



Pioneering Perspectives: Sensing and Imaging as Key Enabling Technologies

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Revolutionizing Health and MedTech: *The Impact of Wearable Devices with Hybrid Printed Electronics*

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DISCLOSURE SLIDE

Employee of TNO Holst Centre



Unaffordable health

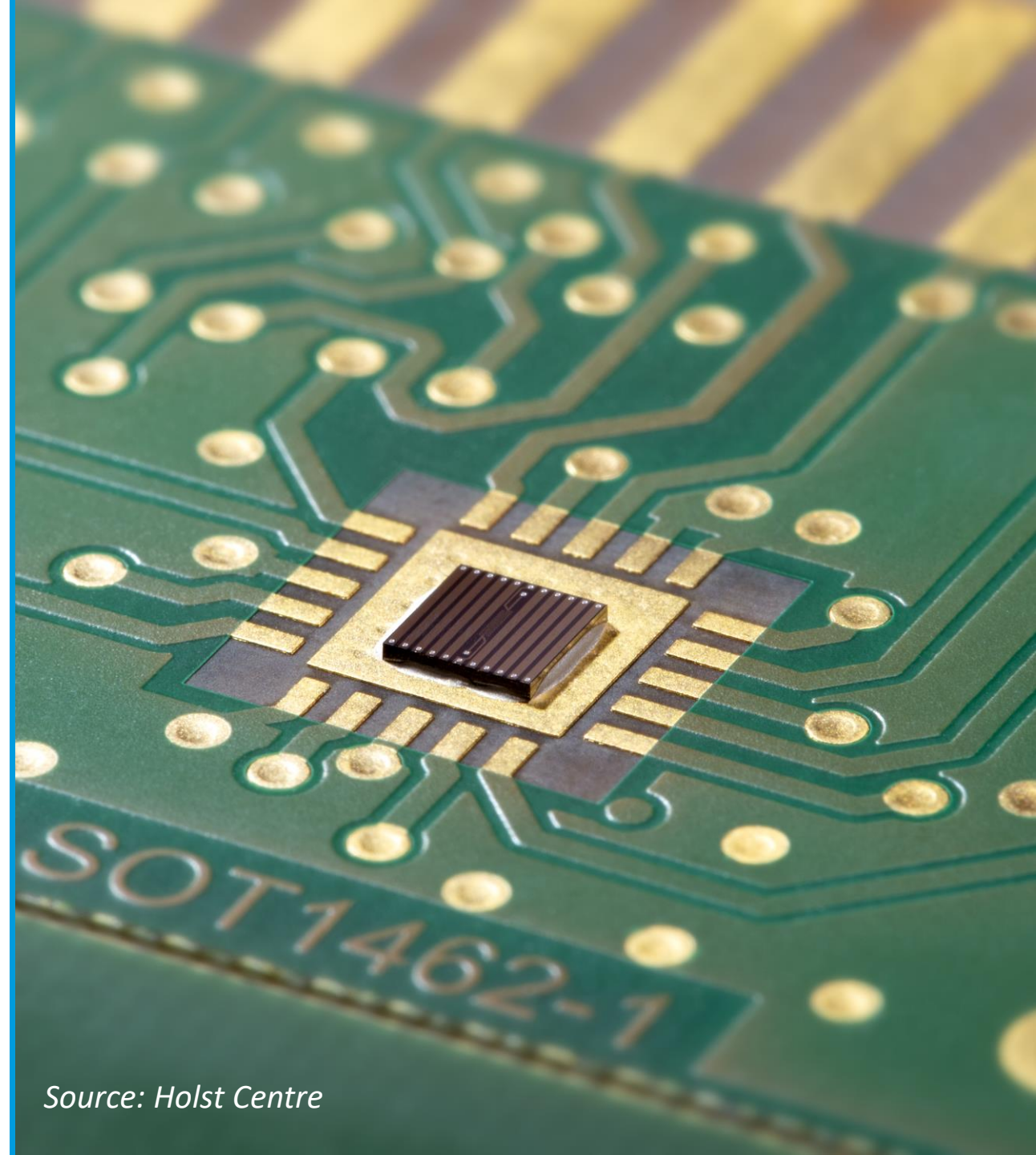
- Rise of **chronic** diseases
- Risks of **pandemics**
- Strained **healthcare** system
- Soaring **costs** of medicines

Source: Rationale Tech4Health coalition



Technology perspective

- **Chiptech**
- **Microelectronics & sensors**
- **New manufacturing technologies**
- 3D printing & **additive manufacturing**
- **Material Science & Nanotechnology**
- Robotics & Automation
- IT | Data Science | AI



Revolutionize health by boosting productivity

Wearable devices are enabler

- Optimizing the **workflow**
- Shifting **care outside** of the **hospital**
- Leveraging the power of **prevention**

Sources: *Rational Tech4Health Coalition*

Holst Centre - Accelerating Innovation



Source: *Holst Centre*

MedTech perspective

- **€ 160 B** market, 2nd largest after US
- **Added value: € 184,000 per employee**
- **Export value:** the Netherlands is **second** in Europe. **Medtech is a revenue model** for the Netherlands
- **IP position:** the **second** largest applicant of patents worldwide with 8.1% of the total

