AMAA - Berlin - 17.03.2005

Realization of failsafe, cost competitive sensor systems with advanced 3D-MEMS elements

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Market for low-g‘s

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ESP (ESC) - Initiator

Source Auto Bild 1997

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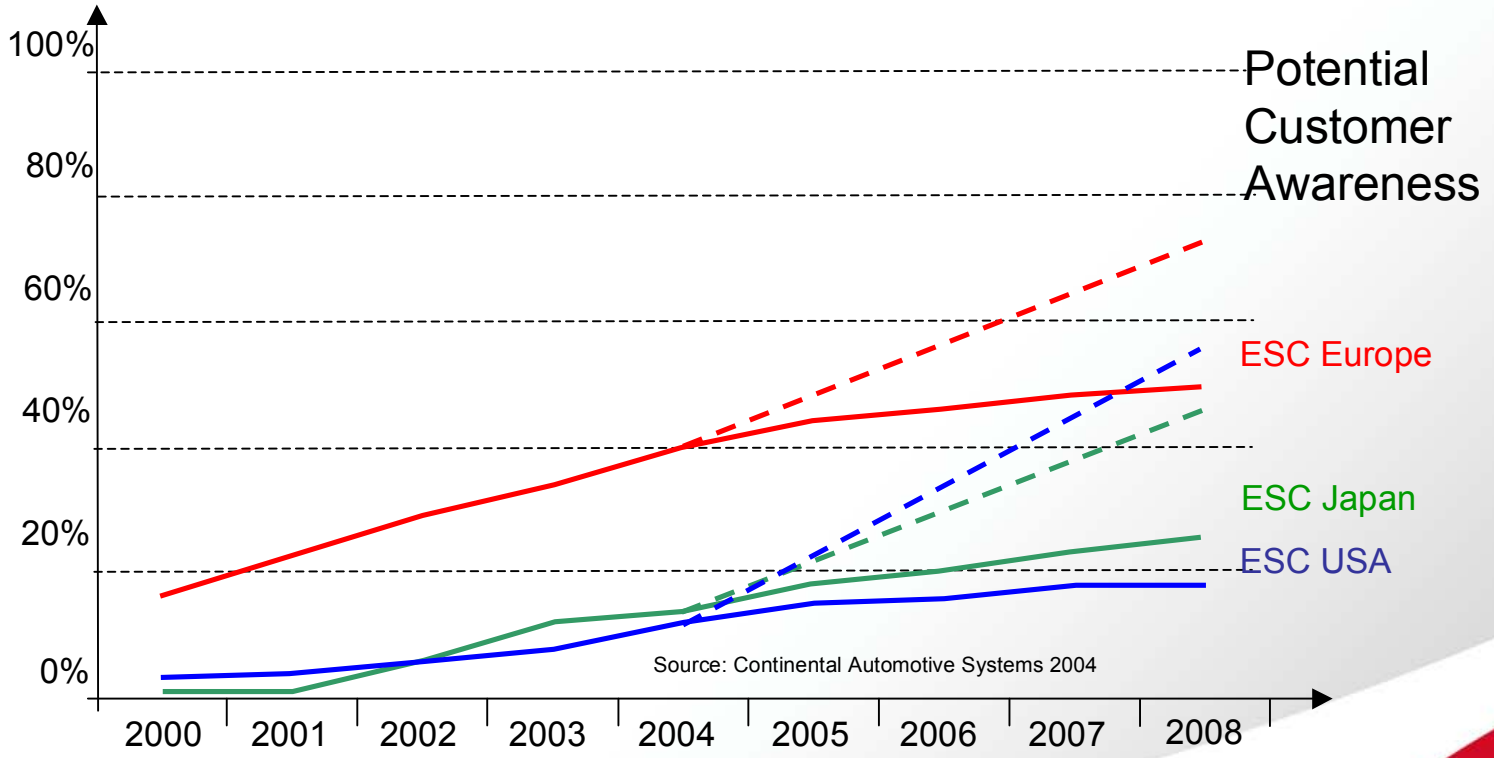
ESC Trend + Market-Penetration



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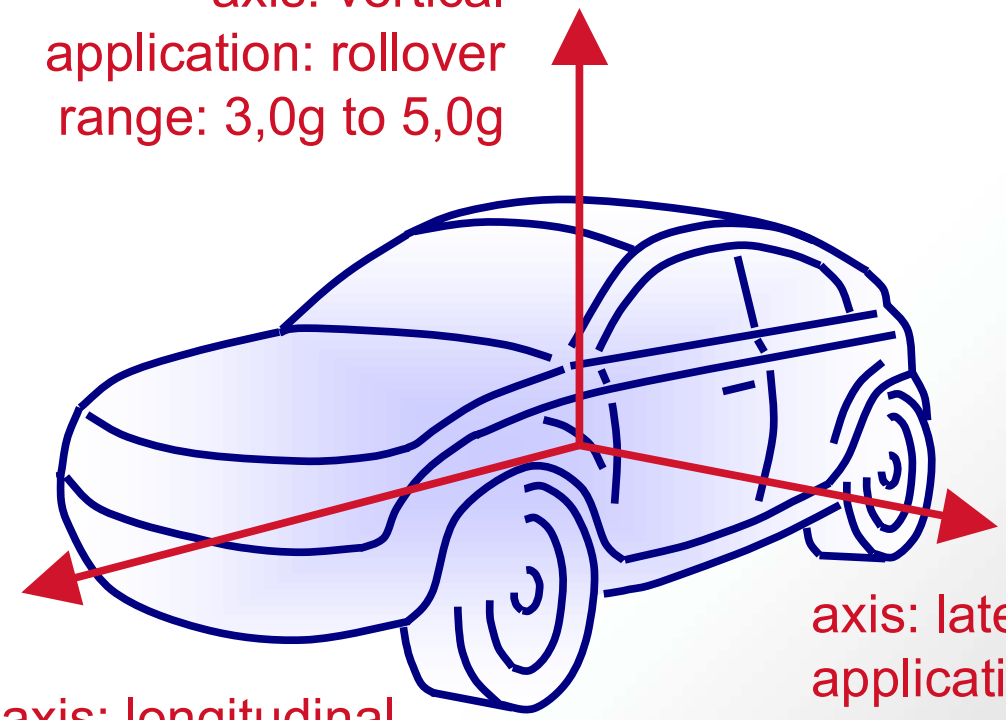
Accelerometers in ESC-environment

axis: vertical
application: rollover
range: 3,0g to 5,0g



axis: lateral
application: ESC
range: 1,5g

axis: longitudinal
application: EPB, HSA, 4x4 ABS
range: 20% inclination= 0,2g
to 1,5g

