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Out-of-Equilibrium Body Potential Measurements in Pseudo-MOSFET for Sensing Applications

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Highlights

The aim of this paper is to present the out-of-equilibrium body potential behaviour in the Ψ-MOSFET configuration. Consistent measurements in this experimental setup succeeded in providing a substantial understanding of its characteristics in the depletion region. The final objective of this work is to envision this new measurement technique for biochemical sensor applications. Among its advantages, the most important are its simplicity, the good sensitivity, the measurement of a potential instead of a current and the low bias needed for detection compared to the conventional drain current measurements.

Abstract – The aim of this paper is to present the out-of-equilibrium body potential behaviour in the Ψ-MOSFET configuration. Consistent measurements in this experimental setup succeeded in providing a substantial understanding of its characteristics in the depletion region. The final objective of this work is to envision this new measurement technique for biochemical sensor applications. Among its advantages, the most important are its simplicity, the good sensitivity, the measurement of a potential instead of a current and the low bias needed for detection compared to the conventional drain current measurements.

Keywords: SOI, Ψ-MOSFET, body potential, biochemical sensor, field-effect

1. Introduction

The Ψ-MOSFET is a characterization technique used for bare silicon on insulator wafers to determine important material parameters such as the mobility and the interface trap density [1]–[4]. This approach uses the innate upside-down structure of a SOI substrate, where the bulk silicon substrate is used as a back-gate (named simply "gate") and the buried oxide (BOX) as a gate dielectric. The gate voltage (V_G) induces a channel at the interface between the top silicon film and the BOX. The drain current (I_D) is measured between two metallic probes placed on the silicon film, which play the roles of source and drain. For low doping concentrations of silicon films (i.e. 10^{15}cm^{-3}), the conduction can be ensured by holes or electrons depending on the polarity of V_G. The coupling between the top free surface charge and the channel leads to threshold/flat band voltage shifts and was first observed during the electrical characterization of Ψ-MOSFET with different states induced at the top surface[4]. For intentionally modified SOI surfaces, these V_T/V_{FB} shifts proved to be useful for chemical detection [5], making the Ψ-MOSFET a detection device. Due to the fact that the channel is very close to the surface, this device has a high sensitivity, especially for the thin silicon films.

This paper aims to propose an alternative detection method, by measuring the body potential rather than the conventionally used drain current. It derives from the body-potential measurements in the out-of-equilibrium regime already performed on SOI-based MOSFETs [6]. In the case of an nMOSFET, if the gate is quickly polarized to induce the inversion regime, an out-of-equilibrium state is generated by the excess of majority carriers (holes) in the channel, which produces a body potential increase. An analogous behaviour can be observed for pMOSFET transistors. The use of a potential measurement instead of a current one for detection ensures the good sensitivity and a lower bias needed for sensing.

We will present the materials and the methods in section 2, the body potential measurements, their dependence on different electrical test parameters such as the scanning speed and their significance are presented in section 3. The invariability to probe pressure and position are an asset for detection (as described in section 4). Section 5 shows an example of detection of charged gold nanoparticles.