

Insulated Substrate Impedance Transducers: an innovative semiconductor device applied to labelled DNA sensing

Rémi PAMPIN¹, Boris FOULTIER², Luis MORENO-HAGELSIEB¹, Bruno HEUSDENS³, Jean-Pierre RASKIN¹, Jacques DESTINE³, José REMACLE², Denis FLANDRE¹

¹ Université catholique de Louvain (UCL), Place du Levant 1, B-1348 Louvain-la-Neuve

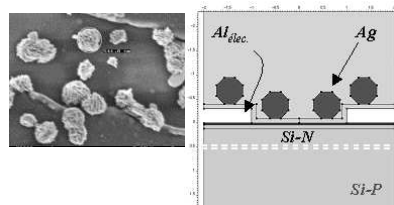
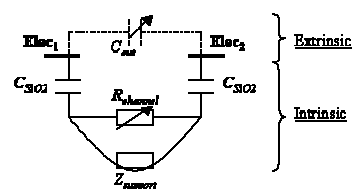
² Facultés Universitaires Notre-Dame de la Paix (FUNDP), Rue de Bruxelles 61, B-5000 Namur

³ Université de Liège (ULg), Sart Tilman B28, B-4000 Liège

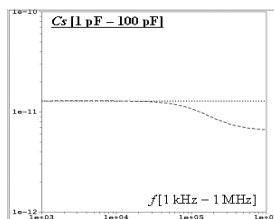
Abstract

Although more and more nanostructured devices allow direct detection of tiny biomolecules, the technology they require currently remains complex in processing or large-scale integration, and expensive with regards to standard CMOS. Moreover, research resources affected to scaling issues conceal or fail at the development of original measurement approaches, most likely addressed in the *smart sensing* field. Biochemical labelling in contrast is a common way to enhance the influence of biomolecular targets on micro-scale devices. Besides, the availability of easy characterization means and various labels sizes permits to deeply investigate sensors in their lowest detection ranges and consequently work on innovative measurement methods at that scale. Following our preceding work on purely capacitive detection, by passivated aluminium electrodes, of hybridized DNA labelled with decananometer silver grains, dielectric impedance spectroscopy has been envisioned as a start design paradigm to push further the devices performance, in a frequency-dependent multiparameter approach. A new semiconductor device has finally been derived, which couples passivated interdigitated micro-electrodes to a surface-doped silicon channel, insulated by a 30nm-thick “gate” oxide (fig. 1). In presence of a label, the channel’s conductance punctual modulation induced by field-effect is measured through the electrode-oxide-channel C_{SiO_2} capacitors (fig. 2), which gives rise to an intrinsic change of the local dielectric relaxation constant. So-called Insulated Substrate Impedance Transducers have thereby been designed to sense the labels’ density and density scattering throughout a DNA spot, by a global change of the dielectric impedance spectrum measured between the electrodes (fig. 3). As a demonstration, concentrations lower than 1 nM of silver-labelled 30bp DNA targets, corresponding to grains densities below 25%, were detected in air on 400x400 μm^2 arrays featuring 2+2 μm fingers (width + spacing) through conductance and capacitance variations by factors of 6 and 3, respectively. Our presentation will focus on simulation, optimization and characterization of ISIT’s electrical operation, and present on-chip tuning possibilities associated with substrate back-contact polarization.

– Fig.1 –
Top microscopic view
and 2-D illustrative cut
of an ISIT for silver
grains sensing



– Fig.2 –
2-D ISIT
electrical
model



– Fig.3 –
Equivalent RC-series ISIT model
.. without silver
-- with 25 % Ag coverage
[← left] complex capacitance
[right →] complex resistance