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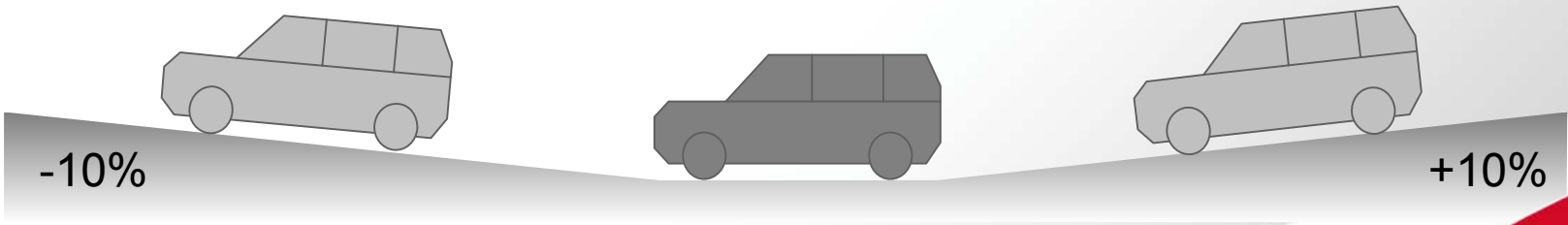
General g-sensor requirements

- Temperature range: -40°C … 125°C
- Temperature shock: up to 3000 cycles
- EMC: up to 600V/m
- Vibration: vs. -3dB frequency requirements
- Mechanical shock: up to 50 000 g
- Offset stability ESC: +/-0,1g = 10% inclination



- Hill Start Assist (**HSA**) & Electronic Parking Brake (**EPB**)
  500% improvements demanded
  -> +/-2% inclination failure (approx. 1°)

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3D-MEMS & periphery

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Historical MEMS overview

	Bulk Micromachining	**Surface Micromachining**
Main products	Low g accelerometers Inclinometers	High g accelerometers
Strength	High sensitivity High stability Robustness	Small size 1-chip-solution
Weaknesses	Size Separate ASIC	Shock Offset stability
Main application	Braking Suspension	Airbags Car-alarm

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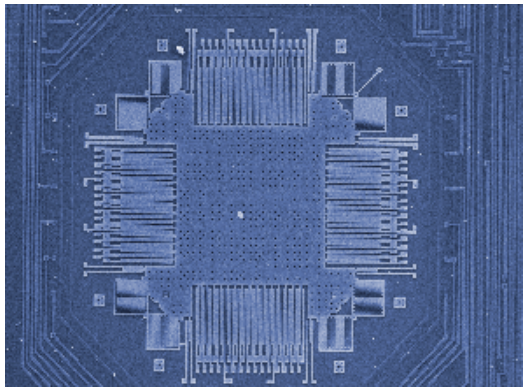
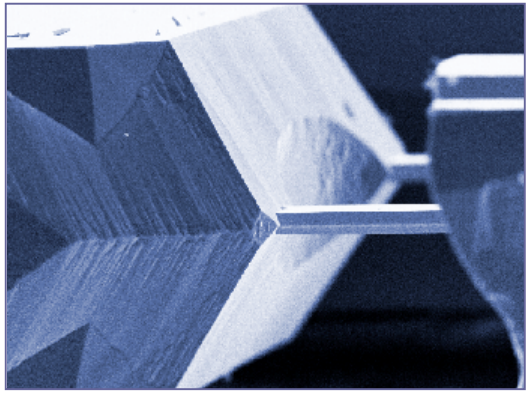
Technology fusion





Surface Micromachining

- RIE
- in-plane motion
- comb electrodes

- deep, thick
- planar electrodes
- out of plane motion
- wafer bonding

Bulk Micromachining

Future MEMS

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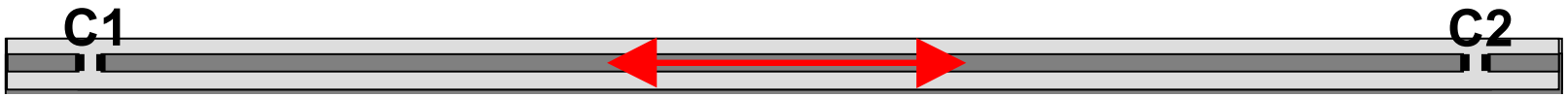
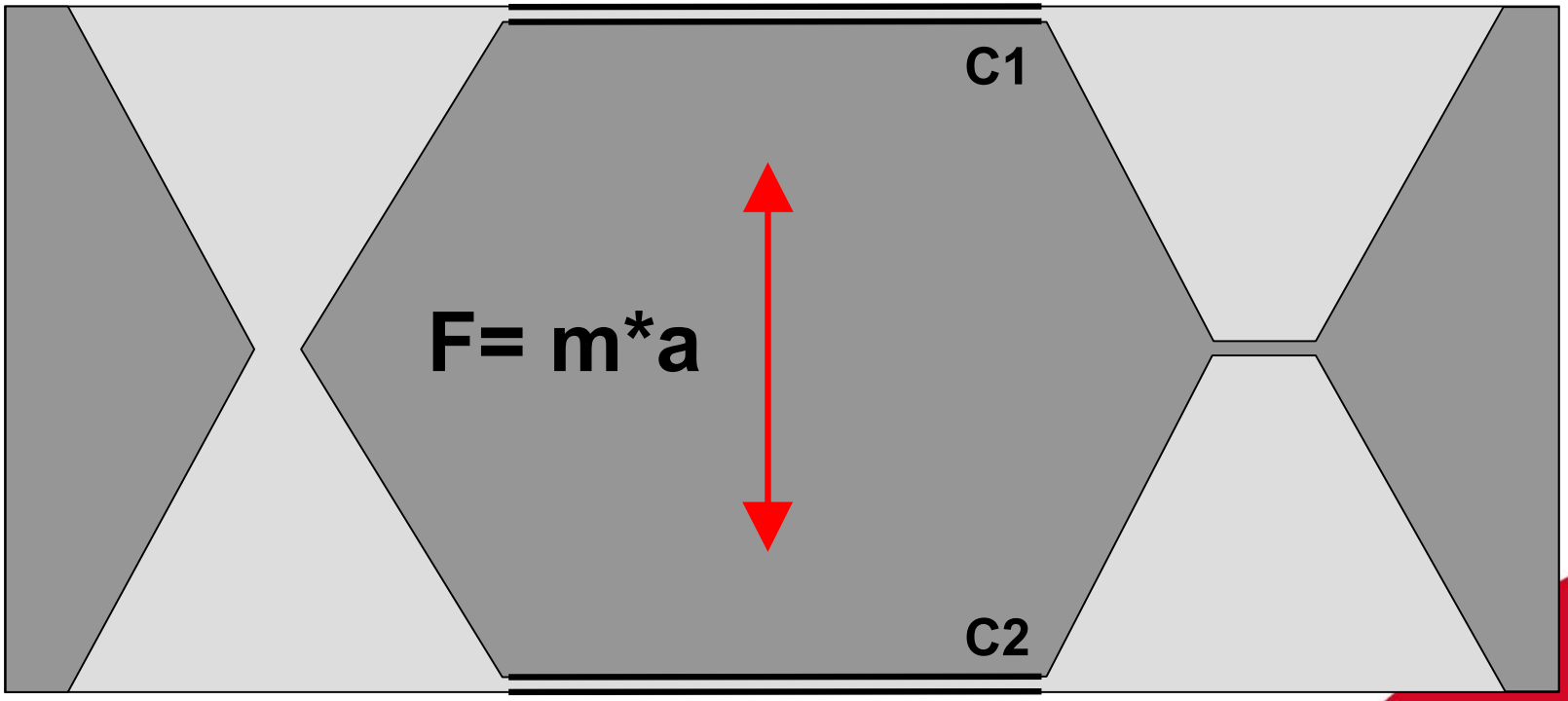
MEMS historical structures



