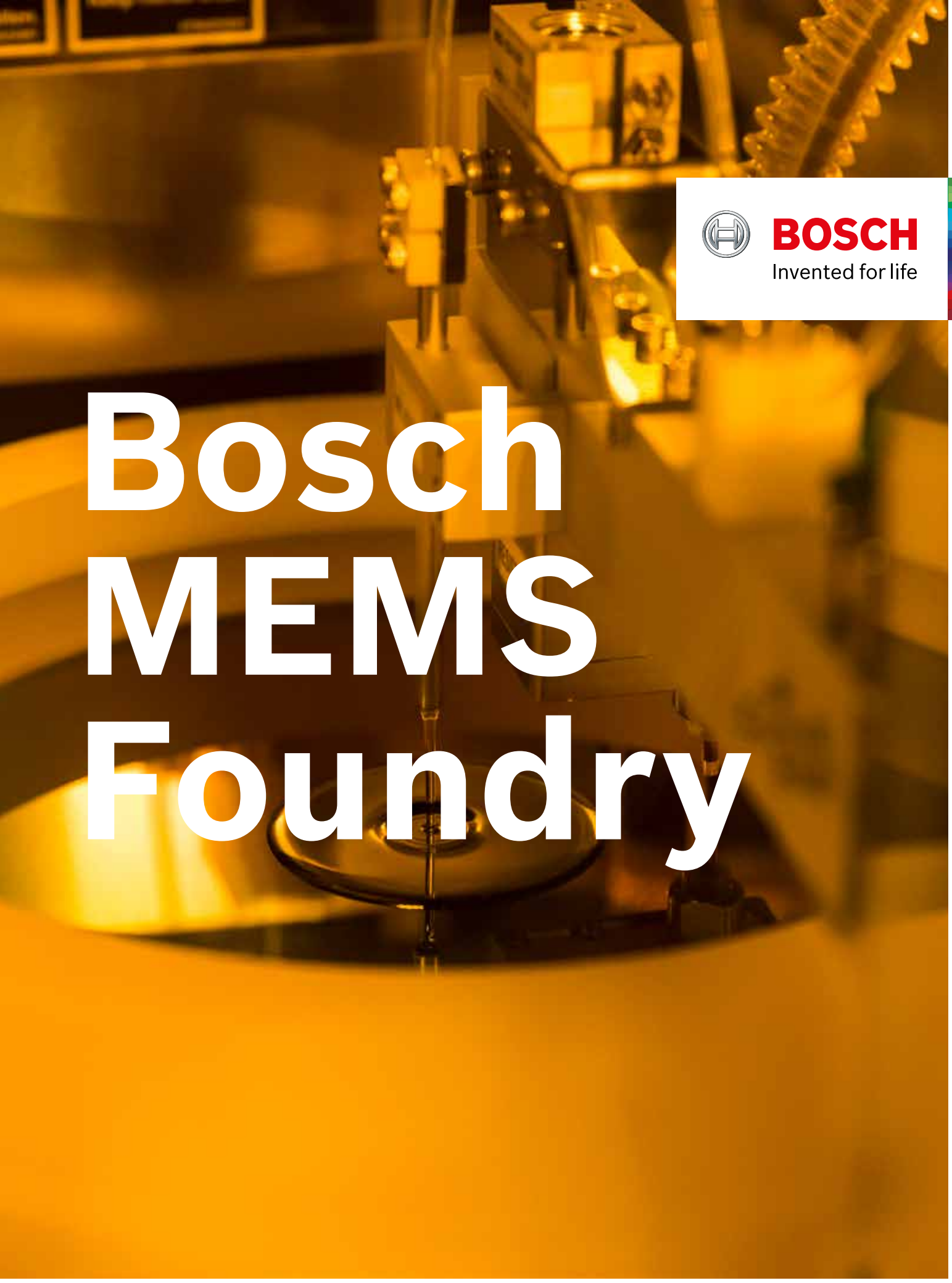


BOSCH
Invented for life

Bosch MEMS Foundry

In cooperation with: THE 21st INTERNATIONAL CONFERENCE ON SOLID-STATE SENSORS, ACTUATORS AND MICROSYSTEMS TRANSDUCERS 2021 ONLINE VIRTUAL CONFERENCE

Bosch MEMS Foundry

Technology

Bosch offers the broadest portfolio of MEMS technologies in the market. This brochure highlights some of the key technologies, providing examples for Bosch‘s technical expertise. The prodution volume for ASIC and MEMS is several thousand wafers per day, primarily 200mm wafers.

The available technologies are intensively tested, deeply understood and proven for mass production. This allows to industrialize new MEMS devices fast and reliable as well as to secure a long term and stable delivery.

