Smart Sensing

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Smart Sensors

Real-World Phenomena to Digital Intelligence

Healthcare & Life Sciences

Mobility & Industrial Systems

Environment, & Agri-Food

- Conversion of physical, chemical, and biological signals into actionable data
- Explosive demand driven by AI, healthcare, mobility, energy, and sustainability
- Shift from raw data acquisition to on-device intelligence and insight
- Enabler for real-time, distributed, and autonomous decision-making

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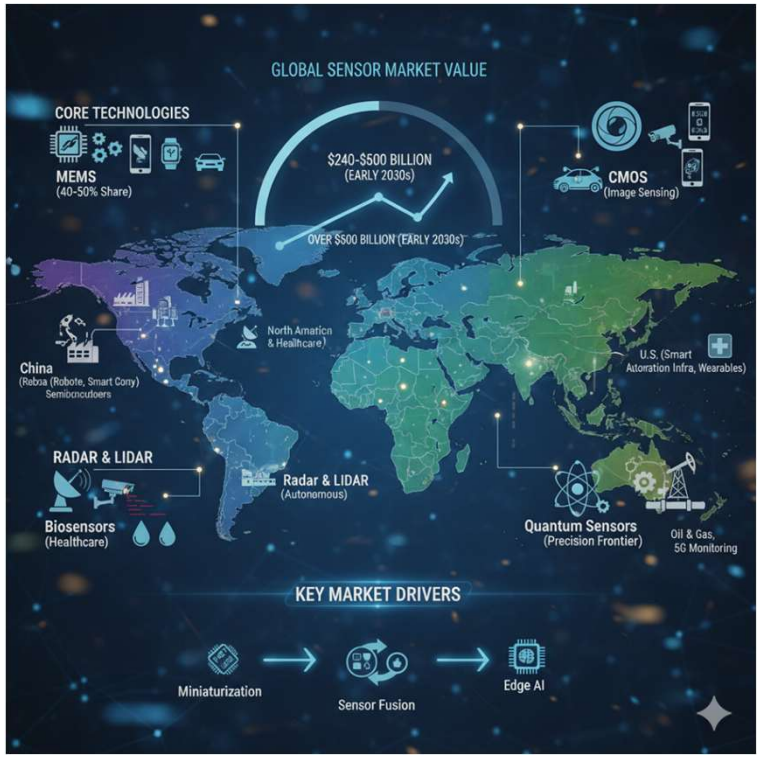
Global Sensor Landscape: Technologies and Regional Strengths



Core Technologies Shaping the Landscape

- MEMS and CMOS sensors enabling scalable, cost-efficient production
- Optical, radar, and LiDAR sensing supporting autonomy and safety
- Chemical and biosensors addressing health, environment, and sustainability
- Smart and AI-enabled sensors enabling system-level innovation

Regional Capabilities

- Asia: leadership in manufacturing scale and advanced packaging
- North America: strengths in system-level innovation and AI integration
- Europe: excellence in automotive, industrial sensing, MEMS, photonics, and reliability
- Emerging regions: infrastructure, energy, and industrial monitoring adoption

Strategic Insight

- Europe’s opportunity lies in heterogeneous integration and value-chain leadership

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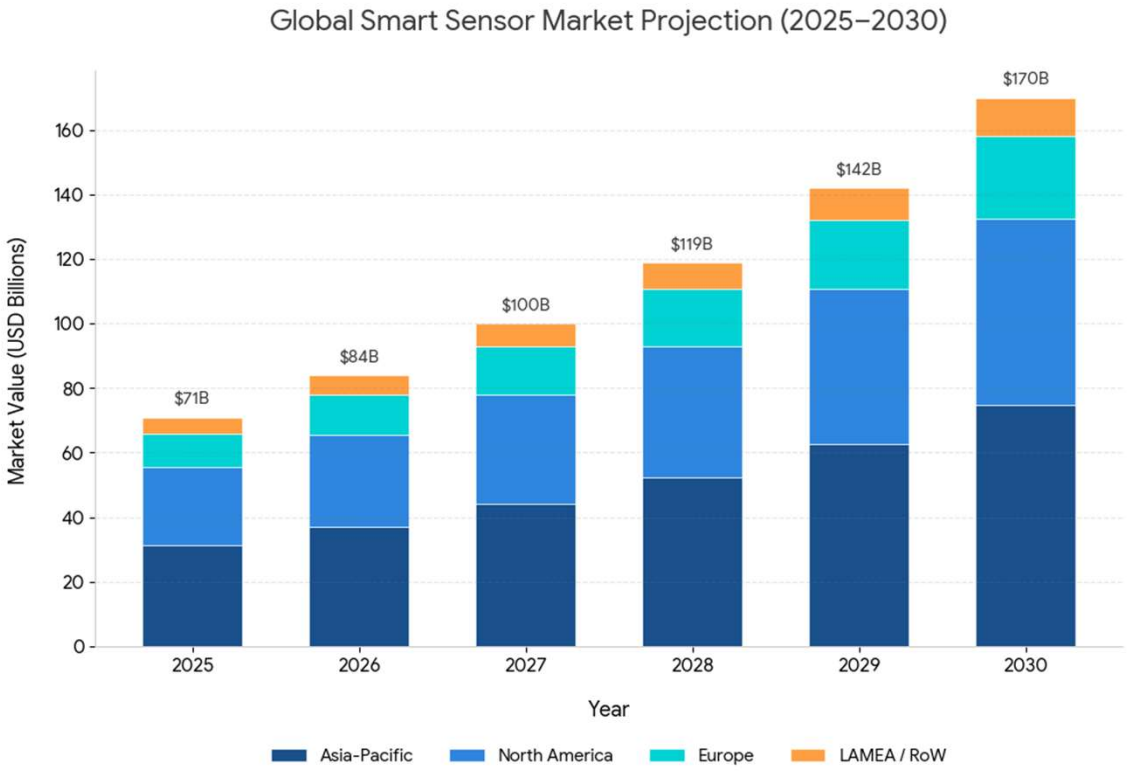
Global Smart Sensor Market



