Sensor Based RFID-Identification System

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ABSTRACT

Daily, millions of goods are shipped around the globe. It appears as a logistical challenge to ensure, that all different goods reach their destination in acceptable condition. Many of them do not arrive in the same condition as they left the producer. Instead of perfect original goods, rusted vehicle parts, defective flat screens, spoiled medicine or overripe fruit arrive at their destination. Only in rare cases is it possible to determine clearly who is responsible and should bear the costs, because the goods generally go through many hands. So it is necessary, to have a reliable measurement technique, which offers transparency to all members of the supply chain. Therefore, a new, semi active, sensor based RFID-Identification system is presented. This RFID-platform offers a multi-chip solution with well-defined interfaces (I^2C-bus) to the sensory unit. For the integration on flexible RFID-Tags novel temperature, humidity and light sensors were developed and characterised. Functional RFID-labels with integrated humidity and temperature sensors were built up for demonstration and field tests.

INTRODUCTION

Nowadays there is high interest in the development of smart and low cost radio frequency identification (RFID) tags to replace bar codes. The monitoring of temperature, light and humidity during shipment of, e.g. automotive parts, chemicals, aircraft engines, medical supplies, ammunition, foodstuffs and other perishables/vulnerable-to-environmental-conditions goods is one important application that could be solved by such devices; one can imagine that the users will set acceptable temperature and humidity ranges for their products and the environmental conformity can be checked. An overview of the trends and latest achievements in this field bringing in play “smart RFID” with increased connectivity and additional facilities can be found in [1].
Nowadays one remarks an increasing interest for intelligent tags, provided with sensing capabilities and able to save and store the acquired information related to both identity and measured parameters (see for example [2,3]). Commercial RFID tags that measure temperature are available [4].
Here, we present the development of novel RFID tag compatible sensors and enabling their system integration. The main ideas behind the development approach are:

• For this type of applications it is crucial to have the possibility to measure with low power consumption and by using standard, cheap, off-shelf circuitry.

• The devices should be low cost and easy to manufacture; a limited number of simple technological steps are to be used.
• The design and realization should be compatible with the future goal of the “full plastic RFID tag” and extensible to the sensing of other gases/sensing tasks.

The integration of the developed small and flexible sensors into a RFID-data communication environment will permit the easy access to the stored data each time when the goods are changing “hands”; the concept is sketched in Figure 1. In the picture clearly appears how it will be possible to get access to the environmental data stored on the tag by using the communication capability of each individual tag that translates in getting information about each individual item. As a consequence, it will be possible to sort out the liability issues and assess the damage on a much finer scale.

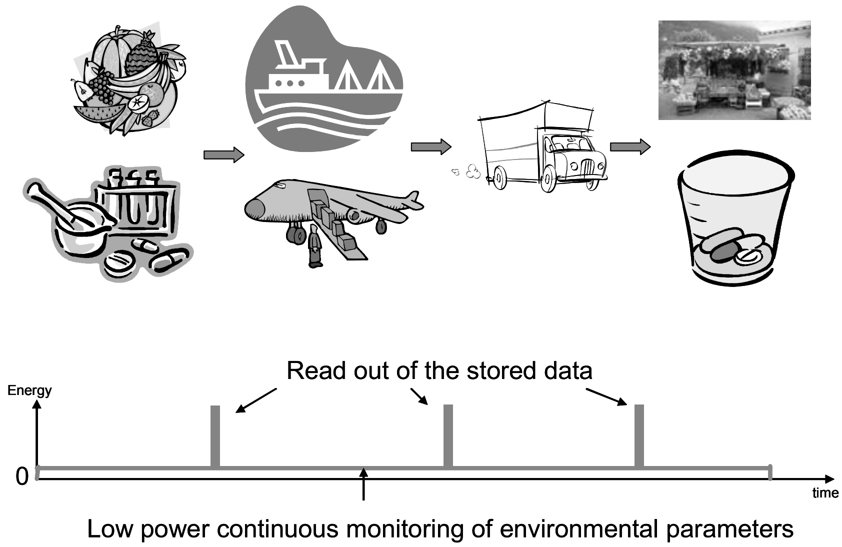

Fig. 1: Planned tracing system for perishable goods with a semi-active multi-sensor RFID tag.

