

Biohybrid Colorimetric Tattoo Sensor for Real-Time Sweat pH-Monitoring and Dynamic Sweat Management

Paulina PILLER¹, Katrin UNGER¹, Stefanie AICHHORN¹, Viktoria SALZMANN¹, Rudolf HEER¹

¹Silicon Austria Labs GmbH, Sensor Systems, 8010 Graz Austria

INTRODUCTION

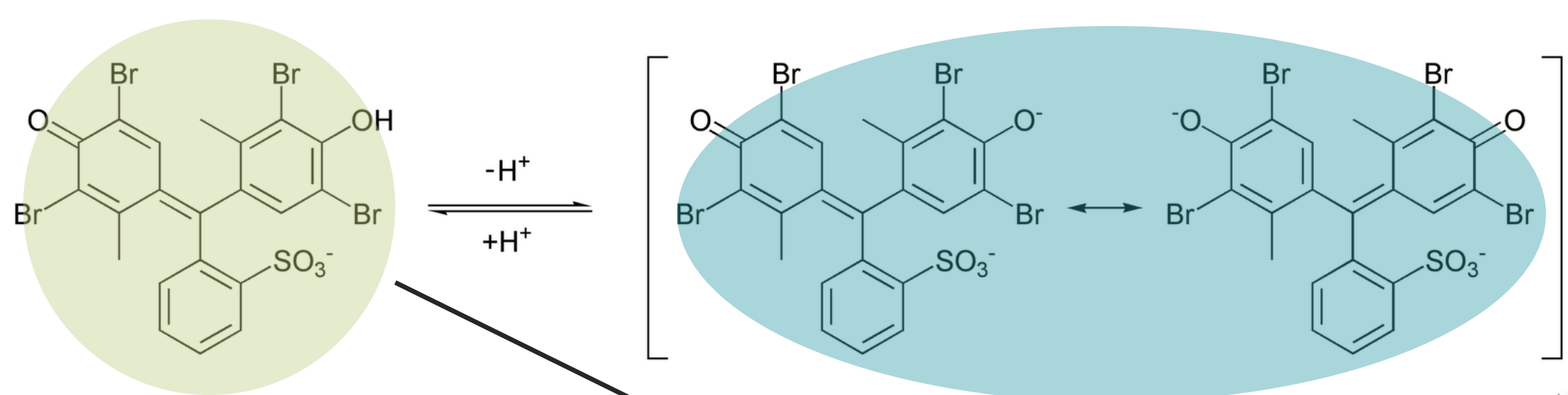
Temporary tattoo-based sensors offer a non-invasive way to monitor sweat biomarkers in real time. A key challenge is maintaining accurate sensing across different sweat rates. Our colorimetric tattoo sensor features a porous, ultrathin design with high water vapor permeability, allowing continuous sweat evaporation. This prevents dilution of biomarkers and ensures steady sweat refreshment, enabling reliable pH monitoring even during physical activity. By balancing sweat transport and analyte diffusion, the sensor delivers consistent, real-time feedback on hydration and physiological stress.

COLORIMETRIC SWEAT SENSOR – ULTRATHIN – POROUS – WATER VAPOR PERMEABILITY – pH-MONITORING

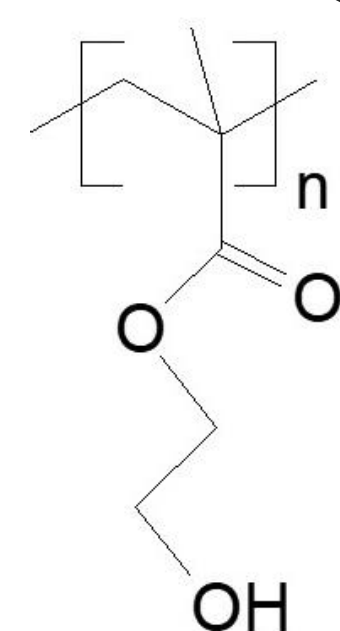
CONCEPT OF THE POROUS TATTOO SENSOR

„Brand new type of sweat sensor: Temporary tattoo functionalized with a smart dye embedded in a hydrogel for analyzing biomarkers.“