MEMS (Micro-Electro-Mechanical Systems)

- Market Share: Dominates with over 50% of the smart sensor market.
- Projected Value: USD 85–90 billion by 2030 (Smart-specific segment).

CMOS (Complementary Metal-Oxide-Semiconductor)

- Growth Rate: Anticipated to be the fastest-growing segment with a CAGR of nearly 20%.
- Projected Value: USD 50–55 billion by 2030.

Optical & Photonics

- Growth Rate: Steady growth with a CAGR of approximately 11–12%.
- Projected Value: USD 55–60 billion by 2030.

Biosensors (Emerging Leader)

- Growth Rate: Emerging as a high-potential segment due to the "Hospital-to-Home" shift.
- Projected Value: USD 25–30 billion by 2030.

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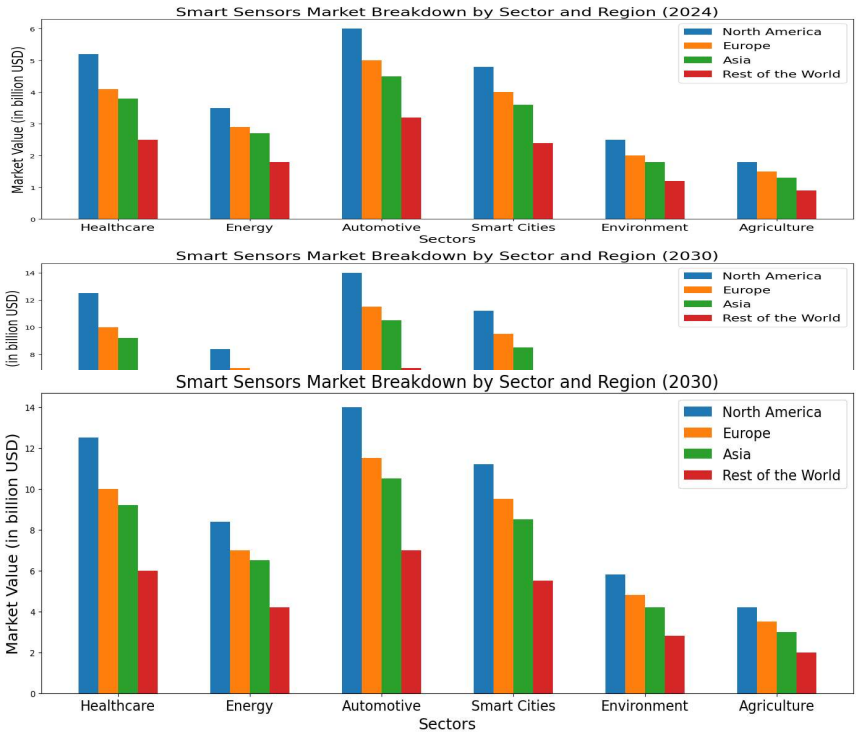
Technology Market by sector



Global values 2024 ➔ 2030

Healthcare: $15.6 ➔ $37.7 billion

Energy: $10.9 ➔ $26.1 billion

Automotive:$18.7 ➔ $43 billion

Smart Cities:$14.8 ➔ $35 billion

Environment: $7.5 ➔ $17.6 billion

Agriculture: $5 ➔ $15 billion

Sources:
grandviewresearch.com
mordorintelligence.com
market.us
emergenresearch.com
theinsightpartners.com

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Sensing Technologies in the EU Semiconductor Strategy

Technology Domain	Strategic Focus ("More-than-Moore")	Key Initiative & Funding	Target EU Application
Emerging & Green Sensing	Developing sustainable, flexible, and biodegradable sensors and materials (Green ICT).	**InfraChip Project:** A new EU research platform providing free access to pilot lines for "Green Sensors" and flexible substrates.	**Smart Packaging:** Biodegradable tracking. **Wearables:** Skin-patch health monitors.
MEMS & Edge AI	Integrating AI directly on-chip for low-power, instant data processing.	**FAMES Pilot Line** (FD-SOI focus for low-power chips).	**Automotive:** Airbags, ESP systems. **Consumer:** Smart wearables, home device.
Integrated Photonics	Miniaturizing optical systems (lasers/detectors on silicon) for speed & sensitivity.	**PhotonHub Europe** & **Chips JU** (Pilot lines for prototyping). **InfraChip:** Supports photonic sensing access for SMEs.	**Autonomous Driving:** LiDAR sensing. **Health:** Lab-on-chip diagnostics.
Quantum Sensing	Developing "chip-scale" sensors for extreme precision beyond classical limits.	**Quantum Technologies Flagship** (€1B+ initiative to commercialize quantum sensors).	**Medical:** Brain imaging (MEG). **Navigation:** GPS-free positioning.
Sensor Fusion	Advanced packaging to stack multiple sensors (Radar + Camera) in one module.	**APECS Pilot Line** (Advanced packaging & heterogeneous integration).	**Industry 4.0:** Robotics & automation. **Defense:** Secure edge sensing.

