Hanitsch, Stefan; Hoffmann, Martin:

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Test Environment for Hydrogels as Functional Sensor Window

Hanitsch S[1], Hoffmann M[1]

[1]Chair for Micromechanical Systems, Ilmenau University of Technology, Germany

Stefan.Hanitsch@tu-ilmenau.de

Abstract: *Sensors in contact with biological environments still suffer a lack of stability due to biological attacks. A functional sensor interface that does not influence the analyte path to the sensor nor the measured signal but protects the sensor from these attacks may be realized by using hydrogels. To minimize this influence and to optimize other interesting properties of these water- containing polymers within a sensor device, a test environment is presented and first results are shown.*

Keywords: *Sensor Window, Hydrogel, Diffusion in Polymers, Test Environment.*

Introduction

Biosensors or sensors monitoring biological environments often have a limited lifespan due to the deposition of plaque and other bio-fouling mechanisms. Especially electrochemical sensors are sensitive to signal drifts and they frequently need recalibration or replacement. With the focus on building more autonomous monitoring devices for electrochemical parameters in biological systems, functionalized hydrogel coatings and 3D structures could provide suitable solutions and should be integrated into sensors. They should facilitate the interface between a well-protected sensor and the external analyte. They realize a "sensor window". To test potentially suitable gels in terms of their influence on the signal (delay, amplitude, selectivity), a test environment was created.

Methods

Setup:
Using LTCC technology in combination with classical ceramic implant materials, different sensor devices for different purposes were fabricated. These consist of electrode structures within a measurement chamber combined with fluidic channels and functional hydrogel coatings or elements. Through the channels and cavities, rinsing or calibration fluids can be applied as well as pressure and temperature changes can be realized. Figure 1 shows the realized interface. The measurement chamber (Ø = 3 mm) with electrodes is covered by a hydrogel scaffold manufactured from zirconium oxide ceramics (Moje Keramik-Implantate GmbH & Co. KG). Fluidic channels and electric leads are located underneath the surface and fed through to the backside of the chip to be connected with the periphery. To test the hydrogel coatings together with the sensor device, the latter is brought into a PTFE housing with a larger test chamber with fluid connections.

Different fluids can be circulated here to generate different external conditions. Hydrogel specimens are brought between test and measurement chamber. They can either be inserted as a foil or fixed onto ceramic scaffolds (shown in Figure 1) which are hold by rubber gaskets within the housing.
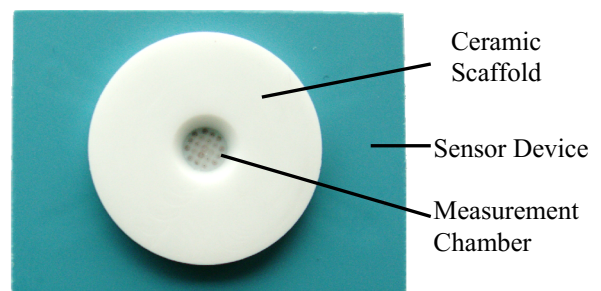

Figure 1: Front view of a sensor device to be tested.

This allows reusing a sensor device for further measurements. Alternatively, the specimen can be brought directly into the measurement chamber as hydrogel patch or as a coating on top of sensor electrodes. Hydrogel specimens within the measurement chamber may also contain microstructured parts to be connected to the fluidic channels of the sensor device. An additional scaffold holds them in place. Figure 2 shows a sketch of the system setup without peripheral equipment. Arrows indicate the fluidic pathways.
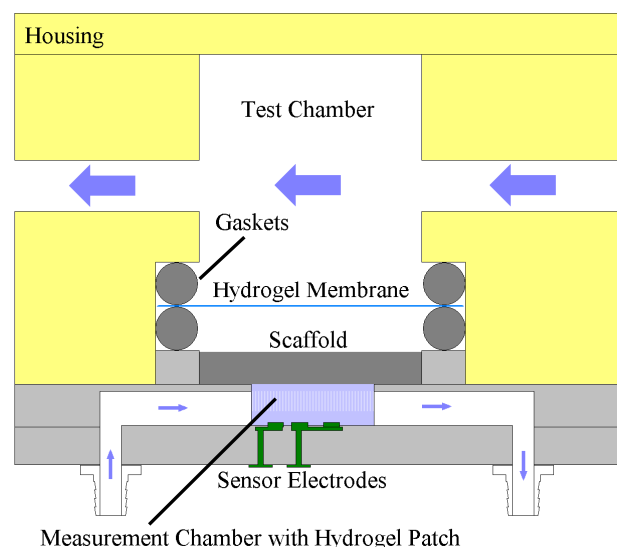

Figure **2**: Schematic system overview.

