Enabling Low Cost UHF RFID Transfer Tattoo Tags by Inkjet Printing Means

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Abstract

In this paper we demonstrate the use of inkjet printing as a facile digital fabrication tool for the cost effective manufacture of radio frequency (RF) features on low-cost flexible and porous substrates. The design presented in this work is a thin, substrate tolerant UHF RFID tag that can be mounted directly onto the skin surface in the form of a transfer patch in much the same way that a temporary tattoo could be applied.

Keywords- *conductive ink, inkjet printing, RFID, frequency selective surfaces, porous substrates, temperature and chemical sensitive substrates, flexible/stretchable electronics, "green" electronic, wireless communication*

Introduction

With the emergence of distributed and wireless sensor technology readable tags will be able to collect a vast set of data that can be processed to provide new information. Such information could be extremely important for security, health care and location applications. Some examples include mission critical environments such as power plants, airports, military bases and depots, refineries, and access restricted areas to provide the highest quality of security to record trends and provide immediate required actions. In these environments as well as health care, identifying, tracking and monitoring people is vital to interface different services to create a more resilient system.

The widespread adoption of passive RFID tag in asset tagging is well documented and its use is also emerging as particularly useful for monitoring, identifying and tracking people particularly in work environments [1-5]. More established RFID systems such as LF and HF RFID can be used for the monitoring of people but the person to be identified must be close to, or even touch, the reader. This is not particularly attractive for many applications where fast access or continuous monitoring is required. UHF RFID systems on the other hand can provide identification distance (read range) of up to 10 m. It is this identification distance, compare to other RFID systems, along with low cost tags and relatively high data rate what makes UHF RFID systems suitable for human monitoring [6].

Current human tagging and monitoring technology, external to the body, typically requires wrist bands or ID badges, electrodes to be mounted on the skin via adhesive tapes, straps, or penetrating needles, often aided by a conductive gel, with terminal connections to separate boxes hosting circuit boards, power supplies and communication components. Solutions which compromise security (bands and badges could be remove and given to another person) and are poorly suited for practical applications outside of research labs or clinical setting [7,8].

Long and short-term skin mounted electronics, such as UHF RFID tags, could provide an effective solution to many of the issues described above. However, in order to make on-skin electronics a technology wide spread and commercially viable electronics must be cheap, flexible, reliable and small in size to appeal to the end user.

To date the electronics industry largely relies on PBC fabrication methods such as photolithography and screen printing. However, these methods are time-consuming, expensive and environmentally detrimental. In addition, the corrosive nature of solvents used in the etching processes makes this technology challenging and cost-inefficient to apply to substrates such as paper. Inkjet printing provides a more versatile, eco-friendly, highly scalable technology to prototype and mass produce electronics on plastics, paper and textiles. Direct additive printing has a number of benefits including, low material usage, additive rather than subtractive processing and in principle eliminates the need for other expensive technologies such as lithography, etching and vacuum processing. Moreover, in inkjet printing there is no need for masks and therefore, pattern designs can be altered almost instantaneously which makes inkjet printing a powerful rapid prototyping technology, especially when antenna and tag design is yet to be optimized. These advantages are expected to result in a substantial reduced production costs making inkjet printing technology suitable for the fabrication of low-cost disposable electronics products.

To date, very little work has been reported in the field of electronics mounted directly on skin. To this end, and in response to the growing interest in non-intrusive human tagging and inkjet printing of conductive features on porous, temperature sensitive, flexible and stretchable substrates, here we introduce an investigation to determine the feasibility of drop-on-demand (DOD) technology to fabricate thin passive UHF RFID tags onto tattoo paper transferable and functional onto skin. The choice of substrate, paper instead of expensive silicon, combined with the inexpensive fabrication method, inkjet printing, will provide a step towards the commercialization of low-cost on-skin electronics for human tagging. This technology could also be applied to other areas such as tags on fabrics and in building communication.

State-of-the-art

RFID antennas and tags mounted directly onto skin are particularly challenging owed to the intrinsic electrical characteristics of the human body which can interfere with RF components. Recent published work from Dae-Hyeong Kim *et al* [9] demonstrated the possibility to attach high-performance electronic functionalities to the surface of the skin. A collection of sensors, circuit elements and radiofrequency (RF) communication components was patterned by a combination of spin-coating, photolithography, dry etching and transfer printing onto the surface of a carefully engineered thin, lightweight, stretchable “skin-like” conformal silicone and Polyvinyl alcohol (PVA) substrates. Transfer of the electronic components onto the surface of the skin was then achieved by soft contact in a similar manner to a temporary transfer tattoo.

