LOW-COST MULTISENSORY PAPER AND PACKAGING APPLICATIONS

To conclude his two-part series, Prof. Wim Deferme presents the remaining prototype designs delivered by the PAPERONICS research team

Last issue we introduced the recently concluded PAPERONICS project, in which 40 research centres and companies investigated the future of efficient, affordable and sustainable printing of electronic components directly in paper and plastics. Today we present the other demonstrators delivered by the research team.

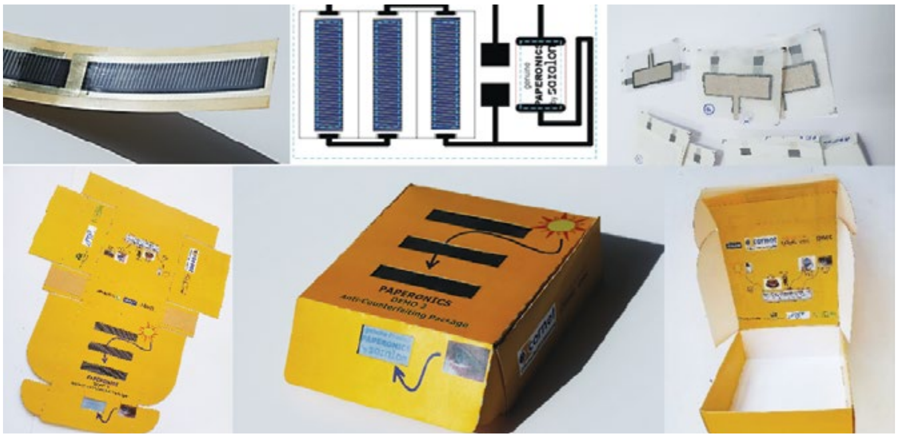


Figure 6: PAPERONICS anti-counterfeiting label in a demonstrator package with on the top left the integrated solar cells and on the top right the printed supercaps

ANTI-TAMPERING PACKAGING

The second demonstrator was anti-tampering packaging (see **Figure 6**). Here, a printed breakage sensor was combined with an organic solar cell, electrochromic display and a supercapacitator (for extra energy storage). The smart label was again integrated in a cardboard box which showed 'genuine' on the display as long as the sensor was not broken. As soon as the box opened, the current in the label was interrupted and the text disappeared from the display.

Protection against oxygen and water vapour was required for the electronic components so an encapsulation strategy was explored by coating the paper with a SiOx barrier layer and incorporating of active oxygen and water absorbers. This demo was developed by the Printing and Media Technology Group from the Chemnitz University of Technology (printed electronics and integration) and Fraunhofer-IVV (barrier coating) in collaboration with Grünperga, Agfa, Felix Schoeller Group, Saralon and Koehler Paper.

TEMPERATURE TRACKING

The third demonstrator envisaged a temperature threshold indicator with a temperature sensor and an antenna, both printed on paper and then connected to each other and to an IGZO RFID microchip (prepared by imec).

Temperature tracking is critical due to the degradation mechanism of various goods (e.g. food or medicine). The demonstrator's working principle was based on an irreversible change of electrical characteristics at a certain threshold temperature. Ideally, a material system would change its state from (semi-) conductive to insulating, or vice versa. For this specific indicator, the polymerisation pathway of polyaniline has been studied to create a temperature sensitive functional print.

The structure of the temperature threshold indicator (see **Figure 7**) consisted of three different layers: (a) silver print of interdigitated electrodes and RFID antenna, (b) non-conductive emeraldine base coating and (c) thermo-responsive layer which released an acidic solution by exceeding the threshold temperature.

The acidic solution was integrated in a thermo-responsive layer and deposited on top of the emeraldine base coating. By exceeding the threshold temperature, the acidic solution was released and shifted the indicator from insulating to (semi-)conductive. For this specific thermo-responsive layer, three material systems were investigated:

- Thermo-responsive nanocapsules
- Diffusion label based on acidic melting point
- Visco-elastic polymer

The proof-of-concept, without the thermo-responsive layer, was developed with three printing technologies, i.e. screen printing, ultrasonic spray coating (IMO-IMOMEC at UHasselt) and aerosol jet printing (AML at KU Leuven) and after connecting with the microchip (imec) validated on its functionality.