Surface micromachining = good surface utilization
e.g. 10µm mass height



Bulk mircomachining = less good surface utilization
e.g. 300µm mass height

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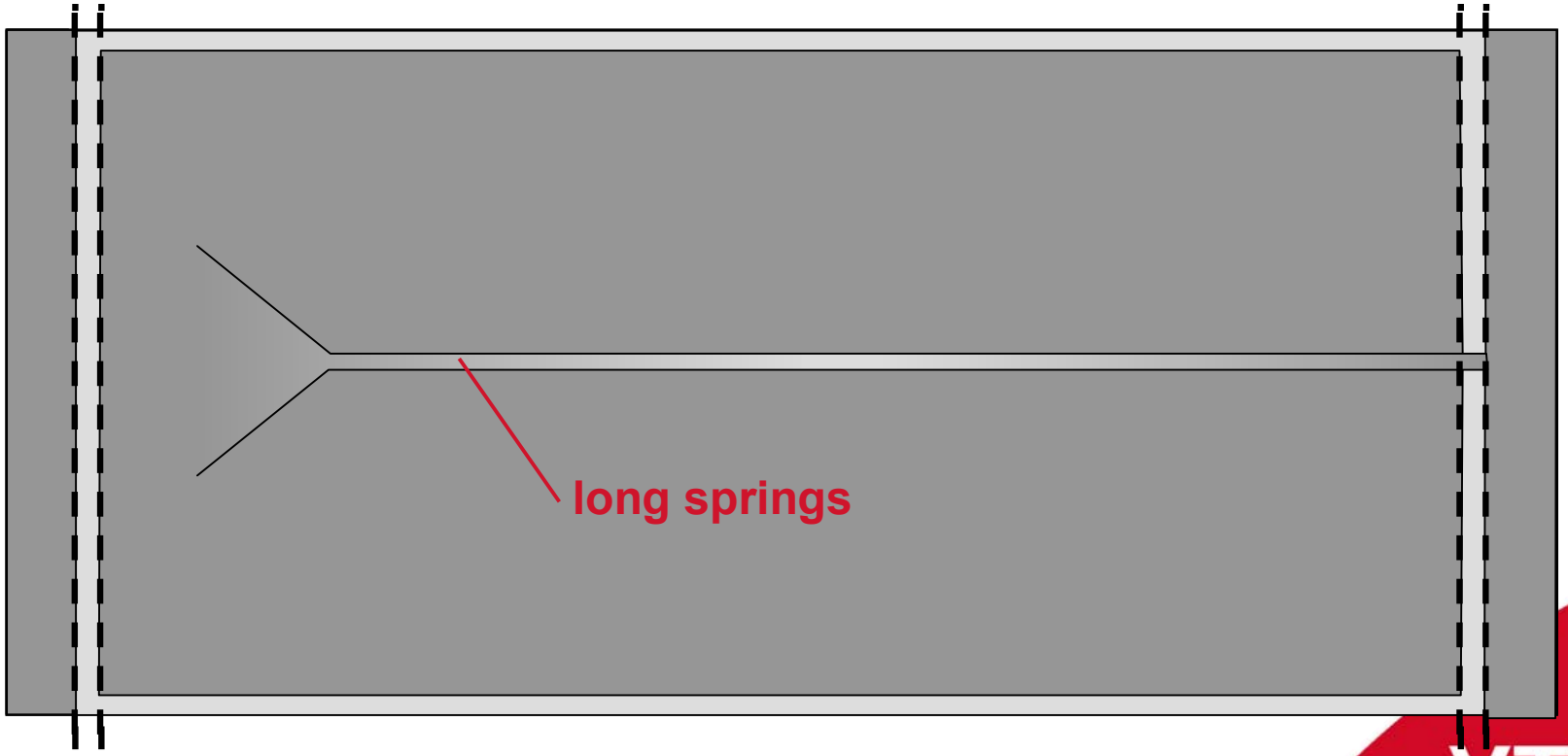
Symbioses: 3D-MEMS

