



COST Action FP1405

Active and intelligent fibre-based packaging – innovation and market introduction

INTELLIGENT PACKAGING

DIANA GREGOR-SVETEC

UNIVERSITY OF LJUBLJANA, FACULTY OF NATURAL SCIENCES AND ENGINEERING

UNIVERSITY OF LJUBLJANA

- Established in 1919.
- Number of staff: 5,481.
- Number of students: 42,922.
- 26 Members.



Among the top 500 of the world's best universities on the Shanghai, Times and Webometrics ranking lists.

HE institution	Shanghai	QS	Webometrics	URAP
University of Ljubljana	401-500	551-600	192	284

FACULTY OF NATURAL SCIENCES AND ENGINEERING

DEPARTMENT OF TEXTILES, GRAPHIC ARTS AND DESIGN

Chair of Information and Graphic Arts Technology

4 study programmes:

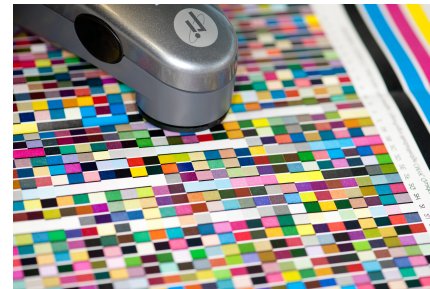
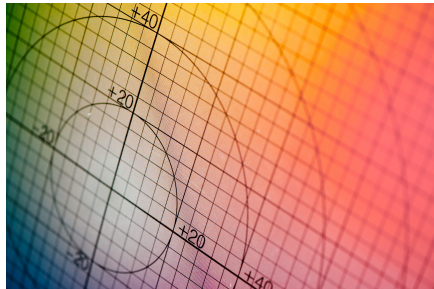
- Graphic and Interactive Communications
(undergraduate level)
- Graphic and Media Technology
(undergraduate level)
- Graphic and Interactive Communications
(postgraduate level)
- Textile Engineering, Graphic Communications and Textile Design
(doctoral study programme)



Chair of Information and Graphic Arts Technology

R&D activities are performed in a variety of fields of modern graphic and information technology:

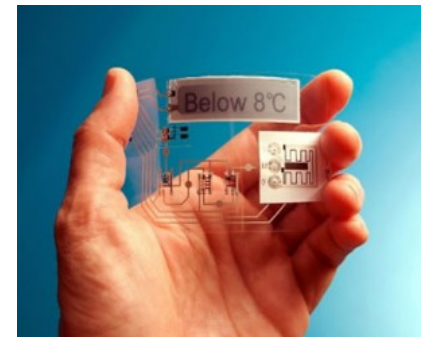
- prepress, printing, finishing,
- graphic and packaging materials, printed electronics, packaging,
- image processing, 3D modelling 3D printing,
- photography, typography, graphic design.



INTELLIGENT PACKAGING

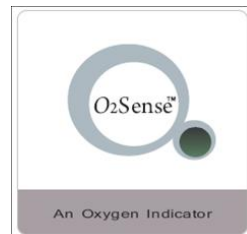
Intelligent packaging is a packaging system that is capable of carrying out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making to extend shelf life, enhance safety, improve quality, provide information, and warn about possible problems.

Intelligent packaging is an extension of the communication function of traditional packaging and communicates to the consumer based on its ability to detect, sense and record the changes in the products environment.



INTELLIGENT PACKAGING

- **data carriers** intended for storage, distribution, and traceability purposes – to make the information flow within the supply chain more efficient;
- **sensors** allow a rapid and definite quantification of the analytes in packed product;
- **indicators** provide more convenience and inform about product quality.



2D BARCODES

2D barcode is an optical, machine-readable representation of data, with information stored both horizontally and vertically.

Advantages: cheap, small physical size, scalability, big capacity of data storage and high data density, good correctness of information and high durability.

Enables use of special encryption technologies, can encode link to web pages.



Data Matrix



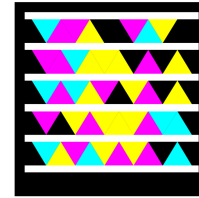
Aztec Code



QR code



Nex Code

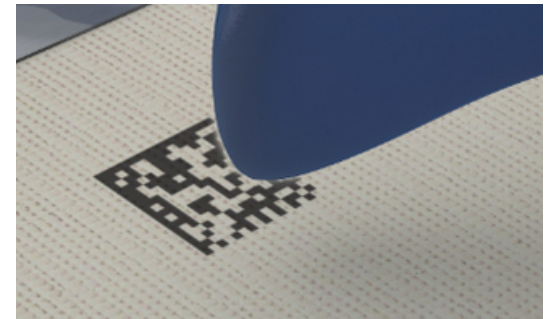


High Capacity Color Barcode



X'track™ software for product serialisation, track and trace and consumer interaction.