Source: MedTechEurope Manifesto



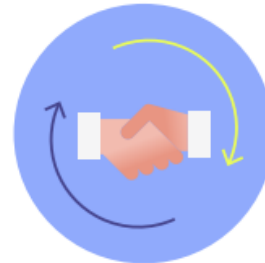
35,000

Medical technology companies in Europe
92% are SMEs



850,000+

People employed directly by the
medical technology industry



Positive medical devices
trade balance of

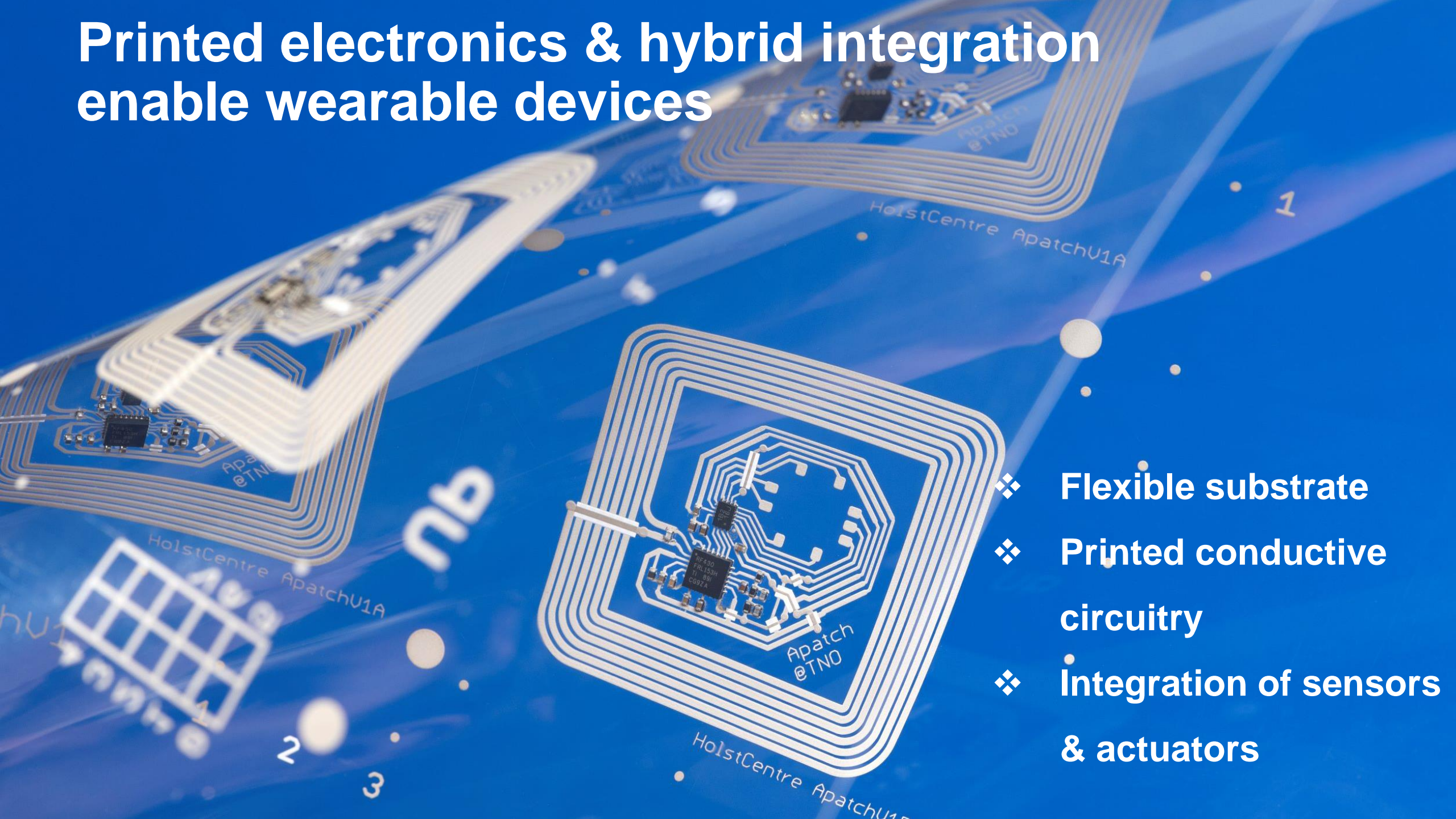
€5.2 billion EUR



**One patent every
30 minutes**

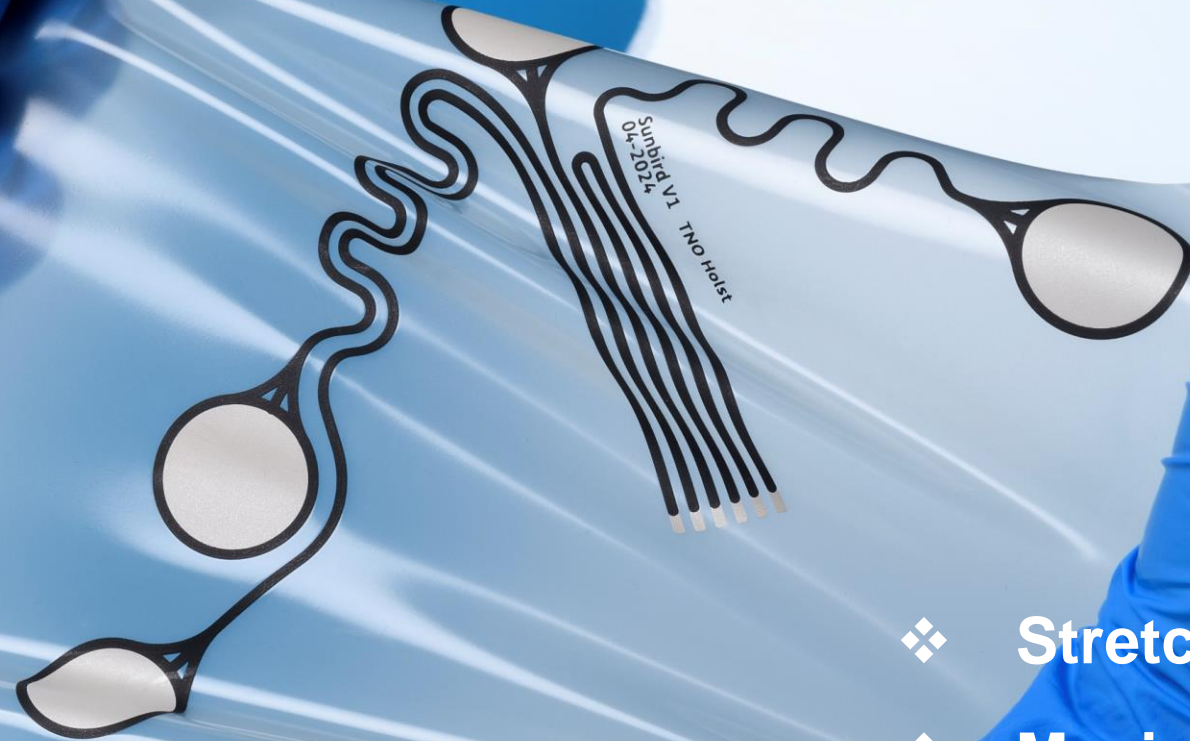
Is filed with the European Patent Office
in the field of medical technology

Printed electronics & hybrid integration enable wearable devices



- ❖ Flexible substrate
- ❖ Printed conductive circuitry
- ❖ Integration of sensors & actuators

Integration on stretchable substrates for extra comfort



- ❖ Stretchable substrate
- ❖ Maximum comfort
- ❖ Longer wearability

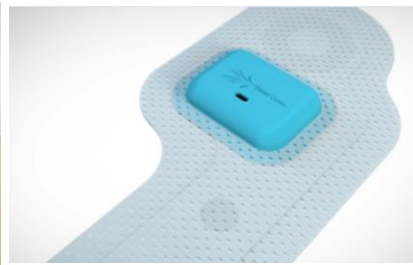
Medical devices at Holst Centre



Heart rate & respiration*



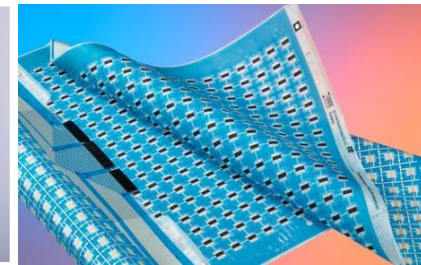
Baby monitoring belt *



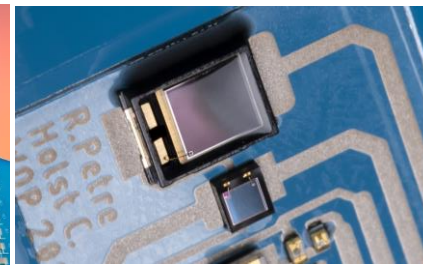
ECG & SpO2 patch



ECG & temperature patch



Non-contact monitoring



Surgical flap monitoring

2010

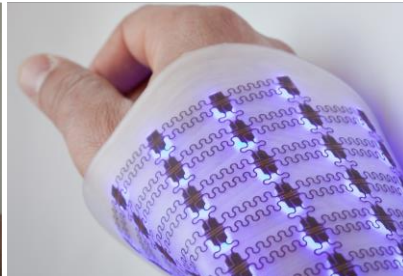
2024



Jaundice Tx blanket *



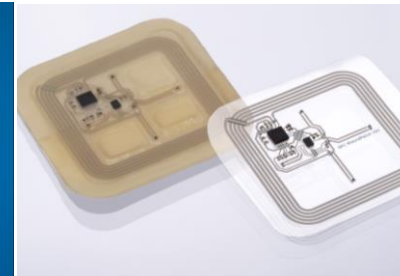
Brain photo-modulation *



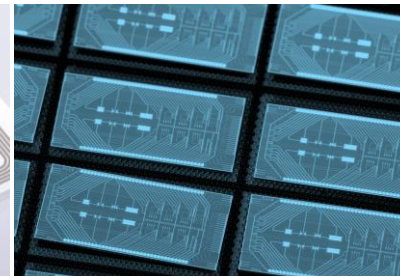
Pain relief *



Wearable sonography



Wound monitoring



Bio-sensing

* Products on the market

ECG, HR, RR



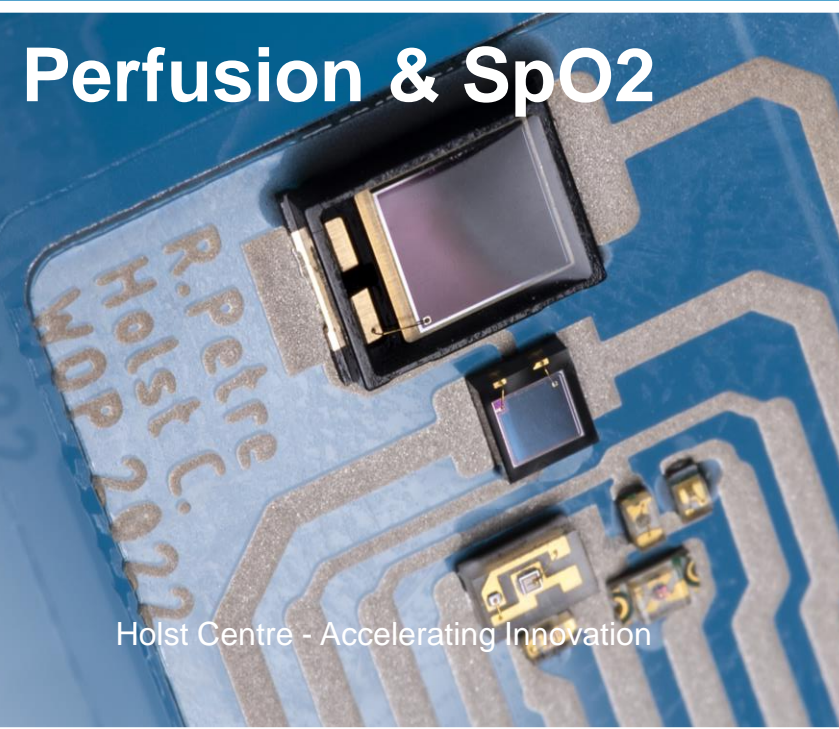
Core body T°C



Wearable sonography



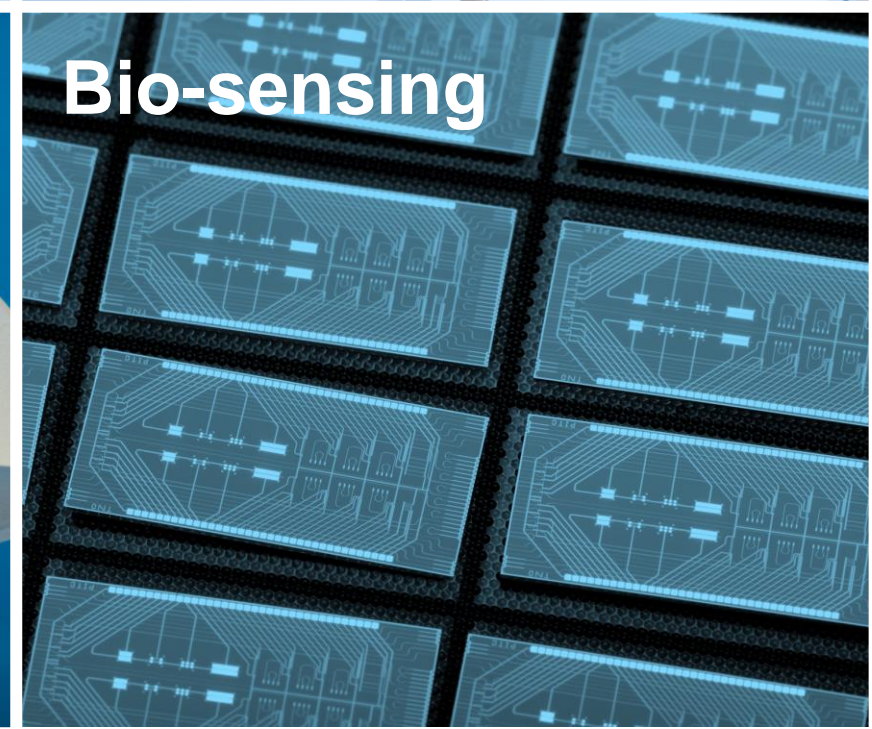
Perfusion & SpO2



Wound monitoring



Bio-sensing



ECG patches

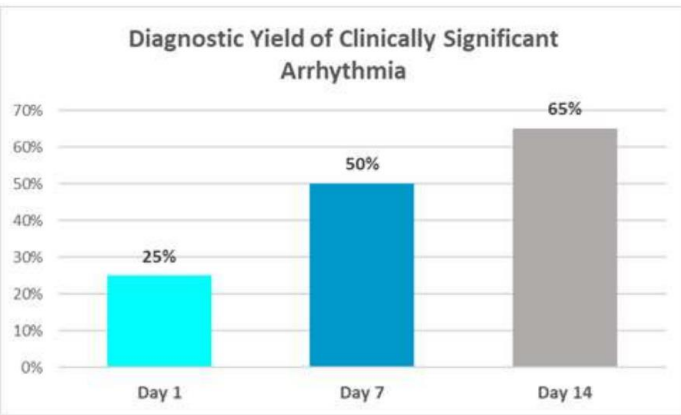
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The need for ECG patch and longer monitoring

