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Fabrication and Encapsulation Processes for Flexible Smart RFID Tags

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1. Introduction

RFID tags are often envisioned as a replacement for the current barcodes. These systems are simple wireless transponders with integrated memory chips. Nowadays the challenge in this field is the integration of sensors on board and there are some examples of tags in the market including temperature and humidity sensors (Opasjumruskit et al. 2006). However, there are no commercial labels containing chemical sensors. In this chapter book, we present an integrated process flow for the integration of gas sensors onto flexible substrates together with a RFID transponder to get a Flexible Tag Microlab (FTM) innovative system for food logistic applications (see figure 1). In the proposed scenario, the FTM is designed to be handled by a specifically designed reader with onboard sensing capabilities (Vergara et al. 2007). RFID technology in the 13.56 MHz band was chosen since it is the best compromise for integration on a flexible tag. Furthermore this band is very suitable for the food logistic application, considering possible constraints such us the surrounding environment (e.g. humidity) and range of communication. In order to be compliant with recent RFID developments the ISO 15693 standard has been selected.

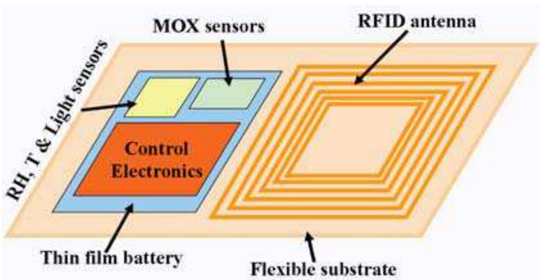

Fig. 1. Main functional blocks of the FTM inlay for food logistics.

Source: Radio Frequency Identification Fundamentals and Applications, Design Methods and Solutions, Book edited by: Cristina Turcu, ISBN 978-953-7619-72-5, pp. 324, February 2010, INTECH, Croatia, downloaded from SCIYO.COM

This visionary application involves both the fabrication of the so-called inlay, which is the flexible substrate, acting mainly as a passive interconnect structure, with all components needed for the FTM assembled on it, and the development of particular assembly and packaging issues for the new ultra-low power consumption substrates for gas sensor integration.

Flexible substrate, microcomponents assembly and encapsulation technologies have been used throughout the electronics industry and continue to play a major role in new designs and applications. Flexible substrate technologies refer to a group of processes for the construction of multi-layer flexible circuits, commonly based on the use of a polyimide as raw material. Typical fabrication of this type of circuit involves the masking and etching methods similar to those employed by printed circuit board manufacturers. The component assembly techniques have been developed to perform a hybrid integration of flexible substrates with integrated electronic circuitry on bare dice. Flip chip bond, wire bond, electrically conductive glues and tapes are some examples of connection methods. Envisioned miniaturized systems could be assembled by combining these techniques and solder steps. There is virtually no limit to the types of terminations possible for flexible circuits. Wire, cable, contacts, printed circuit boards, chips and microstructures can be connected to flex circuitry with these breakthrough technologies.

The process flow employed for the two metal levels interconnect fabrication will be described in detail. The material used is the DuPont™ Pyralux® AP 8525R double-sided copper-clad laminate, formed by a Kapton foil with a copper layer on each side. The vias and windows openings are performed by femtosecond laser ablation. The copper interconnections are realized by photolithography and wet chemical etching.

The MOX sensors hotplates specially developed to fulfil the FTM constrains in terms of low power consumption has been used to prove two integration technologies into the flexible substrates: Chip on Flex (COF) wire bonding and Anisotropic Conductive Adhesive (ACA) flip chip bonding. Both technologies will be compared and benchmarked for future product developments.

2. RFID flexible inlay fabrication

Flexible substrate and component assembly technologies (Numakura 2001) for the FTM have been developed and/or optimised. Flexible circuit technology refers to a group of additive or subtractive processes for the construction of multi-layers flexible circuits, commonly based on the use of a polyimide (PI) as substrate. Specifically, two different materials for substrates can been considered: DuPont Pyralux flexible composites and photosensitive polyimide Pyralin PI2730 products.

Flexible composites technology uses Pyralux copper-clad laminated composites[1], constituted by DuPont Kapton polyimide film and copper foil on one or both sides, as flexible substrate. The copper interconnections can be generated by standard photolithography (using either DuPont adhesive photoresist coverlay that works as a negative photoresist or a positive liquid photoresist) and wet etching. On the other hand, the vias definition in Kapton can be performed either by photolithography and dry etching, or directly by femtosecond laser ablation.

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1 http://www.dupont.com/fcm/products/pyralux.html

The main advantages of this technology are:
- Easy and quick to fabricate
- Good mechanical and electrical properties
- Low price

And the main drawbacks:
- Multilayer circuits need bonding and electrical contact trough vias.

On the other hand, there is the polymer thin film technology based on the use of photosensitive polyimide. The polymer thin film represents an extension of the conventional thin film technology. In this case, thin (< 20 μm) polymer dielectric films are deposited over a substrate such us silicon. Then, a thin (< 2 μm) conductor layer, usually copper, is deposited (PVD or CVD) and processed photolithographically. Vias can be easily achieved by using a photopatternable polymer, as for example the Pyralin PI2730 products[2]. The Pyralin PI2730 series are photosensitive negative working polyimides. Thin films of this product can be applied by spin coating.