Markets

Bosch serves:

- Automotive, with an extreme high quality standard and long-term production commitment
- Consumer, with an extreme fast time-to-market and steep volume ramp-ups

Thanks to this, Bosch is able to perfectly adapt the industrialization process to customers individual needs.

Business Models

Since Bosch provides the complete supply chain from MEMS design to the final system, Bosch can offer the following building blocks to its customers:

- Wafer process
- Test service
- Assembly service

} **Foundry**

- Design and Simulation
- Tested MEMS product
- Assembled and tested modules of MEMS and ASIC

Bosch MEMS capabilities (200 mm)

High precision DRIE (Deep reactive ion etching)

One of the key processes in MEMS is the vertical, anisotropic silicon etch, the so-called „Bosch process“.

Ideally, the trench is:

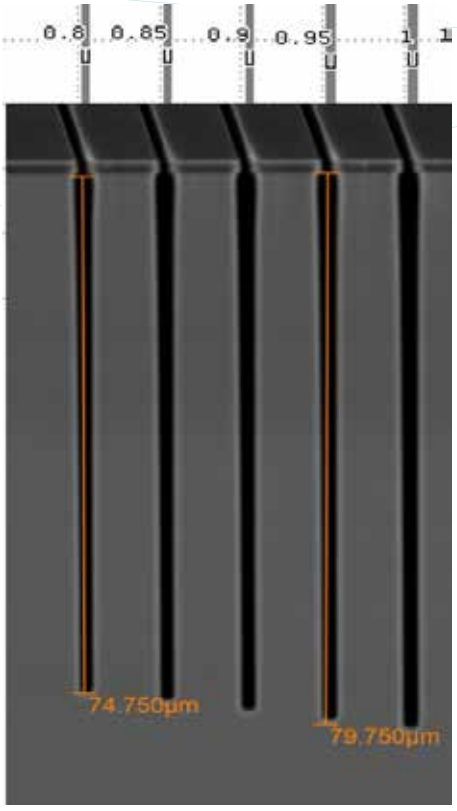
- As vertical as possible
- As narrow as possible
- As deep as possible
- As reliable as possible with minimum variation

} the ratio of depth to width as high as possible

Bosch’s trench performance is outstanding and is one key success factor for Bosch to be #1 in silicon MEMS.

Bosch features for DRIE

- Aspect ratio depth/width 40:1 in mass production, 60:1 in development, 80:1 feasable, see SEM pic above
- Typical selectivity with mask 150:1 for resist and 450:1 for oxide hard masks
- End point detection with stop layer (e.g. SiO2), open area down to 1%
- Tunable etch profile (shape, angle, ...) through process parameters
- Possibility for mimimal etch areas
- Quick and reliable in-process control using optical non-destructive methods,
- resulting in extremely tight space width control

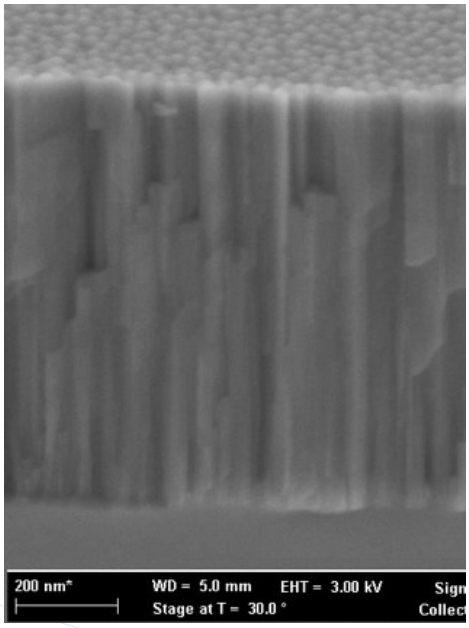


DRIE test structures with different gap widths showing Aspect Ratios of 80:1

Bosch MEMS capabilities (200mm)

AlN

Aluminum Nitride is a non-toxic piezo electric material offering reduced risk of fab contamination since aluminum is used for most semiconductors processes. It is stable over time and also stable against plasma treatment at temperatures of 1,000 ° C and more.
It is compatible with typical semiconductor processes and allows a fast and efficient integration into existing industrial manufacturing processes.