Better utilization of the same surface



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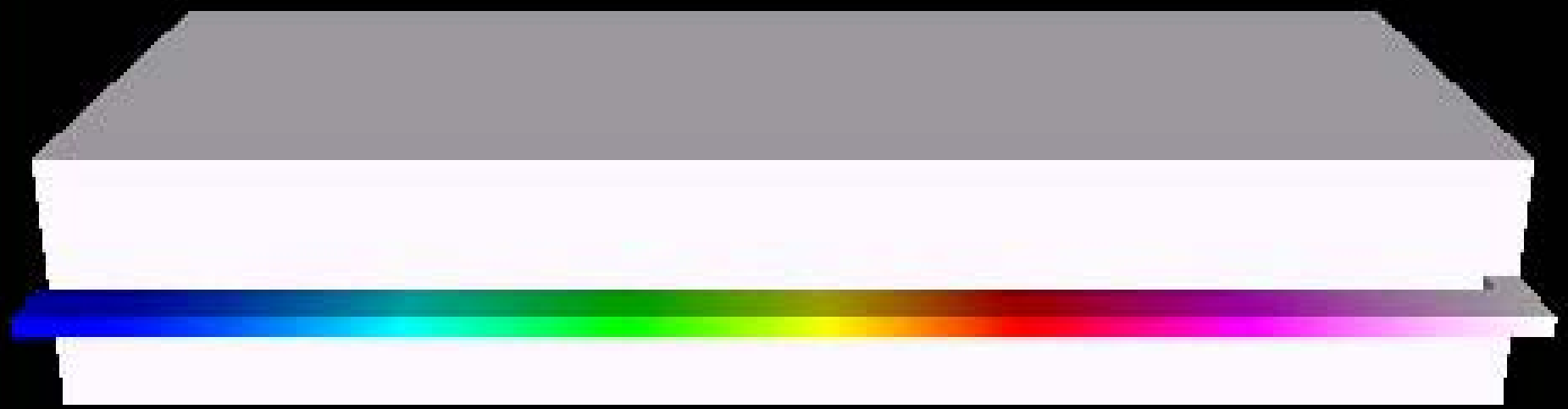
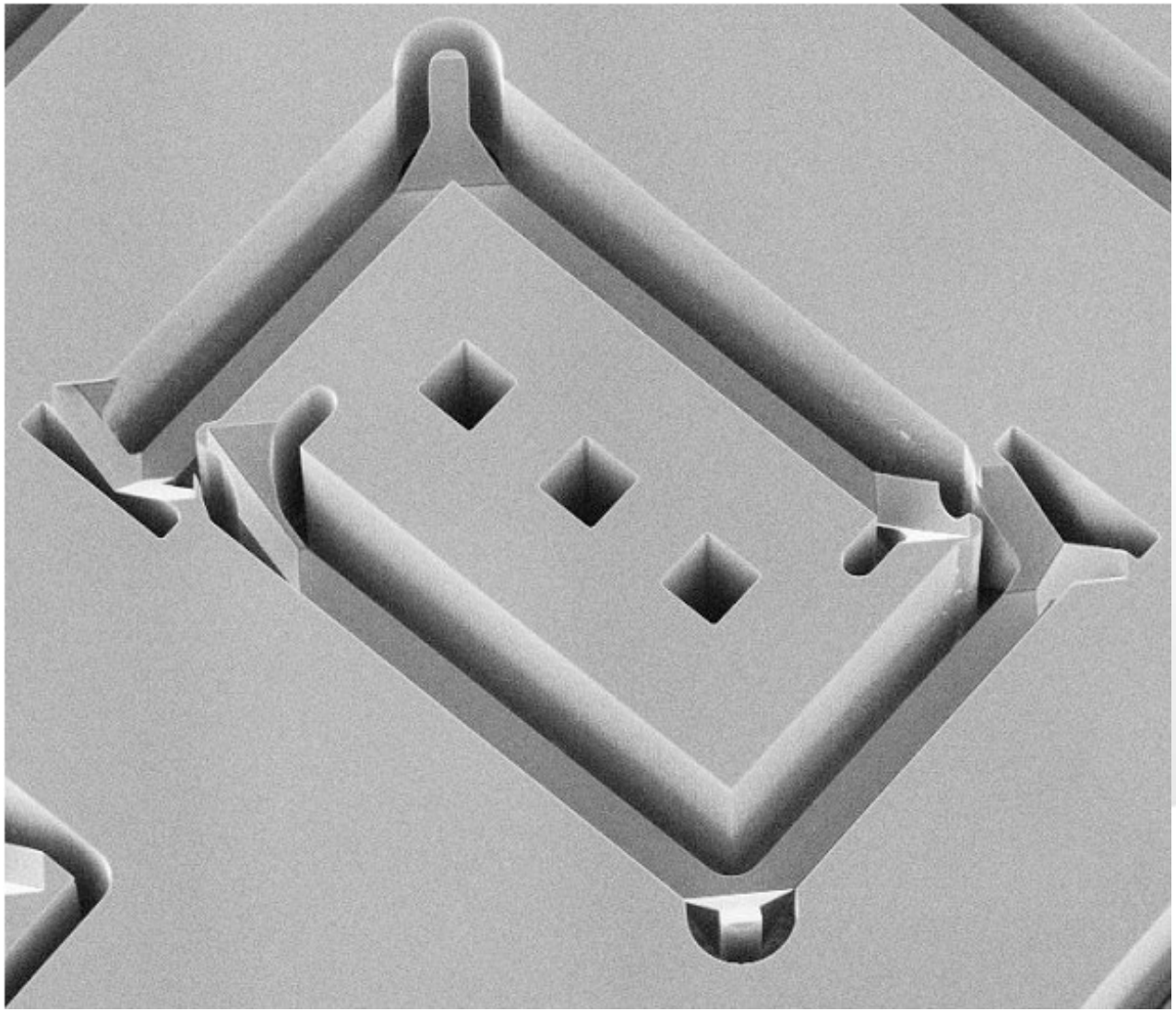
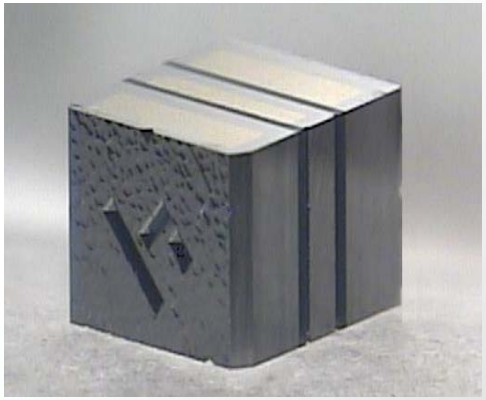
3D-MEMS: Animation mass movement



Single axis element





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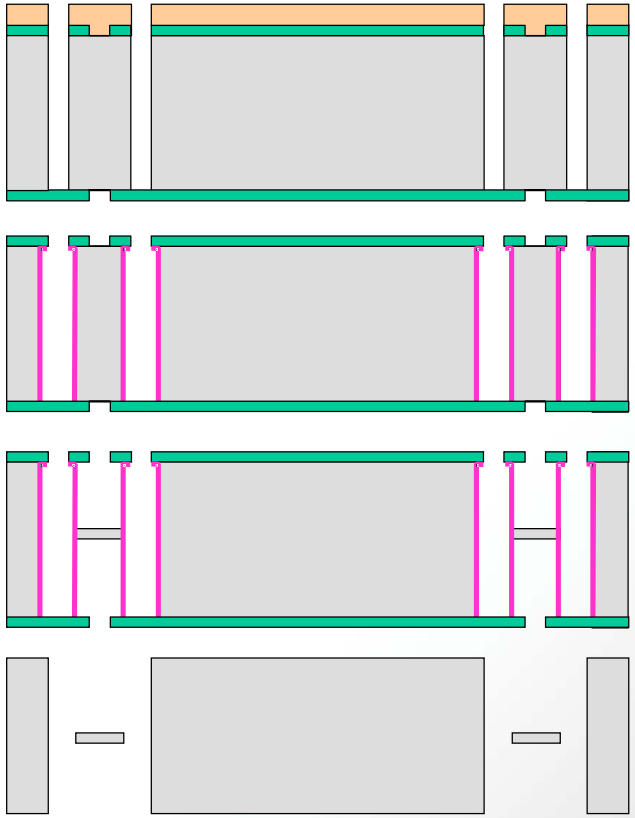
3D-MEMS etching process