The main advantages of the thin film polymer technologies are:
- Narrow lines and vias
- Very high conductor a package density
- Very good mechanical and electrical properties of cured polyimide films
- Multilayer construction

And the main drawbacks:
- High cost
- Immature technology

A multiple spin steps process with the polyimide Pyralin PI2730 represents a powerful solution for the fabrication of multilayer high density integrated circuits. The efficiency and performance of this approach have been tested, comparing with the results obtained by an approach based on the use of Pyralux double sided copper, in terms of feature size, time and easiness of process. The results of this comparison activity (including advantages and drawbacks of both the approaches) are briefly reported in the following:
- Pyralin PI2730, in a multilayer process configuration, allows a better integration of complex circuits in a flexible tag.
- Pyralin PI2730 can be also used for developing the passivation layer.
- The approach based on Pyralin PI2730 shows a lower reproducibility in realizing planar and homogeneous surfaces, when the flexible tag dimensions increase.

On the basis of the above mentioned results experimentally obtained, and considering the low complexity of the tag circuits to be realized together with the usual dimensions of a flexible Tag (credit card), the Pyralin based process is not necessary at this, and therefore the Pyralux double sided copper was selected for developing the flexible tag.

A straightforward process flow for the fabrication of flexible substrates has been implemented. The outline of this process is presented in the left part of Figure 2. The material employed is the DuPont™ Pyralux® AP 8525R double-sided, copper-clad laminate (Kapton), which is an adhesiveless laminate for flexible printed circuit applications. The Kapton has a thickness of 50 μm and the copper layer has a thickness of 18 μm on each side.

[2] Liquid Polyimide: Dupont Pyraline PI2730. http:://www.hdmicrosystems.com

In this procedure, the vias definition in Kapton was performed directly by femtosecond laser ablation. Then, the copper interconnections of the two metal levels necessary for the substrate were generated by standard photolithography and wet etching. Finally, contacting through the vias was also implemented. Further details of this procedure are given elsewhere (Abad et al. 2005). An example of the double sided flexible circuit (a) and antenna (b) fabricated using this process is presented in the right part of Figure 2.

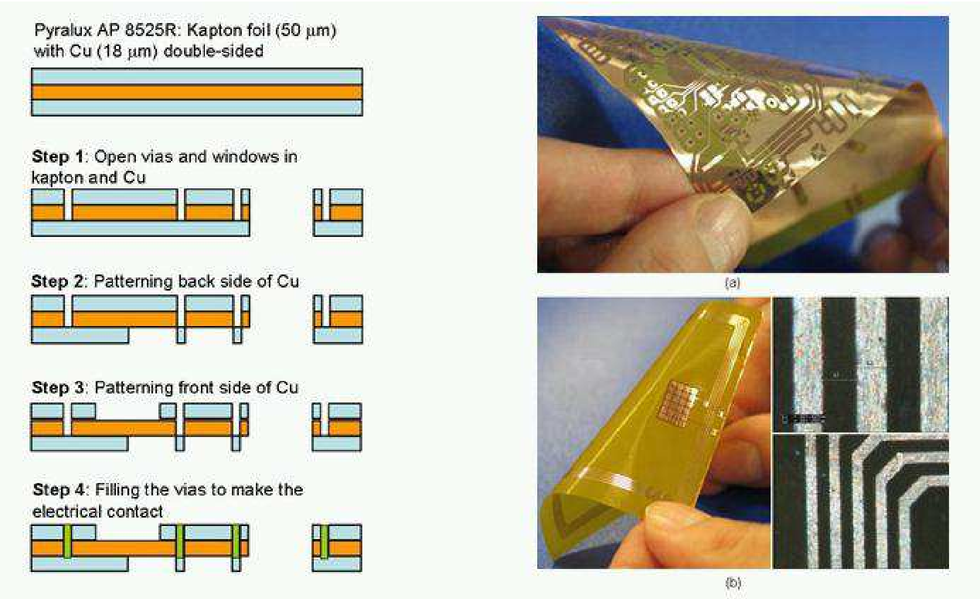


Fig. 2. Process design for flexible substrates fabrication, left image. Photographs and microscope images of the flexible circuit (a) and the flexible antenna (b). Detail of the copper tracks of the inductor.

Figure 3 shows a prototype of the developed FTM. The implemented system is a semi-active tag with a passive read-out and a battery powered sensing part, as reported in (Zampolli et al. 2007). The main functional blocks include a flexible antenna, a microcontroller for sensor control and signal acquisition, a RFID front-end and a complex programmable logic device (CPLD) for signal modulation/demodulation, commercial sensors (relative humidity, temperature and light), an EEPROM memory and a thin film flexible battery. For this prototype packaged chips were integrated on the flexible circuit using conventional assembly technologies.