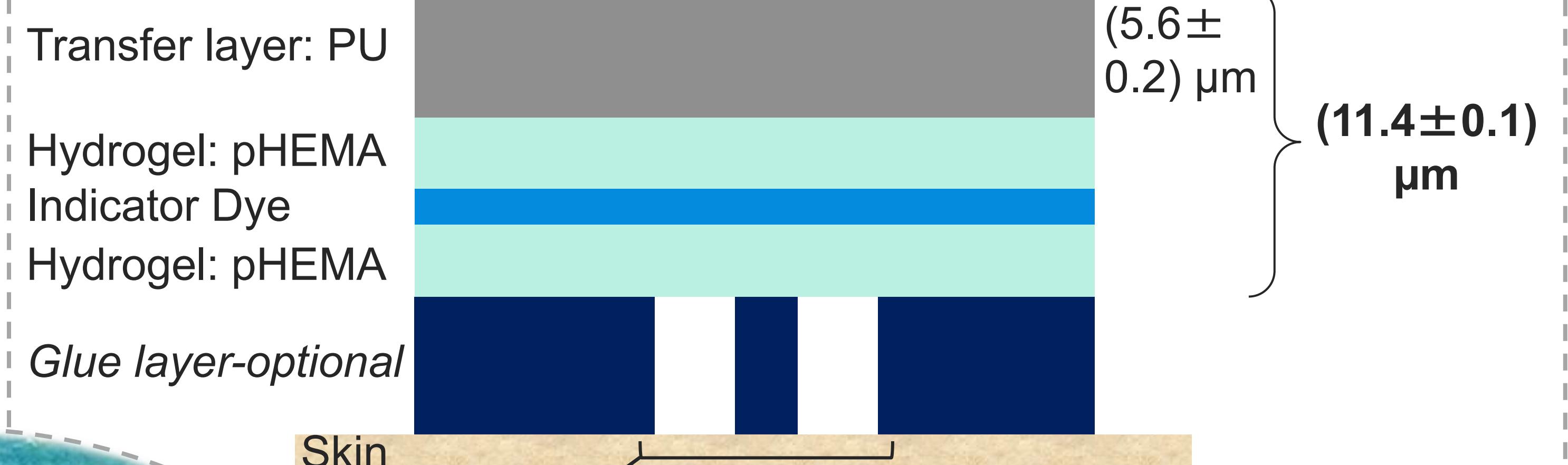
- The colorimetric functionalization of the tattoo substrate is based on the indicator dye **bromocresol green** responsive to pH changes within sweat.



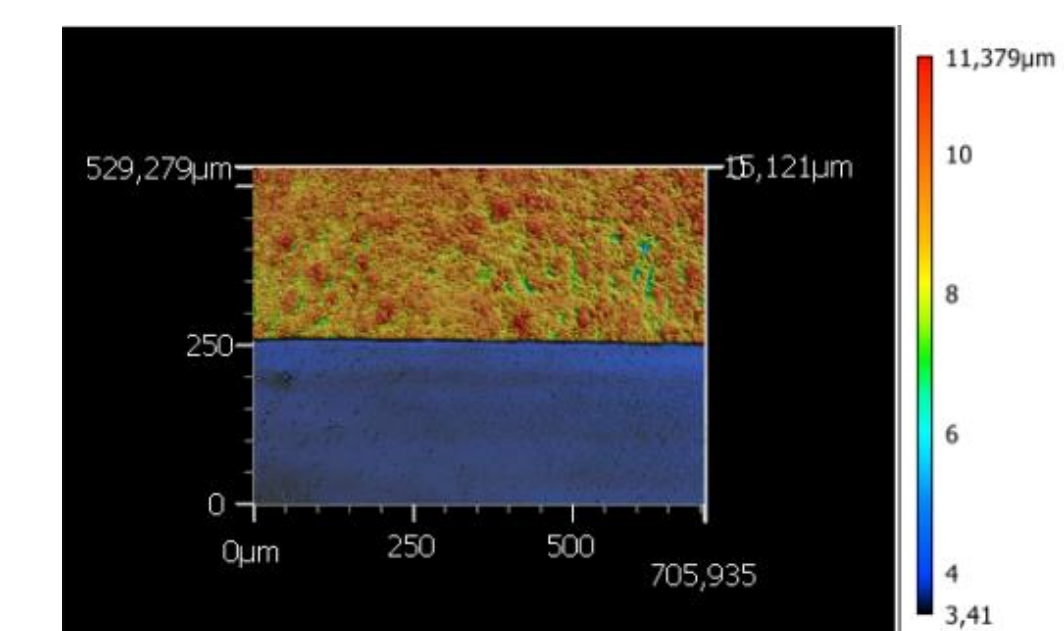
- Continuous on-skin sweat collection requires removal of old sweat. A biocompatible **pHEMA** hydrogel barrier allows sweat to pass and evaporate, while blocking chemical contact with the skin. This enables safe, continuous sampling through the tattoo interface.