Very recently J. C. Batchelor *et al*. successfully engineered a substrate insensitive *thin* antenna and demonstrated the first temporary on-skin passive UHF RFID transfer tag fabricated employing commercially available tattoo paper and screen printing means [10,11]. Our earlier work in the field of Frequency Selective Surfaces (FSS) demonstrated that inkjet printing can be used to produce dipoles (antennas) of similar performance to those obtained by conventional etch processing [12]. Very recently, driven by the interest in “green” and wireless technologies, work in the field of design and fabrication of RFID antennas and tags exploiting paper substrates and inkjet printing technology has recently been published by G. Orcchini *et al* [13].

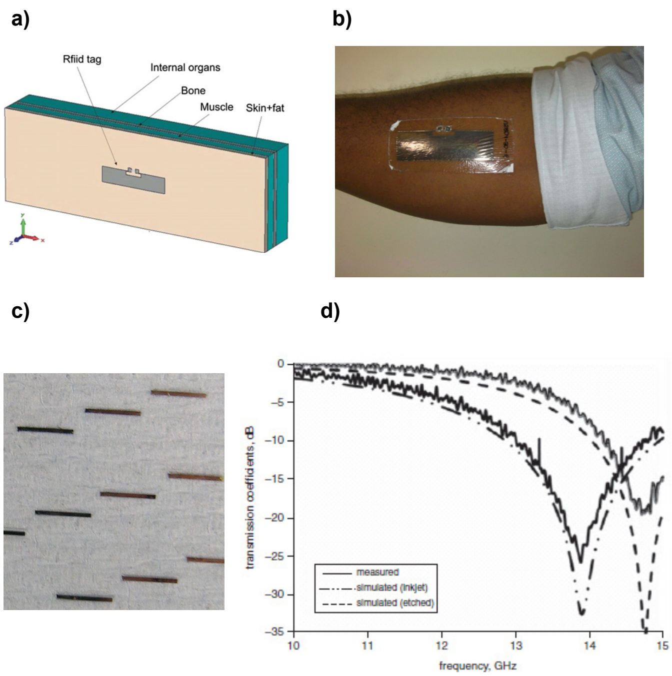

***Figure 1**. a) Model of RFID transfer tag mounted on multilayer human body, b) Inkjet printed RFID tattoo tag transferred on volunteer arm, c) Inkjet printed frequency selected surfaces using array of simple linear silver dipoles on PEN, and d) comparison of measured and simulated transmission curves for inkjet printed and etched frequency selective surfaces [10-12].*

However, although some developments in the field of on-skin electronics and inkjet printing of RFID tags on paper have recently emerged, to date no research has been reported combining both fields. The work here presented is particularly challenging since it touches on many different fields: ink formulation, inkjet printing, porous and temperature sensitive substrates, flexible/stretchable electronics [14,15], antenna technology, on-skin electronics and wireless communication. Unpublished work carried out in our group has demonstrated that it is feasible to inkjet print a silver-based ink onto commercially available tattoo paper and obtain electrically conductive RFID tags transferable onto another substrate. The question remains if upon transfer onto the surface of the skin these inkjet printed RFID tags will be have the appropriate morphological, mechanical and electrical properties to satisfy UHF RFID criteria to make this technology viable and cost-effective for non-intrusive human tagging applications. If the mass production of digitally fabricated UHF RFID transfer tattoos tags is to be realized it is essential to understand, first of all, how fluid properties, printing parameters, substrate properties and pre/post-printing processing (chemical and/or physical treatment) affect morphology, topology and electrical properties of printed features on tattoo paper and upon transfer onto the surface of the skin.

Methodology

In this paper we focus on inkjet printing conductive features to produce thin UHF RFID tags onto temporary tattoo paper, which can be transferred onto the surface of the skin by soft contact. Here we address various key points to consider for the deployment of this technology. First of all, the suitability of a range of commercial and non-commercially available silver-based inks to produce RFID tattoo paper tags of sufficient electrical and mechanical robustness to be used in real life applications (on-body RFID tattoo) has been investigated. The effect of fluid properties (formulation), printing parameters, substrate properties, substrate treatment (chemical and non-chemical) and ink pre/post-printing processing (chemical and/or physical treatment) on the morphology, electrical and mechanical properties of printed features on tattoo paper and upon transfer onto the surface of the skin have been investigated in detail. In addition to this, a tag price comparison based the ink type, volume of ink and ASIC type employed to obtain on-body RFID tattoo tags which yielded industry accepted read ranges has been established. Moreover, aspects of UHF RFID tag design and its suitability for human tagging has been address.

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