3. MOX sensors integration

The integration of MOX sensors on a flexible tag has several critical aspects, mainly due to mechanical reliability and power consumption and requires specific assembling methods and protection of the chips from the environment. The power consumption issues were addressed in the design of Ultra-Low Power Hot Plates (ULPHP) but mechanical aspects

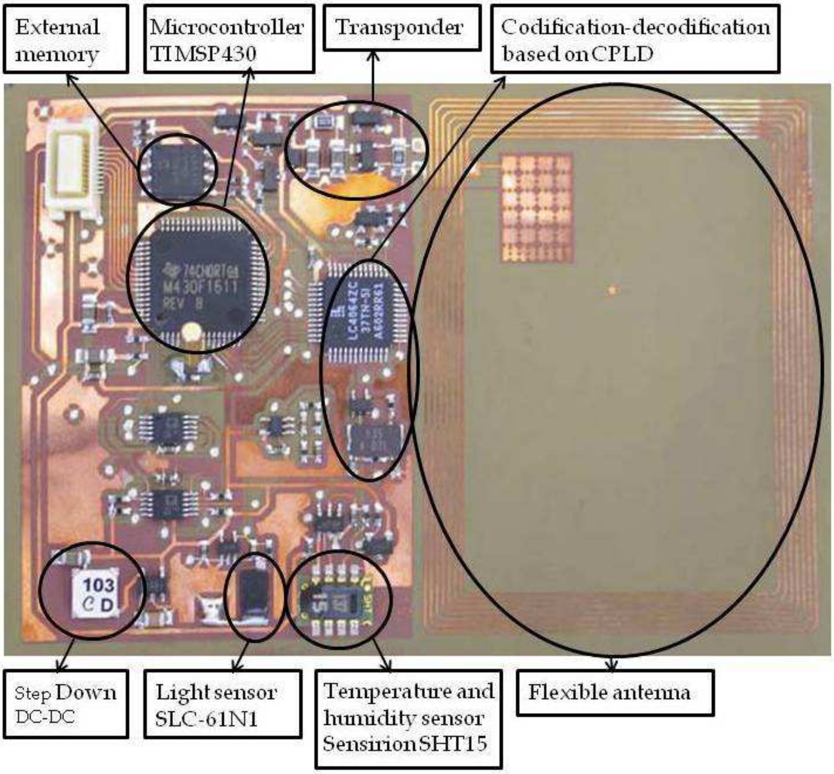


Fig. 3. FTM prototype including relative humidity, temperature and light sensors and a flexible antenna. A credit card size was chosen for the tag.

were considered as well. Details of the design and fabrication of the chips are given elsewhere (Elmi et al. 2008; Abad et al. 2007).

To reach the extremely low power consumption necessary for flexible tag operation, MOX sensors are designed to be used in discontinuous mode as reported in (Sayhan et al. 2008). The gas sensors, based on MEMS structures, need to be electrically connected to the rest of the tag electronics, and subsequently mechanically encapsulated and protected from damaging. While for the electric connections the same strategies as for other dies can be adopted, gas sensors have some mechanical peculiarities: the sensing layer must be exposed to the air sample being analysed. Therefore, assuming to have the sensing layer on the same side as the contact pads, the typical flip-chip underfilling techniques cannot be applied, since they would cover and damage the sensing layer.

The suspended membrane and the sensing layer must be protected from damaging, being generally very fragile they could brake if they get in contact with particulate or water drops. Considering the above issues, two MOX sensor encapsulation strategies were followed in parallel, aiming at an overall risk reduction of this activity.

ACA flip chip bonding

Flip chip technology utilizing ACAs has been proved to be a possible solution for MEMS packaging (Pai et al. 2005 and Johansson et al. 2006). Using this technology, a special procedure has been designed for the integration of the ULPHP, involving the following main steps illustrated in Figure 4 (a):

1. Window opening by femtosecond laser ablation.
2. Patterning of the electrical contacts.
3. ACAs flip-chip for assembly.
4. Polymer casting and curing for encapsulation.

The anisotropic conductive adhesives can provide uni-directional conductivity, which is always in the vertical, or Z axis. The directional conductivity is achieved by using a relative low volume loading of conductive filler. The low volume loading, which is insufficient for inter-particle contact, prevents conductivity in the plane of the adhesive. The Z-axis adhesive is placed between the surfaces to be connected and pressure and/or heat is applied to form the bond, as illustrated in Figure 4 (b). This type of products is now being used in flexible circuit interconnection, especially in copper/polyimide circuits. Due to their anisotropic conductivity, these adhesives can be deposited over the entire surface, thus facilitating the material application and avoiding the use of a dielectric layer and the formation of bumps onto the chip pads.

