EmerTech: Emerging Technologies for Sensing Applications

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Almudena Rivadeneyra
Pervasive Electronics Advanced Research Laboratory (PEARL)
Department of Electronics and Computer Technology
University of Granada, 18071 Granada, Spain
Email:arivadeneyra@ugr.es

***Abstract*—This special track is dedicated to recent developments in emerging technologies for sensing devices and applications. These techniques possess outstanding features with respect conventional silicon-based sensors, such as thin, lightweight, flexible, large-scale manufacturing, environmental-friendly devices and produced at low cost. The special track is expected to provide a common environment for presentation and discussion of relevant emerging technology, while promoting academic and industrial interaction among people from highly diverse technical and industry background.**

Keywords— flexible; printed electronics; laser scribing; sensor integration; sensor nodes

I. INTRODUCTION

Contrary to traditional electronics that are rigid and brittle, flexible thin-film electronic devices are comfortable because they conform to the curved surfaces and are lightweight. Moreover, they can span over large areas and utilize as flexible substrate biocompatible polymers such as polyimide (PI) [1] or polyethylene terephthalate (PET) [2].

EmerTech embraces the gaps currently existing for the successful development of cost-effective and environmental-friendly systems for the Internet of Things (IoT) applications, where a huge amount of electronic devices are required to exchange information among the different entities involved.

Different multidisciplinary aspects compiled in this track, such as the ones described below:

- *Printed electronics (PE)*: For the fabrication of the different electronic elements, such as sensors, harvesters or energy storage elements, PE techniques has arisen as a potential cost-effective and environmental friendly alternative [3]. Inkjet printing, spray coating and dispensing are additive and non-contact methods in nature, which allows the simultaneous deposition and patterning of the desired materials on the same substrate that the rest of the system, but with minimal disturbance to the components already present in the system. Furthermore, PE offers the versatility necessary to adapt to different materials.
- *Non-conventional hybrid electronics:* Thin-film electronics are compatible with industrial scaling. Moreover, the hybrid electronics approach that uses Si chips in combination with thin-film electronics reduces considerably the use of expensive Si chip area and limits its use only to the most demanding tasks.
- *System integration*: All the system components, from the flexible ones to the Si chips needs to be integrated in the same substrate with the optimal conditions [4].
- *Energy management:* In order to broaden the usability of the systems, it is desirable to design them to be energy autonomous, i.e. without the use of batteries. On one hand, there are scenarios where battery replacement may not be a viable option. On the other hand, batteries utilize materials and processes that are altogether not always sustainable (such as Li or Pb) and compatible with the low-cost production of the IoT sensing nodes. Instead of batteries, energy harvesters and supercapacitors are the best alternative to substitute conventional batteries.
- *Sensors:* Pioneer sensor production techniques and materials are crucial for this kind of applications. In particular, the investigation of reliable and low-cost fabrication techniques. It is also important the characterization of both materials and processes together with the sensor performance.

II. SUBMISSIONS

The first contribution to this session describes a novel approach to provide sensing capabilities to a Radiofrequency Identification (RFID) tag working in the Ultra-High Frequency (UHF) band (860 MHz) manufactured by printed electronic (PE) technologies. There have been devoted to many efforts over the last years to develop antennas based on PE [5, 6] because it offers outstanding features compared to conventional fabrication processes, such as flexibility, conformability and cost-effectiveness. Another goal to RFID technology is the inclusion of sensing capabilities in the tag, so it can be not only identified but also shared information of their environment. In this contribution, an innovative solution is presented where a screen printed silver antenna integrates a force sensor in its layout. In particular, the force sensor is manufactured also by screen printing with a matrix of poly(dimethylsiloxane) (PDMS) pillars and silver contact area. The sensor working principle is the variation in the resonance frequency when a pressure is applied in the area where the PDMS pillars are located. When pressing the mentioned area, the resonance frequency is increased and its magnitude decreases. This approach paves the way for including sensor information in printed RFID antennas.

In the future, the influence of the force applied on the resonance frequency together with the analysis of the area where the structured PDMS is located will be studied [7].

In recent years, flexible electronics have attracted the attention of many researchers. This trend is expected to bring out a revolution in diverse fields of technology, such as e-skin, wearables devices or biomedical sensors, among others. Thus, several materials and fabrications processes have been explored with the objective of synthetizing flexible and electrical conductive patterns over large area substrates in a cost-effective way, which have led to outstanding advances in all areas involved in the development of flexible electronics devices, extending from sensors to antennas. However, apart from these latter examples, novel applications are also demanding flexible energy storage devices that allow the integration fully flexible devices to finally avoid the rigid-flex implementations.

In this context, in the second contribution to this track "Screen Printable Electrochemical Capacitors on Flexible Substrates" by *Romero et al.*, the authors present an inexpensive method for the mass fabrication of electrodes to be used in thin-film flexible electrochemical double-layer capacitors (EDLCs) [8]. EDLCs are a type of supercapacitors whose capacitance is associated with the charge accumulation at the interface electrode/electrolyte. Many researchers agree that carbon-based electrodes will play an important role in the supercapacitor technology since they offer both high surface area and relatively high electrical conductivity with an acceptable cost. For that, the authors proposed the use of a commercial carbon-based electrically conductive ink for the fabrication of the electrodes of these flexible supercapacitors. The performance of these electrodes, in combination with a Poly(vinyl alcohol)/phosphoric acid (PVA/ H_3PO_4) electrolyte, was presented by means of cyclic voltammetry and constant current charge/discharge tests, as well as under both mechanical and thermal stress. The results demonstrated that this method paves the way towards an alternative method for the large-scale and cost-effective fabrication of flexible supercapacitors.

The last contribution to this track demonstrates how Radio Frequency Energy Harvesting (RFEH) and printed flexible technology (a growing technology for sensors) can solve the concerns through cost-effective mass-production and utilization of energy harvesting for the development of energy-autonomous nodes, as part of a wireless sensor network [9]. To address the current requirements of the Internet of Things and 5G regarding the costs and powering of the nodes part of wireless sensor networks, they introduced a solution for the use of RFEH in conjunction with flexible printed sensors. RFEH avoids the changing or recharging of batteries, as well as its contaminant wastes, making the nodes energy-autonomous. On the other end of the system, the use of flexible printed technology for the sensors provides a boost in manufacturing and integration savings, besides its ultra-low power requirements.

To demonstrate this, they presented a sprayed Graphene Oxide (GO)-based flexible relative humidity sensor powered with RFEH under the store-and-use principle. This methodology stores energy in time through an analogic energy management circuit, including impedance matching and level adaption. The sensor, consisting of 16 inter-digitally arranged electrodes, takes advantage of the outstanding sensitivity to humidity changes of the dielectric constant of GO through a capacitive structure. In conjunction, we achieved satisfactory measurement results in an extremely cost-effective and green manner.

III. Conclusions

The EmerTech special track includes a broad range of topics related to innovation solutions for green electronics and IoT applications. It contains academic and industry research papers introducing interesting ideas and perspectives for future work in this thriving research domain

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