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Europe's Position in the Sensor Value Chain

Europe's Global Strengths

LEADERSHIP in MEMS, automotive-grade sensors, and industrial sensing.

STRONG CAPABILITIES in CMOS design, integrated photonics, and reliability engineering.

EXCELLENCE in globally recognized research (IMEC/Leti) and standards leadership.

Global Context

ASIA dominates high-volume manufacturing and advanced packaging.

NORTH AMERICA leads in system-level innovation and AI-driven sensing.

EUROPE competes by **differentiation** (quality/complexity), not scale.

Strategic Positioning

FOCUS on heterogeneous integration (stacking sensors) and smart sensor systems.

STRENGTHEN global partnerships while ensuring value capture stays in Europe.

BRIDGE TRLs using pilot lines (Chips Act) and shared infrastructure (**InfraChip**) to scale innovation.

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Market Pull: Applications Driving Sensor Integration

What the Market Is Demanding

- Smaller, cheaper, more reliable end-to-end systems
- Multi-modal, multistate sensing (electrical, optical, chemical, biological)
- Low power and edge intelligence
- High robustness and long lifetime
- Scalable manufacturing and certification readiness

Why Integration Is Essential

- System-level performance >> component-level optimization
- Reduced latency, power, and data bandwidth
- Enables sensor + processing + AI in one package
- Critical for deployment outside controlled lab environments

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Heterogeneous Integration: Definition and Scope

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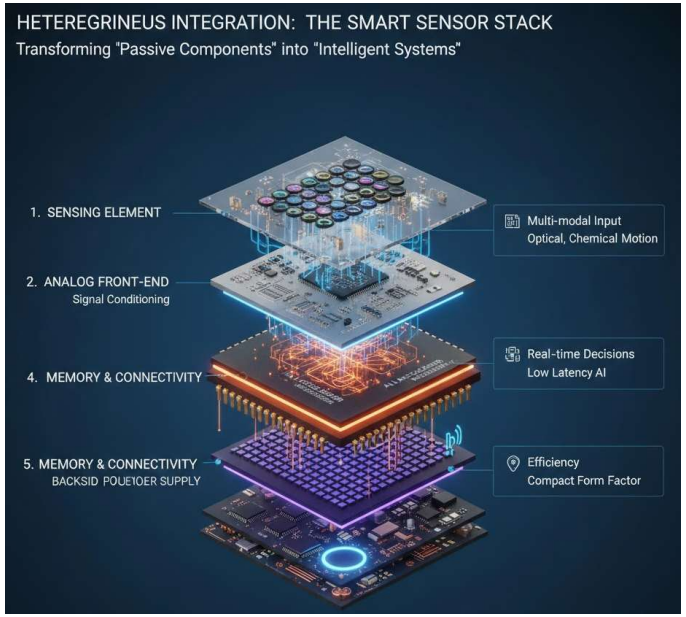
Why Heterogeneous Integration Matters for Sensors

Driver	The Challenge (Traditional)	The HI Solution (Integration)	The Strategic Value
1. Economics & Yield	**Technology Mismatch:** Logic needs 5nm; Sensors need mature nodes (e.g., 180nm). Cannot be built on one wafer.	**"Mix & Match":** Build sensor and logic on their ideal nodes, then stack them. Increased selectivity	**Optimized Cost:** Don't waste expensive silicon on simple functions.
2. Performance (Edge AI)	**Data Bottleneck:** Sending raw Gbps data off-chip to a CPU creates high latency and burns power.	**Near-Sensor Processing:** Stack the AI accelerator *directly* under the sensor.	**Real-Time Decisions:** Instant reaction (critical for L4/L5 Autonomy).
3. Signal Integrity	**Noise & Parasitics:** Analog signals degrade when traveling centimeters across a PCB wire.	**Micron-Scale Interconnects:** 3D TSVs shorten the path to mere microns.	**Extreme Precision:** High SNR required for Quantum & Medical sensing.
4. Form Factor	**2D Sprawl:** Placing components side-by-side takes up too much X-Y space.	**3D Vertical Stacking:** Building upwards instead of outwards.	**Miniaturization:** Enables "Invisible" wearables and implants.