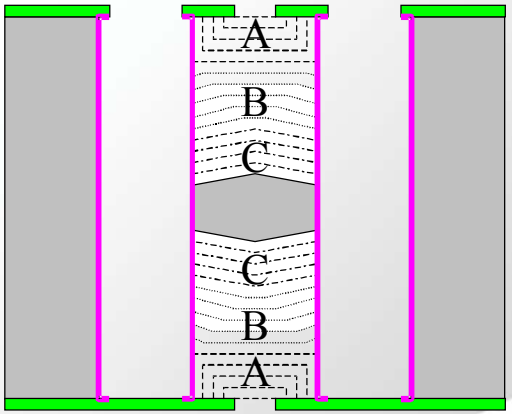
Dry etching using DRIE

Side masking

Wet etching in KOH

Mask layers stripping





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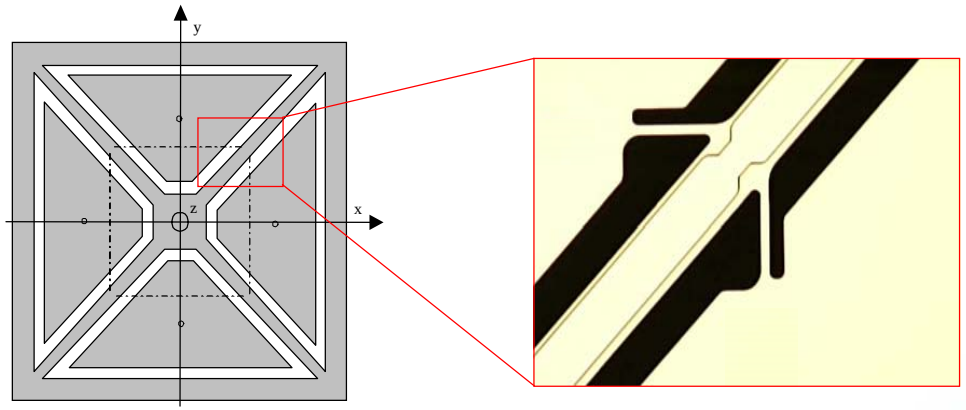
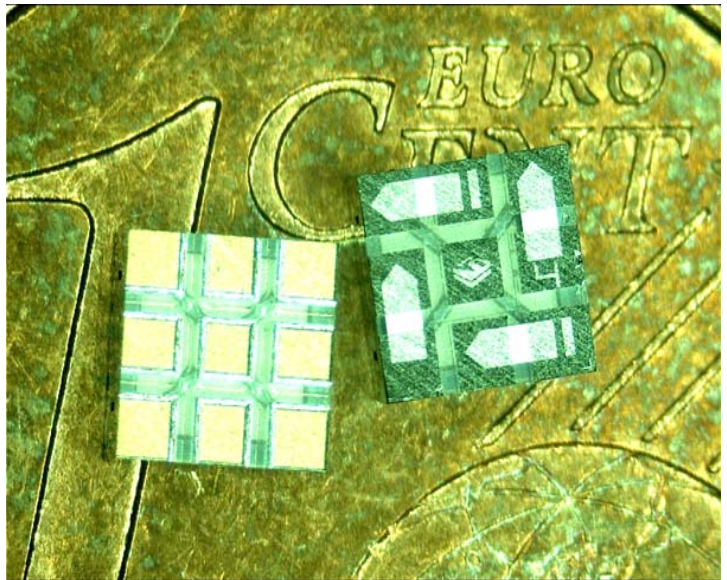
2nd example: 3-axes element

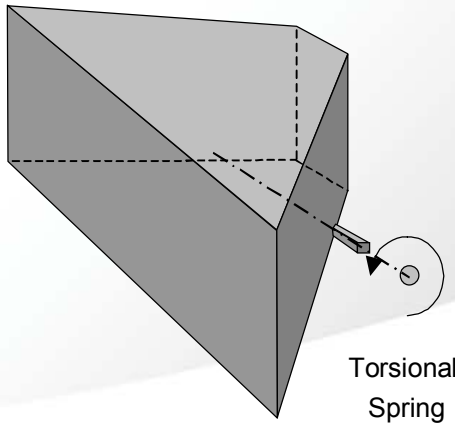


detailed
presentation
in AMAA 2004

- SOI wafer

- combination
  DRIE etching
  KOH etching





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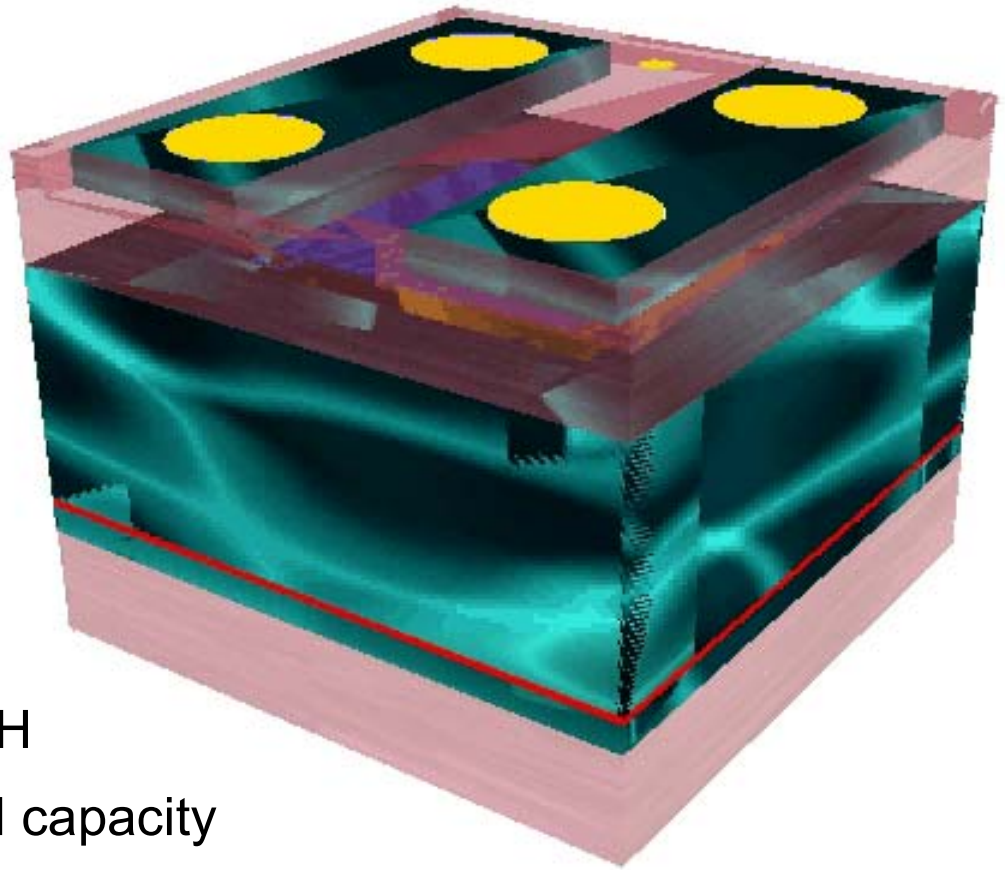
3rd example: motion sensing elements