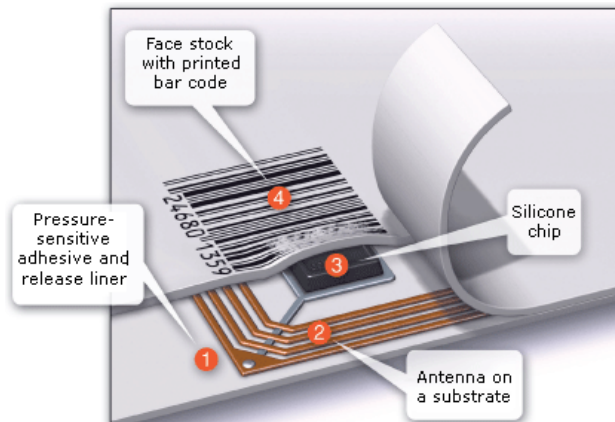
DATAG™ is a visible security ink used to authenticate and secure printed serialisation or identification codes.



RADIOFREQUENCY IDENTIFICATION DEVICES (RFID)

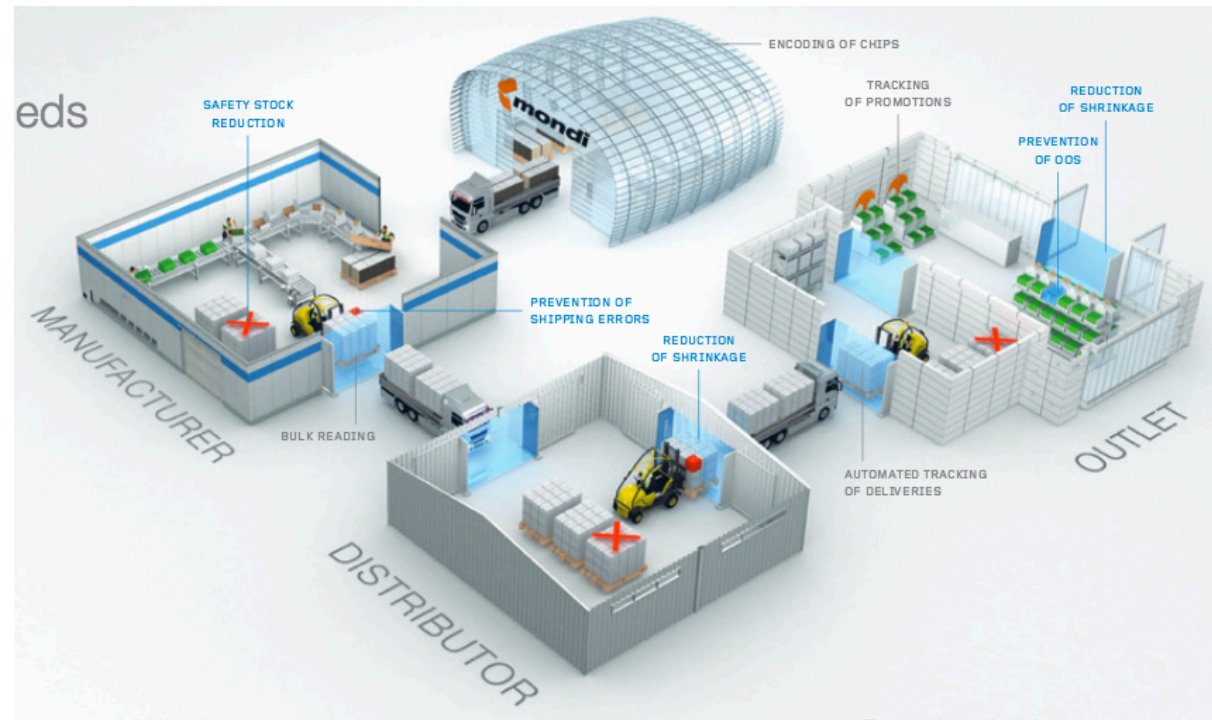
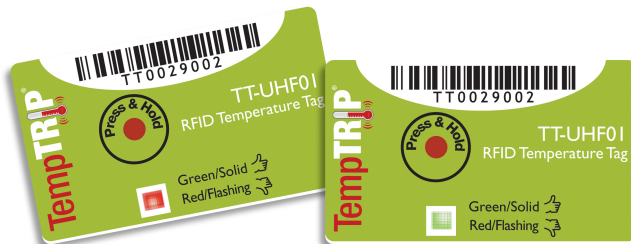
RFID tags are an advanced form of data information carrier, that use RF electromagnetic fields to store and communicate information of the product identification and traceability.

	DataMatrix	QR	RFID (passive)
Data capacity	Medium (1.5 KB)	Medium (3 KB)	High (1 MB)
Characters	up to 2,335 alphanumeric	up to 4,296 alphanumeric	100-1000
Data nature	Read only	Read only	Re-writeable
Readability	Visible	Visible	Hidden
Operating distance	Medium	Medium	High
Line of sight	Required	Required	Not required
Security	Medium (higher than QR)	Medium	High
Cost	Low	Low	High
Main advantage	<ul style="list-style-type: none">• Inexpensive• Small• Additional information• For small businesses, especially for marketing		<ul style="list-style-type: none">• Useful for tracking vast quantities of goods• Tracking of item-specific information• Additional information



RADIOFREQUENCY IDENTIFICATION DEVICES (RFID)

- Benefits:
 - improved traceability, inventory management, customer service, and safety regulations;
 - facilitating automation and antitheft prevention or counterfeit protection;
 - real-time information, additional information: temperature, relative humidity, microbiological data, instructions, information about product,.....



SENSORS

Devices used to detect, locate or quantify energy or matter; receptor transforms physical or chemical information into a form of energy, transducer converts energy into a signal.