Specifications for standard layer

- e31 of 1 (Cm-2), corresponding to a d33 value of roughly 3,75 pm/V

Capabilities

- Film thickness up to 3 µm
- AlN Stress tuning from –2500 to + 400 MPa
- In situ DeGas and soft-etch of wafers
- Extreme tight process control with regard to physical base parameters
- High experience in process control regarding defects, stability, reliability

Other features

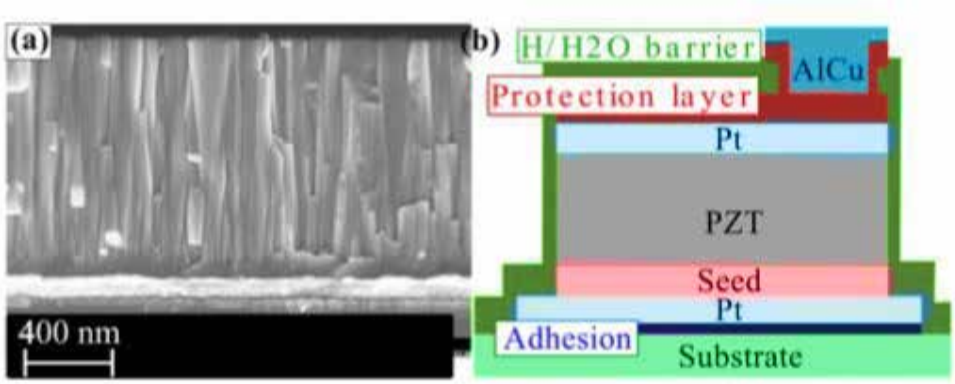
- Ion Beam Trimming of AlN
- Step coverage: Good grow conditions on oxide step.
- In line process control and characterization at Bosch: thickness, stress, etc
- Short loop monitoring: d33 (piezoelectric coefficient)
- Lab Monitoring: texture, roughness

Bosch MEMS capabilities (200 mm)

PZT

PZT is a piezoelectric material which is ideal for an actuator. PZT can be deposited by solgel or by sputtering, whereas sputtering is the typical semiconductor approach. The sputtered material is well defined and not contaminated with residuals from the used solvents. Bosch is working with sputtered PZT since more than six years. During this time, quality and control of Bosch's PZT reached high automotive standards in terms of reproducibility and reliability.

- State of the art 8" PVD equipment:
- Tool in use since Jan, 2016
- Process ready for mass production
- Deposition temperature between 450° and 490°C, very low (!)



Typical material properties

- PZT: e31: -13 ...-15 C/m2 @1000nm and 200 kV/cm
- Thickness range: 500 – 4000 nm (depends on application), uniformity: < 10%
- Refractive index 2.6

Process integration of a complex PZT stack

- Adhesion layer
- Pt electrodes
- Seed layer
- H/H2O barrier
- Protection layer

Specific Metrology

- AixHALT test bench for lifetime under bias
- AixCCT tool for d33 and e31 on
- Ellipsometry for thickness measurements

Bosch MEMS capabilities (200mm)

