Ph.D. in Information Technology:

Ciccarella, dell'Erba, Grimoldi and Mulaosmanovic Final Dissertations

DEIB Conference Room

February 24th, 2016

2.00 pm

First Ph.D. presentation and discussion:

Pietro CICCARELLA – XXVIII Cycle

"High Sensitivity CMOS Dedicated Electronics for Innovative Impedance-based Sensors"

Supervisor: Prof. **Giorgio Ferrari**

Abstract:

Impedance measurement is a powerful tool exploited in many fields of research to inspect the properties of materials and detect a variety of phenomena. At the micro-scale, low-noise electronics is required for very small signals detection. CMOS integrated circuits offer advantages in terms of: (i) higher detection sensitivity, (ii) multichannel operation, (iii) higher bandwidth and (iv) a considerable miniaturization of the instrumentation. Aim of the research of this PhD work is the design and the implementation of CMOS electronics for innovative impedance-based sensors. A 32-channel ASIC for non-invasive light monitoring in photonic circuits by means of impedance sensing of waveguide conductance variations has been designed. The low noise front-end allows to access the waveguide conductance with very high sensitivity and to track its variation upon changes of the photon flux with a resolution better than 10 pS, i.e. -30dBm in optical intensity. Four independent electronic channels feature a capacitive feedback transimpedance amplifier, double-balanced square-wave demodulators and a low parasitics 8x multiplexers to address 32 different optical probes. The ASIC performs multi-point monitoring and reconfiguration in photonic systems with many sensing sites and the non-invasive local feedback, light path tracking and optical circuits reconfiguration demonstrated in this work, pave the way for the large-scale integration of photonic microsystems.

High sensitivity microelectronics for impedance measurements allows airborne particulate matter (PM) detection; standard detection methods lack portability, hampering low cost pervasive monitoring. A monolithic CMOS PM detector has been designed and tested for the counting of single dust particles by means of a capacitive measurement through integrated planar interdigitated electrodes. The required high resolution is achieved by dividing the sensitive area into 32 pixels. Each channel is based on a lock-in architecture, featuring a digital-to-capacitance converter (DCC) for mismatches compensation, a DC bias network that diminishes the low-frequency noise and integrated low pass filters. The sensor has a resolution better than 65 zFrms (20 ms response time) allowing a real-time detection, counting and sizing of PM with an equivalent diameter down to 1 µm deposited on the active area of 1.15 mm2. The miniaturization and low-power consumption of the resulting system go beyond the state of art of the actual PM detectors, paving the way to pervasive (smartphone-embeddable) high performance air quality monitoring and control strategies.

Second Ph.D. presentation and discussion:

Giorgio DELL'ERBA – XXVIII Cycle

“Organic Complementary Logic and Analog Circuits”

Supervisor: Prof. **Dario Natali**

Abstract:

Printed electronics is a new paradigm-shifting technology that may enable flexible and low-cost applications on large-area and, ideally, on any substrate. Main target applications are flexible displays, integrated systems for distributed and wearable sensing and interactive surfaces, with applications in automation, health-care, industrial diagnostic and security.

One of the major concerns about printed electronics is the need for robust electronic devices. The presented work proposes a method to successfully implement fully-printed and all-polymer complementary circuits on plastic substrates. After a study on the charge injection engineering for ambipolar semiconductors for complementary logic applications, the research focuses onto a fully-printed approach using only roll-to-roll compatible techniques such as ink-jet printing and bar-coating. After an explanation of the fabrication procedure and the demonstration of complementary circuits both on thin and ultra-thin substrates, the realization of a twilight switch - a complex fully-printed analog system integrating multiple circuital elements - is proposed.

This study demonstrates the suitability of printed electronics for everyday-life applications and its growing readiness to consumer market application.

Third Ph.D. presentation and discussion:

Andrea GRIMOLDI – XXVIII Cycle

“Integration of Direct-Written Organic Photodetectors and Organic Transistors: Towards Passive Pixels for Plastic Large-Area Imagers”

Supervisor: Prof. **Dario Natali**

Abstract:

Large area imagers can be of great advantage in X-ray medical and industrial diagnostic or security applications every time that the object to image is large and focusing optics too expensive, e.g. for X-ray imaging. Organic electronics combined with graphic arts printing techniques not only can help in reducing fabrication costs, but also allow new applications that exploit their intrinsic advantages: solution processability, mechanical flexibility, tunable optical capabilities, fast prototyping and reduced waste of

material.

In this thesis work a careful optimization of inkjet printed photodetector (PD) prototypes was performed helped by feedback from characterization and comparison with literature. The non-trivial task related to the design and the integration of the photosensitive element realized with an addressing laser ablated thin film transistor (TFT) was taken into account. The functionality of PD as photosensitive element and TFT as addressing one once integrated on the same substrate was verified. To demonstrate the versatility of the approach used alternative pixel architectures were explored such as stacking the photodetector on TFT dielectric or using an inkjet-printed diode as addressing element. The latter structure opens the way not only to the simplification of the process flow, but also to the fabrication of a crossbar array of pixels with high geometrical fill factor. Finally, a direct-written organic imager was fabricated and characterized taking care of the issues related to the realization of many pixels on the same substrate one next to the other, their electrical interconnection, the proper electrical insulation between conducting lines belonging to different planes, the driving signals characteristics for a proper readout.

The fabrication of photodetectors with good optoelectronic performances (specific detectivity reaches 6.2 × 1012 Jones) via cost-effective and additive inkjet printing technique will be presented. Additional key features as semi-transparency and fully-patternability possessed by the devices offer advantages for their integration in complex electronic systems. A matrix with 6 pixels detecting two order of magnitudes of impinging light intensity demonstrates the possibility to realize a semitransparent imager prototype by inkjet printing and femtosecond laser ablation on flexible substrate without the use of vacuum techniques or masks and keeping low overall thermal budget and the material waste.

Fourth Ph.D. presentation and discussion:

Halid MULAOSMANOVIC – XXVIII Cycle

“Characterization and Modeling of Innovative Solid-State Memory Technologies”

Supervisor: Prof. **Christian Monzio Compagnoni**

Abstract:

Over the past decade, both volatile and non-volatile solid-state memory devices have seen their physical size aggressively shrunk in order to meet the scaling process requirements. Although this led to a remarkable increase in device integration density, and consequently, to a reduction of the cost per bit, it pushed the respective technologies to their physical limits. On the one hand, Dynamic Random Access Memory (DRAM), as the most densely integrated volatile memory, is faced with ever increasing leakage currents, while the integration of the storage capacitor became the main issue for the ultra-scaled devices. On the other hand, Flash memory, today's leading non-volatile memory technology, is approaching the point where the discreteness of the matter and of the charge flows is severely impacting its performance.

The goal of this thesis is to investigate two innovative memory devices, one of volatile and the other of non-volatile nature, which appear to be promising candidates for the future replacement of DRAM and Flash technologies, respectively. The former exploits the bistability of gated-thyristors to store the volatile data in a simple and reliable fashion and is called Thyristor-based RAM (T-RAM) cell. The latter one relies, instead, on the permanent polarization reversal within the gate stack of a Hafnium oxide-based Ferroelectric Field Effect Transistor (FeFET) to encode the two binary states. Not only are the two devices fully CMOS compatible, which would facilitate their path towards the semiconductor industry, but they also exhibit simple working principles and excellent performance features in view of their future memory applications.