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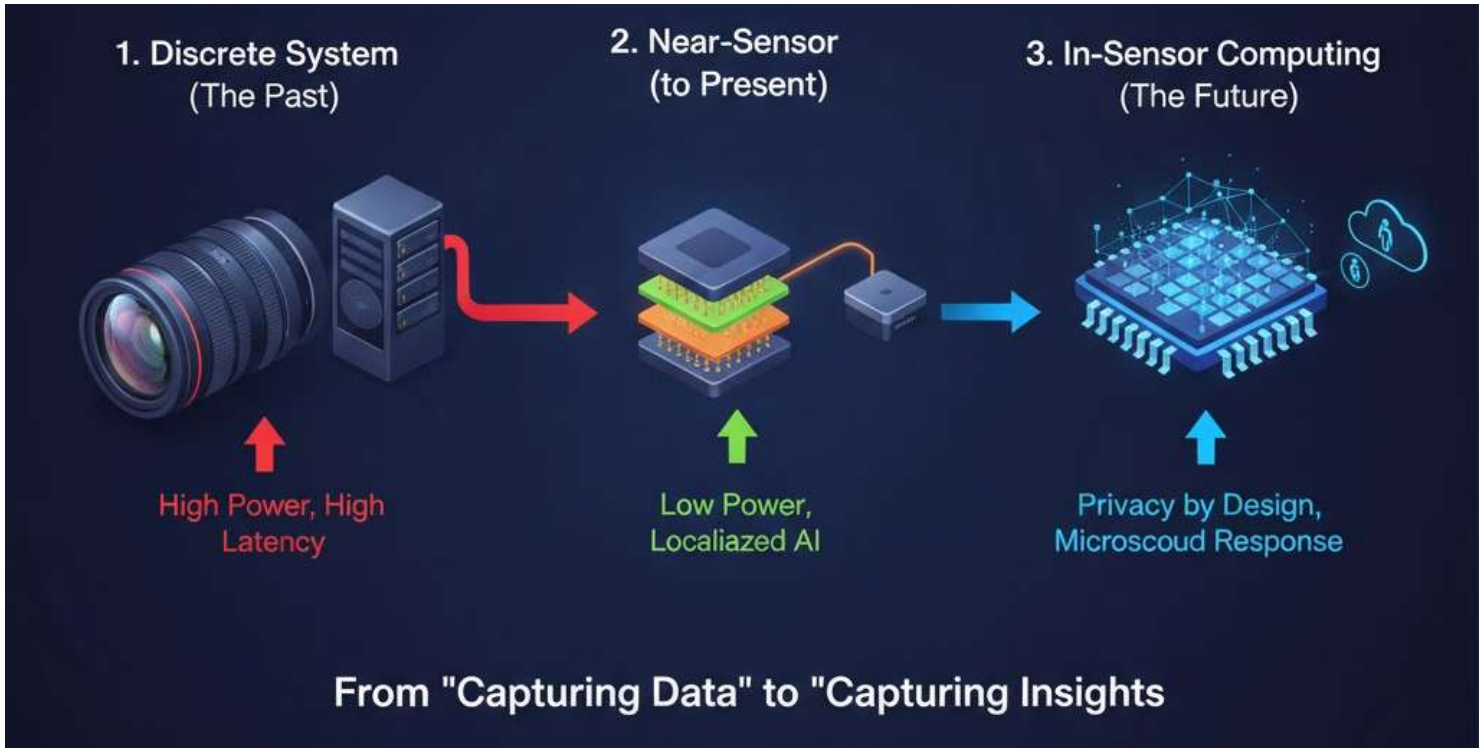
From Image Sensors to In-Sensor AI Computing



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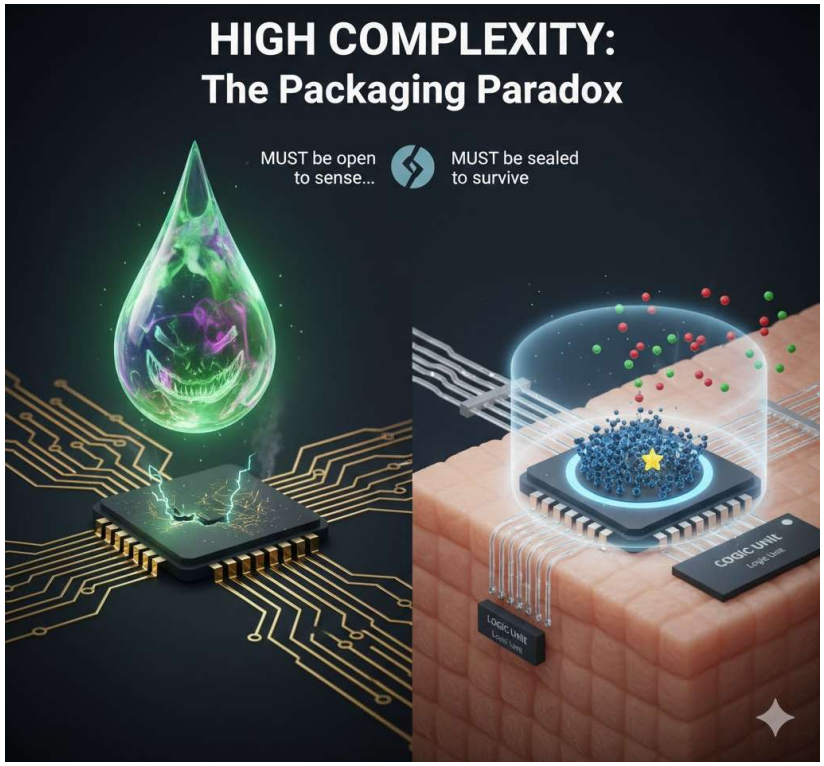
Chemical and Biochemical Sensors: High Impact, High Complexity