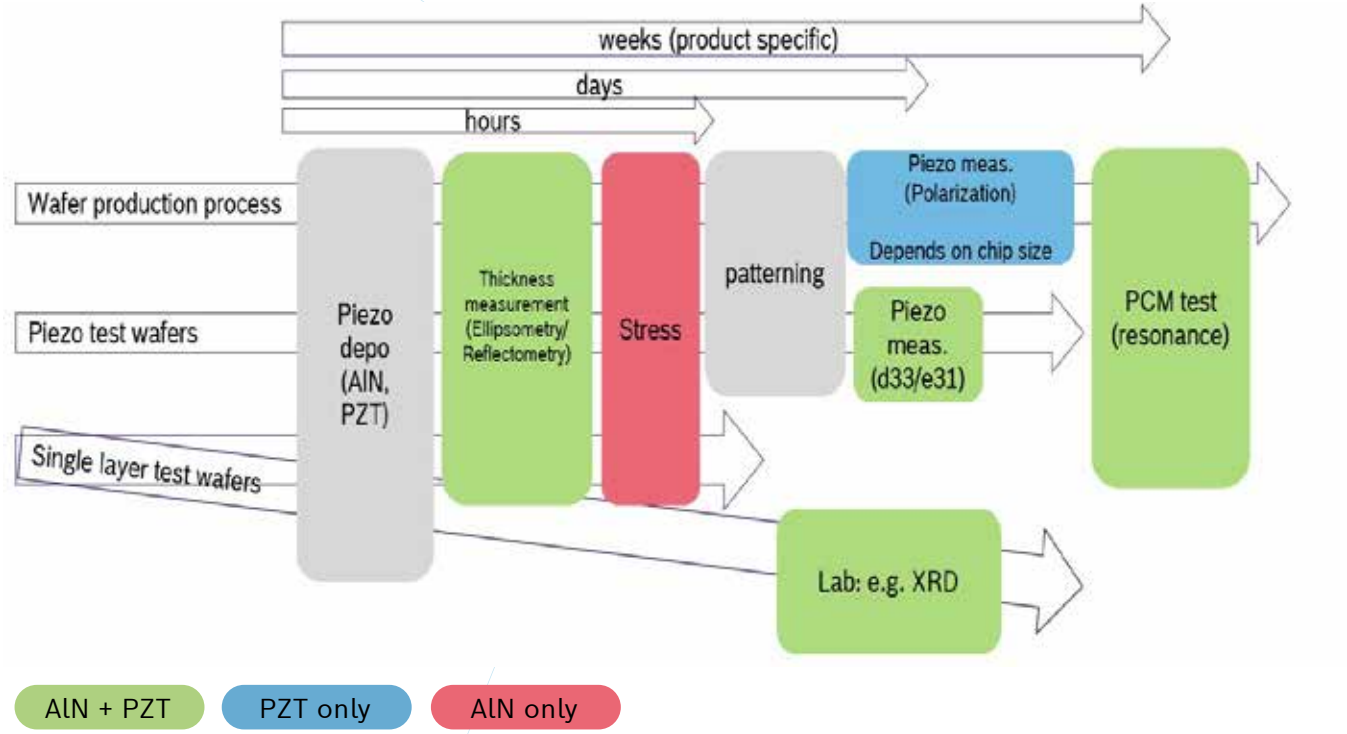
Piezo metrology concept

Monitoring and controlling of piezoelectric material is at least as important as the deposition itself. Different levels of quality checks can be performed, requiring different timeframes after deposition.

The basic material parameters like film thickness, refractive index and stress can be obtained within hours after deposition on product or test wafers. However, those parameters are not suitable to assess the piezo performance. Crystal quality is one factor impacting the piezo performance. It can be measured by XRD within a few days on test wafers.

For PZT, defect monitoring is crucial. Since 2016, Bosch continuously performs regular measurements on product and test wafers.

Basic piezo parameters like d33 and e31 or polarization contain better information regarding performance. Also here, separate test wafers are prepared and measured on AixACCT tools. Resonance can be tested during PCM test or wafer test.



Bosch MEMS capabilities (200mm)

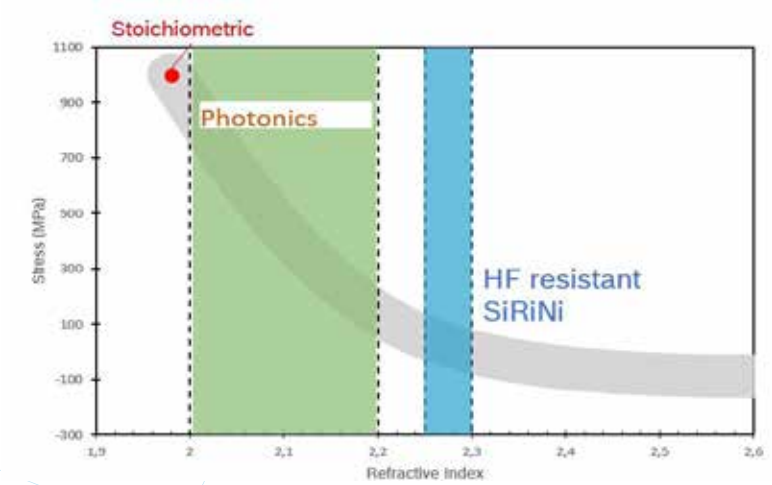
SiN

Silicon Nitride is an insulating material, suitable for various applications. It is typically used in stoichiometric compostion as diffusion barrier. When the silicon content is increased, the silicon rich nitride “SiRiN” changes its material properties.

By adjusting the silicon content:

- the stress can be chosen
- the refractive index can be chosen, important for photonic devices
- the resistivity in HF etching can be achieved

This allows a wide range of additional applications in MEMS. The know-how regarding set up, operation and controlling SiRiN is crucial for success in MEMS. Bosch uses SiRiN for numerous applications.



Capabilities:

- Film thickness up to 1400 nm
- SiN Stress tuning from –100 to + 1000 Mpa
- Refractive index tuning from 1.98 to 2.50 (@780 nm measured)
- Applications
  - Stoichiometric Si3N4: passivation, diffusion barrier.
  - Silicon Rich Nitride (SiRiNi): electrical insulation layer, resistant to vapour-HF.
  - Medium refractive index: photonic layer.

Clean requirements:

- FEOL (Front End of Line) only
- Input only with cleaned wafers with following allowed materials: Si, O, H.
  No Metals allowed.

Click here for more information:

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