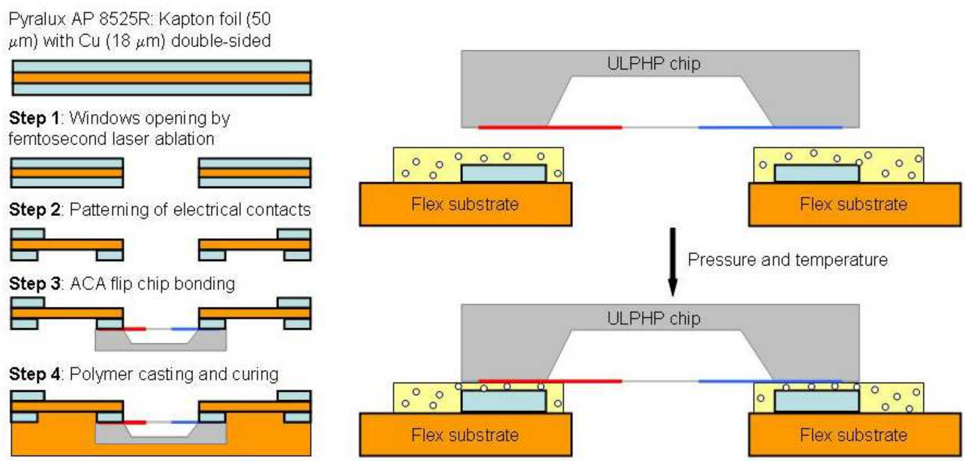


Fig. 4. (a) Process design for the MOX sensor integration. (b) Schematic view of the thermo-compression bonding using ACAs. Conductive particles are trapped between the flexible circuit and the chip pads.

A simple flexible substrate layout was designed in order to prove the viability of ACA flip chip assembly of the ULPHP. For this initial trial, the single sided flexible substrates shown in Figure 5 (a) were produced. Each test substrate includes a 1.15 mm x 0.4 mm laser ablated window and 12 copper pads (140 µm x 100 µm size and 60 µm spaced) linked to connectors. The ACA bonding can be tested by measuring the resistance at the corresponding connectors with a multimeter.

The adhesive employed to assemble the ULPHP onto the flexible substrate was the Z-axis film 5460R from 3M™. The 5460R ACA film is a 40 µm cyanate ester and epoxy/thermoplastic blend loaded with 7 µm size gold plated nickel particles. The film is attached to a liner to facilitate the handling and supports a maximum current of 100 mA / 0.1 mm^2. Using this film it should be possible to achieve an interconnect resistance of less than 0.05 Ω.

Electrical interconnections in ACA flip chip bonding are formed by a thermo-compression cycle. The procedure for the flip chip assembly includes several steps: (1) heat pre-tacking the film to the flexible circuit, (2) removal of the release liner, (3) ULPHP flipping and alignment to the substrate and (4) bonding by a thermo-compression cycle. All these operations are performed in a Dr. Treski AG 8800 flip chip station with alignment errors below 10 µm. Manufacturer's recommendations were used for the pre-tacking and thermo-compression bonding steps. The values employed for these steps are gathered in Table 1. The heating was realised by placing the test flexible substrate on the hot chuck of the flip chip system. The temperature control over the film and the applied pressure are the key parameters to achieve a good bonding. For this reason, a thermocouple was employed during the thermo-compression cycle to assure that the required film temperature was reached. The pressure was applied by pushing the ULPHP towards the substrate using the vacuum gripper of the system with a force previously calibrated.

Figures 5 (b) and (c) show the images of an ULPHP chip assembled on the flexible substrate using the Z-axis film 5460R following the procedure described previously. The mechanical reliability of the assembly was tested by bending the flexible substrate after ACA flip chip bonding of the ULPHP die chip. The assembly supports sharp bending without any damage.

Step	Temperature	Pressure	Time
Tacking	80 °C	0.1-1 MPa	5 s
Bonding	170 °C	3 MPa	20 s

Table 1. Pre-tacking and bonding parameter for the ACA 5460R from 3M™.

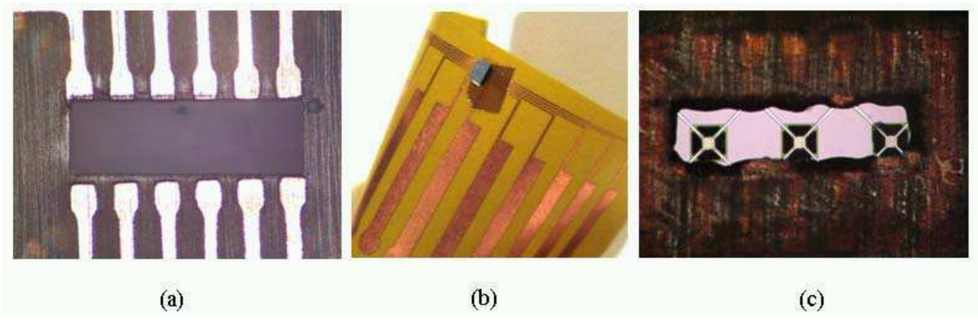


Fig. 5. (a) Flexible substrate fabricated to prove the viability of ACA flip chip assembly of ULPHP. (b)ULPHP chip assembled on the flexible substrate (c) View of the sensor membranes exposed to the air throw the ablated window.