- SOI wafer
- DRIE & KOH
- single sided capacity
- single crystal silicon mass wafer
- extremely small size < 1mm³

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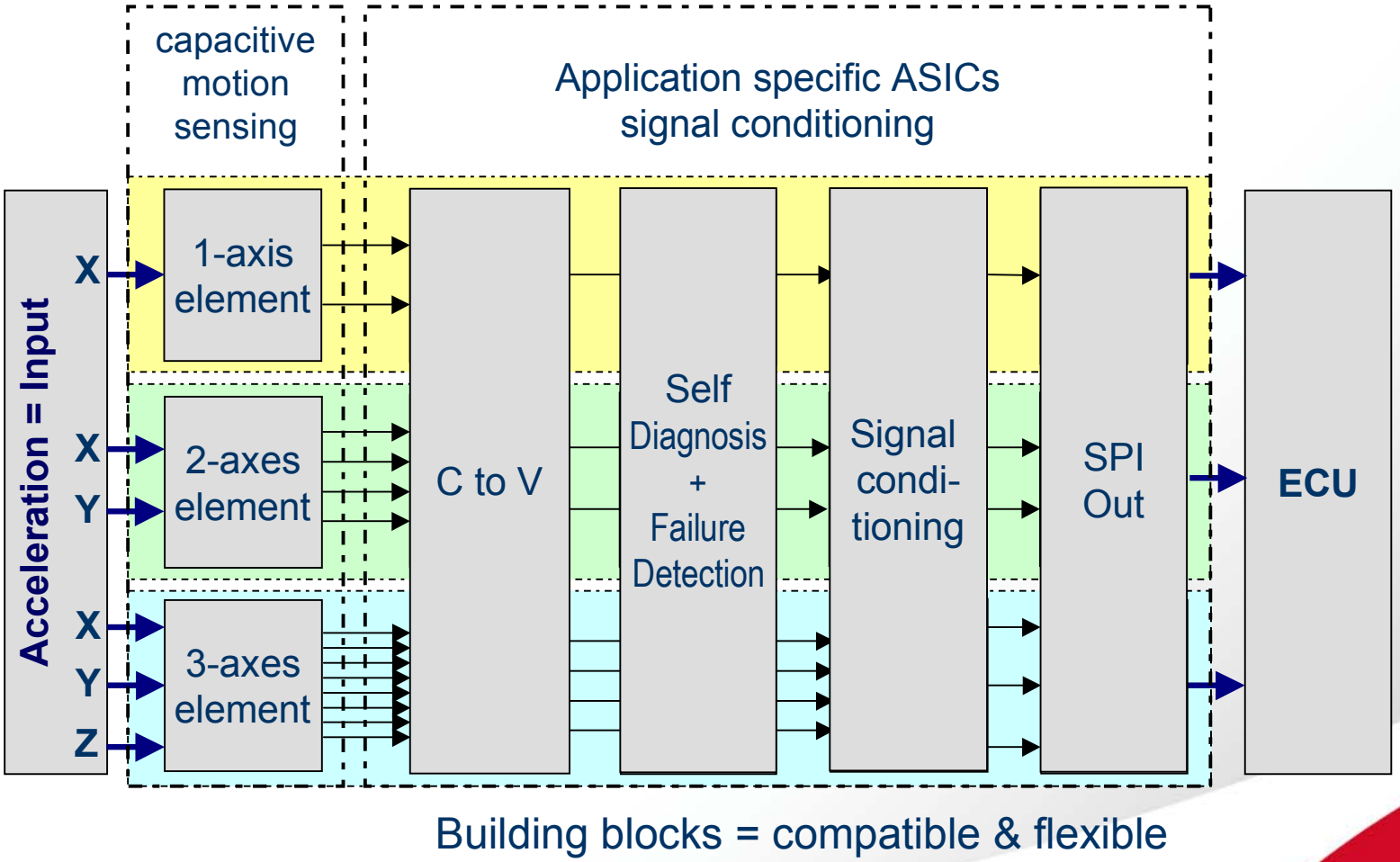
Signal conditioning



Building blocks = compatible & flexible

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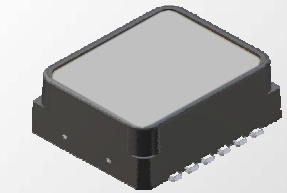
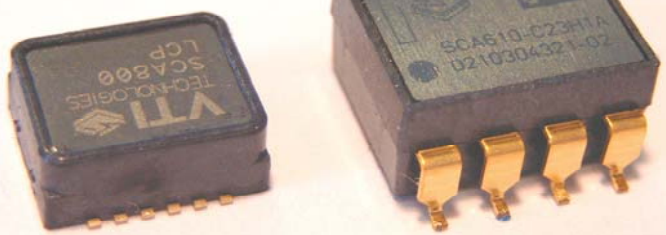
New Platform = 1 Housing

Name	Axis	Performance	MEMS technology
SCA800	**X**	standard performance	KOH wet etching
SCA810	**X**	high performance	**3D-MEMS**
SCA820	**Z**	high performance	**3D-MEMS**
SCA31xx	**ZY,XY**	high performance	**3D-MEMS**
SCA3100	**X-Y-Z**	high performance	**3D-MEMS**