FIGURE 1



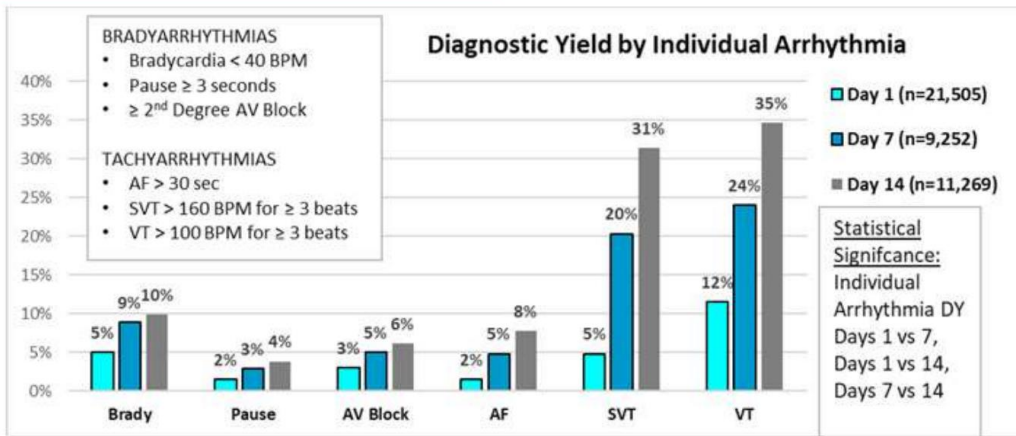
DY for any CSA with ePatch was:

- 25% on Day 1 (n= 21,505)
- 50% on Day 7 (n=9,252)
- 65% on Day 14 (n=11,269)

Statistical significance: Days 1 vs 7, 1 vs 14, and 7 vs 14

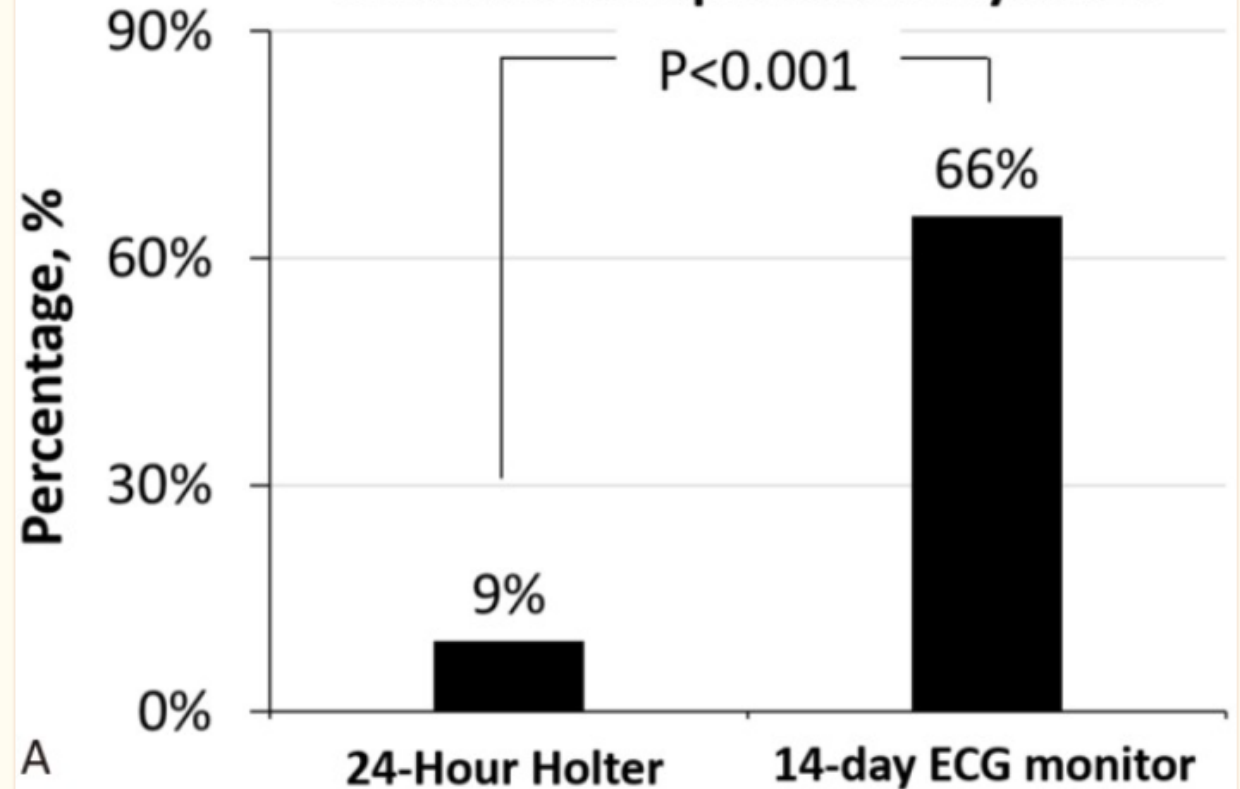
- P<0.00001 for any CSA

FIGURE 2



Source: P. Parikh et al. Diagnostic yield of 24 hour Holter vs 7 and 14 day ePatch

Detection of Specific Arrhythmia



Source: Chua SK et al. Comparison of Arrhythmia Detection by 24-Hour Holter and 14-Day Continuous Electrocardiography Patch Monitoring. Acta Cardiol Sin.

ECG patches today

State of the art - hydrogel electrodes:

- Data loss, short wear time & shelf lifetime, risk of skin irritation

Key requirements:

- High-quality signal
- Long-term monitoring
- Patient **comfort** & compliance

ECG patches

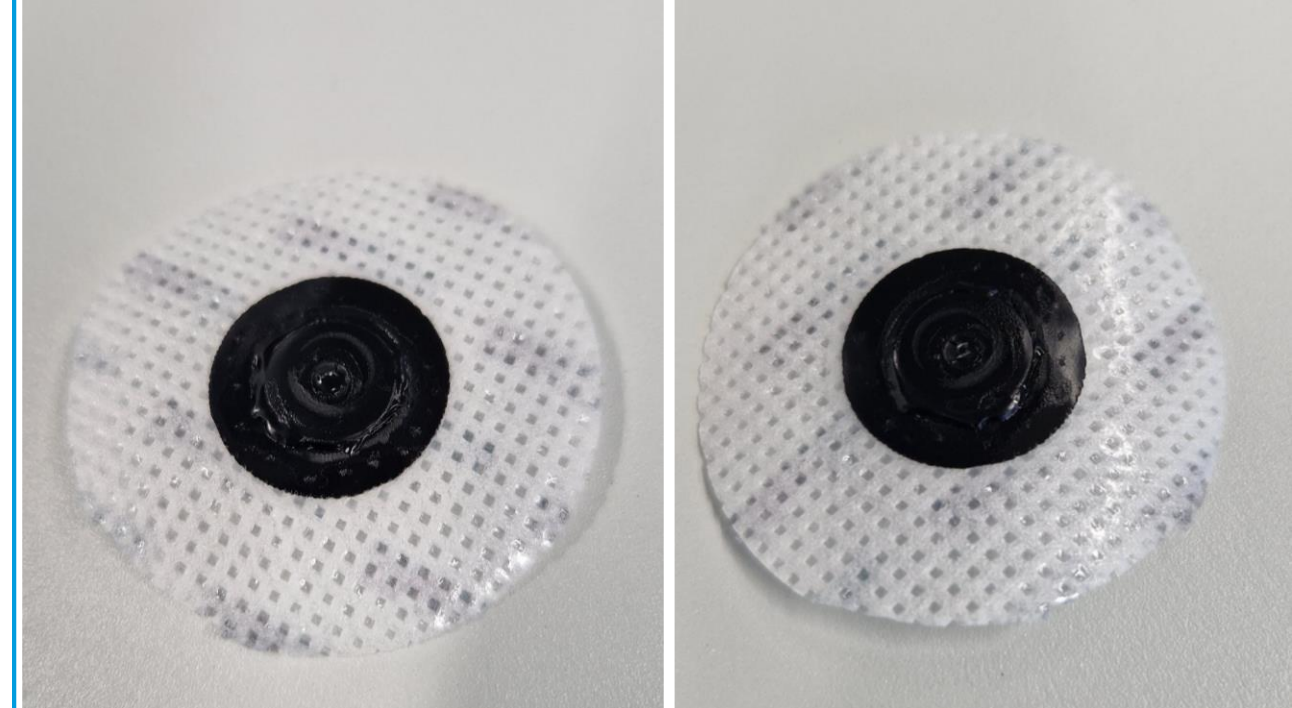


Gel electrode



New generation of ECG patches: dry electrodes

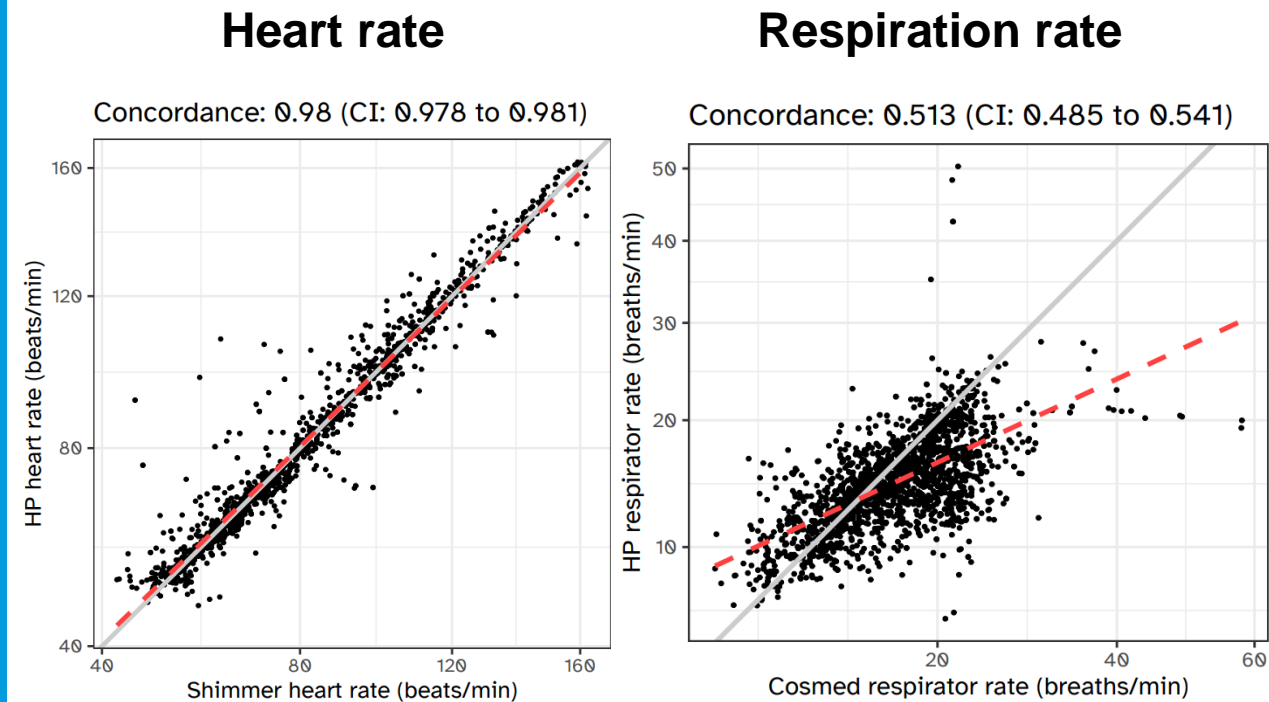
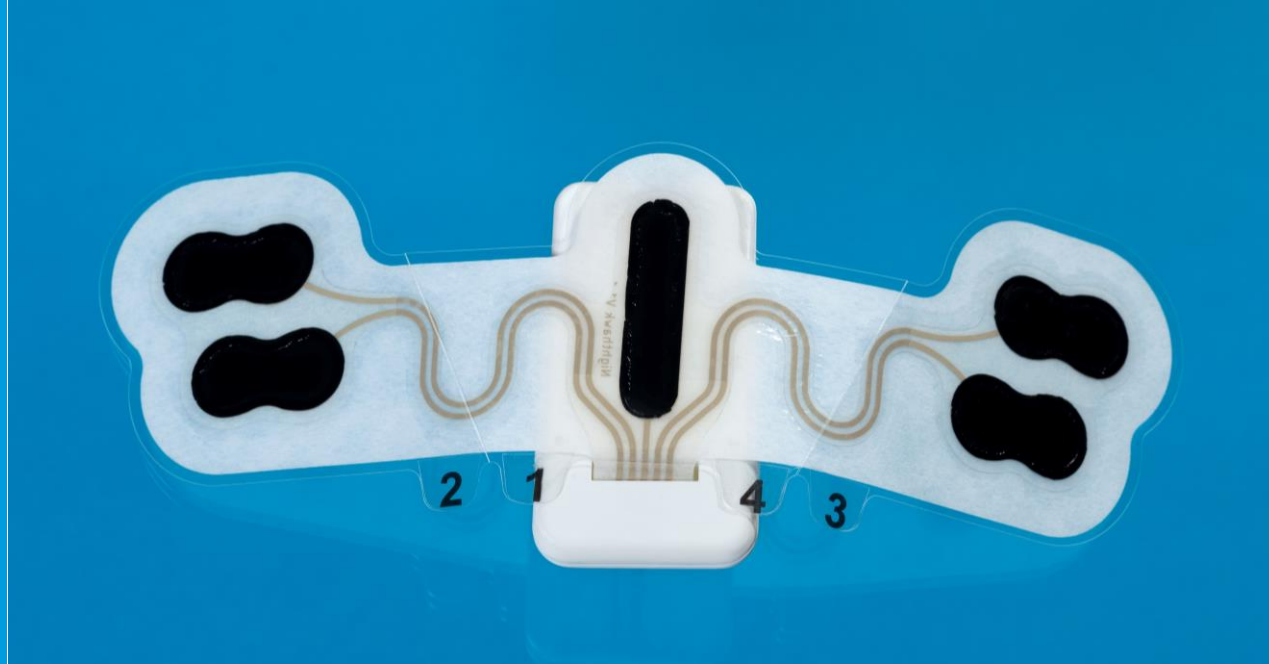
- **Self-adhesive dry electrodes**
advantages: longer wear & shelf lifetime at no irritation
- **Multi-year collaboration** of Holst Centre and material developer
- **Feedback** of OEM of **medical device** enabled progress



Performance	Start	Now
ANSI test	Good	Continuous improvement, with OEM input
Shelf time	Good	Extended
Electrical impedance	1000 Ohm	<1 Ohm
Settling time w/o external aid	1h	Negligible, immediate ECG acquisition
Residue on skin	Noticeable	No residue
Skin preparation	Must	Not needed

ECG patch: performance vs. gold standard

- **Gold standard:** 3 lead ECG & Cosmed for respiration
- **Healthy** subjects, n=20
- **Single day** wear
- **At rest** and during **exercise**
- **High correlation** for **heart rate** & **respiration rate** vs. reference
- **Skin comfort:** no irritation



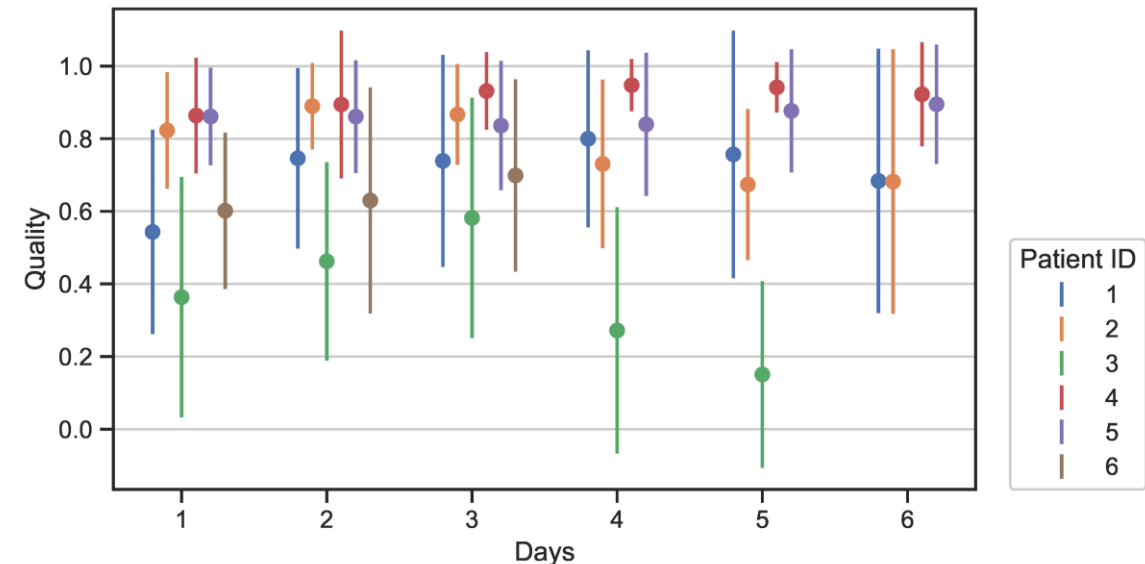
ECG patch: good performance over time

- **Gold standard:** 12 lead ECG
- Exercise-induced arrhythmia, n=6
- **Six days wear**, showering
- At rest and during **exercise**