The electrical behaviour of the bonding connections was characterized using some preliminary ULPHP test dies integrating 6 heater resistors. At first, the series resistance formed by the heaters and the ACA bonding connections was compared to the resistance of the heaters of a new, not encapsulated die. The resistance was measured with an I-V ramp in the range from -10 mA to +10 mA, which is higher than the 7 mA maximum current expected during the ULPHP sensor operation. The comparison of the average curves of 6 heaters is shown in Figure 6 (a), and no significant difference can be discerned between the resistance of the stand-alone ULPHP and the ULPHP integrated on the flexible substrate.

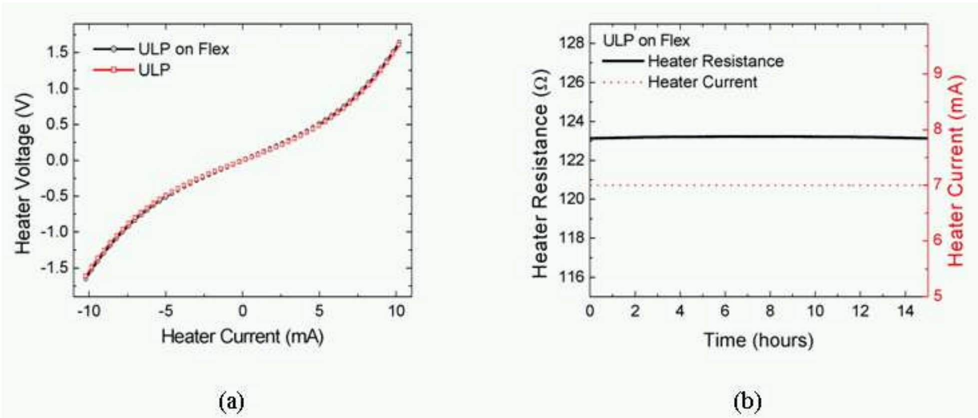


Fig. 6. (a) Comparison of resistance measurements between ULPHP (red) and encapsulated ULPHP (black). Each curve is the average of 6 different heaters within the test die. (b) Electrical short-term stability of the ACA flip chip bonding. The heater resistance does not change significantly during 15 hours of hotplate operation at 7 mA.

The characteristic non-linearity of the I-V curve is due to the temperature increase of the hotplate heater resistors while dissipating power.

To evaluate the short-term stability of the electrical connections, a 7 mA current was applied continuously for 15 hours and the heater resistance was acquired. As can be seen from Figure 6 (b), the heater resistance of 123.1 Ω does not change during the 15 hours of operation.

These measurements experimentally confirm that the 7 mA current supply necessary for powering the ULPHP and the pad dimensions of 0.012 mm^2 are compatible with the specifications of the ACA film, resulting in approximately half of the maximum specified current density of 100 mA / 0.1 mm^2.

3.1 Chip on flex wire bonding

Wire bonding is a valid and well-established method for attaching chips directly to flex circuits for both low and high volume applications. A rigid support, called stiffener, is necessary to obtain a more reliable connection between the MOX sensor and the flexible circuit. Stiffeners are very important in wire bonding to flex. The most common stiffener materials for COF are aluminium and stainless steel, but other materials like ceramic are also used.

These materials keep the bond pad area rigid, preventing ultrasonic energy from being absorbed by the flex circuit. Moreover, by cutting a hole in the flex circuit by laser ablation,

the die can be mounted directly on the metal stiffener, which can act also as very efficient heat sink. A perforated cap, put on the top, allows gas flow to the sensing layer and protects the bonding wires. The cap can be equipped with an air filter; the filter allows protecting the sensor from the atmospheric particulate and water drops.
Figure 7 shows a schematization of the COF structure.

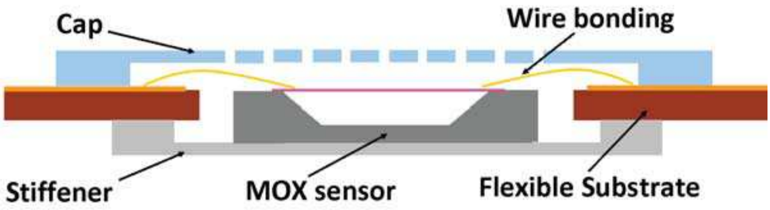


Fig. 7. Schematization of the chip-on-Flex structure.

For this work, two types of hot plates have been integrated on the flexible tag:

- a 5x5 mm^2 hotplate;
- a 1.0x1.5 mm^2 hotplate (also called Ultra-Low Power Hot Plate).

The 5x5 mm^2 hotplate has been used to test and to validate the Chip on Flex process for the integration of the MOX sensors. The successive step, the integration of the miniaturized sensor, has been a more challenging work, because of the dimension of the hotplate.
For these sensors, two kinds of stiffener have been realized:

- a stiffener of 10x10 mm^2 fabricated with a milling machine, for the first version of hotplate (the bigger one) with a central opening of 6x6 mm^2, to lodge the sensor die (Figure8(a));
- a stiffener of 2.5x2.5 mm^2 realized on aluminium cylindrical support with a Kern HSPC micro CNC, which is a 5 axes CNC micro-milling and drilling machine with a tolerance of 1 μm. All the components fabricated are cut with a Sodick AP 200L WEDM, a fine Wire high precision 6 axis Electrical Discharge Machine (Figure 8(b)).

