NIIDS—Digital Urine Analysis with Printed Electrochemical Sensors

N. Glaser, D. Migliorelli, M. Zinggeler, L. Burr, K. Petropoulos, H. Gao L. Mühlebach, R. Junuzovic, N. Schmid, F. Geister, S. Fricke, S. Paoletti, C. Abongomera •, D. Paris •, S. Generelli

There is a need for developing new solutions that enable rapid diagnostic tests in low resource settings. CSEM is working on the development of a hand-held fluidic cartridge, containing an array of printed electrochemical sensors for the digital recording of urinary glucose and pH. The system is being developed for the Swiss Tropical and Public Health Institute (Swiss TPH) to assist clinical decision making in low-resource settings such as refugee camps.

Clinical decision making in low-resource settings is often based on limited diagnostic information. Inaccurate treatment of febrile illnesses (e.g. by broadband antibiotics) is often the consequence. The Swiss TPH (www.swisstph.ch) aims to develop a diagnostic tool for the most common pathogens and febrile illnesses, to fight migrant diseases. Nowadays, basic urinalysis is done with urine paper dipsticks with color indicators. These results are prone to misinterpretation and need to be manually recorded in most cases.

Figure 1: In collaboration with the Swiss TPH we study in Switzerland and Ethiopia the use of new tools for better decision making in low-resource settings such as refugee camps like these.

We have developed a digital sensing device to detect important ions and metabolites in urine. Among these are pH, sodium, lactate and glucose. Sensors for glucose and pH have been realized on the device and showed good results in first urine tests.

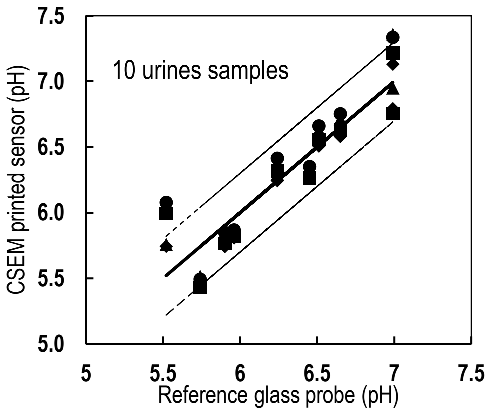

Figure 2: Results of 4 printed pH-sensors (round, square, triangle and diamond) in 10 human urine samples. Zero deviation from the reference sensor is indicated by the solid line and +/- 0.3 pH units by the dashed lines.

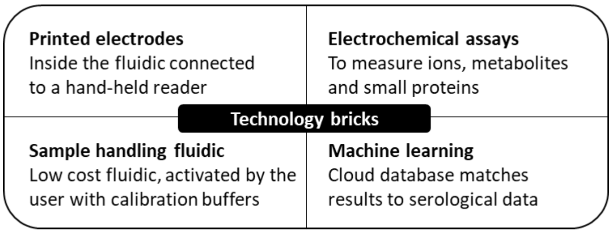

Figure 3: The technologies at CSEM to develop a urine sensor.

Our printed pH sensors show excellent agreement with the reference system and very good sensor reproducibility (Figure 2). Glucose (data not shown here) can be measured with higher sensitivity compared to urine dipsticks, which may allow to detect diabetes at an early stage. Later, sensors for additional analytes, such as lactate and sodium, will be added to the device array.

A fluidic cartridge is developed with integrated printed electrodes and pre-stored buffers for sensor calibration. These cartridges will be interfaced to a hand-held reader and provide results within 5 minutes. The device shown in Figure 4 incorporates a sensing chamber for pH and glucose and two additional analytes to be added later. In the next phase of the collaboration, we aim to add sensors to detect small proteins in urine.

Our device provides quantitative data, which is going to be uploaded to a cloud-based database. Within the NIIDS project of the Swiss TPH (PI: Prof. Dr. med. Daniel H. Paris), results will be collated from blood analyses (serological and molecular data), reference diagnostics and complemented with our urine data. By means of a learning database, the Swiss TPH aims to assist low-resource clinics with point of care tests and cloud-based data analysis procedures.

Figure 4: Prototype device for the electrochemical urine analysis of 1-4 analytes.

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• Swiss THP, CH

Artificial Ear Canal with Integrated Pressure Sensors

M. Zinggeler, N. Glaser, J. Disser, F. Geister, A. Lücke, C. Seitz, S. Fricke

Unsatisfactory wearing comfort of earpieces, which are placed in the ear canal, is a major reason for not wearing hearing instruments. In order to address this problem, a better understanding of the contact pressure of earpieces and its distribution is needed. In this project, we have developed a custom-made research setup for the company Sonova AG. The system is based on a printed, highly sensitive pressure sensor matrix on foil, which was integrated into an ear canal model using a simple roll up procedure.

