This course is focused on two relevant aspects of the Electrochemical Nano-Bio-technology for CMOS sensing in medical applications: the Nano/Bio and the Bio/CMOS interfaces. Improvement due to nano-structures in bioactive interfaces and special architectures for CMOS-based detection of bio-functionality will be demonstrated. The Physics of the obtained nano-bio interfaces will be deeply discussed with special focus on the improvements in terms of specificity and sensitivity. Several examples of different CMOS architectures integrated with nano- and bio-structures for sensing purposes will be presented and deeply discussed.

Prof. Sandro Carrara is an IEEE Fellow for his outstanding record of accomplishments in the field of design of nanoscale biological CMOS sensors. He is also the recipient of the IEEE Sensors Council Technical Achievement Award in 2016 for his leadership in the emerging area of co-design in Bio/Nano/CMOS interfaces. He is a faculty member (MER) at the EPFL in Lausanne (Switzerland). He is former professor of optical and electrical biosensors at the Department of Electrical Engineering and Biophysics (DIBE) of the University of Genoa (Italy) and former professor of nanobiotechnology at the University of Bologna (Italy). Along his career, he published 7 books, one as author with Springer on Bio/CMOS interfaces and, more recently, a Handbook of Bioelectronics with Cambridge University Press. He also published more than 200 scientific papers and is author of 12 patents. He has been appointed as IEEE CASS Distinguished Lecturer for the years 2013-2014. His work received several international recognitions. He has been the General Chairman of the Conference IEEE BioCAS 2014, the premier worldwide international conference in the area of circuits and systems for biomedical applications.
## Course Schedule

<table>
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<tr>
<th>Time</th>
<th>Mon July 3</th>
<th>Tue July 4</th>
<th>Wed July 5</th>
<th>Thu July 6</th>
<th>Fri July 7</th>
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<tr>
<td>9:00 - 12:30</td>
<td>Lecture 2 BioSensors</td>
<td>Lecture 3 Nanotechnologies</td>
<td>Lecture 4 Bio/CMOS Interfaces</td>
<td>Lecture 5 Bio-CMOS Application Examples</td>
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<td>12:30 - 14:00</td>
<td>Lunch Break</td>
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<td>14:00 - 17:30</td>
<td>Lecture 1 Introduction to BioChemistry</td>
<td>Seminar 1 IEEE Sensors Council Distinguished Lecture by Prof. Sandro Carrara Bio/Nano/CMOS interfaces for Ultrasensitive Memristive Biosensors</td>
<td>Seminar 2 Yosi Shacham Tel Aviv University Nanomaterial based electrochemical sensors</td>
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## Course Program

- Probes and Targets Building Blocks
- Probes/Target interactions with DNA or Antibodies
- Probes/Target interactions with Oxidases and Cytochromes P450
- Probes Detection Principles with DNA or Oxidases
- Probes Detection Principles with cytochromes P450
- Probes immobilization
- Checking Probes-layer quality (RR+SPR+SEM)
- Checking Probes-layer quality (AFM+STM)
- Nanotechnology to prevent Electron Transfer
- Nanotechnology to enhance Electron Transfer
- Circuits for metabolites detection in Fixed-Voltage
- Circuits for metabolites detection in Scanning Voltage
- Circuits for metabolites detection with multi-panel systems
- Circuits for DNA Capacitance Detection
- Remote Data and Powering transmission
Seminars

Inside the course two Seminars will be held, related to the presented topics.