Gas sensor: detect product deterioration or microbial contamination by sensing gas analytes (oxygen, hydrogen sulphide, carbon dioxide, amines).

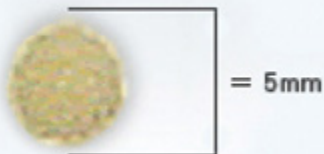
- OxySense® and O2xyDot™

Positioning of the O2xyDot® Sensors

Within a Package



THE OXYDOT SENSOR



Within A Pet Bottle



Dot in the
Headspace

Dot in Product
for DO₂

O2xyDot®



C) OxySense Portable Oxygen Analyzer



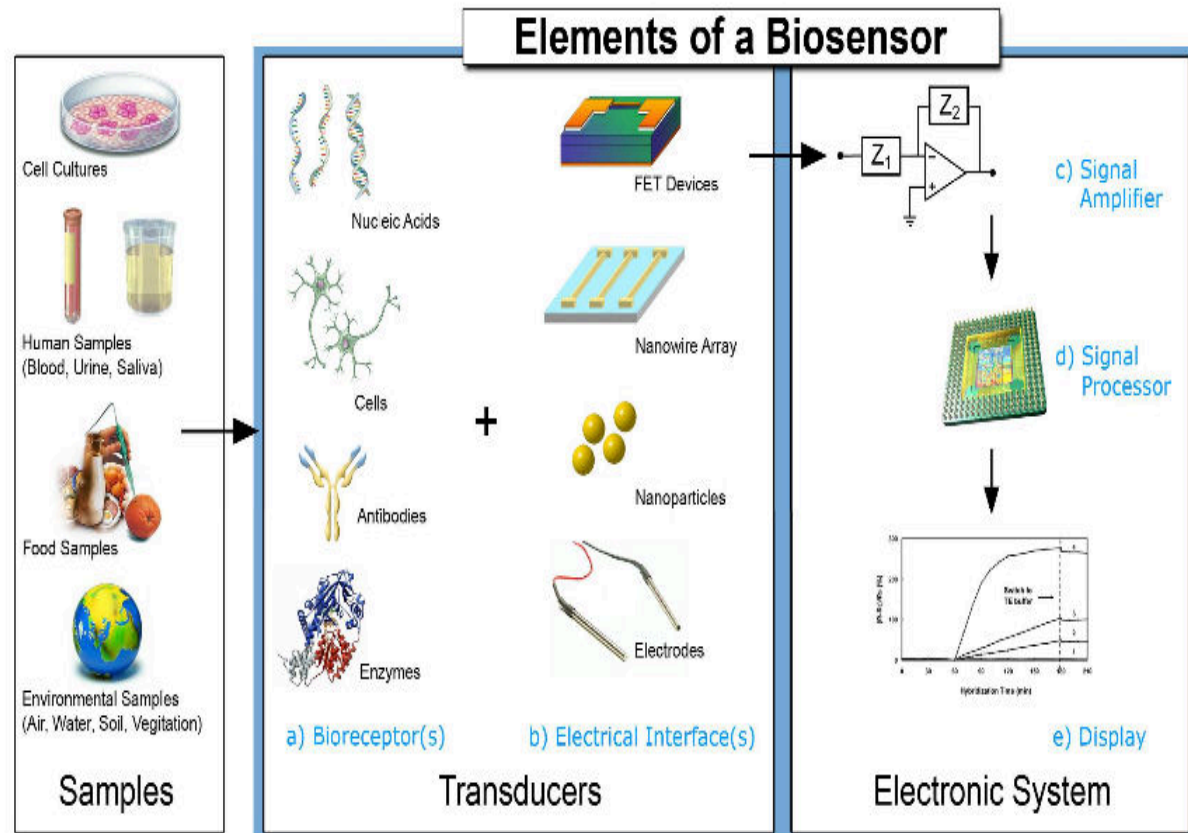
D)



SENSORS

Biosensor: detect, record and transmit information pertaining to biological reaction. They consist of a bioreceptor specific to a target analyte and a signal transducer element (optical, colorimetric, electrochemical) which is connected to the data acquisition and processing systems.

- Toxin Guard™
- Food Sentinel System®



INDICATORS

Devices that indicate the presence or absence of a target substance or degree of reaction between substances with a characteristic change, usually in colour. They can indicate elapsed time, change in temperature, humidity, concentration of defined substance, shock abuse.

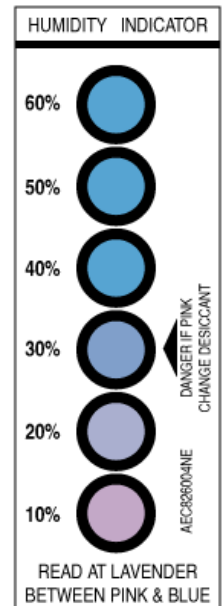
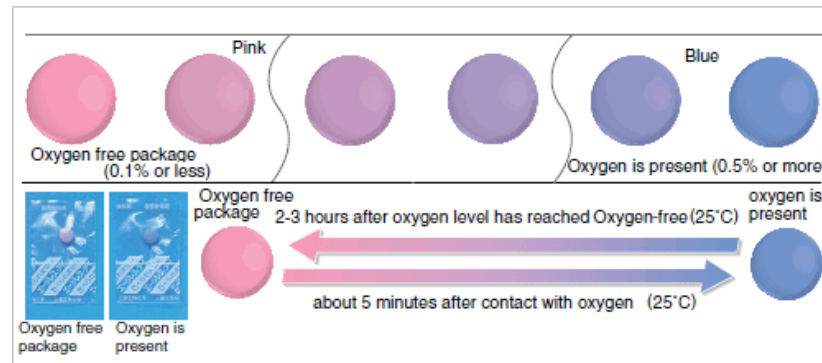
Integrity or gas indicators: colour change due to chemical or enzymatic reaction, providing information about the presence or absence of particular gas or altered gas concentration (oxygen, carbon dioxide, ethanol) in packaging .