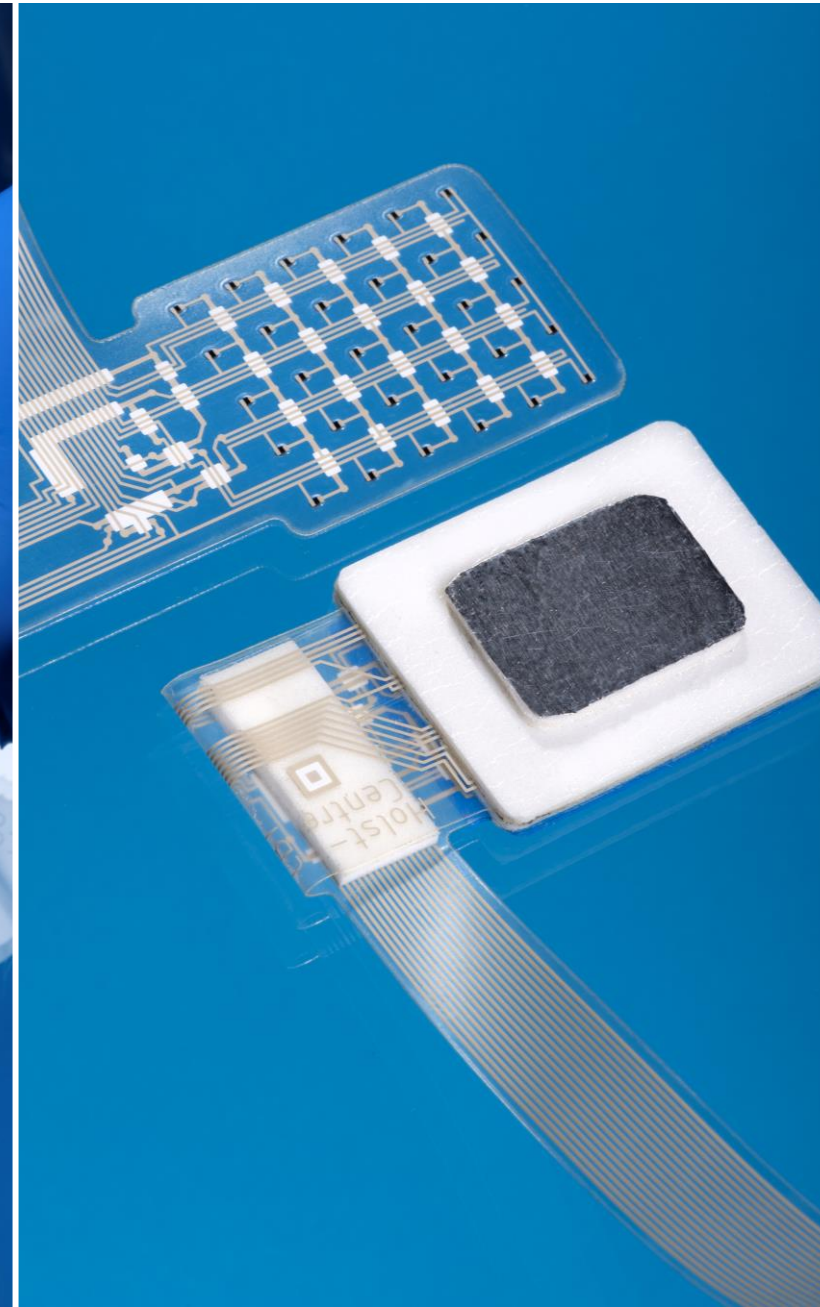
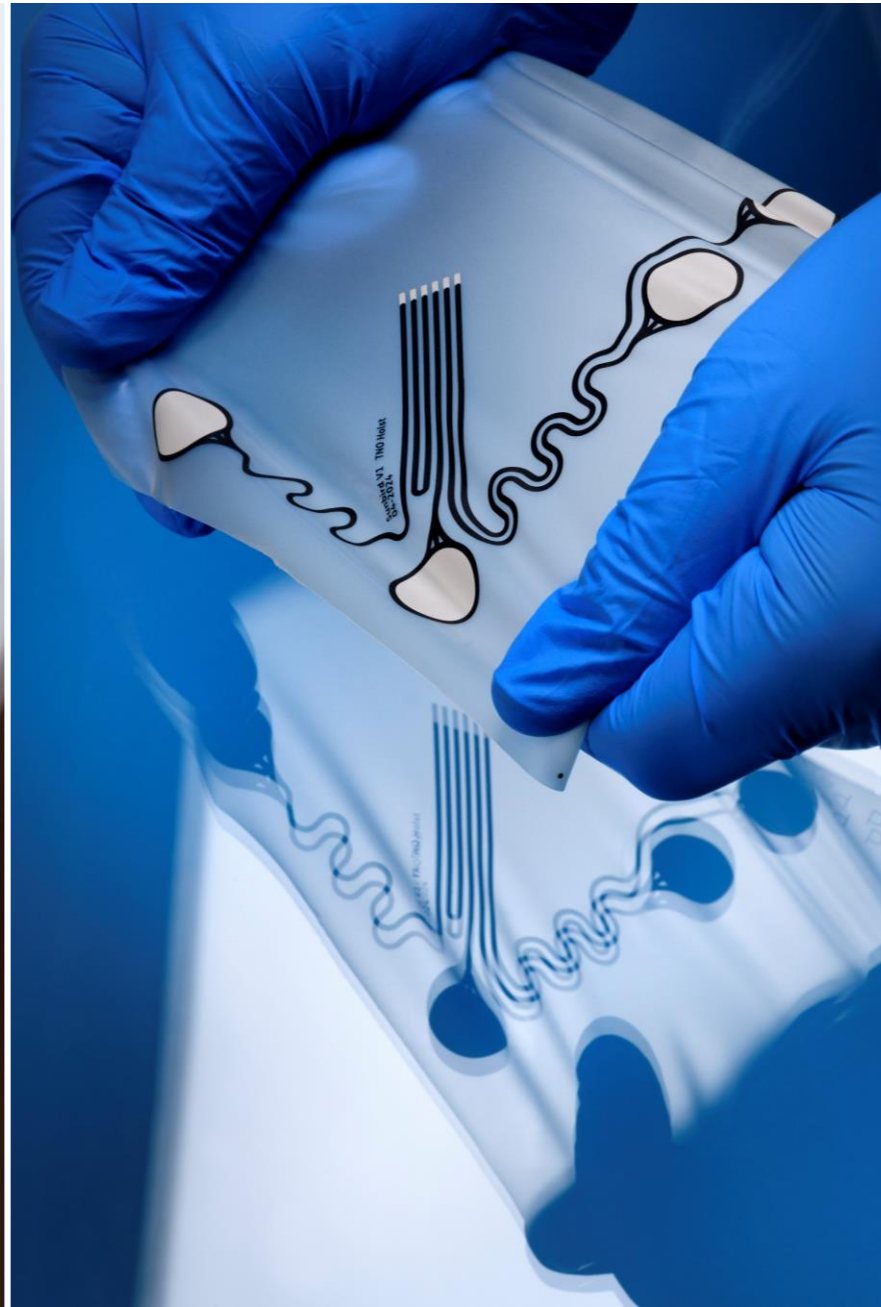
- **Good signal quality**
- **Cardiologist statement:** “Single-lead can be used for “arrhythmia detection”



Good signal quality over prolonged wear

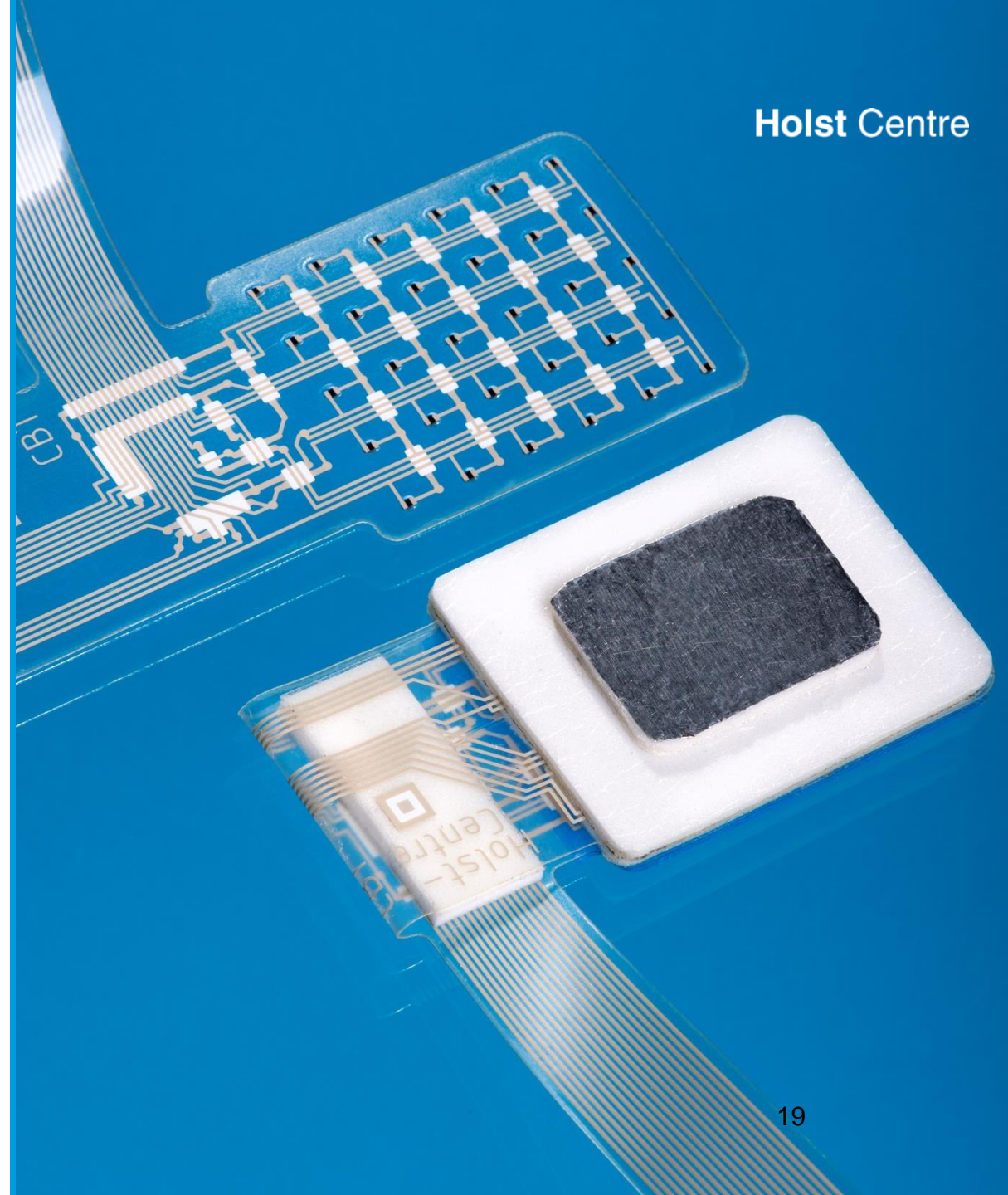


Pipeline: materials, signal quality, new sensors



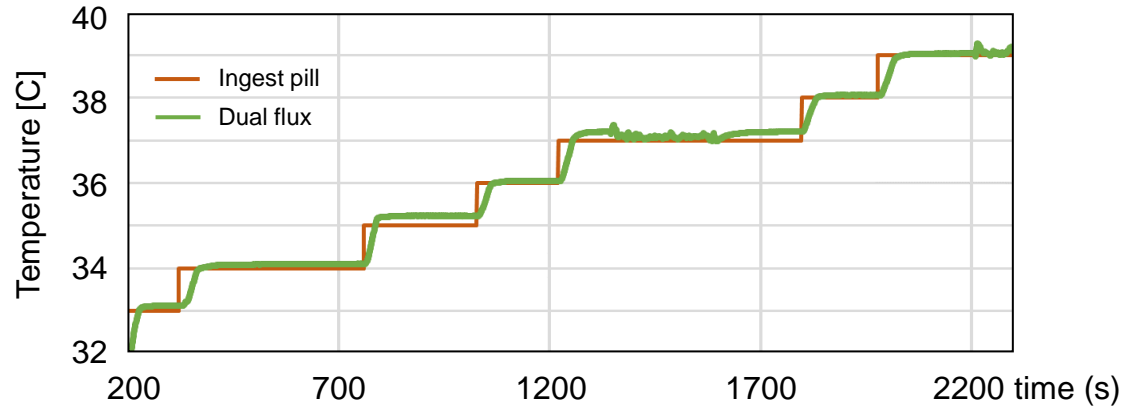
New sensors: Core body temperature

- **Challenge**
 - Solutions not accurate, impacted by thermal fluctuations
- **Our solution**
 - Passive, compact sensor array based on dual flux measurement
 - Proprietary design
- **Benefits**
 - High accuracy, variable body location, calibration-free