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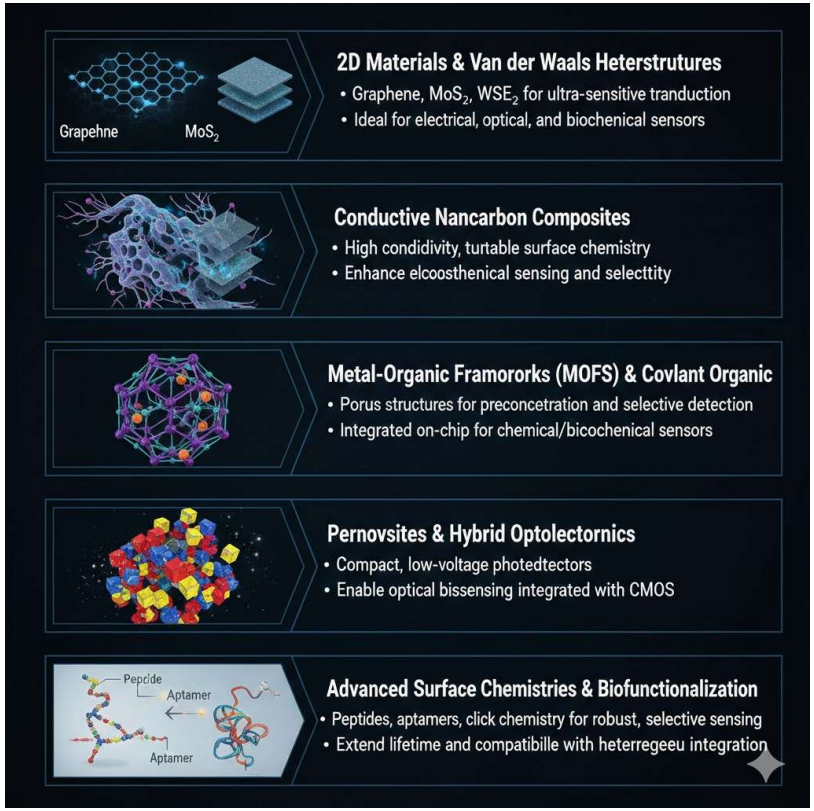
Advanced Materials for Ultra-Sensitive and Selective Sensing



Why These Materials?

- Silicon is excellent for logic, but inert for chemical sensing.
- Advanced materials are the active interface between the target molecule and the electronic readout.

The Power of Integration:

- Enables ultra-low detection limits (ng/L, ppb) critical for health and environmental applications.
- Achieves enhanced selectivity in complex, multi-analyte mixtures.
- Supports heterogeneous integration for multi-modal sensors in one package.

Driving EU Innovation:

- Essential for next-generation AI-enabled sensor systems.
- Strengthens EU leadership in high-value, system-level sensing solutions.

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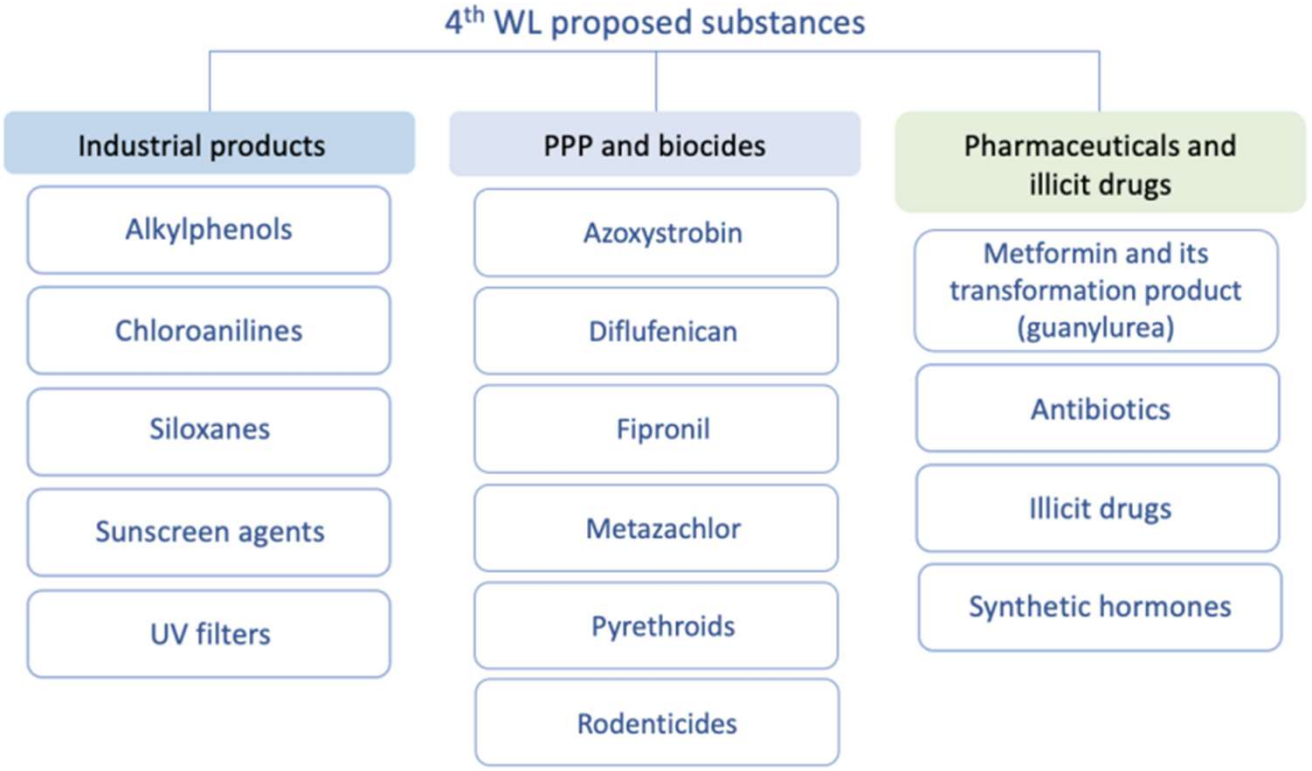
Water Framework Directive – watchlist