- Ageless-eye®
- Timestrip®
- O₂Sense™



Photographs of oxygen indicator ink printed on a MAPed food package.

Left: Before UV activation. Middle: After UV activation.
Right: On opening the package.



INDICATORS

Freshness indicators: react to the changes in product as a result of chemical changes, microbial growth or metabolism due to the exposure to detrimental conditions or exceeded shelf life . They detect volatile and non-volatile compounds, changes in the concentration of metabolites:

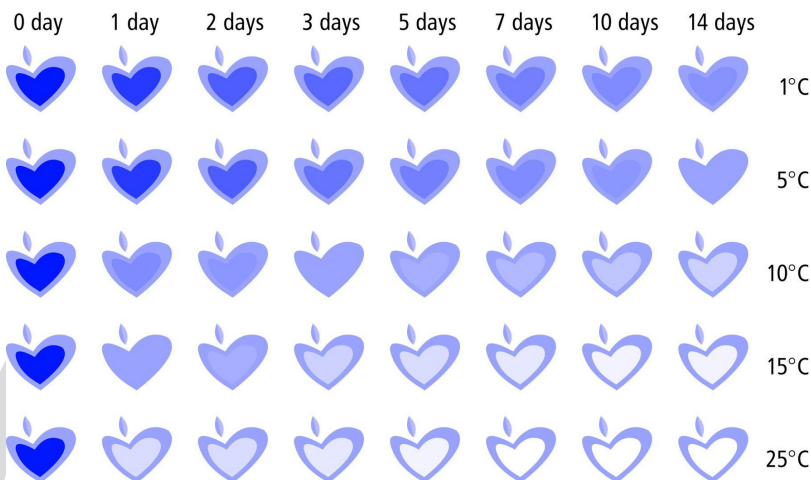
- volatile nitrogen compounds (amines) – FreshTags®
- sulfide gas – SensorQ™
- aromatic compounds – RipeSense®



INDICATORS

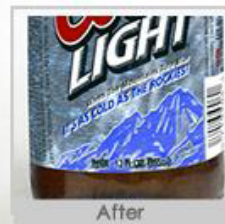
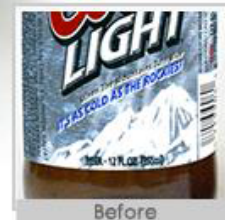
Time-temperature indicators: show the accumulated time-temperature history of a product. Mechanical, chemical, electrochemical, microbiological or enzymatic reaction, which results in an irreversible colour change at change of temperature.

- diffusion- based TTI - MonitorMark™
- microbial TTI – eO® or TopCyro®
- enzymatic TTI – CheckPoint®
- polymer-based TTI – Fresh-Check®
- photochromic TTI – OnVu™



INDICATORS

Critical time indicators: are simple thermal recorders which show whether products have been heated above or cooled below a reference (i.e. critical) temperature .

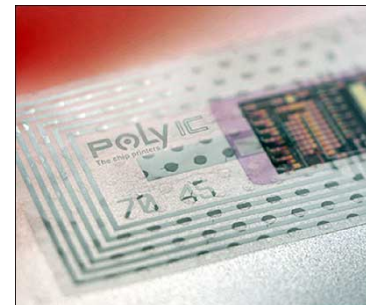
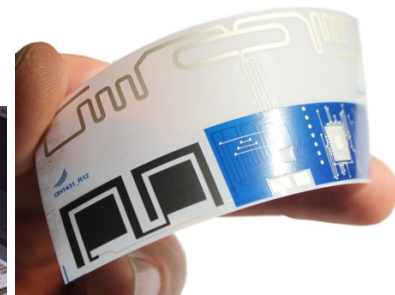


FUNCTIONAL INKS FOR INTELLIGENT PACKAGING

Diana Gregor-Svetec, Marta Klanjšek Gunde, Maristiina Nurmi, Viera Jančovičová, Miguel A. Cerqueira, Fanny Hoeng, Aurore Denneulin, Julien Bras, Wim Deferme

PRINTED ELECTRONICS

A process in which printing technology is used to produce various kinds of electronic goods, such as electronic circuits, displays, sensors, RFID,.....



PRINTED ELECTRONICS

Integrated smart systems are built from different components, such as printed batteries, printed memory, active (transistors, diodes, logic circuits, display elements) or passive (resistors, capacitors, conductors) devices integrated by one process or by a combination of separately produced components.