**Seminar 1. IEEE Sensor Council Distinguished Lecture, held by Prof. Carrara himself, titled "Bio/Nano/CMOS interfaces for Ultrasensitive Memristive Biosensors".** In this Distinguished Lecture, the very best worldwide ever-reported electrochemical biosensors based on a memristive effect and aptamers or antibodies are presented. These novel sensing devices are developed to propose a completely new approach in the co-design of Bio/Nano/CMOS interfaces for cancer diagnostics. In this research, affinity-based techniques are presented for the detection of the prostate specific antigen (PSA) and the Vascular Endothelial Growth Factor (VEGF). The hysteretic properties of memristive silicon nanowires functionalized with proper biomolecules provide a label-free and ultrasensitive bio-detection technique. In order to develop full systems for diagnostics, the integration with CMOS frontend, in one side of the interface, and microfluidics, in the other side, is required too. Therefore, this lecture also discusses novel circuit approaches for an automated and quick characterization of arrays of memristive biosensors. One memristive parameter, the width of the voltage gap, is directly proportional to the target molecules concentration. Thus, CMOS readouts acquiring such width, meanwhile sorting-out faulty devices, i.e. non-conducting nanowires in the array, are presented together with analog-to-digital conversion for the acquired voltage gap. A prototype of these circuits is shown as an example of design in 0.35μm CMOS technology. The integration of the CMOS readout with the nanoscale sensors and a microfluidic platform is a must for the design of robust biosensing-systems for quick data acquisition in cancer diagnostics. Therefore, the development of an improved chip-platform for cancer diagnostics based on nanofabricated Memristive Biosensors integrated, for the first time, with a microfluidic structure is also presented in this lecture by also addressing critical issues, e.g., the problems related to long connections between the Memristive Biosensors and the CMOS frontend.
Seminar 2. Nanomaterial based electrochemical sensors. Prof. Yosi Shacham–Diamand, Tel Aviv University. In this talk we review the topic of electrochemical sensors in general and biological applications in particular. The main applications are in the fields of medicine and healthcare, food and agro and environment. Initially we present an overview of the fundamentals of applied electrochemistry for both nano fabrication and the application of nano scale electrochemical devices. A short review of the basic electrochemical theory will be presented; followed by a review of basic electrical (DC &AC) and also optical characterization methods of such sensors. Next, a review of conventional microelectrodes will be presented in general and the use of nano-material based electrodes in particular. Finally, few electrode systems will be demonstrated; for example, 1. Silicon nano wire electrodes, 2. Metal (i.e. Au, Pt, AuPt etc.) nano particle on conjugate polymers electrodes and 3. Inkjet printed silver nano-particle electrodes modified by electroless plating. We present enzyme based sensors using nano-structured electrodes tested by both amperometric and electrochemical impedance spectroscopy.

Yosi Shacham-Diamand is a professor for electrical engineering at the department of electrical engineering, physical electronics, school of electrical engineering and also in the department of materials science and engineering, both at the faculty of engineering Tel Aviv University. He got his D.Sc. EE 1983, M.Sc. EE 1978, and B.Sc. EE (Summa-cum Laude) 1974, all in Technion, Israel. 1983-1986 post-doctorate at U.C. Berkeley. 1987-1989 senior lecturer, the Technion, Israel. 1989-1996 assistant professor Cornell university, 1997-2001 Associate professor and since 2001 a full professor at the school of electrical engineering, Physical Electronics department, Tel-Aviv University. He is a Visiting professor, CNR-IMM, Rome, Italy, Visiting Professor, Waseda University, Tokyo, Japan and a distinguished international chair professor, Feng Chia University. He published >220 journal papers, >300 conference papers in registered proceedings, 4 chapters in books, 20 patents, edited two conference proceedings books, and two books. Currently he is a member of the Israeli National committee for generic technology (MAGNET), office of the chief scientists, ministry of economy.
He is a member of the advisory committee of the advanced metallization conference (AMC), the Materials for Microelectronic (MAM) conference and electrochemical micro and nano technologies (EMNT). He is a member of the editorial board of the Journal of Micro Electronics Engineering and the editor of special issues in the Journal of Micro Electronics Engineering and Electrochimica Acta.

His research activity is in the field of micro and nano fabrication and metallization science and technology. For more than 25 years he investigates electroless plating micro and nano fabrication for various applications such as for microelectronics, micromachining, and biochips. For the last 15 years, he conducts also a significant research program on whole cell biochips and solid-state biosensors.
How to reach the Room LED3, 2nd Floor of Cittadella Politecnica, Department of Electronics and Telecommunications

The LED3 room is located at the Second Floor of the Department of Electronics, in the Cittadella Politecnica, and indicated in the following map. For reaching it you must enter in Politecnico's entrance in Corso Castelfidardo 39 and then go to the 2nd Floor. The room is on the left "bridge" crossing Corso Castelfidardo.

LED 3 - LABORATORI ESERCITAZIONI DIDATTICHE

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<tr>
<th>Sede:</th>
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<tr>
<td>Struttura:</td>
<td>Dipartimento di Elettronica e Telecomunicazioni</td>
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<td>Piano Secondo</td>
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<td>Dettagli:</td>
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<td>Fabbricato: Scavalchi Manica Approdo</td>
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