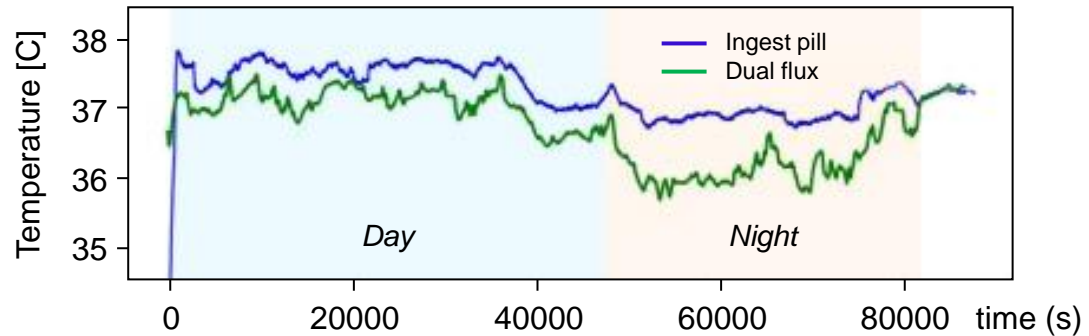


Core body temperature performance

Tests on a heating-controlled phantom

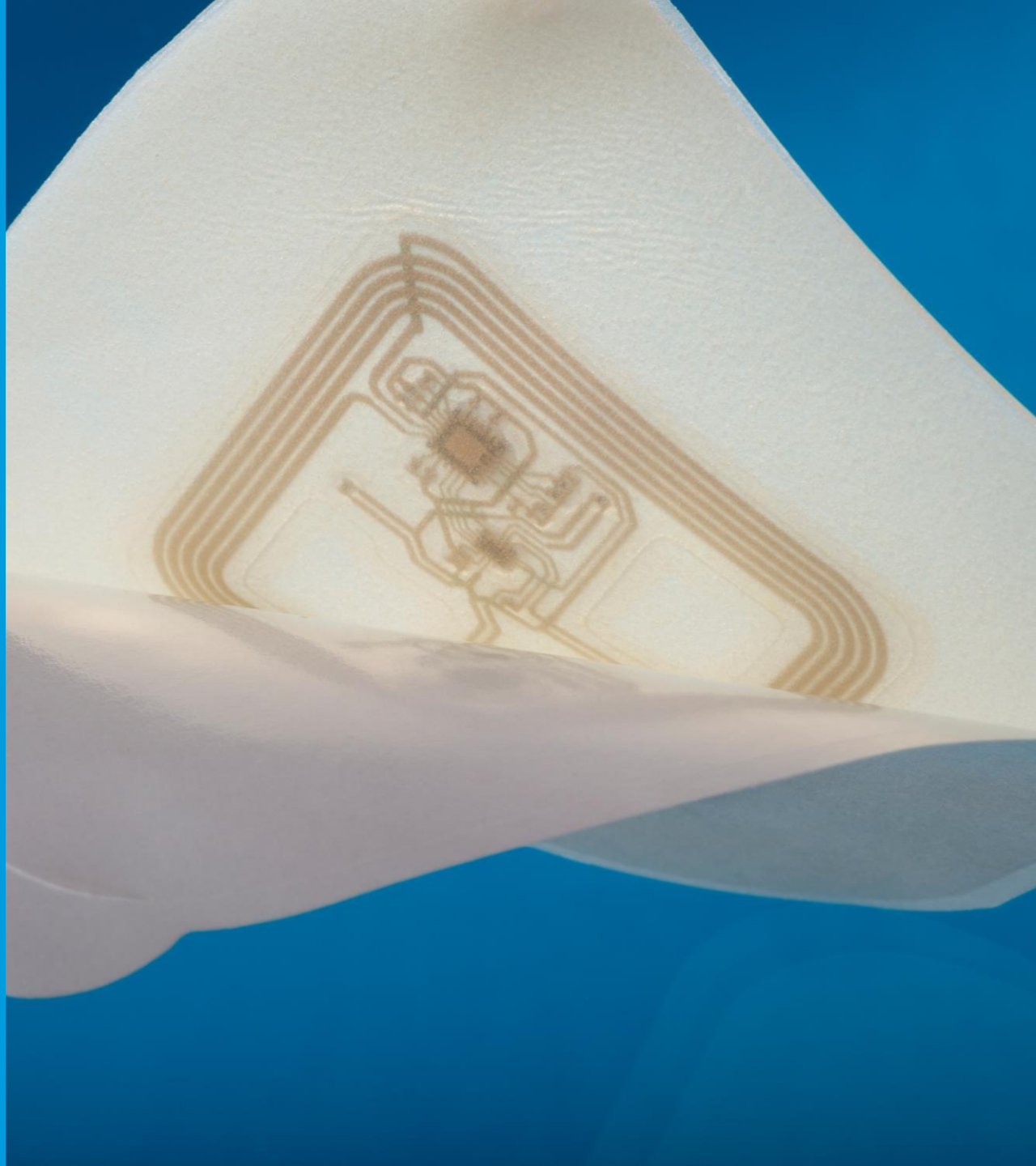


24-hour comparison on human subjects vs. ingestible temperature pill



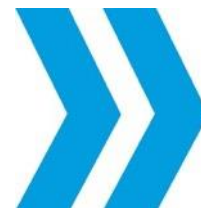
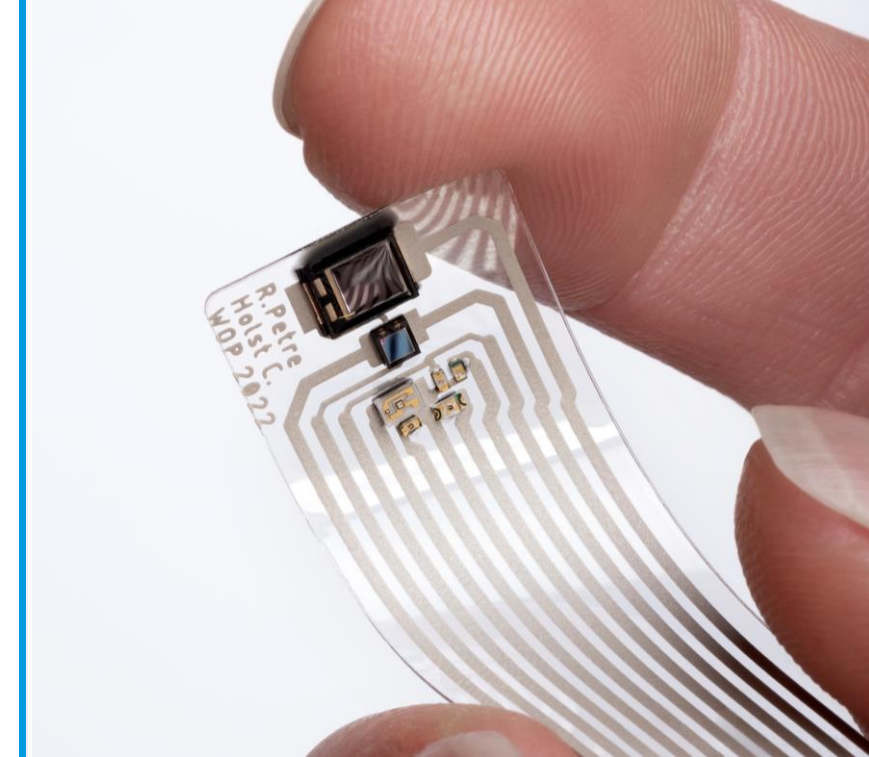
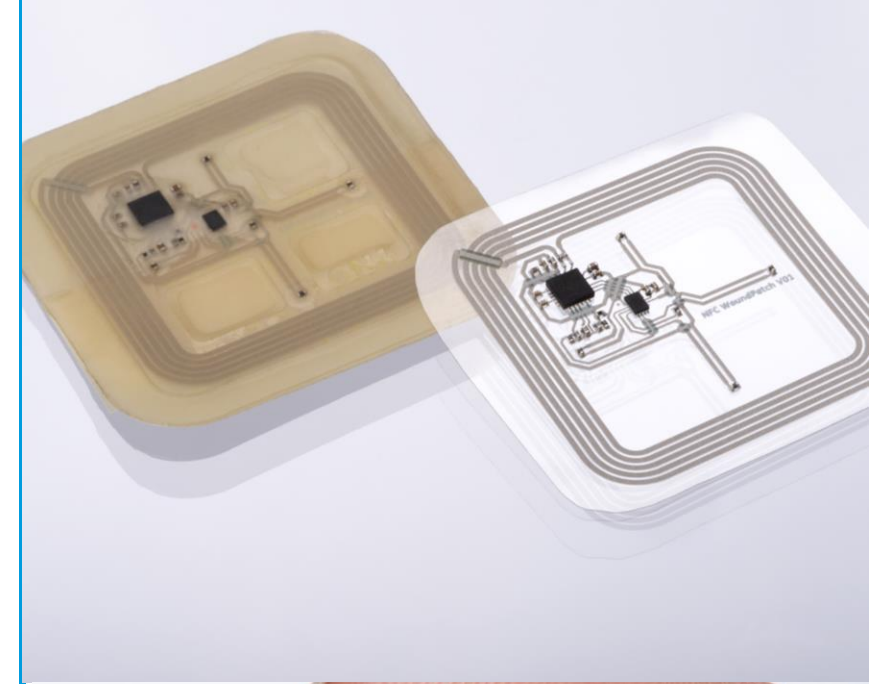
New application: wound monitoring

- **USD 32B** costs for Medicare due to infections, amputations, mortality
- **Economic, clinical, and social** impact of **wounds** continues to rise
- **Rudimental inspection:** ruler, smell, color



Wound care tomorrow: smart wound monitoring

- Integration of **sensors: temperature, optical, biochemical**
- **Quasi-continuous** monitoring, at home
- Improved **patient outcome**, increased **productivity**