Ambient Intelligence



RFID System

System Integration



Smart Package

Smart System



Battery Assisted Label

System-in-Foil



RFID Label

Functional Layers



Printed Antenna

Printable Ink



Silver Ink

- Turbo Tag™ RFID Time and Temperature Monitoring System
- ThinFilm RF Temperature-Tracking Sensor System



University of Ljubljana
Faculty of *Natural Sciences and Engineering*
Department of Textiles, Graphic Arts and Design

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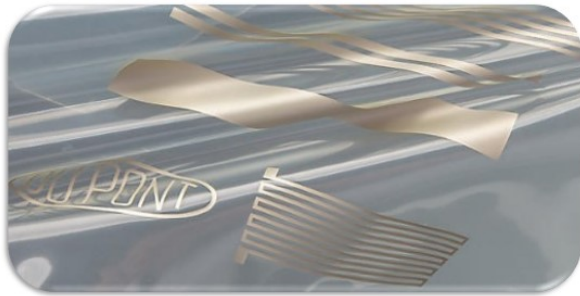
Chair of Information and
Graphic Arts Technology

FUNCTIONAL INKS

Printing inks in packaging are made to provide images and deliver certain message, they can be spot colors, formulated especially for particular product, or include some functionality, such as security features to protect from fraud, or add some intelligent features to packaging.

Functional inks need to perform certain tasks, such as conduct or block electric current, change color. They may possess electromagnetic, thermal, chemical, optical properties.

Inks may be conductive, semiconductive, dielectric, thermochromic, photochromic, magnetic or may have another targeted functionality.

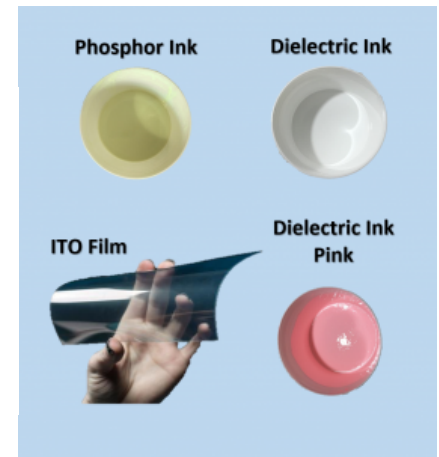


CONDUCTIVE, SEMICONDUCTIVE, DIELECTRIC INKS

Uses: RFID, optoelectronic devices, transistors, conductive electrodes, sensors, energy-storage devices.

- **semiconductive inks** composed of semiconducting organic polymers in solvents, inorganic nanoparticles suspended in carrier fluids, or organic-inorganic blends;
- **conductive inks** composed of conductive organic polymers in solvents, metallic particles suspended in binders or organic-metallic blends;
- **dielectric inks** composed of organic polymers in solvents, organic polymer thermosets or ceramic-filled organic polymers.

Organic semiconductive powder - solution



CONDUCTIVE INKS

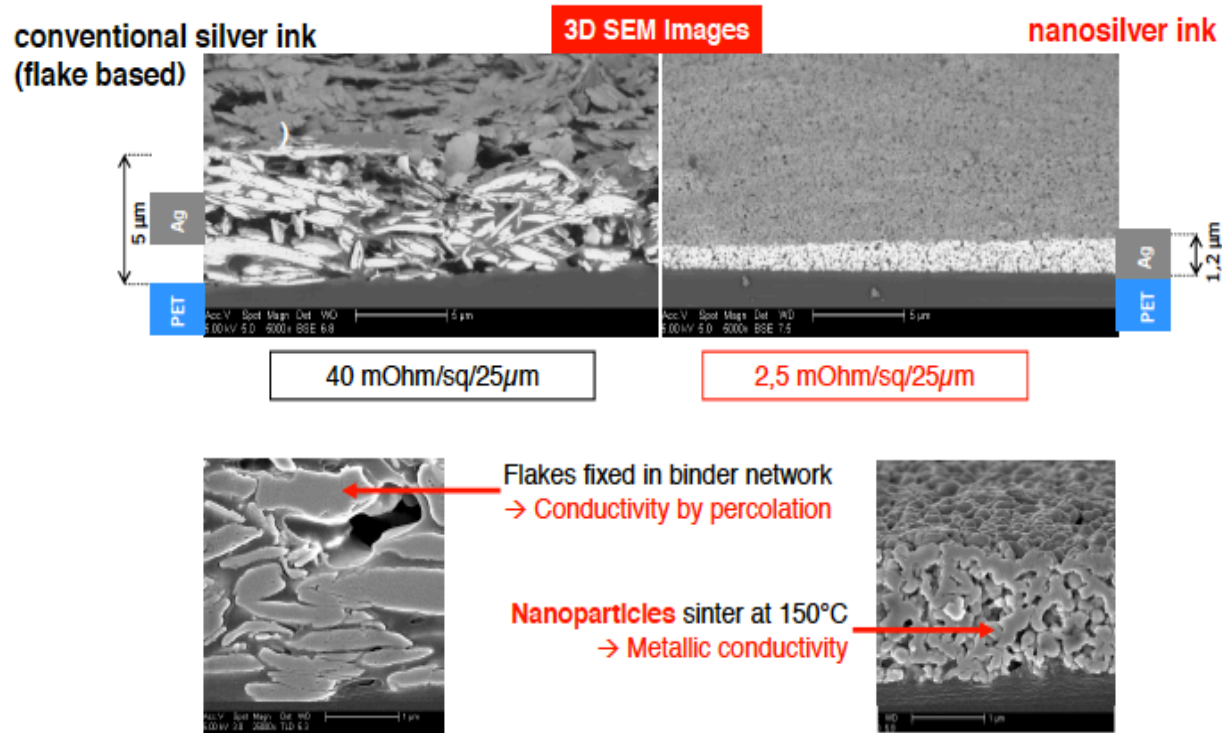
- Uses: electroluminescent displays, sensors, membrane switches, flexible circuits, resistance pads, printed heater circuits, additive circuits, etc.
- Inks conductivity:

		Metal nanoparticles based inks						
		Silver particles based inks						
	Carbon nanotubes							
Conductive polymers								
Conductivity (S/cm)	10^{-1}	1	10	10^2	10^3	10^4	10^5	10^6

- The conductivity of ink depends on the amount of metal filler in the ink, size of the particles, percentage of binder used, uniformity/continuity of the printed layer, that is determined by the printing and drying process.

CONDUCTIVE INKS

The basic constituent of a conductive inks are metallic particles, either nanoparticles or micron size particles (flakes) that are highly conductive (silver, gold, copper, nickel or platinum).



P. Willaert, Orgacon™ Conductive Inks. From our lab to your fab, Hightech printing technology, VIGC, Antwerpen, 25. 11. 2016.

CONDUCTIVE INKS

Ink	Advantage	Disadvantage
metal nanoparticle inks	highly conductive, less particles in ink, thinner printed layer	lower colloidal stability, lower printability, susceptibility to electro migration
organometallic inks	cheaper, good rheological properties, easier prepared into an ink of better stability	only low viscosity inks, poor mechanical quality
conductive polymers	dissolved in water-based dispersion for ink-jet printing	lower conductivity, limited solubility, stability and processability when included into ink
carbon nanotubes,	excellent thermal conductivity, good mechanical characteristics, advance field-emission behaviour	expensive

CHROMOGENIC INKS

Chromogenic materials are those that change their optical properties in response to an external stimulus:

- change in temperature (thermochromic),
- irradiation from light (photochromic),
- change of pH (chemochromic),
- electric potential (electrochromic).



INDOORS (WITHOUT UV/SUN)

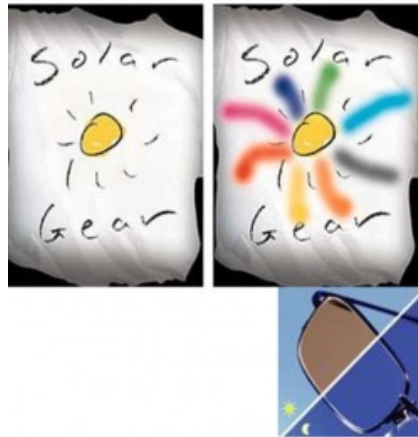


OUTDOORS (WITH UV/SUN)

PHOTOCHROMIC INKS

Use: smart labels and packaging materials, indicators and displays.

Colour change with the incoming light intensity or spectral distribution of light. They are reversible and nearly invisible when they are not exposed to UV light, exposure to UV light causes fast transition and the darkening of the ink.



THERMOCHROMIC INKS

Use: smart labels and packaging materials, indicators and displays.

Temperature-sensitive materials that change color if exposed to different temperatures, whether from colorless to colored, from colored to colorless or from one color to another color.



THERMOCROMATIC INK COLD
When the beer is perfect cold, the color ink appears, is the "sign of the gods".



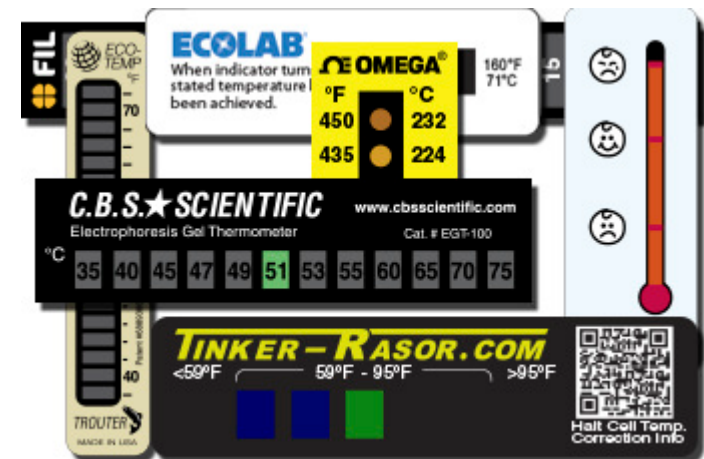
THERMOCHROMIC INKS (TI)

On the basis of their activation temperatures:

- low temperature TI: when activated, changes from clear to color, used on labels and packaging to indicate refrigeration of drinks or food products;
- high temperature TI: when activated, changes from color to clear, used to alert the customer to a safety hazard or when the food has reached appropriate temperature for consumption;
- body temperature TI: is touch activated, and is usually used for interactive graphics or packaging.