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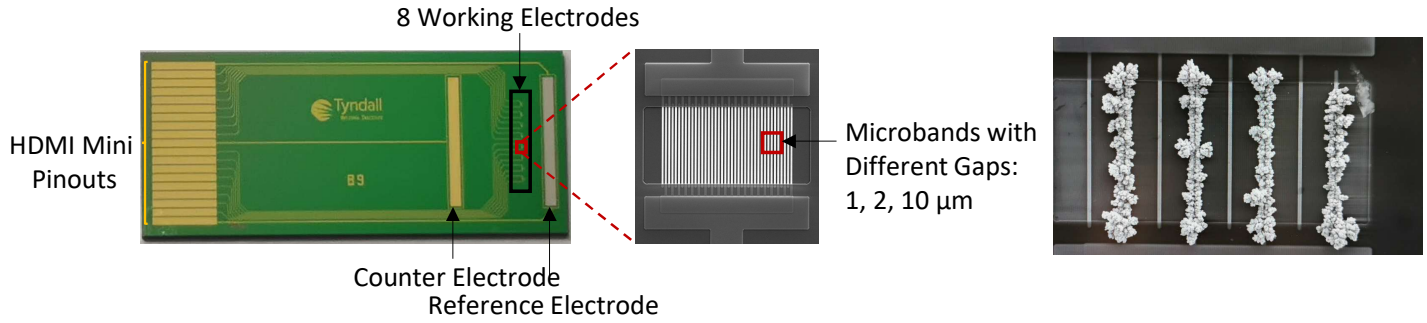

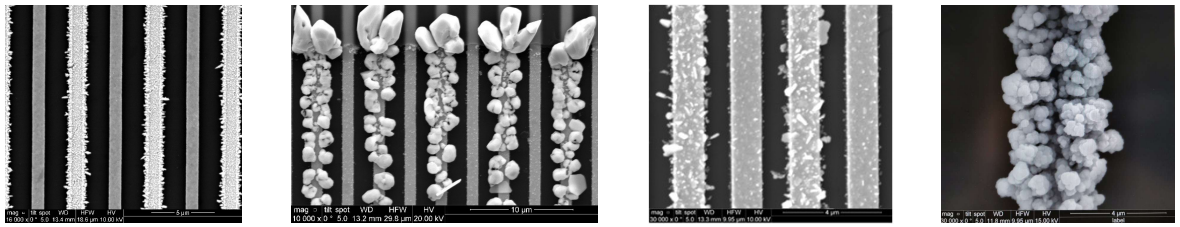

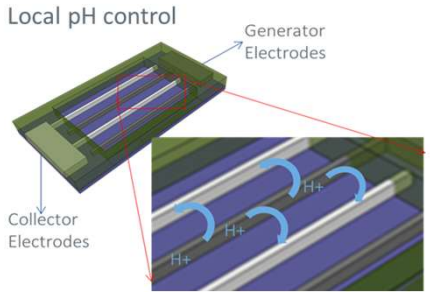

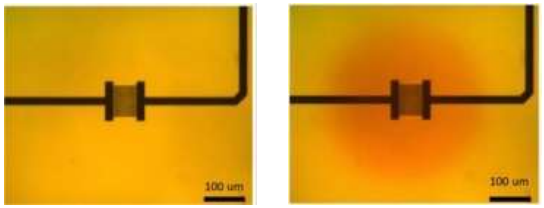

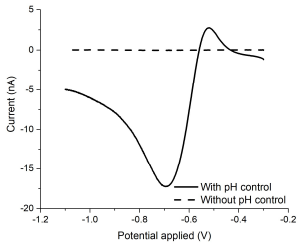

Visualisation of pH change using methyl orange pH indicator dye

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Reliability, Packaging, and Operational Lifetime

The "Packaging Paradox":

- Challenge: Electronics require total sealing (hermetic), but chemical sensors require exposure to the environment.
- Solution: Open-Cavity Packaging.
  - Sensitive interconnects (wire bonds/ASIC) are sealed with Globtop/Dam-and-Fill encapsulation.
  - Sensing pixels remain exposed via a defined "sensing window."
  - Integrated Microfluidics control sample flow and prevent flooding.