Wearable sonography

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Ultrasound tomorrow

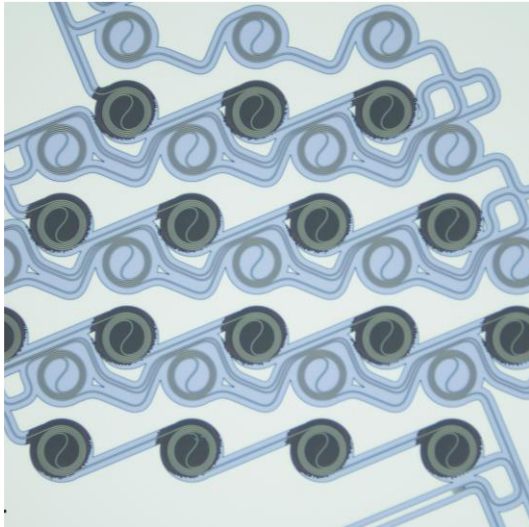
- **Autonomous / wearable**, hands-free
- Beyond hospital settings, **at home**
- Used by a **patients / citizens**



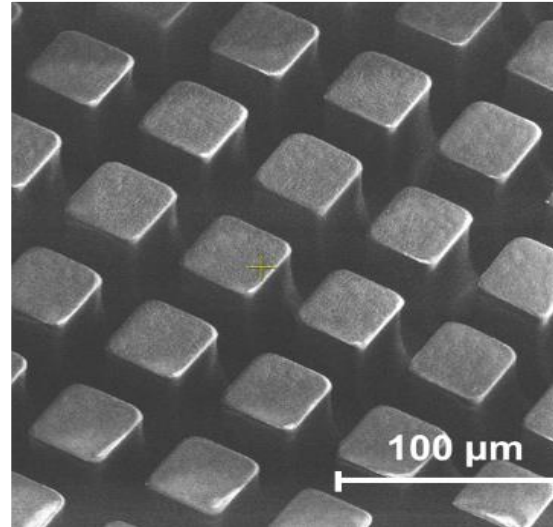
Wearable ultrasound Partners fueling innovation pipeline



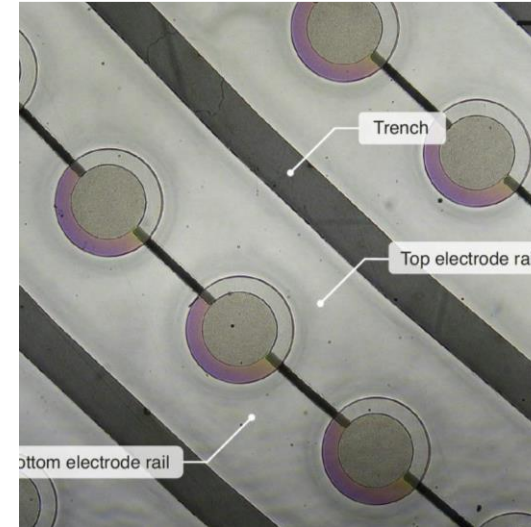
IPUT



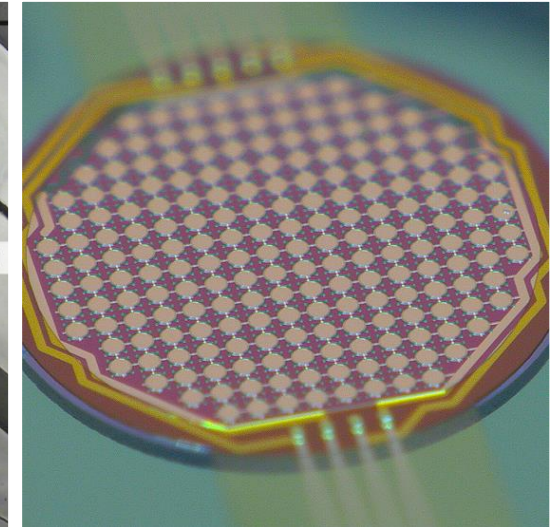
PillarWave



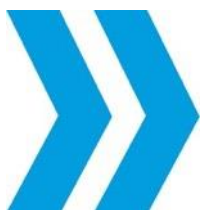
pMUT



CMUT



For sensing, imaging, photo-acoustics
Variation of materials, specifications, integration capabilities,....



Example: PillarWave™ ultrasound

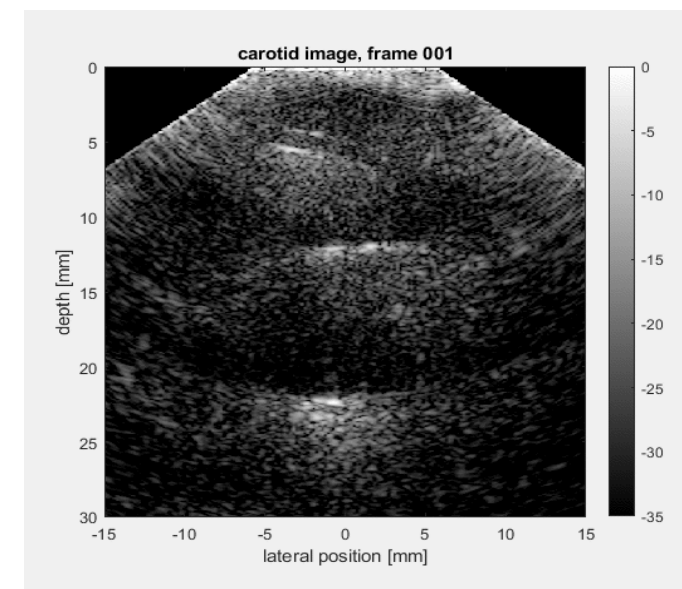
- Low TRL
- Flexible thin-film based ultrasound array
- **First real-time** imaging using 128 channel array of carotid artery
- 7 MHz central frequency
- Potential for applications for different healthcare domains



