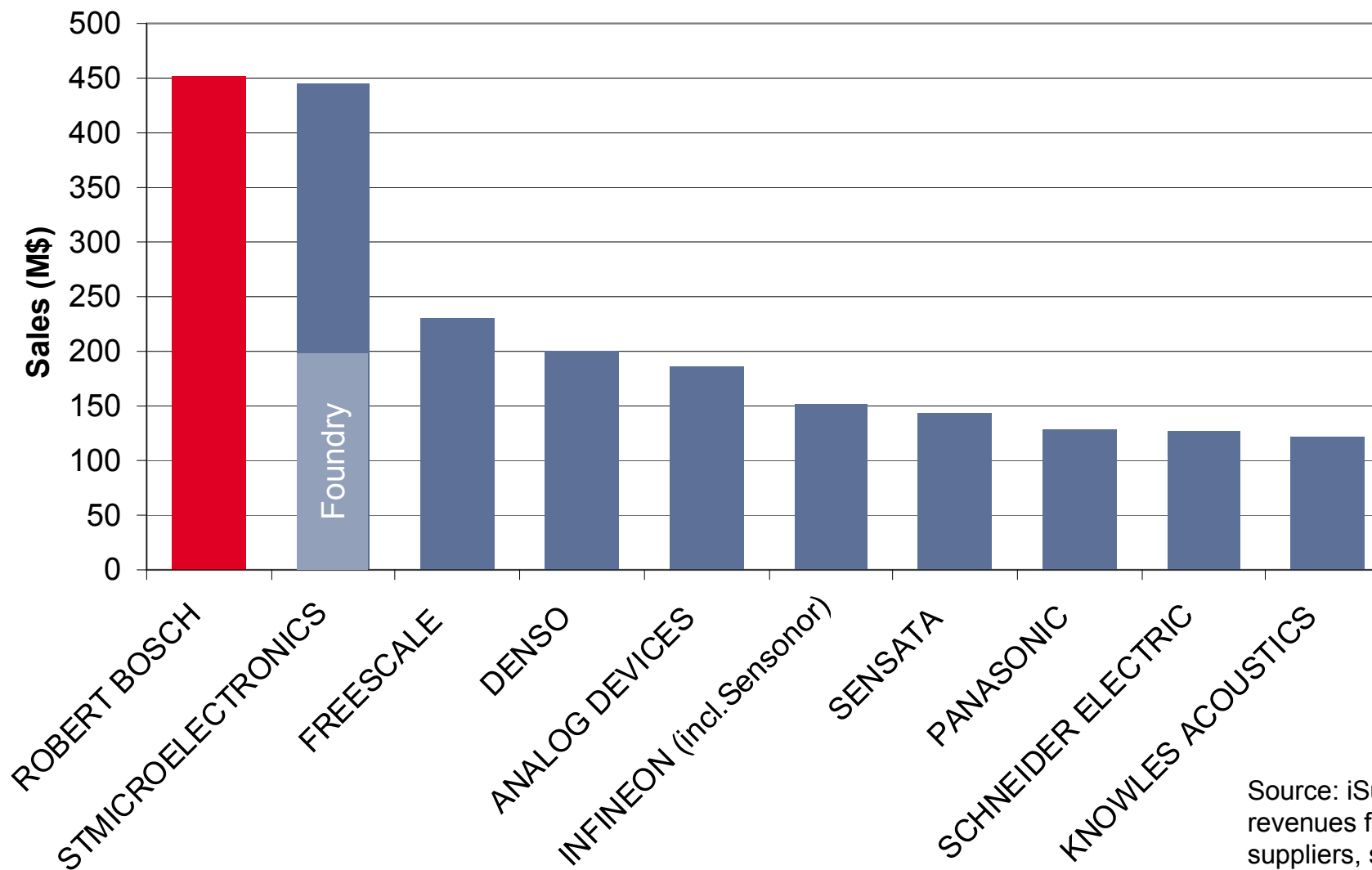
- Step counting
- Activity monitoring
- Power management