Moreover, for the integration of the ULPHP, the cap for protecting the membrane of the sensor has been realized (Figure 8(c)), by means of the same technology used for the fabrication of the stiffener.

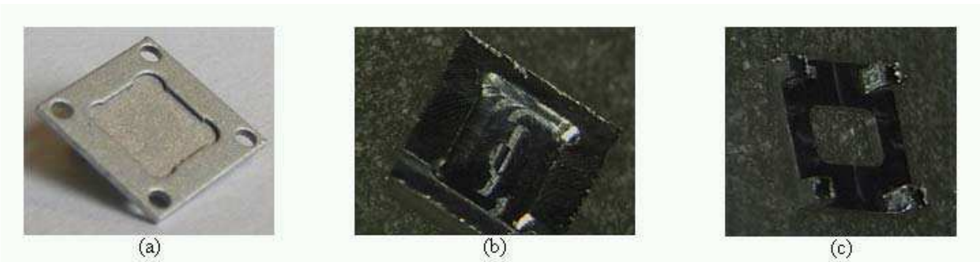


Fig. 8. (a) Stiffener 10 x 10 mm^2; (b) Stiffener 2.5 x 2.5 mm^2; (c) Cap 2.5 x 2.5 mm^2.

The wire bonding has been realized with a Kuliche&Soffa 4523 digital wire bonder with a 25 μm aluminium wire for both the hot plates versions. As previously described, an important function of the stiffener is the role of rigid support during the bonding step. In fact, the flexible circuit has been designed in order to have the copper pads along the stiffener board (Figure 9(a)). In this way the bonding is most efficient and it permits to obtain more reliable connections, which are very important during the tag manipulation. Regarding the flexible substrate, a high resolution has been necessary for the realization of the bonding pads. In particular, pads of 140 µm x 100 µm spaced by 60 µm (figure 9(b)) are required.

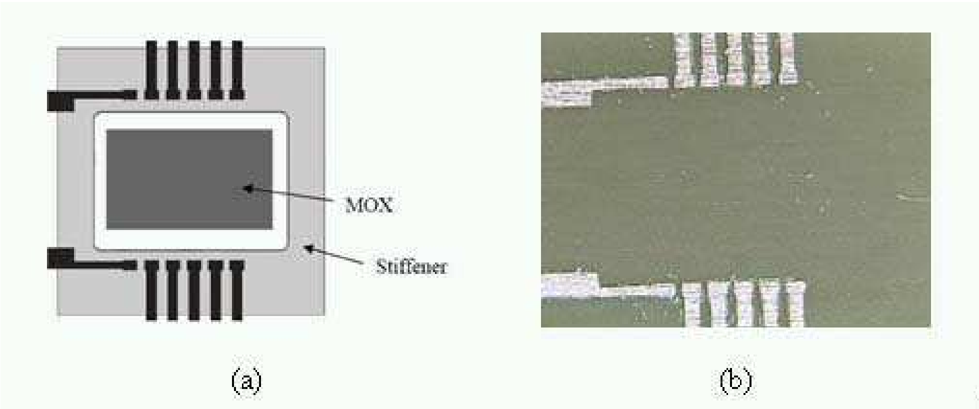


Fig. 9. (a) Assembling scheme; (b) Flexible substrate fabricated to prove the viability of COF wire bonding.

Figure 10 shows the first prototype of COF gas sensor integration, realized with the 5 x 5 mm^2 hotplates. The integration has shown good results concerning the electrical connection and the reliability of the whole structure. Regarding the mechanical property, this realisation leads to a quite large rigid portion (100 mm^2) on the flexible substrate, which affects the flexibility of the tag and makes it relatively weighty.

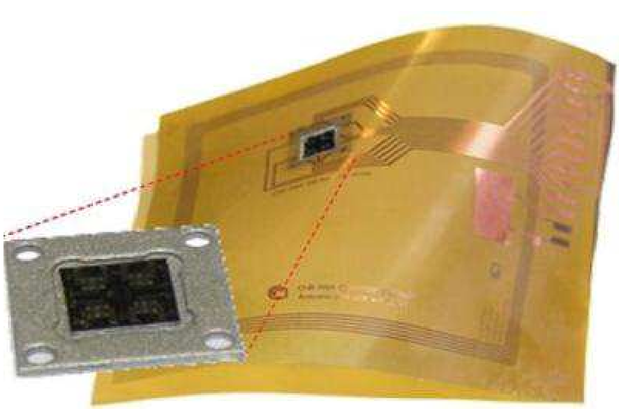


Fig. 10. First prototype of COF gas sensor integration.

The second prototype integrates the ULP array die of 1.5x1.0 mm^2 by COF wire bonding technique on a circuit realized on Kapton. Figure 11(a) shows the wire bonding between a ULP 4-sensor-array and the copper tracks on the Kapton substrate, and Figure 11(b) shows the protective cap on top of the sensor array. The mechanical bending of a prototype and the stiffener on the back-side of the sensor array can be easily disclosed. In this case the rigid surface is 6.25 mm^2, 16 times less than the first prototype, and this rigid surface does not affect the flexibility of the tag (Figure 11(c)).