RECYCLING SMART PACKAGING

An additional aspect that was studied by another project partner, the Papiertechnische Stiftung (PTS) for all three demonstrators was recyclability. Whether smart packaging is suitable for recycling basically depends on: 1) the availability of sorting and recycling

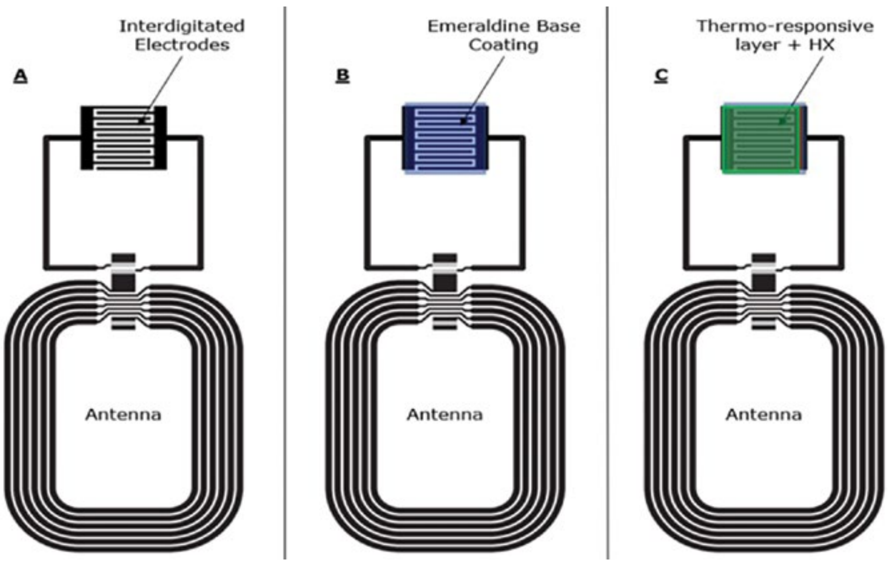
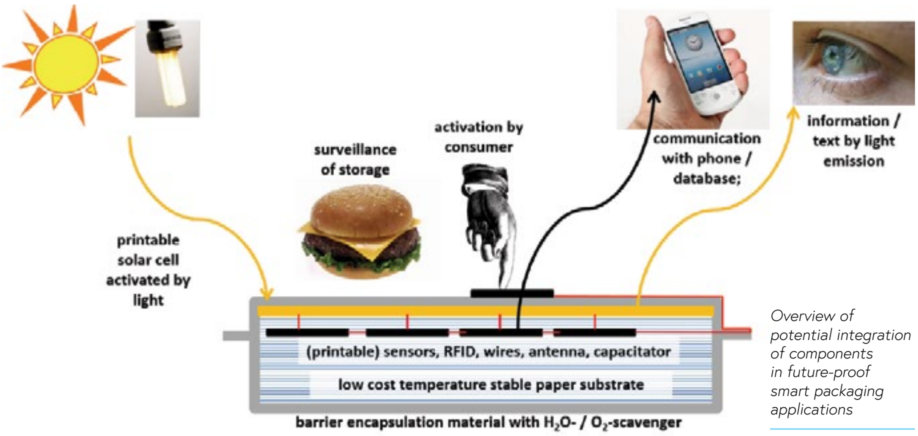


Figure 7: Layer structure of the temperature threshold indicator



Overview of potential integration of components in future-proof smart packaging applications

infrastructure; 2) the ability to sort the packaging from a certain waste stream and to separate the (electronic) components; and finally 3) whether specific components or certain chemicals may prevent use after recycling. The tests that were carried out show that recycling printed antennas produced a recyclate with visual impurities. This negative effect was even more pronounced with coated paper. If smart cardboard packaging is recycled via the general flow, this would probably have little effect due to the low ratio of electronic components (e.g. RFID tag) versus the amount of fibre-based material of the cardboard box. However, regulations regarding cardboard packaging and electronics will have to be followed closely.

"PAPERONICS can encourage companies to think about applications enabled by printed electronics"

CONCLUSION

In conclusion, the PAPERONICS project has resulted in three different smart packaging applications which can encourage companies to think about similar and other applications enabled by printed electronics. Moreover, the co-operation for developing the demonstrators encouraged all involved to set up new networks and connections in order to create new joint developments related to or sprouting from the PAPERONICS project. Our aim was to inspire companies in the paper industry that paper as a substrate can also be used in printed electronics. Hopefully, project learnings will reach companies that can offer smart solutions for this. ■

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Driving Print Excellence

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