Baby's Bottle
The best partner to the new father and mother

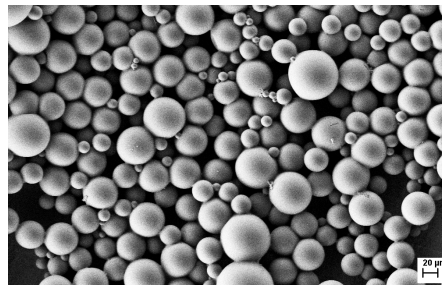
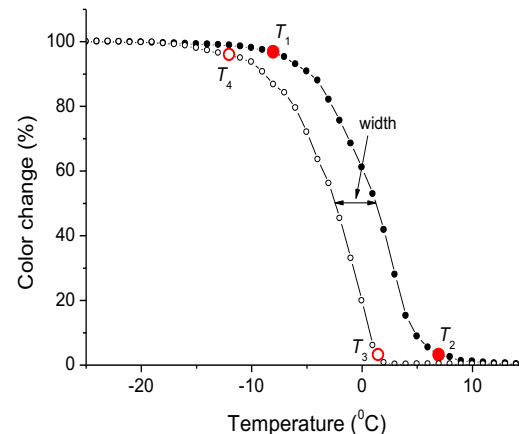
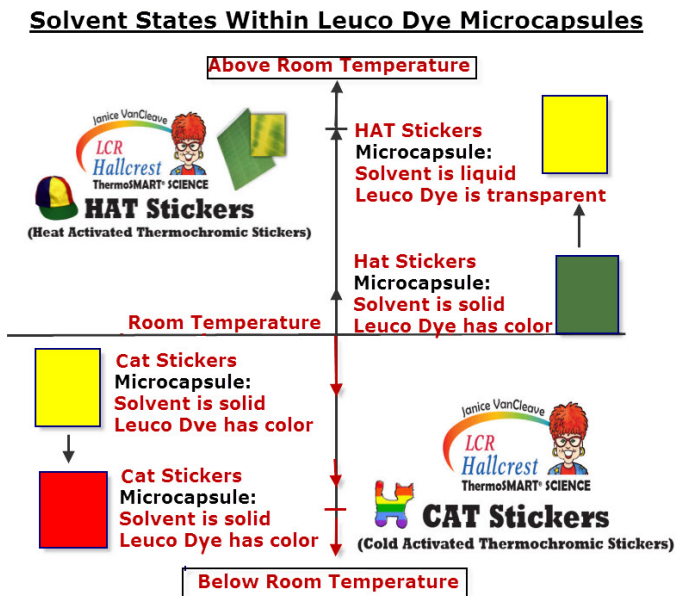


THERMOCHROMIC INKS (TI)

Thermoresponsive material in ink:

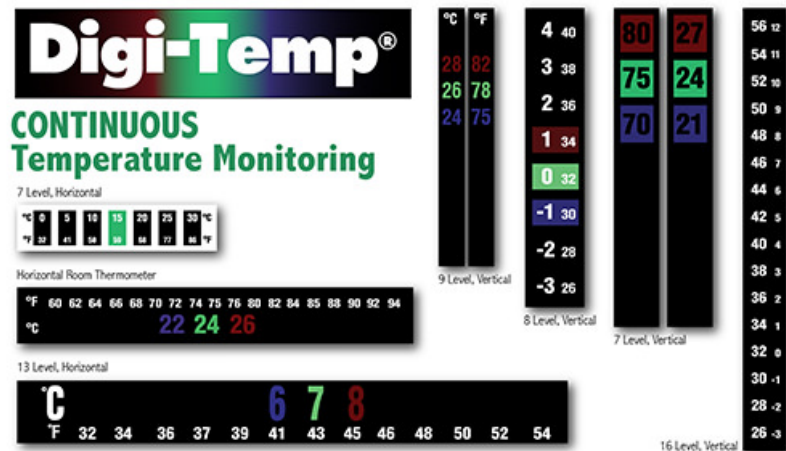
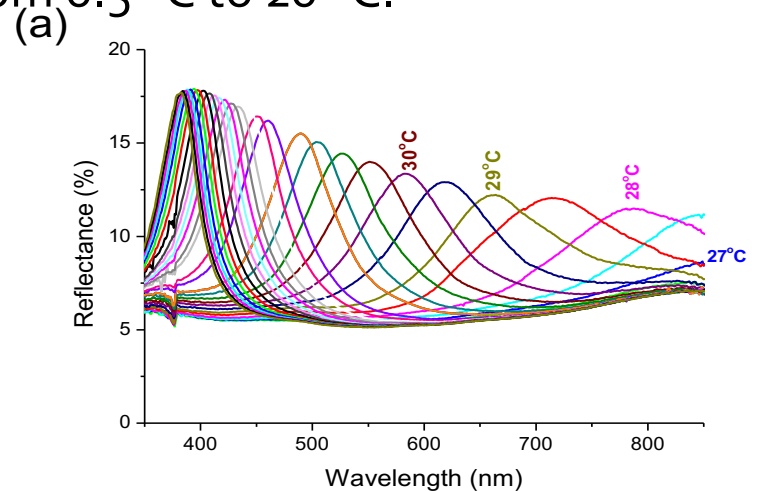
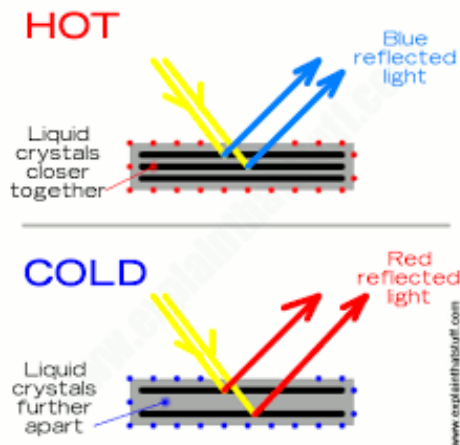
- inorganic: metal salts and metal oxides
- organic: leuco dye-based composites and liquid crystals

