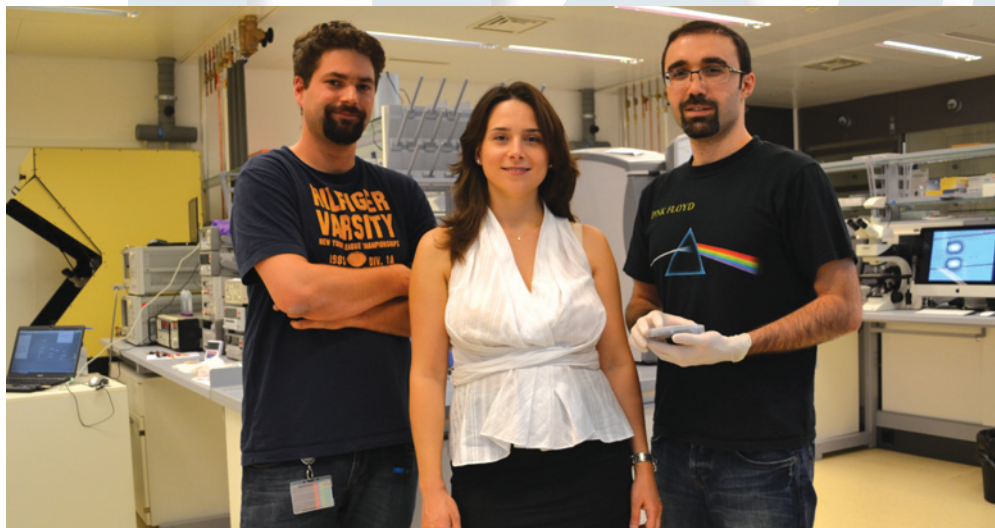


Carlotta Guiducci

École Polytechnique Fédérale de Lausanne (EPFL)



CARLOTTA GUIDUCCI is Assistant Professor at the Swiss Federal Institute of Technology (EPFL) where she holds a double appointment at the Institutes of Bioengineering and Electrical Engineering. She developed, with Infineon Technologies, the first CMOS chip for DNA label-free electrical detection. In 2011 she served as invited lecturer at the IEEE Solid-State Circuits Conference. She is Associate Editor of the ACM Journal on Emerging Technologies in Computing Systems.

Assistant Professor Carlotta Guiducci (centre) with PhD students Samuel Kilchenmann (left) and Yuksel Temiz (right)

Q. What inspired you to become a researcher?

A. At the time of my graduation, I believed that research was an activity based on sharing ideas and results at a global level, on passion for knowledge and discovery, and that a researcher was supposed to believe strongly in his/her own intuitions while nevertheless respecting the quality of other people's work. I wanted to be part of this community, and to grow as a professional and as a person with this approach. I guess all this made me a little romantic and naïve (but I am pleased to say after ten years I have not changed much).

Q. How did you get started in your academic career?

A. During my Master's project, I spent a few months in MINATEC in Grenoble working on the characterisation of ultra-thin oxides of FETs. That was the most enriching, exciting and rewarding experience I'd had so far. The people who were supervising me were generous, outstanding teachers, and truly committed and experienced researchers. We came up with a new technique to characterise high-leakage oxides and I can still remember the moment we got the idea.

Q. When did you start working in the biomedical field?

A. I started with my PhD thesis. My previous background was solid-state physics and I got interested in investigating the ability of electron devices to interact with molecules at the same scale. During my PhD, I spent most of my time in the laboratory of Nanobiotechnologies at the University of Bologna, where I complemented my know-how with practical and theoretical skills in biology and chemistry.

Q. Has the biomedical field developed as you might have expected?

A. High-density microarrays for genome-wide analysis based on a photolithographic technique at the wafer level showed up about 15 years ago. So far, the features' density has increased at an even higher rate than the number of FET transistors per unit area (one feature having reached the order of few tens of μm^2). This demonstrated how microtechnologies developed in the electronics field could lead to enormous breakthroughs in the biomedical field. On the other side, the miniaturisation and development of hybrid processes brought the first prototypes of *in vivo* ingestible sensors/drug-delivery chips. I perceive a big interest in these developments, but in my view the solutions to overcome safety and data security issues are still far from being fully accomplished, not to mention that the employment of *in vivo* devices often encounters distrust from the medical community and from patients, and is considered acceptable only in a limited number of specific treatments. In other words, such systems can be a huge innovation – as in the case of the 'Smartpill' for endoscopy – but they do not represent a suitable answer to all diagnostics and treatment demands.

Q. Tell us a little bit about your current research activities.

A. I supervise an enthusiastic group of young researchers, ranging from engineers in microtechnologies and electronics to bioengineers and pure biologists. Among our projects are sensors for point-of-care drug quantification in blood for therapeutic drug monitoring, systems for membrane-amyloids interaction studies to unveil the mechanisms of neurodegenerative diseases, and parallel cell counting microdevices. Our research activities range from the development of new technological processes for disposing and substituting the surface of biochips, to the development of novel molecular probes, to the characterisation of silicon nanowire devices for ultra-sensitive biodetection.

Q. Within your area, what are the key challenges?

A. In the area of so-called biochips, the following issues are certainly critical. First, the contact of the

chip surface with a wet environment that can have different levels of aggressiveness towards circuit passivation. This compromises the reliability of the measurements and prevents extended operation. Secondly, the establishment of solid-liquid interfaces on the sensor surface leads to an unstable and hardly controllable sensing platform. Thirdly, temperature rising on the chip surface might become critical in the case of *in vivo* applications and of molecular detection taking place on integrated sensors.

Q. It has often been said that 'CMOS is an enabling technology for novel healthcare applications' – do you agree?

A. Yes, I do. For instance, integrating measurement circuits with neural sensing electrodes is the only way to realise high-parallelism and low-noise sensing. Even for less demanding applications, CMOS is a highly flexible platform providing addressing, measurement and elaboration functions on the same device and, moreover, allowing a general-purpose biochip to be configured for different applications.

Nevertheless, I would say that a CMOS ++ would be that enabling technology, since hybrid solutions require hybrid technologies. CMOS needs a suitable interface with the bio/wet world; a set of novel high-tech packages that would allow, for instance, to dispose of the sensing surfaces.

Q. What do you see as the prospects for exploiting semiconductors for use in personalised medicine, and what are the key barriers?

A. In my view, the costs of semiconductor technologies are still too high for the low production volumes foreseen in the short-medium term. As previously mentioned, new designs are needed to provide configurability of the core signal processing and sensing part of the biochip, and to cope with the need to dispose of the surface used for human sample testing.

Q. What one key thing would transform the healthcare field?

A. It might sound trivial to say, but enabling widespread use of personalised medicine approaches would bring massive changes to the healthcare field. Allowing correct dosing and prescription of drugs would bring a non-negligible reduction of the cost of the cure. Last but not least, an improved patient awareness would reduce patient non-adherence to prescriptions, which is as high as 50% for chronic diseases (source: WHO).

Q. What are the potential applications that you find the most exciting?

A. Here are a few of my dreams and beliefs: affordable chips that screen the patient based on integrated personalised medicine approaches (genome-based, biomarker-based and drug dynamics); real-time parallel systems based on electrical sensing to allow new discoveries in cellular membrane studies, cell migrations, and single molecule characterisation; ultra-dense general-purpose electrode arrays integrated on CMOS for interaction at the subcellular level for applications ranging from cell studies to cell-based environmental sensing and synthetic biology applications.