Foot print surface PCB: -47%

10,5 mm x 11,3 mm to

7,4 mm x 8,4 mm

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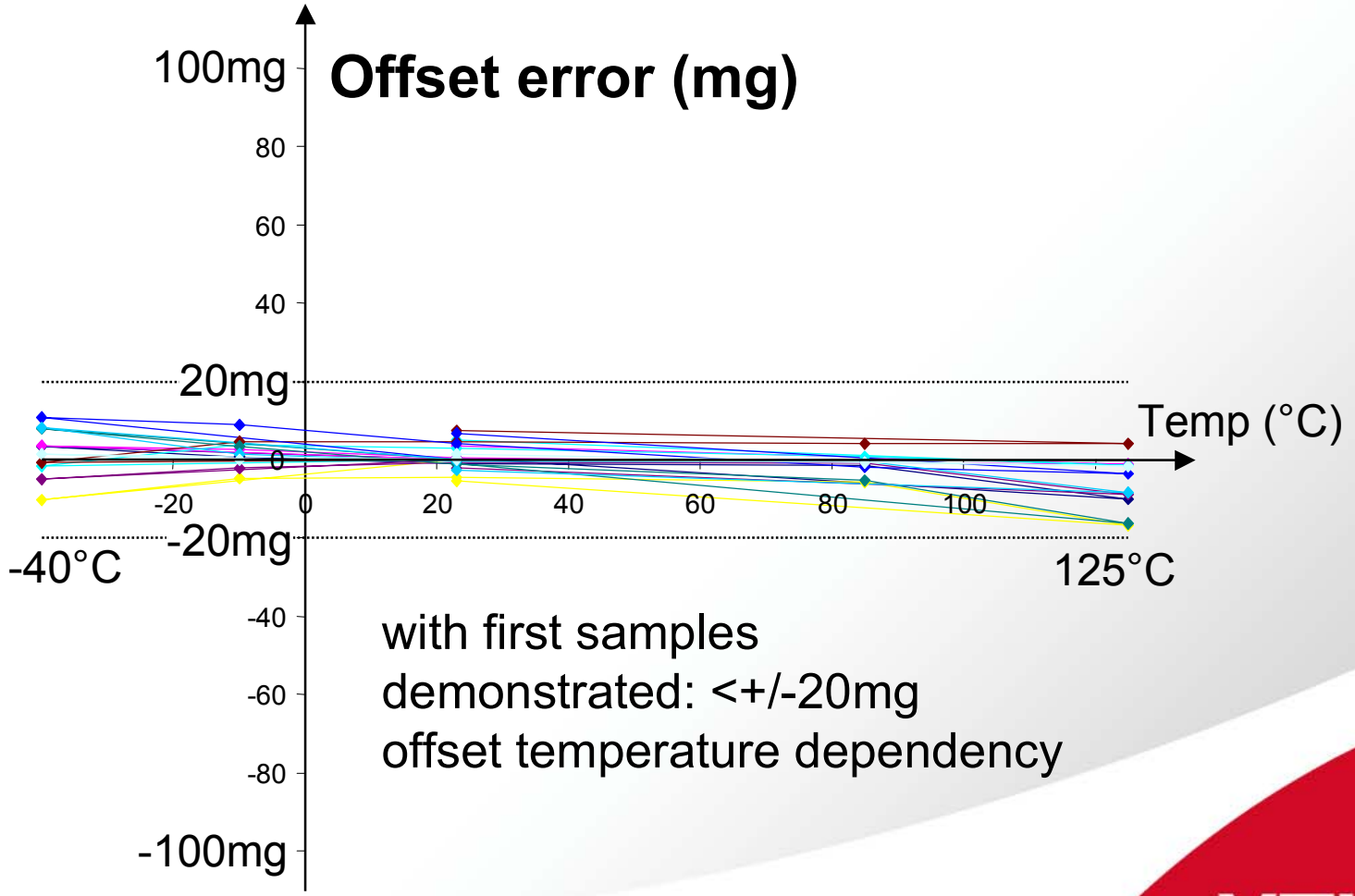
Test results single axis SCA810



with first samples
demonstrated: <+/-20mg
offset temperature dependency

DFL housing prototypes
3D-MEMS element prototypes
MPC wafer ASICs

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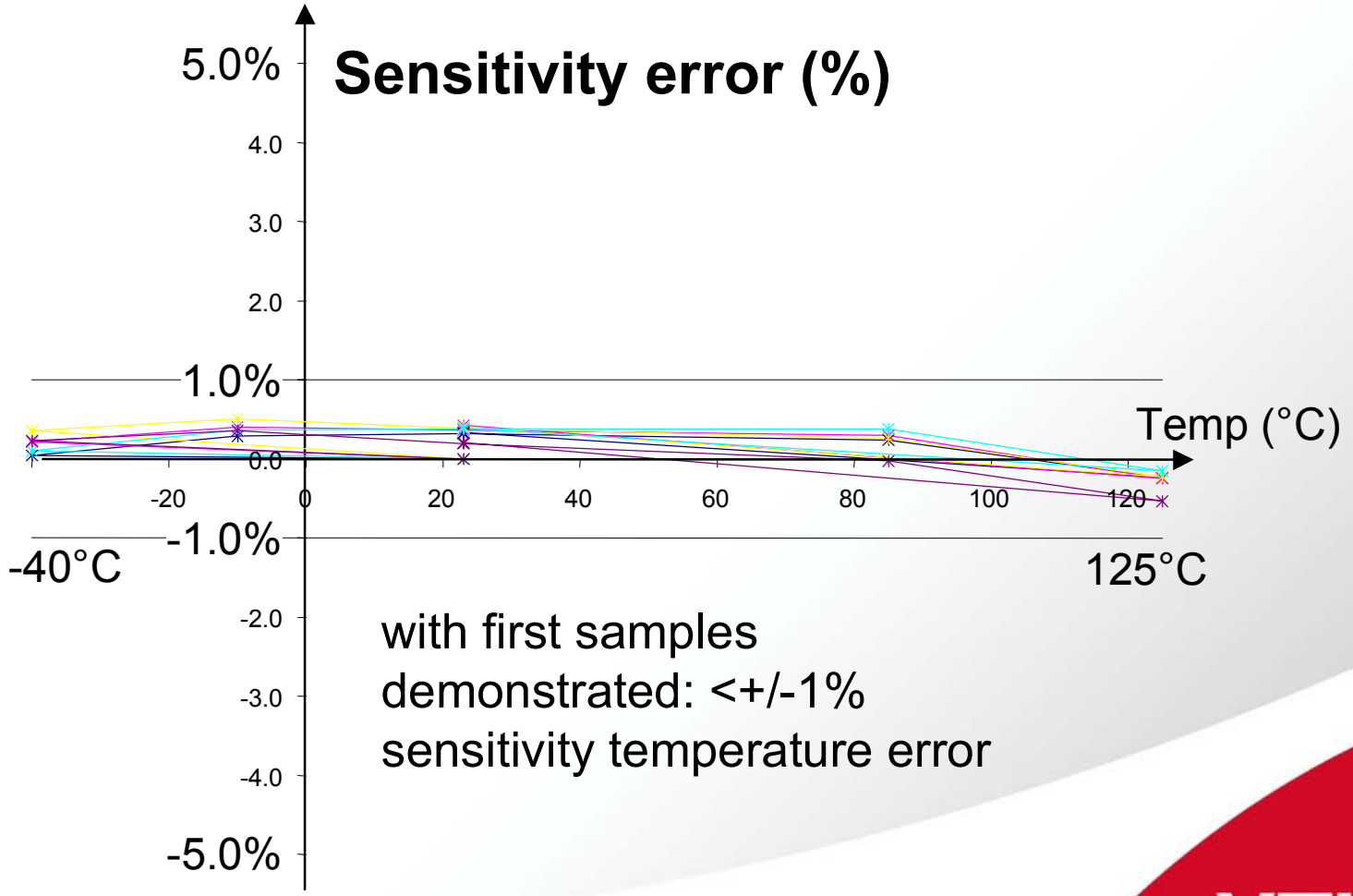
Test results single axis SCA810