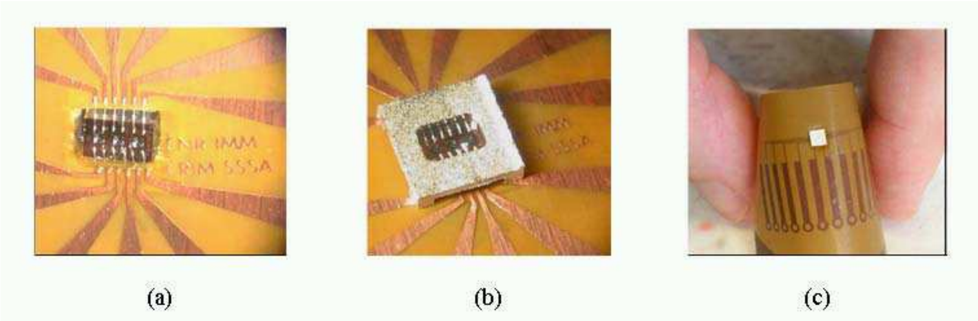


Fig. 11. Final prototype of ULP gas sensor array die integrated on flex. (a) wire-bonded array on stiffener. (b) array covered by protection cap. (c) effect of the stiffener during bending of the flex tag.

The whole height of the structure is about 0.5 mm without cap and 1 mm with the cap. The reliability of the electric connections was tested, and a 100% yield was found in the first 3 test arrays fabricated. The electric connections did not show any damages, even after a sharp bending of the substrate, with a bending radius of less than 1 cm as shown in Figure 11(c).

Test Array 1			Test Array 2			Test Array 3		
91.89	92.18	91.17	92.34	91.89	91.95	91.45	91.78	91.78

Table 2. Measured heater resistance values in Ohms (Ω).

The ULPHP used for integration with the COF technique were characterized by a heater resistance of 91.5 Ω (average value specified by the supplier). The 3 test arrays encapsulated shown the heater resistance values reported in Table 2. These measures show an average value of 91.83 Ω that confirms how the wire bonding does not introduce a significant resistance series.

3.2 Comparison of both technologies and outlook

In the previous sections, we have presented the two specific strategies developed in this work for MOX sensor assembly on flexible substrates. Using both technologies ULPHP for MOX sensors have been successfully integrated on test substrates.

In the first case, an Anisotropic Conductive Adhesive is used in a flip-chip-like technique. This approach has been proved to be very simple, low cost and mechanically and electrically very reliable. The use of ACAs present several advantages, these adhesives can be deposited over the entire surface, thus facilitating the material application and does generally not require underfilling layers and bumps formation. Furthermore in this process a small window is opened in the flexible substrate by laser ablation, exposing the sensing layer to the air on the opposite side of the tag without using any mechanical part. Being very small, the hole mechanically protects the sensing layer and the suspended membranes. If more protection of the sensing layer were needed, the window could be perforated instead completely ablated.

The second approach is based on the Chip-On-Flex wire bonding technique. In this case, a very reliable mechanical structure is used to protect the MEMS die, based on a metallic "stiffener" on the backside and on a perforated cap on the front-side of the gas sensor. The electric connections are realised by wire-bonds, which is a very mature bonding technology, and the whole gas sensor area, though being only 2 mm small, is in fact a stable zone within the flexible tag, ensuring high mechanical reliability. The COF technique is already widely used in industrial fabrication of mechanically critical flexible circuits, though it was never applied to gas sensor integration before.

Despite the higher complexity of the COF implementation with respect to the ACA flip-chip technique, which does not require caps or stiffeners, the COF technology has one main advantage over ACA: the conductivity of the bonding wires is superior in terms of low series resistance and maximum allowed current compared to the specifications of the ACA materials. Although at the present status the maximum current to be provided to the hotplates is compatible with the ACA specifications, for some applications higher currents may be necessary, and the COF technique could be exploited there.

In summary, the ACA flip chip bonding process represents a cost effective way to manufacture tags with MOX sensors using reel to reel production lines. If highly reliable tags are needed for harsh environments, the robust COF solution is advisable. However, a silicon based solution for the stiffener and the cap instead of the metallic one is envisaged in order to realise a "classical" microsystem. By doing so the integration of a micro reactor (Becker et al. 2000) could be realised as well. Figure 12 shows the cross section of a micro reactor integrated into a flexible tag.

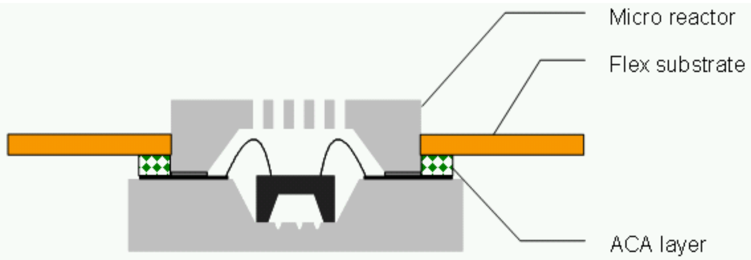


Fig. 12. Proposed all silicon MST solution using a silicon micro reactor chamber embedded into the flexible substrate. The bonding can be done by ACA flip chip bonding.

