ION-SELECTIVE FIELD EFFECT TRANSISTORS DEVELOPMENT AND CHARACTERISTICS MEASUREMENTS

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One of the main branches of science and technology is a creation of miniature and cheap sensor elements for health care, agriculture and technological processes applications. A great number of chemical and biochemical reactions cause the concentration of protons H^+ (pH) in solutions to change. Basic application for pH measurements is standard potentiometric glass electrode. Unfortunately when one wants to use it as bio- or chemo-sensor device with chemical sensitive polymer membrane being attached, several problems occur. It is difficult to attach a selective membrane robustly to a wide non-plane pH sensitive glass surface and even attached once, membranes have to be changed frequently. In the case of bulky glass electrodes it is hardly to imagine using several electrodes with various selective membranes (with expensive ferments inhibited) in single solution simultaneously. That's why ion-selective field effect transistors (ISFET) tend to be the main application for such measurements.

The concept of ISFET has been known since 1970 and was explained by Bergveld and Eijkel [1]. In general ISFET electrodes have a number of advantages comparing to standard glass electrodes: fabrication process based on standard MOS technology; low cost and diminutiveness — smaller amount of ferment required; accurate regulation of membrane thickness; using both chemo-selective and reference transistors on single crystal wafer.

It is shown in the report the designed topology of sensors and device for automated current measurements linked to PC by RS-232 bus. This project started in the Institute of Semiconductor Physics [2] and now the main customer is the Institute of Molecular Biology and Genetics (NASU).

Practical using ISFET as biosensor is based on the calibration characteristic has been accurately measured. One transistor is a reference (REFET) and measures pH of the bulk solution and another has chemo-selective membrane (chemo-ISFET). The measured response as a dependence from chemical agent concentration in solution (measured in milliMoles per liter) is the difference between current in REFET and chemo-ISFET. These responses tend to be from 5 μA to 40 μA.

To achieve a good quality of calibration characteristic the stability of ISFET even without membrane is needed. Characteristics shown in tab. 1 depend on the gate dielectric surface quality, wafer fabrication quality and storage conditions. That's why fabricated ISFET electrodes can't be maintained to chemists and biologists "as is" but with some kind of suitability certificate.

The author of report performs ISFET characteristics measurements using IV (current-voltage) curves, drift characteristics; develops electrodes selection methods by analyzing the suitability of ISFET parameters for measurements.

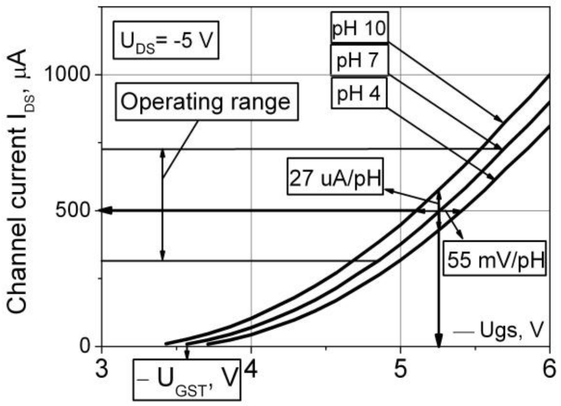

Fig.1. Obtaining ISFET parameters from transient I-V curve

A lot of parameters could be obtained using transient IV-curves of ISFET measured in different pH buffer solutions. Fig. 1 shows us three curves of p-type ISFET for different pH and operating point of device. Changing gate-source voltage (U_{GS}) — (–1…–6) V with fixed drain-source voltage (U_{DS}) –5 V transistor works in saturation mode. Current range — (300…700) µA gives the best linearity (error less than 2%) and constant transconductance and is used for measurements in current device versions.

Also 4 hours (long-time) ISFET current measurements were performed and the average current drift was calculated.

Average parameters for the fabricated ISFET group are shown in Table 1 and are sorted by significance for biosensor or chemosensor measurements.

Table 1

Current difference drift, µA/hour	less than 0.5
Current drift in channels, µA/hour	max 10
Dielectric pH sensitivity, mV/pH	50…55
ISFET pH sensitivity, µA/pH	25…30
Transconductance, µA/V	500…600
Threshold voltage, V	–(3…3.5)

Fabricated ISFET electrodes before being applied as biosensors require checking theirs parameters. Not only because of every technological process issues but also storing and surface handling procedures change important characteristics. The problem becomes complicated when polymer membrane is attached to the dielectric surface and in some cases causes ISFET parameters to change significantly.

References

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