STRUCTURE AND THICKNESS OF THE LAYERS



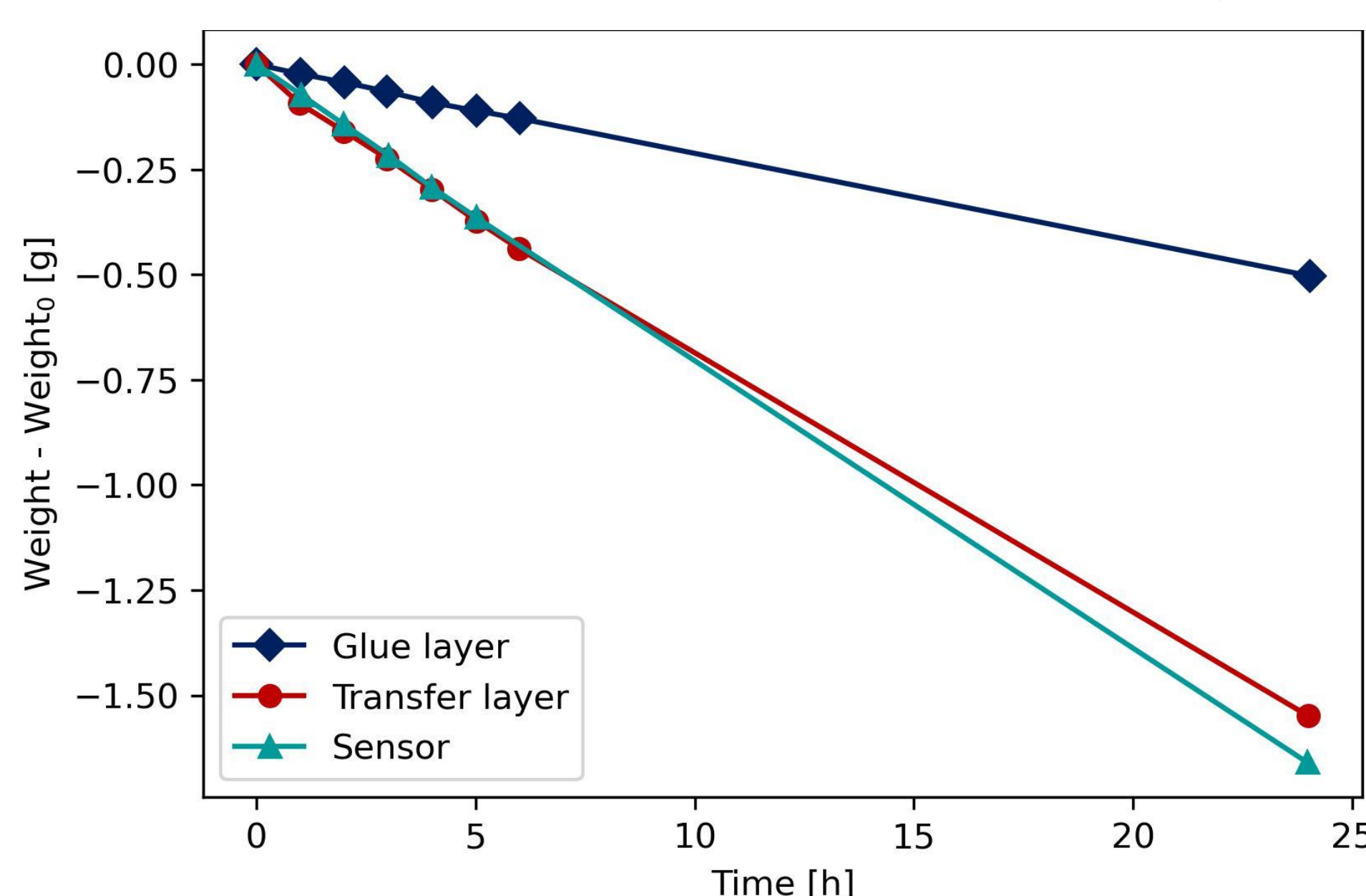
- The layer thickness was measured via laser confocal microscopy.