PillarWave technology

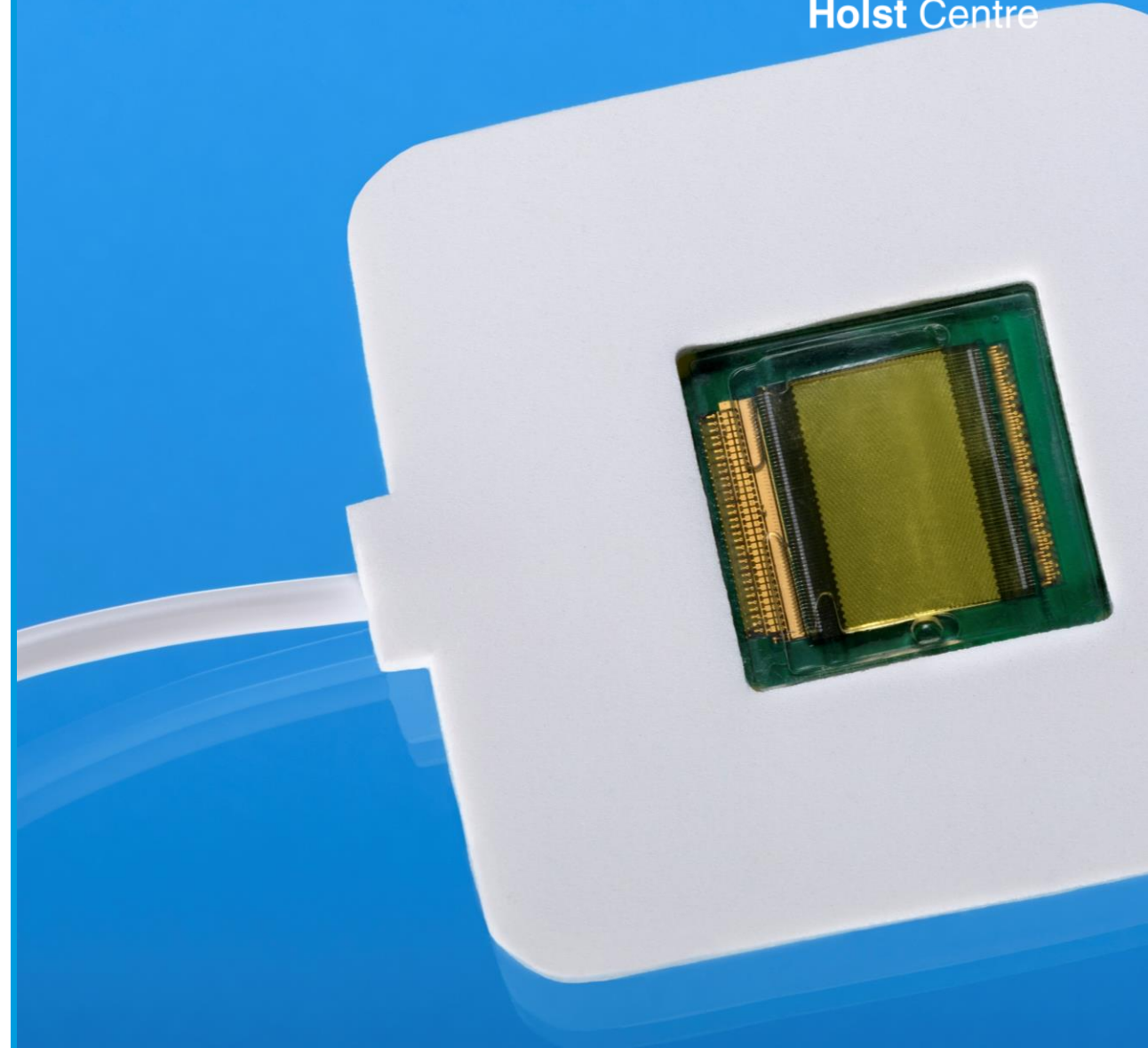


In vivo imaging of carotid artery



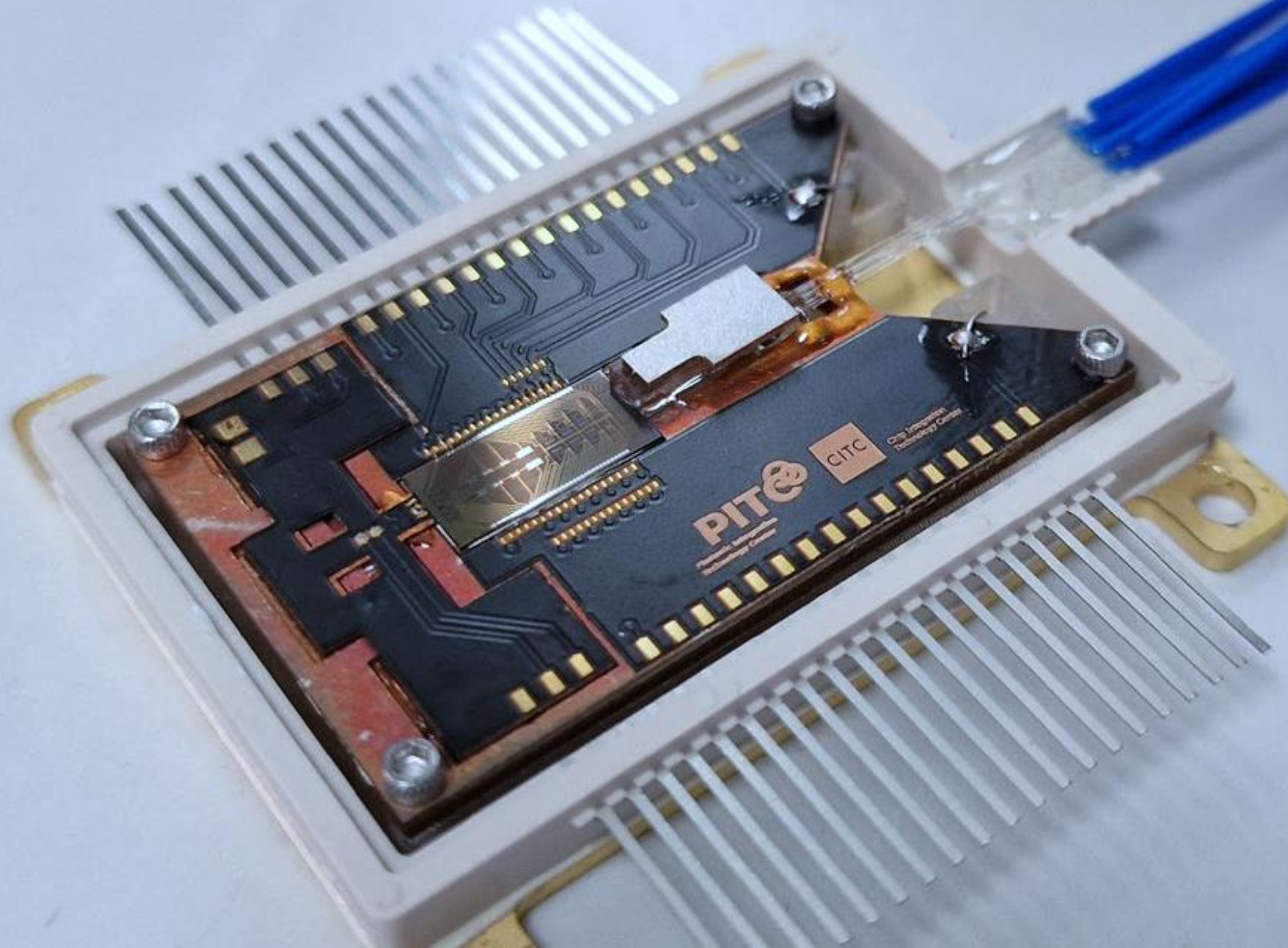
Example: CMUT ultrasound

- High TRL
- **State of the art CMUT transducer**
- **Integration** / transducer / electronics
- Patch build up / **materials**
- ASIC / Connectivity / **AI / Autonomous**



Bio-sensing

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We need faster, cheaper and more accessible molecular diagnostics



- **Infectious** diseases & pandemics
- Biological **threats**
- **Chronic** diseases
- Rising costs of drug development
- **Multiplexing** is a must in **bio-sensing**

- **\$ 42.26B** total **MDx** market
- **\$5.5B** point of care market and rising

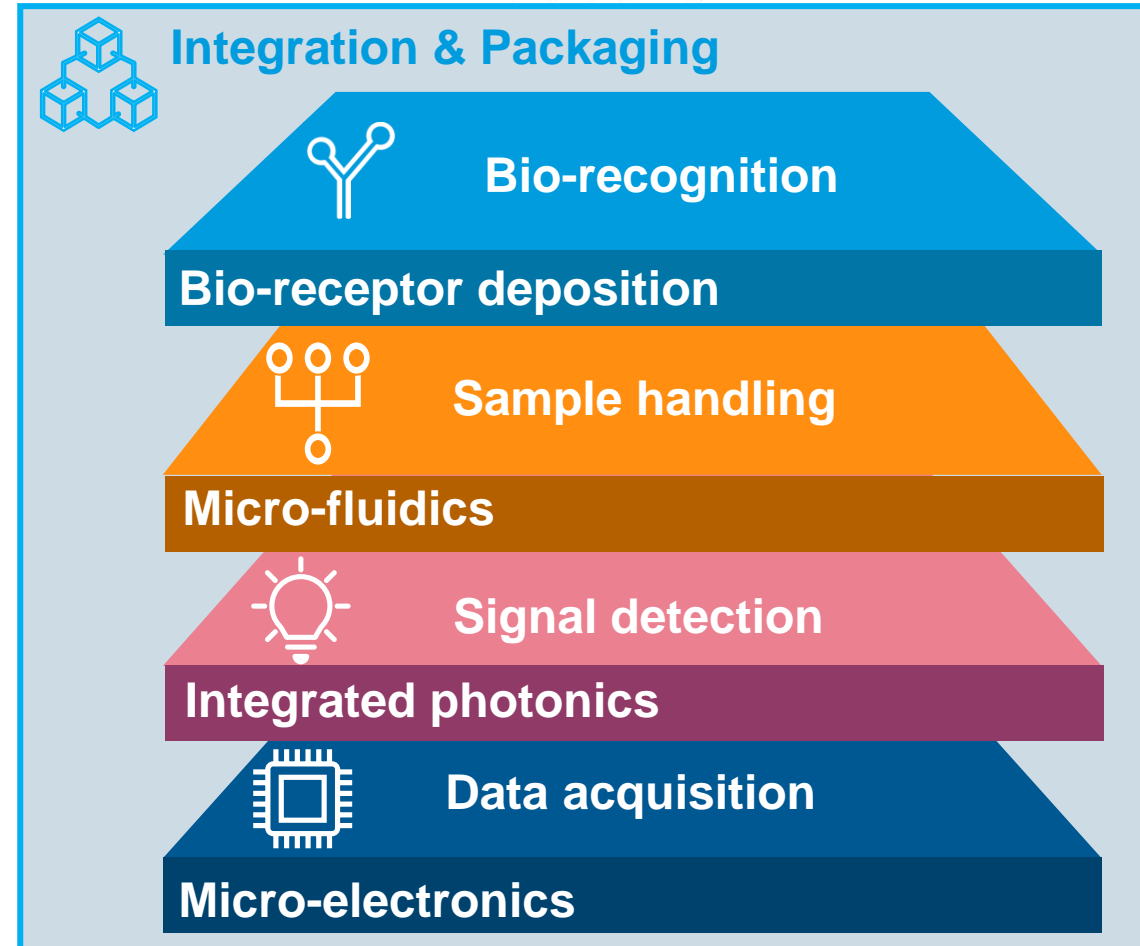


Source: *Biomarkers Consortium | FNIH*

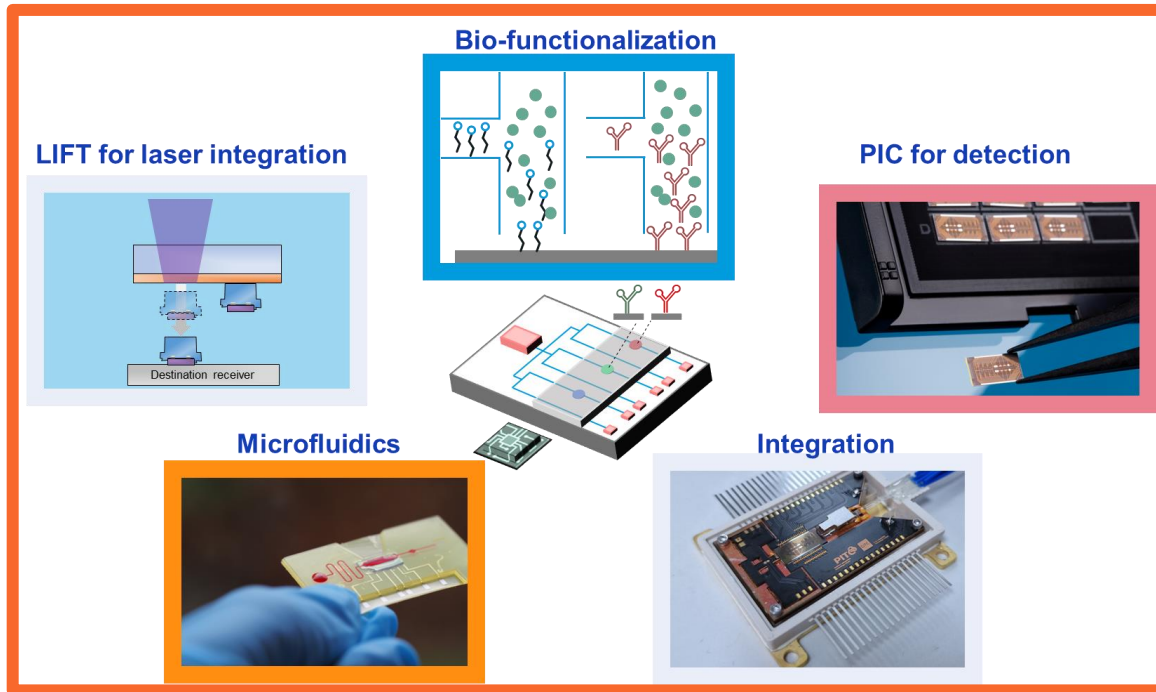


Bio-sensor functional blocks & technology enablers

- **Bio-receptor deposition**
- **Microfluidics**
- **Integrated photonics**
- **(Micro)-electronics**
- **Integration**



Netherlands is well positioned to play in integrated photonics for bio-sensing



Summary

- **High potential of wearables** to impact **healthcare** system & grow **MedTech**
- **Innovation pipeline from high TRL ECG patches to new sensors** – thermal, optical, **ultrasound**
- **Smart wound care**: an **entry area** with high potential
- **Integrated photonics for bio-sensing**: Netherlands is well positioned to play in integrated photonics for bio-sensing
- **Collaborations drive progress**

THE TECHMED EVENT

BRIDGING PAST AND FUTURE: FIVE YEARS
OF MEDTECH ADVANCEMENTS AND BEYOND