Combatting Environmental Degradation

- Bio-Fouling: Application of anti-fouling coatings (e.g., PEG hydrogels, zwitterionic polymers) to prevent protein buildup in medical fluids.
- Drift Mitigation: Real-time Auto-Calibration using on-chip temperature sensors and reference electrodes (Site C).
- Corrosion Resistance: Utilizing inert passivation layers (Si_3N_4) to protect non-sensing areas from harsh electrolytes.

Validation & Lifetime Extension

- Shelf-Life: Dry-storage techniques (e.g., on-chip lyophilization) for biological receptors.
- Testing: Accelerated Aging protocols (High Temp/Humidity) to predict failure modes.
- Standardization: Moving towards industrial compliance (IEC/ISO) to ensure manufacturing repeatability.

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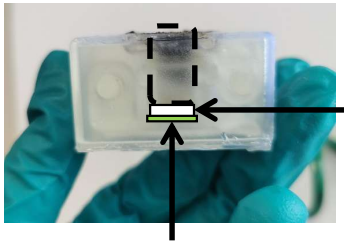

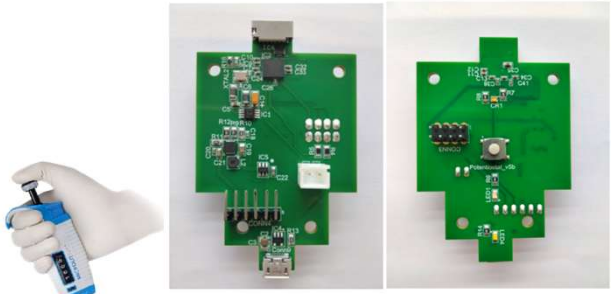

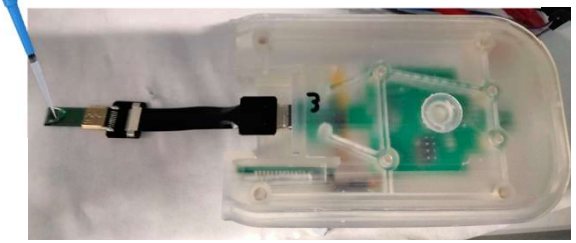

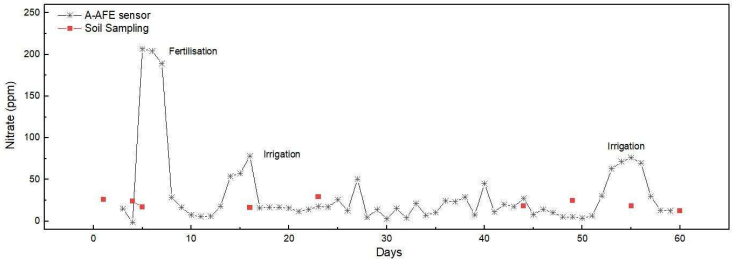

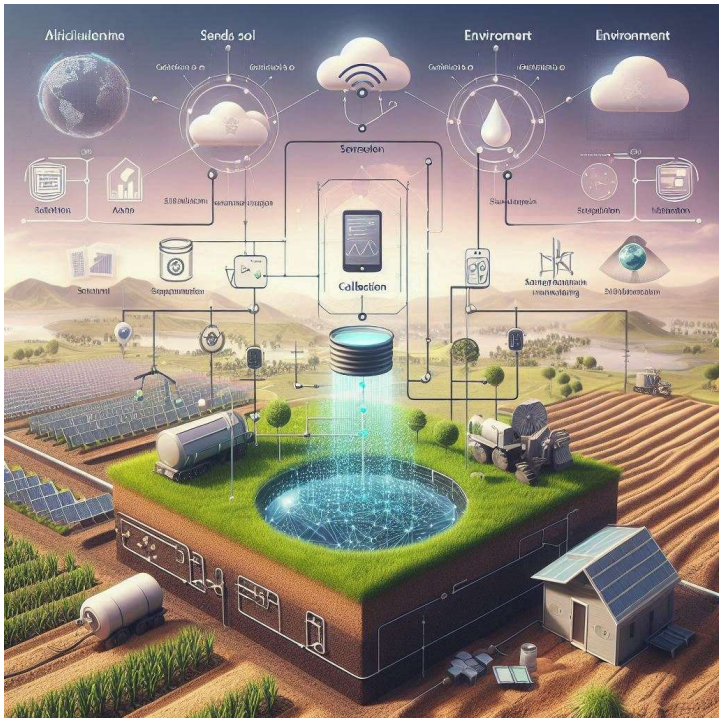

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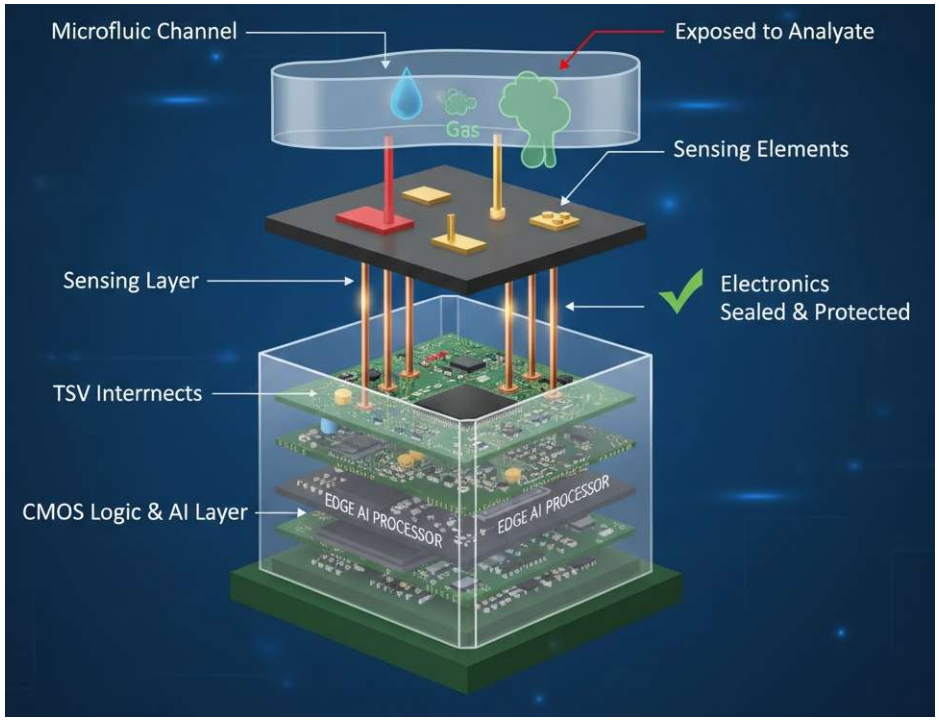
System-Level Innovation: From Sensors to Smart Microsystems



The Hardware Architecture (Heterogeneous Integration)

- Multi-Modal Sensing: Combining Chemical (Graphene/MOx), Physical (Temp/Strain), and Biological sensors on a single module.
- ASIC Readout (AFE): Ultra-low noise Analog Front-End tailored for high-impedance materials (2D materials).
- Power Management: Integrated battery management and potential for energy harvesting (NFC/RF).

Smart Functionality (The "Brain")

- Edge AI & ML: On-chip data processing to classify analytes locally (reducing data transmission).
- Connectivity: Seamless integration with BLE / NFC / NB-IoT for real-time data transmission to the cloud/smartphone.
- Feedback Loops: Active control of microfluidics or heaters based on sensor feedback.

Key Advantages

- Miniaturization: Lab-on-Chip performance in a wearable/implantable form factor.
- Low Power: "Wake-up" modes and local processing extend battery life from days to months.
- Scalability: Standardized integration allows for rapid prototyping of different sensor combinations.

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EU Impact and International Cooperation Opportunities

Impact for the European Union

Strengthening Semiconductor Sovereignty

- **Strategic Pillar**: Positioning sensors as a core layer of the **EU Chips Act** and the "**More-than-Moore**" roadmap.