The peripheral equipment consists of two peristaltic pumps and the sensor electronics. A handheld conductivity-meter is used for all conductivity measurements. Additionally all liquids can be thermostated within their reservoirs by a water bath. Usually all experiments are carried out at 25°C.

Measurement Routines:

A basic measurement routine consists of three steps:

1. Rinsing. All cavities are filled and emptied twice with deionized water (G ≤ 1 µS). The rinsing steps endure until the conductivity reaches a steady state. The fluid from the second rising step is used further on.

2. Diffusion. The test chamber is perfused with the analyte of interest (e.g. saline solution, acids or model solutions for biological environments). The measurement chamber is than filled with deionized water.

3. Measurement. The parameters to be measured are: the cumulated conductivity of the fluid returning from the measurement chamber, the temperature and the sensor signal. The overall sampling rate should be selected according to the expected process length. For diffusion tests with durations of several hours sampling rates of about one per minute have been purposeful.

Interpretation methods:

Depending on the fluid paths different methods for the determination of diffusion coefficients, as defined by [1] can be deployed. If both chambers are at any time perfused with fresh liquids the "True Steady State Method" can be chosen. If only the test chamber is perfused with fresh fluid and the fluid in the measurement chamber is cycled the "Time-Lag Method" is more appropriate to perform. The "Quasi Steady State Method" is also suitable if the liquids in both compartments are cycled.

Results

As an example for a possible measurement a porous polymer membrane was set into place and the "Quasi Steady State Method" for the determination of the diffusion coefficient was performed. Figure 3 shows the course of the cumulated conductivity in the cycled perfusion liquid of the measurement chamber relative to the conductivity measured in the test chamber after an infinite time of diffusion when an equilibrium between both chambers has been reached (simulated by mixing the perfusion liquids of both cycles together).

For the experiment a potassium chloride solution (KCl) with a concentration of c = 1 mol/l was circulated in the test chamber, while the measurement chamber was perfused with deionized water which accumulated the diffused KCl. As the KCl-concentration, within the relevant range, can be assumed to be directly proportional to the conductivity of the solution, the chart for the relative conductivity and the relative KCl-concentration are identical.
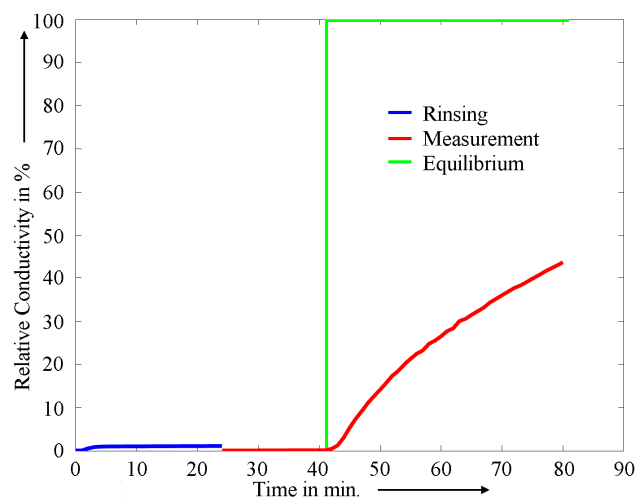

Figure 3: Relative cumulated conductivty diffused through a porous polymere membrane.

That is only the case if other sources of conductivity can be excluded. This has been done by subtracting the conductivity offset measured during the second rinsing period. With the appropriate factor the saline concentration can then be calculated (for KCl this factor is about 78 mS/mol) and the desired parameters of the membrane can be determined according to [2].

Discussion

A test environment for the evaluation of polymers for the use as passive sensor components has been built and tested. The setup consists of different modules which can be assembled differently according to the needs of the experiment. So far polymer coatings, such as hydrogels can be tested on a scaffold or as a foil for a first evaluation of the desired properties. Later on they can be tested as hydrogel patch or a coating on the sensor element itself. Therefore the test environment enables a large number of tests to be conducted with different and modified polymers with a limited number of potentially complex and expensive sensor samples.

Acknowledgement

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