with first samples
demonstrated: <+/-1%
sensitivity temperature error

DFL housing prototypes
3D-MEMS element prototypes
MPC wafer ASICs

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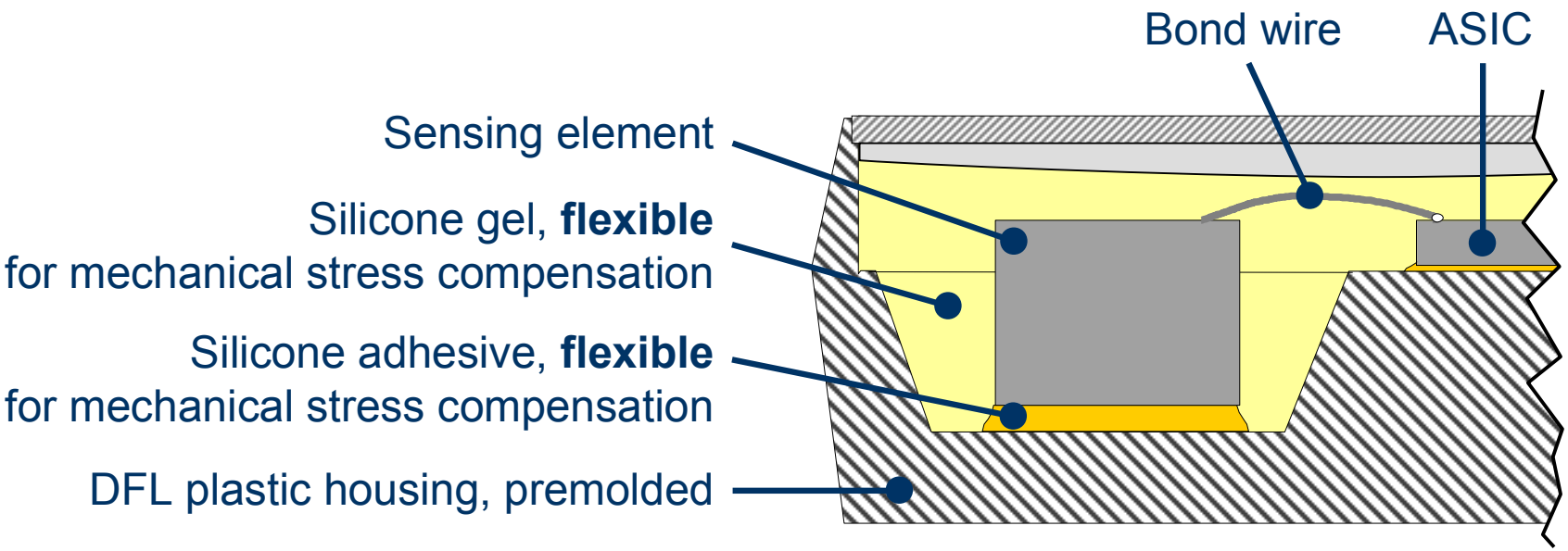
Internal interconnections



Motion MEMS:

- **Motion sensing = Mechanics**, not semiconductors
- **Mechanical influence to MEMS**
  - as temperature induced stress -> changes output signal
    fix: mechanical de-coupling
  - vibration
    fix: gas damping inside sensing element

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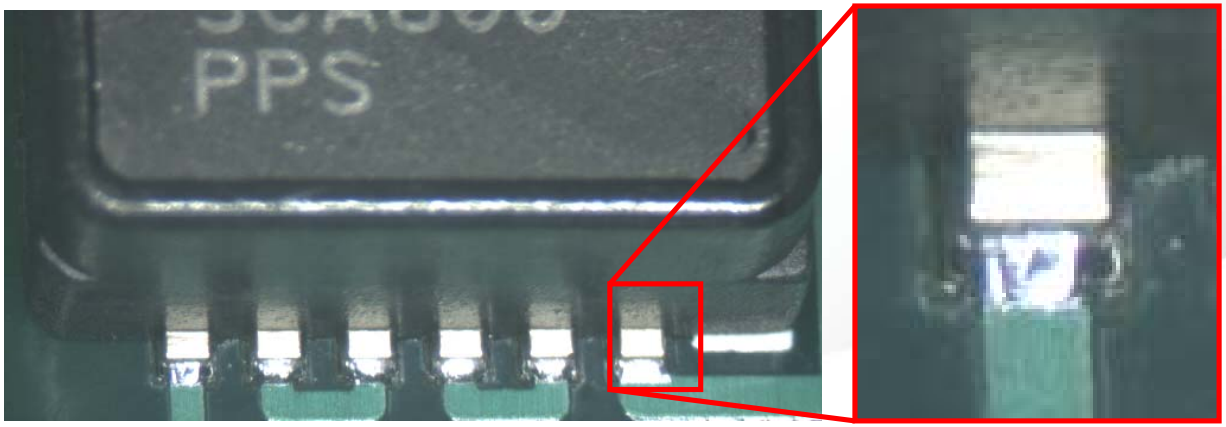
External interconnections

- Safe DFL housing concept
  for 15 years automotive lifetime & performance
- 3000 Thermal shocks in application environment
- Overlapping pins for solder meniscus
  -> better reliability
  -> optical control possible



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Reliability

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Reliability & Failure recognition

- **System understanding:**
  - Always >1 sensor for redundancy
  - Failure recognition can be done by 1 sensor
  - Job sharing:
    Failure recognition by sensor or system ?
  - Tool box for FIT calculations
  - **Importance of sensor for the system ?**

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Failure detection strategy

Single axis sensor:

- Dynamic bi-directional selftest checks the vitality and integrity of the entire signal chain
- Does not provide any information on offset integrity since gravity is always present static (especially low-g - example: slope of 10% creates 0,1g static signal while parking)

Three axes sensor:

- Overspecified **4 moving mass** system information for 3 axes measurements is used as **redundancy** to **identify inplausible conditions** as forbidden status

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Bottom line

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3D-MEMS development results

- 65% smaller element size with same performance
- 50% enhanced capacity dynamic
- 100% higher relative capacitive sensitivity
- 200% improved mechanical sensitivity
- Better linearity of the sensing element
- Reduced vulnerability to vibration

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3D-MEMS motion sensors: benefits

Better performance for new applications

Less vulnerable against vibration

State of the art failure detection

Smaller size and lower costs

Thank you - let's keep the motion

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