- **Resilient Value Chains**: Reducing critical dependencies in high-value sectors (Automotive, Industry 4.0, Energy).

Accelerating TRL Scaling & Competitiveness

- **From Lab to Fab**: Bridging the gap from prototype to manufacturing via **Pilot Lines** and **INFRACHIP** facilities.
- **SME & Startup Enablement**: Providing access to shared infrastructure, advanced packaging, and heterogeneous integration capabilities.

Enabling Horizon Europe Priorities

- **Green Deal**: Advanced environmental monitoring for climate action.
- **Health**: Point-of-care diagnostics for the European Health Union.
- **Digital**: Smart microsystems driving the digital transition.

International Cooperation Opportunities

Regional Strategic Synergies

- **Europe–North America**: Collaboration on Advanced R&D, AI algorithms, biomedical sensing, and system architectures.
- **Europe–East Asia**: Partnerships for manufacturing excellence, image sensors, materials reliability, and scale-up.

Global Standardization & Interoperability

- **Regulatory Alignment**: Joint qualification and testing protocols for medical and industrial devices.
- **Global Value Chains**: Connecting the full stack: Materials ➔ Devices ➔ Packaging ➔ Systems ➔ Applications.

Open Invitation

- **Call for Action**: We invite discussion on matchmaking, joint project ideas, and defining resilient, globally connected supply chains.

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Conclusions

Key Value Drivers

- The Critical Interface: Sensors are the non-negotiable bridge connecting the Digital, Physical, and Biological worlds.
- The Scaling Key: Heterogeneous Integration (HI) is essential to overcome physical limits, transforming passive components into intelligent systems.
- The Winning Formula: Combining Advanced Materials + HI + Edge AI unlocks the compact, low-power, real-time systems required by industry.

The European Competitive Edge

- Strong Foundations: Global leadership in CMOS, MEMS, Photonics, and Advanced Packaging.
- Unique Assets: A robust "Lab-to-Fab" ecosystem driven by Pilot Lines and access projects (e.eg infrachip).
- Strategic Alignment: Direct value-chain support for the EU Chips Act and the Green & Health Transitions

Challenges:

- Geopolitical stability
- Reliance on US IT and Software
- Scaling & Infrastructure Gaps
- Economic Competitive Disadvantage
- The Talent & Systems Deficit

THANK YOU

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