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Novel biosensor combining conductimetric technique with a MOSFET transducer

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Abstract – New detection strategies are relevant for designing more sensitive biosensors based on structures compatible with the microelectronic microfabrication processes. This goal can be achieved combining different transduction techniques. Materials with chemical-sensitive conductance, such as arrays of molecular modified nanoparticles and nanostrucutred membranes can be incorporated in the biasing circuit of a MOSFET transistor with tunnel oxides (Fig. 1). This strategy leads to transistor characteristic curves, which are sensible to different target species (Fig. 2). The sensing element could be deposited on the field oxide as a back-end process reducing the fabrication steps, in a totally CMOS compatible device.

A biosensor consists of a bio-recognition element in contact with a transducer, which operates according to different principles: electrochemical, mechanical, piezoelectric, optical, etc. Among electrochemical detection strategies, amperometric biosensors are most widely used, followed by potentiometric devices, mainly those based on field effect transistors [1]. Different transducers can be combined to achieve more sensitive devices or structures, which are better integrated with the electronic components for signal conditioning, amplification and displaying. Several materials and structures exhibiting conductance change in the presence of a chemical or biological species have been used in biosensors. Arrays of capped metallic nanoparticles, for example, have been used in chemiresistor sensors [2]. The same behavior can be observed in organic membranes containing nanoparticles and catalytic agents such as enzymes for different target analytes. A possible approach to construct biosensors could combine conductimetric techniques with a MOSFET structure, for example introducing the sensing element in the biasing circuit of a MOSFET as shown in Fig. 1. The sensing element of conductance σ is connected in series with the gate. In the case of a thick oxide MOSFET, no current flows through the device, and the whole voltage drops across MOSFET. However, if a thin oxide were used, the voltage drop across the sensing element would be equal to the tunneling current divided the conductance, J_t/σ, and the potential distribution between the sensing element and the MOSFET would be given by Eq. (1).

$$V_A = \frac{1}{\sigma} J_T(V_G) + V_G \tag{1}$$

When the conductance changes due to the presence of the target species the potential distribution varies and consequently the gate voltage and drain current will also change. At lower voltages, tunneling is predominantly in the direct regime for which the current depends exponentially on gate voltage [3]. Using an appropriate model for tunneling current in this regime, Eq. (1) can be solved numerically for the potential distribution. Fig. (3) shows the gate voltage, fulfilling Eq. (1), and the corresponding saturation drain current as a function of conductance for three applied voltages. The structure parameters are indicated in the figure. A threshold voltage of 0.7V has also been considered. The sensing element could be designed to operate within the linear part of the Id vs. σ curve, and could be deposited on the field oxide using CMOS compatible back-end processes.

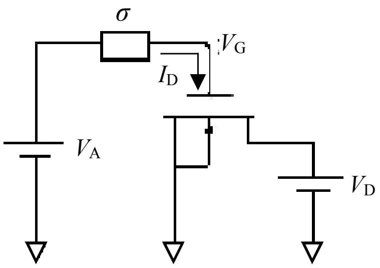

Figure 1: Circuit diagram showing the conductimetric element (σ). V_A is the applied voltage, V_D the drain voltage and V_G is the gate voltage.

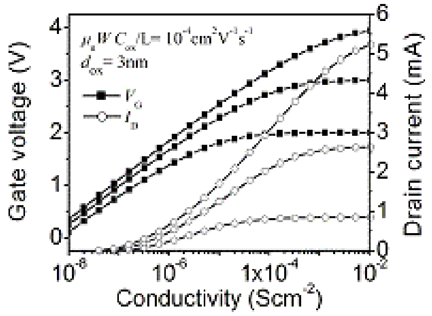

Figure 2: Gate voltage and drain current vs conductivity of the bio-recognition element, for different applied voltages: 2, 3 and 4V. A threshold voltage of 0.7V was considered.

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