Short bio

Carlotta Guiducci is associate professor of Bioengineering at the Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland. She received the Ph.D. degree in Electrical Engineering from University of Bologna (I). Her research interests are in the field of microsystems for bioanalytics and individualized medicine. Her team has been recently working on microfabrication technologies for high-throughput on-chip cytometry and on innovative methods for nucleic acids tests. Carlotta Guiducci was a recipient of the 2013 Intel Early Career Faculty Honor Program Award and the coordinator of a Swiss consortium on Therapeutic Drug Monitoring (Nano-tera.ch).

Abstract

Tri-gate silicon devices for the new generation of on-chip nucleic-acid bioanalytics

We were invited to comment on Nature Methods on the impact of pH-based quantitative Polymerase Chain Reaction (qPCR)[1]. In that paper, we stated that, although pH-based qPCR already presented several advantages with respect to classical fluorescence approaches, **the scalability of integrated electronics could be harnessed to develop ideal digital PCR systems** (dPCR). In fact, CMOS technology combines effectively very large-scale arrays with high speed of readout. The viability of this approach stems from the **scalability of the single pH sensor**, which implies r**educing its size while maintaining sufficiently high signal-to-noise ratio** (SNR).

We carried out an extensive work on CMOS-compatible top-down tri gate silicon nanowires **(SiNWs) fabricated in the semi-industrial facilities at LETI-CEA** (Grenoble, France). These chips were conceived as a platform to study the effect of size and other technological parameters on charge sensitivity. Our results show that pH sensitivity is enhanced for devices of a size below 100 nm. In addition, our work demonstrates that **multi-wire devices allow to resolve a 0.8 ‰ pH shift in only 1 μm^2** footprint. This level of **pH resolution on such a limited chip area represents an unprecedented achievement**, at least to our knowledge[2]. In collaboration with the University of Udine (Italy), we compared our experimental results with a custom-developed Technology Computer-Aided Design (TCAD) simulator that implements an original modelization of the electrolyte environment (available at: https://nanohub.org/resources/biolabisfet). The simulations are in good agreement with our experimental results, and they corroborate the **non-trivial dependence of the threshold voltage and drain current sensitivities on pH we observed**[3].

Stemming from our recent work on the ultimate pH resolution attainable in one micron-square footprint based on the advanced features of tri-gate nano-sized devices, we are working towards the development of a **fully integrated system for digital PCR**. The need for statistical validity of dPCR experiments will be addressed by the development of medium-density arrays. We will address this major technological requirement exploring both chip-level and wafer-level heterogeneous integration approaches.

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[1] C. Guiducci, F. M. Spiga, “Another Transistor-Based Revolution: On-Chip qPCR”, Nature Methods 10, 617–618 (2013).

[2] E. Accastelli, P. Scarbolo, T. Ernst, P. Palestri, L. Selmi, and C. Guiducci, “Multi-wire tri-gate silicon nanowires reaching milli-units pH resolution in one-micron square footprint”, Biosens., Volume 6(1), Issue 9, Mar. 2016.

[3] P. Scarbolo, E. Accastelli, F. Pittino, T. Ernst, C. Guiducci, and L. Selmi, “Analysis of dielectric microbead detection by impedance spectroscopy with nanoribbons”, in Proc. of the IEEE 16th International Conference on Nanotechnology (IEEE-NANO), Sendai (Japan), Aug. 2016.

P. Scarbolo, E. Accastelli, F. Pittino, T. Ernst, C. Guiducci, and L. Selmi “Characterization and modelling of differential sensitivity of nanoribbon-based pH-sensors”, in Proc. of the 18th International Conference on Solid-State Sensors, Actuators and Microsystems (TRANSDUCERS 2015), Anchorage (Alaska, USA), pp. 2188–2191, June 2015.