4. Conclusions

Flexible substrate technologies and assembly of components, in particular of the new ULPHP specifically developed for MOX sensor integration using special bonding technologies have been accomplished with the aim of developing a FTM inlay for food logistic control. A prototype of an ISO 15693 compliant semi-active tag, including low power control electronics, RFID antenna, commercial sensors, memory and a thin film battery, has been presented. The assembly of the ULPHP on flexible substrates using ACA flip chip technology and COF bonding has also been proved. Considering that the HP is the mechanically critical structural component of the gas sensors, these achievements will allow the integration of chemical sensors in the RFID tag that represents the major innovation of this FTM realisation.

5. Ackowledgements

This work was co-financed by the EU Frame Program VI within the IST priority, through the Integrated Project GoodFood (FP6-IST-1-508744-IP). The authors wish to thank CNR-IMM Bologna to have supplied the MOX sensor hotplates. The authors appreciate the technical support with the flip chip station by Mr. Javier Berganzo and Mr. Rafael Salido. The authors also wish to acknowledge 3M for providing ACA samples.

6. References

Abad, E.; Raffa, V.S.; Mazzolai, B.; Marco., S.; Krenkow, A. & Becker, Th. (2005). Development of a flexible tag microlab. *Proceedings of SPIE,* Vol., 5836, 599-606.

Abad, E.; Zampolli, S., Marco, S. Scorzoni, A., Mazzolai, B., Juarros, A., Gómez, D., Elmi, I., Cardinali, G. C., Gómez, J.M., Palacio, F., Cicioni, M., Mondini, A., Becker, T., Sayhan, I. (2007). Flexible tag microlab development: Gas sensors integration in RFID flexible tags for food logistic. *Sensors and Actuators B,* 127, 2–7.

Becker, Th.; Mühlberger, S.; Bosch, V.; Braunmül, C.; Müller, G. & Benecke, W. (2000) Gas mixture analysis using silicon micro-reactor systems. *J. Microelectromech. Sys.,* Vol., 9, 478-484.

Elmi, S. Zampolli, E. Cozzani, F. Mancarella, and G.C. Cardinali, (2008) Development of Ultra Low Power Consumption MOX Sensors with ppb-level VOC Detection Capabilities for Emerging Applications. *Sensors and Actuators:* B. 135 342-351.

Johansson, A.; Janting, J.; Schultz, P.; Hoppe, K.; Hansen, I.N. & Boisen A. (2006) A SU8 cantilever chip interconnection. *J. Micromech. Microeng.,* Vol., 16, 314-319.

Numakura, D. (2001) Flexible circuits. *Coombs' Printed Circuits Handbook*. 5th ed. 1205-1344, McGraw Hill, New York.

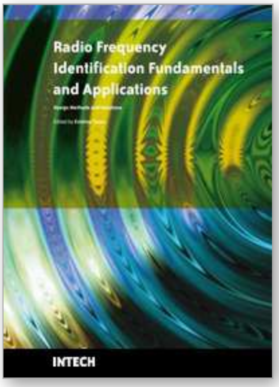
Opasjumruskit, K.; Thanthipwan, T.; Sathusen, O.; Sirinamarattana, P.; Gadmanee, P.; Pootarapan, E.; Wongkomet, N.; Thanachayanont, A. & Thamsirianunt, M. (2006) Self-Powered Wireless Temperature Sensors Exploit RFID Technology. *IEEE Pervasive computing,* Vol., 5, 1536-1268.

Pai, R.S. & Walsh, K.M. (2005) The viability of anisotropic conductive film as a flip chip interconnect technology for MEMS devices. *J. Micromech. Microeng.,* Vol., 15, 1131-1139.

Sayhan, I., Helwig, A., Becker, T., Müller, G., Elmi, I., Zampolli, S., Padilla, M., Marco, S. (2008). Discontinuously Operated Metal Oxide Gas Sensors for Flexible Tag Microlab Applications. *IEEE Sensors Journal*, 8, 176-181.

Vergara, A., Llobet, E., Ramírez, J.L., Ivanov, P., Fonseca, L., Zampolli, S., Scorzoni, A., Becker, T., Marco, S., Wöllenstein, S. (2007) An RFID reader with onboard sensing capability for monitoring fruit quality. *Sensors and Actuators: B.*, 127, 143-149.

Zampolli, S., Elmi, I., Cozzani, E., Cardinali, G.C., Scorzoni, A., Cicioni, M., Marco, S., Palacio, F., Gómez-Cama, J.M., Sahyan, I., Becker, T. (2007). Ultra-low-power components for an RFID Tag with physical and chemical sensors. *Microsystem Technologies*, 14, 581-588.



ISBN 978-953-7619-72-5
Hard cover, 324 pages
Publisher InTech
Published online 01, February, 2010
Published in print edition February, 2010