"High order" hybrid sensor module based on an identical transducer principle

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A novel approach for a multifunctional sensor module (Fig. 1) using the same transducer principle for both (bio-)chemical and physical sensors is suggested. Here, the same chemical sensor can also serve as a physical sensor, and thus, multifunctionality or "high order" is achieved by means of different sensor arrangements and/or operation modes. The number of obtained (bio-)chemical and physical information is higher than the number of the sensors needed. Moreover, a influence of disturbing factors can be minimised by using a differential measuring set-up. The modules are easy exchangeable.

In the presented experiment, a hybrid module for the determination of two (bio-)chemical parameters (pH, penicillin concentration) and three physical parameters (temperature, flow velocity and flow direction) has been realised. The n-channel Ta_2O_5-gate ISFET (ion-sensitive field-effect transistor) was used as the transducer for all sensors.

pH ISFET/penicillin FET dual chip

The chip consists of two pH ISFETs with nearly identical characteristics (pH sensitivity: 56-58 mV/pH, linear range: pH 2-12; drift: ~0.5 mV/h; hysteresis: <2 mV); the gate of one was covered with the enzyme penicillinase. This sensor design allows measurements of the pH and penicillin concentration as well as to minimise the influence of temperature, drift and possible pH variations of the bulk solution using a differential measuring mode. The high sensitivity, low detection limit, small hysteresis and long lifetime were achieved for the penicillin sensor with the adsorptively immobilised penicillinase (see Fig. 2 and specfications).

ISFET-based temperature sensor

The temperature sensor consists of two identical ISFETs operating at different drain currents I_{D1} and I_{D2} (Fig. 3). The temperature sensitivity of the differential output signal is nearly linear in the range of 20-37°C with a slope of ~ 2.1 mV/°C and practically independent of the pH value.

ISFET-based flow-velocity and flow-direction sensor

The flow-velocity sensor is built-up of one H^+-ion generator and one pH ISFET which detects the generated H^+ ions (Fig. 4). Measuring the time difference between generation and detection, the flow velocity (flow rate) can be determined. A disign with one ion generator and two ISFETs allows also to realise a flow-direction sensor.

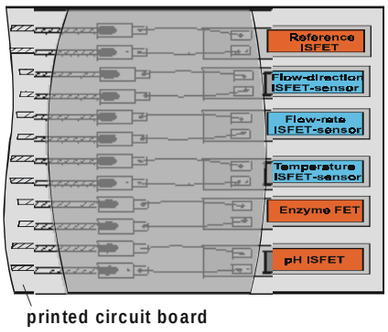

Fig. 1. Schematic configuration of multifunctional hybrid sensor module based on an identical transducer principle.

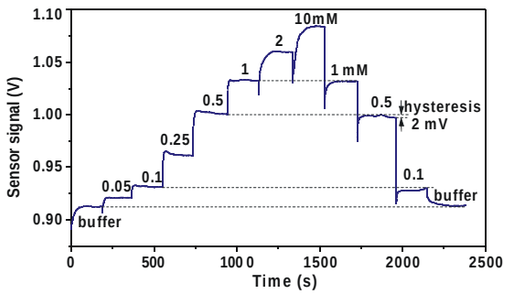

Fig. 2. Response of a penicillin FET.

Specifications of the penicillin sensor

Sensitivity	120 ±10 mV/mM
Linear range	0.05 - 1 mM
Lower detection limit	5 µM
Upper detection limit	20 mM
Hysteresis	<4 mV
Response time	0.5 - 3 min
Lifetime	>1 year

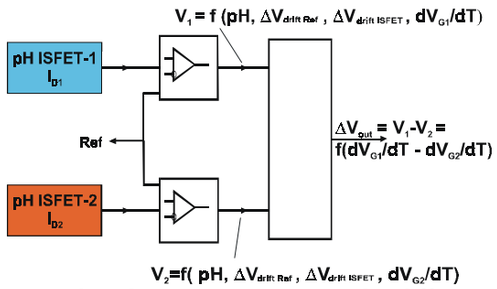

Fig. 3. ISFET-based temperature sensor with a differential measuring set-up.

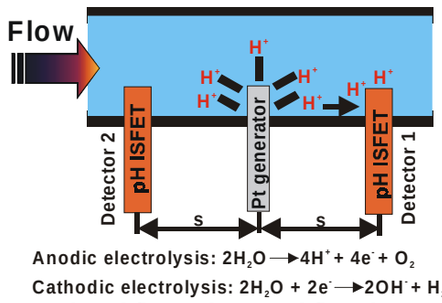

Fig. 4. ISFET-based flow-velocity and flow-direction sensor: functional principle.