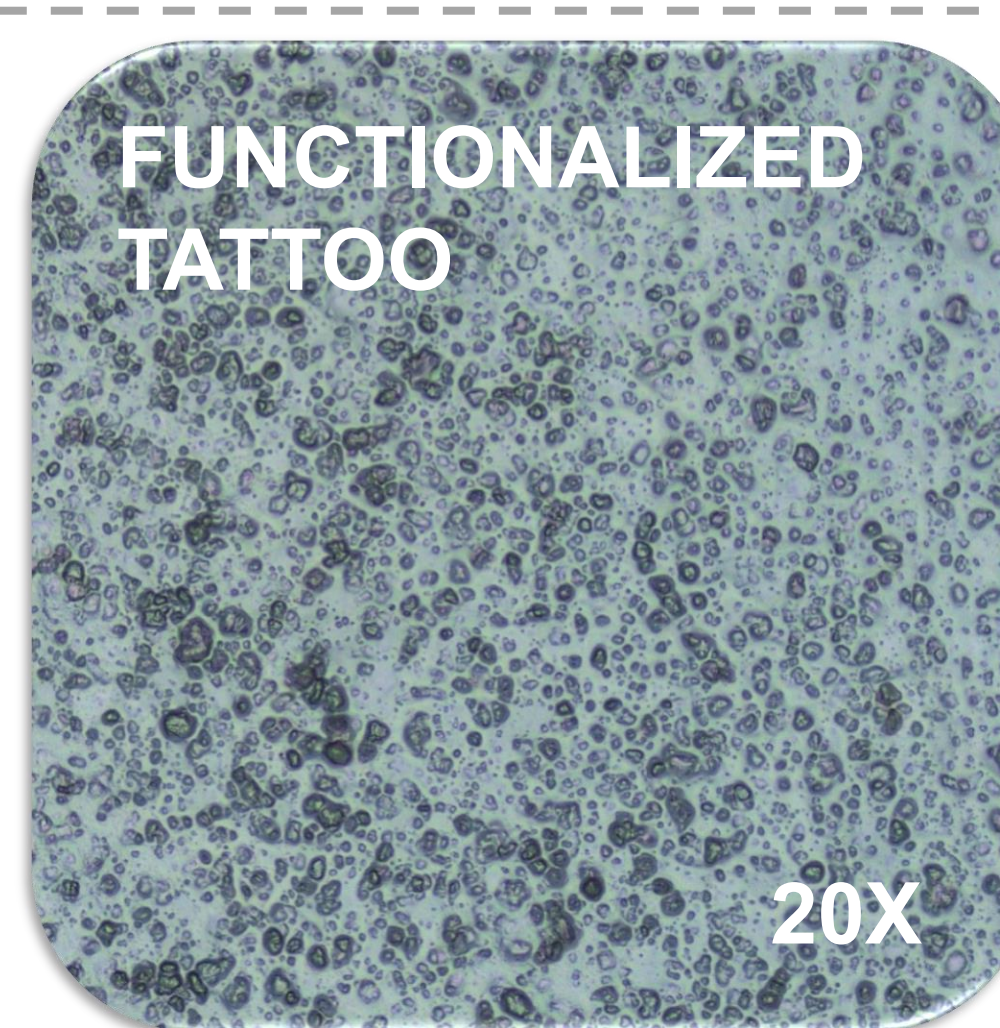
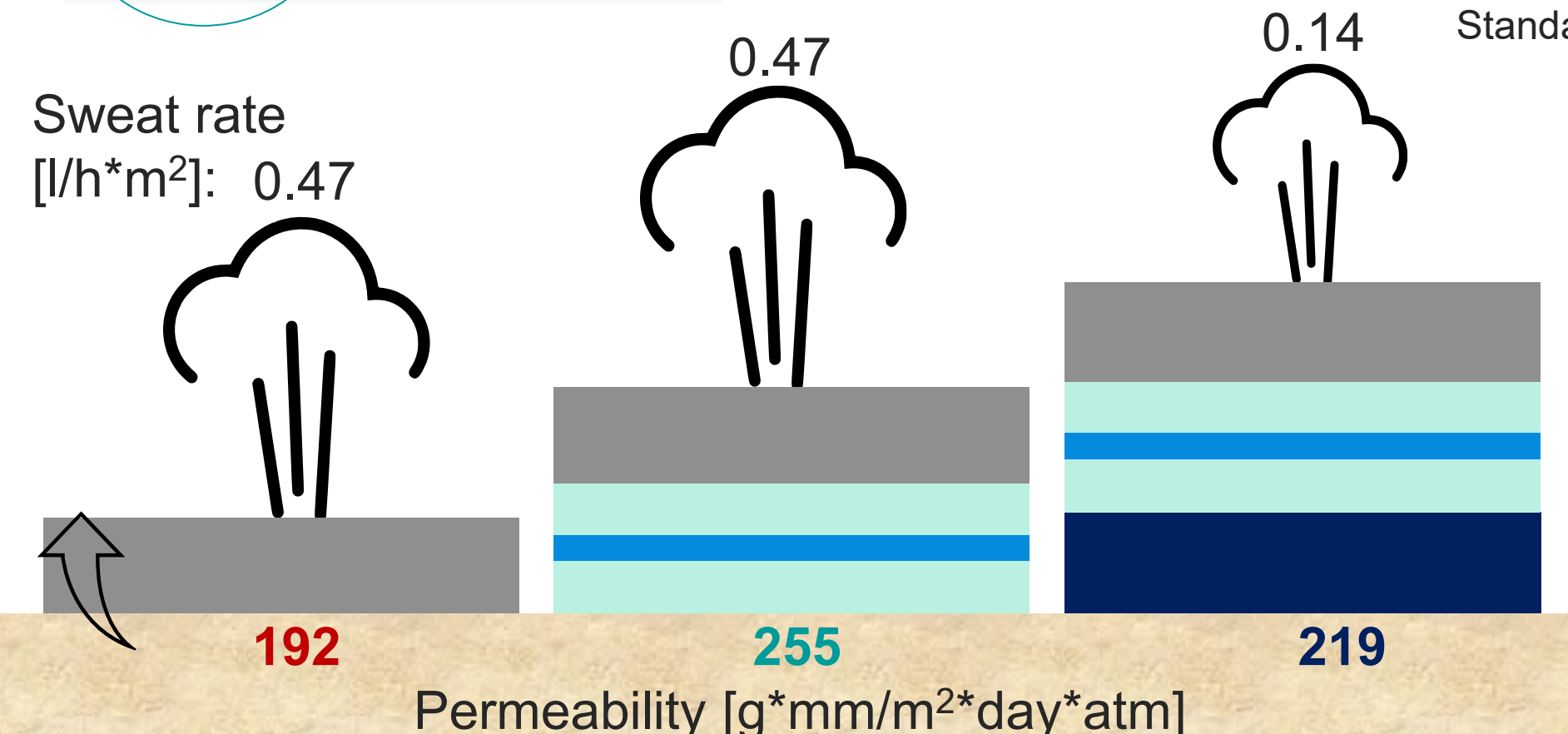
- The sensor is up to one order of magnitude thinner than the epidermis, depending on the body location.

PERMEABILITY AND VAPOR TRANSPORT RATE OF THE SENSOR

- A key requirement for the on-skin collection, transport, and detection system is the efficient removal of old sweat. This is achieved by allowing sweat to evaporate through the tattoo sensor's permeable layer.
- The rate of the transported water vapor dM_{gas}/dt through the layers depends on the material's permeability P , the area A of the layers, the difference in partial pressures Δp and the layer thickness l .



$$\frac{dM_{gas}}{dt} = P \cdot A \cdot \frac{\Delta p}{l}$$



Measurement according to ASTM-E96 Standard

CONFORMALITY ON THE SKIN

- Ultrathin layer** – volume between sweat gland and sensor is minimized
- Skin-alike sensation** – fits smoothly to skin's complex topography, allowing the skin to breathe



The tattoo sweat sensor combines ultra-conformal skin adhesion with high vapor permeability, enabling pH detection in sweat under both low and heavy perspiration.