Around 15% of adults suffer from some degree of hearing impairment. However, only about 20% of affected people in developed countries are wearing a hearing instrument. One of the top three reasons why people are not wearing it, is unsatisfactory wearing comfort (source: Sonova internal report). The contact pressure and the contact pressure distribution of the earpiece, which is placed deep in the ear canal of the patient, has been identified as one of the key factors influencing wearing comfort. However, little is known so far about the underlying biophysics. In order to address this shortcoming, we have developed a custom-made research instrument for Sonova.

We realized a pressure sensitive matrix on foil with a total thickness of about 250 µm using screen-printing. The matrix consists of 96 (12 x 8) pressure sensitive pixels with a size of 1.8 mm x 1.8 mm (Figure 1). The pixels show a pressure dependent electrical resistance (i.e. resistance between silver fingers contacted by a carbon pad) and their design was optimized to enable contact pressure measurements in the low millibar range.

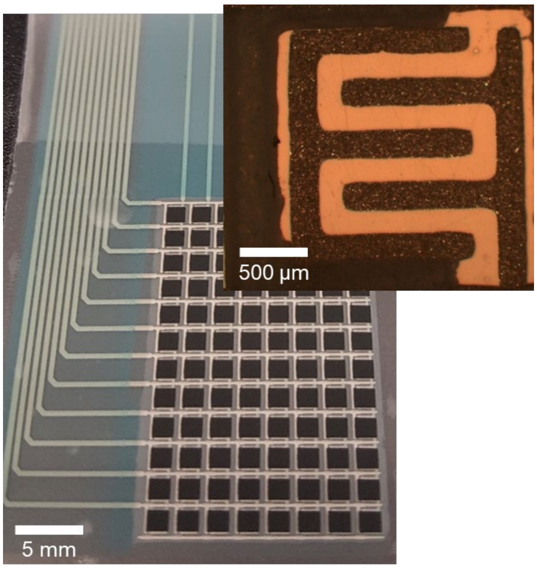

Figure 1: Photograph of the fabricated pressure sensitive matrix on foil (bottom image) and micrograph showing the inner workings (i.e. silver fingers) of a single pixel (inset).

The flexible matrix was rolled up and inserted into a PMMA tube with 11 mm inner diameter resembling a simple ear canal geometry (Figure 2). The electrical connections were passed through a slot opening which was sealed with silicone. Hard- and software for electrical read-out was developed and the system was calibrated using controlled air pressure.

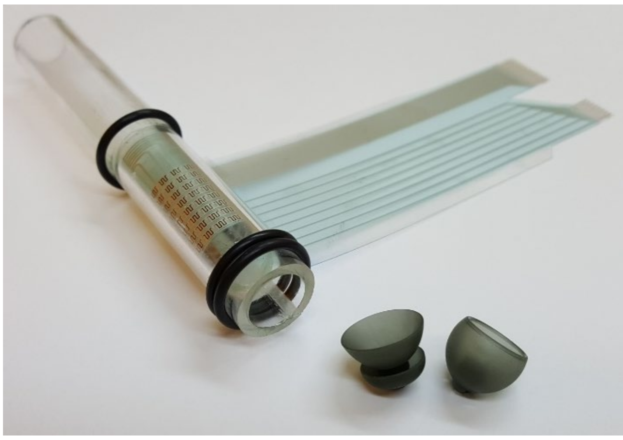

Figure 2: Photograph of the developed ear canal model with integrated pressure sensors.

The system enables real-time pressure mapping and was tested using different silicone earpieces from Sonova, both in static (i.e. no movement of earpieces) and dynamic (i.e. moving earpieces) experiments. An example of a dynamic test is shown in Figure 3.

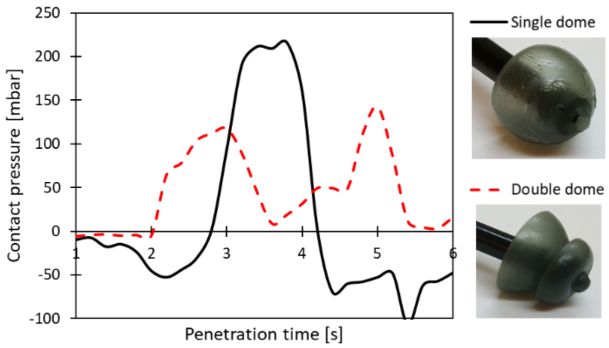

Figure 3: Real-time contact pressure responses of a selected pixel for different silicone earpieces (single vs. double dome) passing through the system. While positive pressure readings show the contact pressure of the different domes, negative pressure readings are indicative for shear stresses.

Our printed pressure sensor technology enables the fabrication of custom-made pressure mapping systems on flexible substrates. The design of the systems can readily be adapted to cover the targeted pressure range (mbar to bar). The low thickness and high flexibility of the pressure sensitive foils greatly facilitate system integration. This capability was successfully demonstrated in this project by the realization of an artificial ear canal with integrated pressure sensors for the company Sonova.

We thank Dr. Markus Müller, Paul Wagner, Dr. Petra Gunde and Dr. Erwin Kuipers from Sonova AG for a great collaboration.