EXPERIMENTAL

Temperature sensor

A micromachined temperature sensor suitable for use in RFID applications is being developed. Here, the challenge is to create a particularly small platinum sensor with extremely high resistance: the higher the resistance, the lower the current passing through the sensor. The sensor measures temperature changes by changing its resistance – a simple and energy- saving approach. A platinum resistor with a resistance of 10,000 Ohms serves as the benchmark presently in the branch. Various procedures for structuring the extremely small sensor area of 2 mm^2 have been tested, including: wet chemical etching, lift-off process as well as laser structuring. Highly promising results were obtained particularly with the lift-off method: Structure widths of 2 µm were achieved at intervals of 3 µm on a ceramic substrate. The accuracy of the structures was ± 3 µm, the resistance 10,000 Ohms.

Humidity sensor

The concept of “low power”, “self-supported”, planar, flexible and “directly integratable” sensor for “smart RFIDs” was implemented in the form of interdigitated chemo-capacitance provided with humidity sensitive polymers and shows promising results (fig 2). Details can be found in [5]. In the same time different technological alternatives such as simple polymer foil (which can be the substrate of the RFID tag itself) single or composite polymer layers deposited onto polymer foil or complicated multilayer/foil structures have been designed and produced. The devices, manufactured on 30–100µm PI and PEN substrates, with ~1 cm^2 active area, 30–40µm interdigital traces and gaps and 4–20 pF nominal capacitance, have good sensitivities, of about 100–1000 ppm/% r.h. The readout with the capacitance-to-digital converters ensures a resolution of about 100 aF at a full scale of ±4 pF. They offer a large range of response types, from linear (better than ±3%) up to strongly nonlinear (more than a factor 5 for 100% r.h.), being suitable for the wide spectrum of practical applications required by the potential users (humidity monitoring, humidity threshold alarm, dew point detection, etc.). The developed sensor is versatile, dissipate very low power (<1pW at 1 reading/min @ 1 kHz @ 50ms active period per reading), has good response time constants (1–2 min) and can be extended to other classes of applications for which sensing materials with appropriate characteristics are already or will be soon available. Through electrical, electrochemical and optical measurements, performed over wide ranges of operating conditions, the devices and their sensing materials have been extensively characterised. In this context, the equivalence of the investigation methods employed to evaluate the specific sensitivity towards humidity of the deposited layers and self-supported films has been additionally addressed.

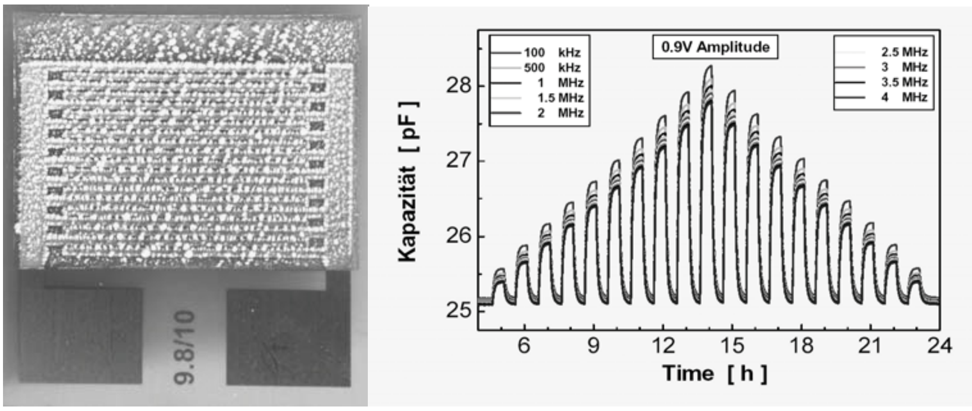

Fig. 2: (left) Humidity sensitive CA/PMMA on top of five micrometers thick copper-electrodes on polyimide foil for the capacitive readout. (left) The response of the PI sensor to humidity (from 0% to 90 % rel. hum. and back to 0% relative humidity in 10% steps). The measurement was performed at 25°C in synthetic air.

Light sensor

Dye based solar cells have been studied thoroughly in recent years. However, using this technology for dye based light sensors in polymer based systems offers several advantages compared to classical devices. A printable light sensor could be easily integrated into current smart label fabrication processes. Moreover, printable light sensors combined with novel conductive polymers could solve reliability issues resulting from bonding processes. Investigations on the fabrication of dye based light sensors using Ruthenium 535-bis-TBA as active dye and Iodide solution as charge transporting layer were carried out. A prototype has been developed and tested successfully. Technological details can be found in [6]. In order to improve the technology towards smart label integration, silica gel has been used to harden the Iodide liquid electrolyte. Depending on the silica gel concentrations, different stiffness levels can be achieved. Whereas the first light sensor prototypes have been made on glass substrates, the new ones are based on polymer substrates. The polymer foil KAPTON by Du Pont has been used as substrate. Special care has to be taken regarding the preparation of the transparent electrodes. The transparent conductive oxide (TCO) Indium Tin Oxide (ITO), which has been used as transparent electrode has to be cured at elevated temperatures.

