PRISENSE: Printed Sensors

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Abstract—**In the past decade, a lot of money has been devoted for the development of Smart Cities and Smart houses. While Smart Cities require significant technological advancements in several areas, such as Big Data, Internet of Things (IoT) and Sustainability, a lot of effort have been directed towards the area of sensors. The most vital step for upgrading to Smart Cities/buildings is to develop the technology that will acquire information from the environment and will provide that information to the controllers of the system. The escalating interest in the Internet of Things has raised the need for the development of solutions for real-time monitoring of several parameters with the use of smart sensors. Some of those parameters require high-density sensor networks, which feature unique challenges. Although sensing technologies for most of those parameters already exist, they lack in overcoming these unique challenges such as cost, flexibility, ruggedness and the ability to operate in real-time. Furthermore, delocalised monitoring points of several utilities, such as water or gas, can only be realised with low-cost sensor networks. Printed sensors feature several advantages in this area, such as low-cost, high versatility, high robustness and the fact that they can survive in harsh environments. This special session will focus on novel printed sensors for applications ranging from soil mechanical properties to textile-based touchpads.**

Keywords-Thick-Film Technology; Screen printing; Printed sensors; Printed bio-sensors.

I. INTRODUCTION

The aim of the PRISENSE special session is to bring together researchers from the area of sensors that are specifically working on sensors that are specifically fabricated by printing techniques such as Thick-Film, Thin-Film, Spray Coating, Inkjet or simple Printed Circuit Board (PCB) fabrication.

There are several manufacturing technologies that can be used for the fabrication of sensors. One of the oldest printing technologies is Thick-Film Technology [1], which was initially used for printing circuit boards, is now being used significantly for sensor fabrication. Other technologies used for sensor fabrication are Thin-Film [2], Inkjet [3], 3D printing [4] and spray coating [5]. Each one of these technologies features various advantages and disadvantages and that is why for different applications, different technologies are used. In general, the quality of printed sensors depends highly on the technological level of advanced manufacturing but at the same time, the level of advanced manufacturing technologies depends on the ability of the sensors to provide the required information.

Usually, printed sensors are chosen when the sensor is required to operate in harsh environments such as soil [6] or in applications where miniaturisation is of high importance. In addition, due to fabrication ease the cost of these sensors is significantly lower than other sensors. Their ability to operate in harsh environments and low-cost allows their use in high-density sensor networks used in Smart Cities/Buildings or IoT.

This special track will present research of new and improved printed sensors, as well as improvements in sensor printing techniques or new inks for the development of the sensors. We aim to provide a vibrant forum for exchanging ideas, methodologies and insights of smart printed sensors and their printing techniques for improved performance and ruggedness, while maintaining low fabrication costs.

II. SUBMISSIONS

The first paper is entitled “Printed Textile Touchpad” [7]. The paper presents a printed touchpad that can be printed on textile and it is based on projected capacitive technologies. The touchpad can be used with textile substrates and using techniques of low-cost such as screen-printing. The system works on both flat and curved surfaces, which allows it to be used in parts of clothes such as sleeves, trouser legs or textiles for furniture such as sofas, armchairs etc. Two different architectures were tested by the authors while in both cases the structures were tested using a specific controller for projected capacitive technologies. One architecture was called One-Layer-

Design (OLD) and the other Two-Layers-Design (TLD). The microchip MTCH6102 was used to test the two designs and it was found that for both designs all gestures could be identified. It was found that the structure and type of dielectric can have a great influence on the value of the capacity of the capacitive sensor used. This paper can clearly serve as the basis of a low-cost touchpad that could be printed on clothing to control other electronic interfaces.

The second paper is entitled “Printed, microwave-based, transmission-line sensor for investigating the electromagnetic behaviour of pure bacteria culture and algae in water” [8]. The paper illustrates the use of radio-frequency waves to investigate the electromagnetic behaviour of bacteria and algae in water. Currently, most available methods for monitoring the water quality are laboratory-based, which is time-consuming and expensive. This sensing technique is fast, robust, low-cost and requires a very simple sample preparation. A transmission-line, microstrip sensor is developed that could be used for a wide frequency range. The sensor needs only 50μL of the sample and 60 seconds to analyze it. The sensor was tested with fresh water algae (*Chlorella vulgaris* GIEC-179) and bacterium (*Pseudomonas aeruginosa*) to characterize their electromagnetic properties. Their reflection coefficient (S11) resonance peak changes were investigated at low (0.01-1.0 GHz) and high frequency (1.5-2.5 GHz) ranges. The authors suggested that the S11 resonance peaks are identical for different concentrations of the same cell types (i.e. bacteria, algae and mixture of both) in de-ionised water. Furthermore, the S11 parameter of their dead cells were also investigated, showing significant differences between different cell types, whether the cells were dead or alive. The prototype sensor is able to detect bacterial cell in the range of 100 Cell/mL and algae 2.04 x10- 10 g/L, which is sensitive and selective enough for fresh water quality monitoring. This paper provides a method that could be a potential approach to real-time monitoring of the pathogenic detection of freshwater quality.

The last paper is entitled “Thick-Film Sensors for Soil Measurements” [9]. The paper presents a soil resistivity sensor that in combination of a water-content sensor can be used to monitor soil mechanical properties such as porosity and/or permeability. Water content has considerable influence on soil pore water pressure and shear strength, potentially leading to failure in earthworks. This paper aims to provide the foundational work for the development of novel sensors (employing Thick-Film electrodes) intended to detect changes in soil parameters such as conductivity, porosity and water content while determining whether these are indicative of earthworks instability (potential slope failure). The use of Thick-Film electrodes to measure soil parameters could be a very cost effective method for condition monitoring. The resistivity/conductivity output of the sensors and its relationship to soil water content is of vital importance and yet needs to be further understood. A framework of working conditions for this sensing technology needs to be established. The authors present the behaviour of the Thick-Film cell, that was tested for a particular soil particle size by, simulating heavy rainfall and rising of the water table within a soil column. The results are very promising while the hypothesis of air bubbles controlling the readings from the sensor, requires further investigation.

III. CONCLUSION

The PRISENSE special session includes a broad range of topics related to printed sensors and their performances in applications ranging from textile touchpad to soil monitoring to radio-frequency monitoring of bacteria. It further includes a round table discussion for future work in this thriving research domain.

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