MEMS Sensors: From Automotive to Consumer Electronic Applications

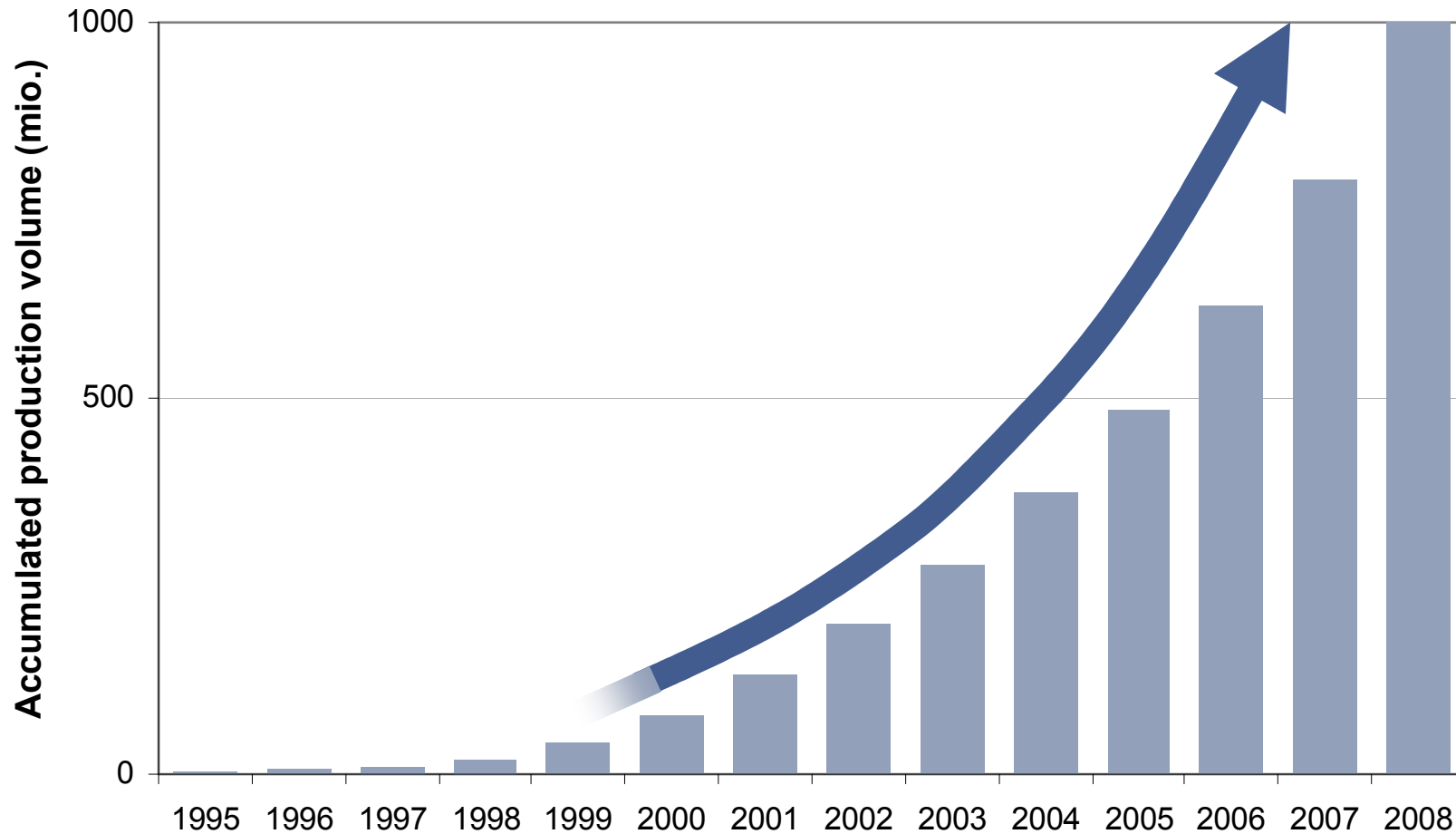
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Bosch – leading the market in MEMS sensors