When the sensors are exposed to light, electrons in the colour molecules are excited. This results in a voltage pulse which is stored in the RFID chip. In daylight, the voltages produced are around 600 mV, in rooms with medium illumination, 200 mV. This provides reliable proof of unauthorized opening of the containers. In conclusion we have shown that dye based light sensors can be used for the integration into smart labels. Moreover modifications in the process lead to a light sensor which is compatible to future polymer based systems

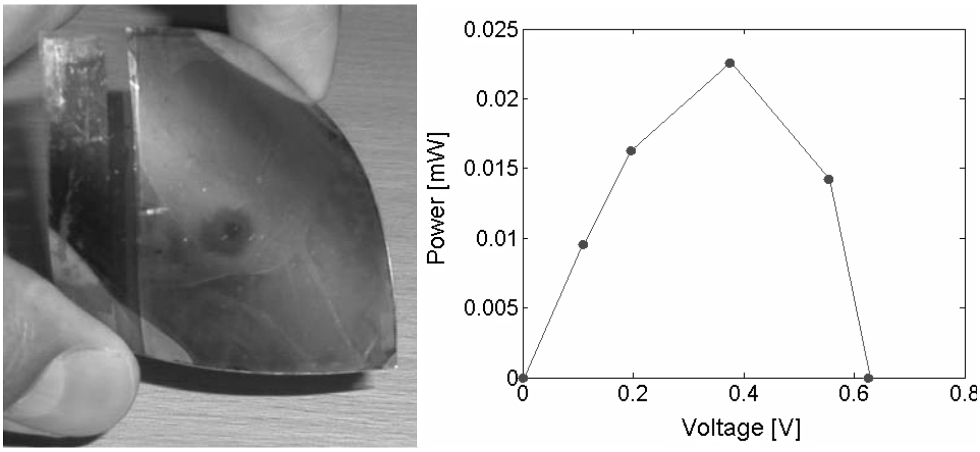

Fig. 3: (left) Prototype of a light sensor, which produces a voltage of 500mV under sunny conditions. (right) Performance of the light sensor with liquid electrolyte at different loadings. The maximum produced voltage is 612mV and the maximum generated power is 23µW at 400mV.

Fig. 4: Prototype of a RFID-tag with integrated humidity and temperature sensors.

System Integration

A semi active, sensor based RFID-Identification system was developed, where the RFID-platform offers a multi-chip solution with well-defined interfaces (I^2C-bus) to the sensory unit. A completely functional RFID demonstrational platform is shown in figure 4. The substrate carries not only the electronic parts and an antenna for 13,56 MHz but also sensors for humidity and temperature.

The labels can be read out with a radio wand, the information can then be transferred to a small packet computer using the Bluetooth RF standard and from there, via Wlan to a merchandise management system. In the opposite direction, information can be written to the tags from the merchandise management system – identification numbers as well as commands, for example, the time intervals at which the sensor label is to check its environment. There is still quite a bit to do to make this vision reality: tests of the temperatures sensing RFID labels for monitoring vaccination serum are already carried out successfully. A logistics company started to test the sensor labels in their own storage facilities on automotive parts.

The tests will show which improvements are still required for the sensors as well as for the transponder and reader technology. However, it is already clear that the combination of conventional transponder technology and sensors will be a decisive step toward a break-through in RFID technology.
Particularly for high-quality goods, the anticipated benefit will easily justify the price of a few euros per sensor tag. Today, data loggers with a value of several hundred euros are generally in use for monitoring goods, which is justifiable only for extremely high quality goods.

SUMMARY

The main objective of presented work has been the developing of innovative RFID tag compatible sensors and enabling their system integration. The target outcome of the work are semi-active multi-sensor RFID tags for monitoring the environmental conditions along the transportation chain for perishable products (e.g. agricultural and pharmaceutical goods), the use of which will ensure the reduction of transportation and storing related losses as well as an increase of the quality of the goods delivered to the consumers.

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