Silicon Fabrication Handbook
MEMS Overview
Version: 1.0
Date: 2026-02-21

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Slide 1: What Is MEMS?
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- MEMS = Micro-Electro-Mechanical Systems.
- Devices combine mechanical structures, sensors/actuators, and electronics.
- Typical size: micrometers to millimeters.
- Materials: silicon, silicon dioxide, silicon nitride, metals, polymers.

Examples:
- Accelerometers and gyroscopes
- Pressure sensors
- Microphones
- RF switches and resonators

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Slide 2: Why MEMS Is Important
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MEMS enables:
- High-volume, low-cost sensing in consumer electronics.
- Harsh-environment sensing in automotive and industrial systems.
- Miniaturized diagnostics in medical and biotech applications.

Value proposition:
- Small form factor
- Low power operation
- Batch fabrication using semiconductor-style processes

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Slide 3: Core MEMS Building Blocks
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Mechanical elements:
- Beams, membranes, comb fingers, masses, anchors

Transduction mechanisms:
- Capacitive (most common in inertial MEMS)
- Piezoresistive
- Piezoelectric
- Thermal / optical (application-specific)

Readout and interface:
- Analog front-end (AFE)
- ADC and digital filtering
- Calibration and compensation algorithms

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Slide 4: Surface Micromachining
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Concept:
- Build structures layer-by-layer on wafer surface.
- Use sacrificial layers to create air gaps and movable parts.

Typical flow:
1) Deposit sacrificial layer
2) Deposit structural layer (e.g., polysilicon)
3) Pattern and etch
4) Release sacrificial material
5) Dry to avoid stiction

Pros:
- Good CMOS compatibility
- Fine feature control
Cons:
- Limited structural thickness

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Slide 5: Bulk Micromachining
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Concept:
- Sculpt the wafer itself (deep cavities, diaphragms, high-aspect structures).

Key methods:
- Wet etch (KOH, TMAH)
- Deep reactive ion etch (DRIE / Bosch process)
- SOI-based etching for thickness control

Pros:
- Thick, robust structures
- Excellent for pressure sensors and inertial masses

Cons:
- Process complexity and stress management challenges

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Slide 6: MEMS + CMOS Integration
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Integration strategies:
- Monolithic: MEMS and CMOS on same die
- Hybrid/multi-chip: separate dies in one package
- Wafer-level bonding approaches for cavity sealing

Tradeoffs:
- Monolithic gives compact systems but stricter thermal/process budgets.
- Hybrid gives process flexibility but may increase parasitics and assembly cost
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Design goal:
Optimize performance, yield, and cost simultaneously.

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Slide 7: Packaging and Reliability
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MEMS packaging is often part of the device physics.

Critical packaging functions:
- Mechanical protection
- Controlled cavity pressure (vacuum or gas)
- Environmental isolation (moisture/particles)
- Electrical interconnect and thermal path

Reliability topics:
- Stiction and wear
- Drift and bias instability
- Shock/vibration survivability
- Temperature and humidity effects

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Slide 8: Test and Calibration
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Production test includes:
- Electrical continuity and leakage
- Sensor response linearity and sensitivity
- Noise density and bandwidth checks
- Self-test actuator verification (when available)

Calibration includes:
- Offset/bias correction
- Scale-factor trimming
- Temperature compensation coefficients

Output quality metric examples:
- Bias stability (gyro)
- g-sensitivity and cross-axis sensitivity (accelerometer)

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Slide 9: Application Snapshots
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Consumer:
- Phone IMU (accelerometer + gyroscope)
- MEMS microphone arrays

Automotive:
- Airbag accelerometers
- Tire pressure monitoring sensors
- In-cabin sensing

Industrial/medical:
- Vibration monitoring
- Pressure/flow sensing
- Microfluidic lab-on-chip interfaces

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Slide 10: Summary and Next Steps
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Key takeaways:
- MEMS combines mechanics and microfabrication for scalable sensing/actuation.
- Surface and bulk micromachining serve different geometry and integration needs.
- Packaging, testing, and calibration are central to real-world performance.
- Co-design across device, circuit, and package is essential.

Recommended repository reading:
- docs/04-mems-surface-micromachining/device-examples.md
- docs/05-mems-bulk-micromachining/pressure-sensors.md
- docs/08-integrated-mems-cmos/integration-strategies.md
- docs/07-testing-yield/reliability-testing.md

End of deck.