Source: iSupply estimation, 2008 revenues for TOP50 MEMS suppliers, shown here: TOP10 MEMS sensor suppliers

1 billion MEMS sensors produced*



*Bosch total MEMS production (automotive and consumer)

Future of MEMS

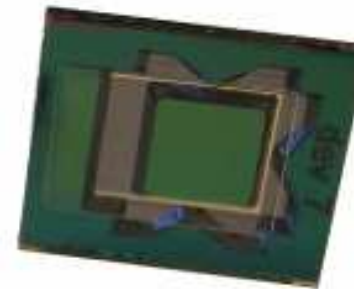
→ New applications are arising

MEMS autofocus



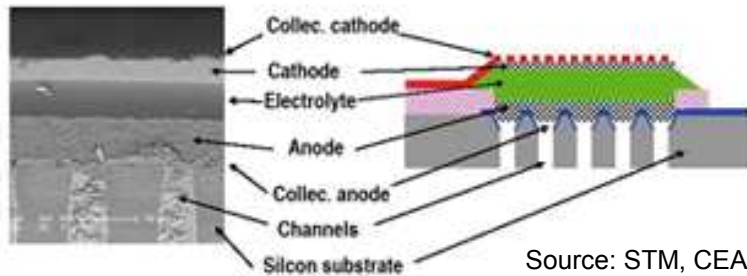
Source: Siimpel

Energy Harvester



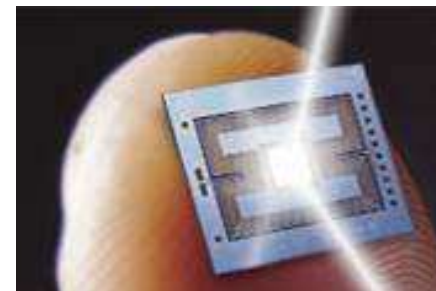
Source: IMEC

Micro Fuel Cell



Source: STM, CEA

Micromirror for microprojection systems



Source: Microvision

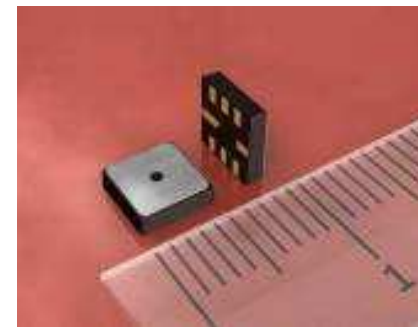
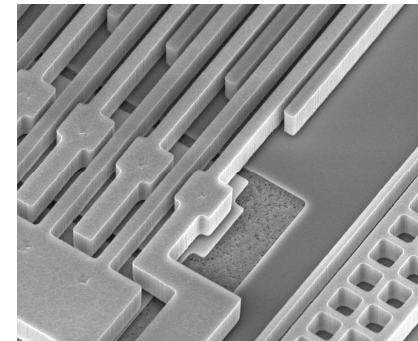
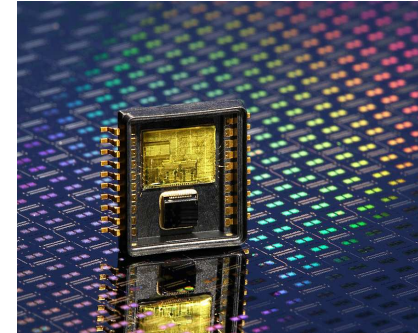
Summary

Automotive

- MEMS is main driver for sensor development
- Permanent enhancements of MEMS technology enables miniaturization of components and new functions
- Continuous development of new device generations

Consumer electronics

- MEMS is enabling technology for new functions in CE
- Key factors: size, power consumption, price
- In future large variety of new applications in many areas



Thank you for your attention!