Leuco dyes: -25 °C up to 66 °C, with the interval of the change 3-5 °C



THERMOCHROMIC INKS (TI)

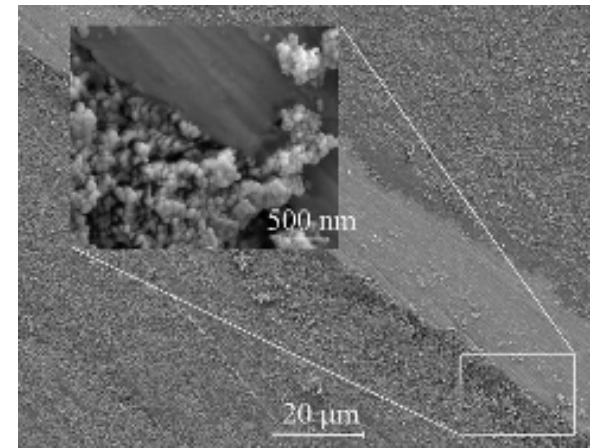
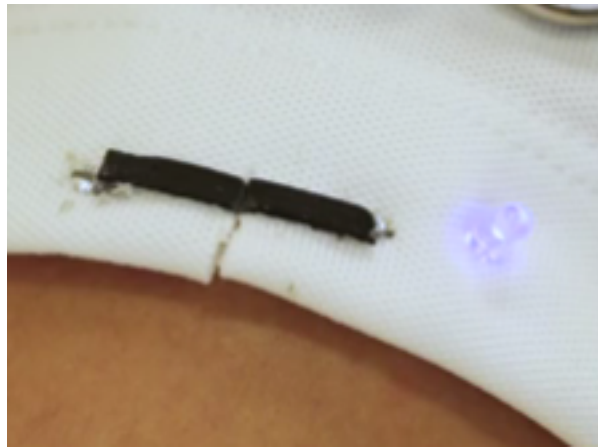
- liquid crystals: are optically active mixtures of organic chemicals that can be highly temperature sensitive and change to many colors.
- 30 °C to 120 °C, the size of intervals is from 0.5 °C to 20 °C.



MAGNETIC INKS

Used: magnetic ink character recognition for security documents;

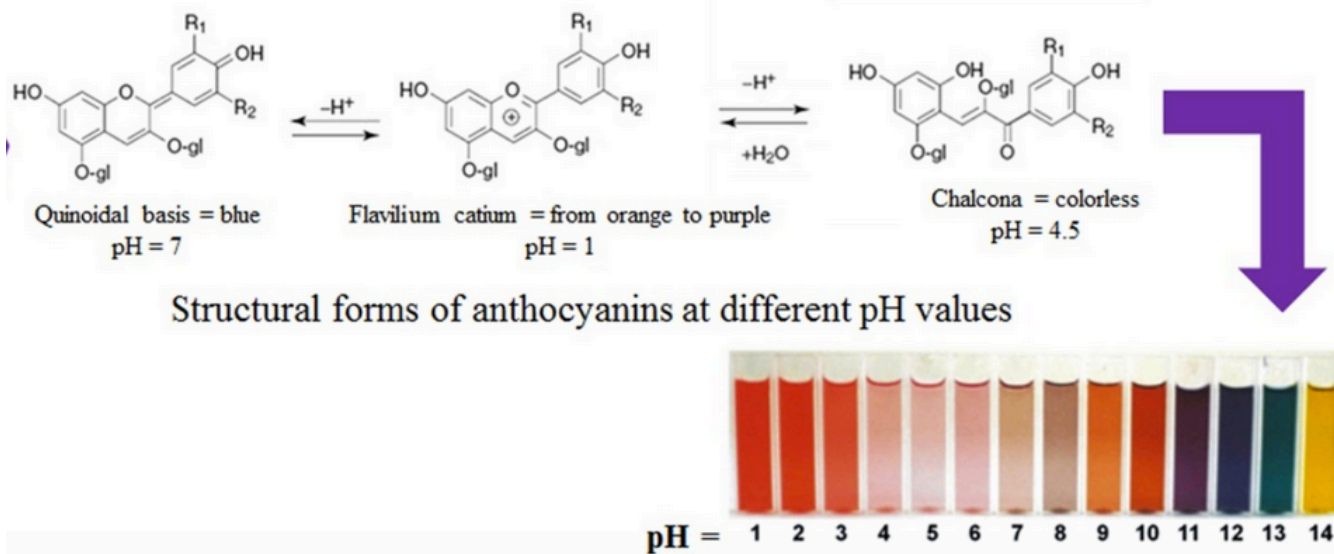
- to print self-healing batteries, electrochemical sensors and wearable, textile-based electrical circuits;
- antenna miniaturization (Co nanoparticles for patch antennas).



NATURAL INKS

Inks based on non-toxic, biodegradable, natural materials

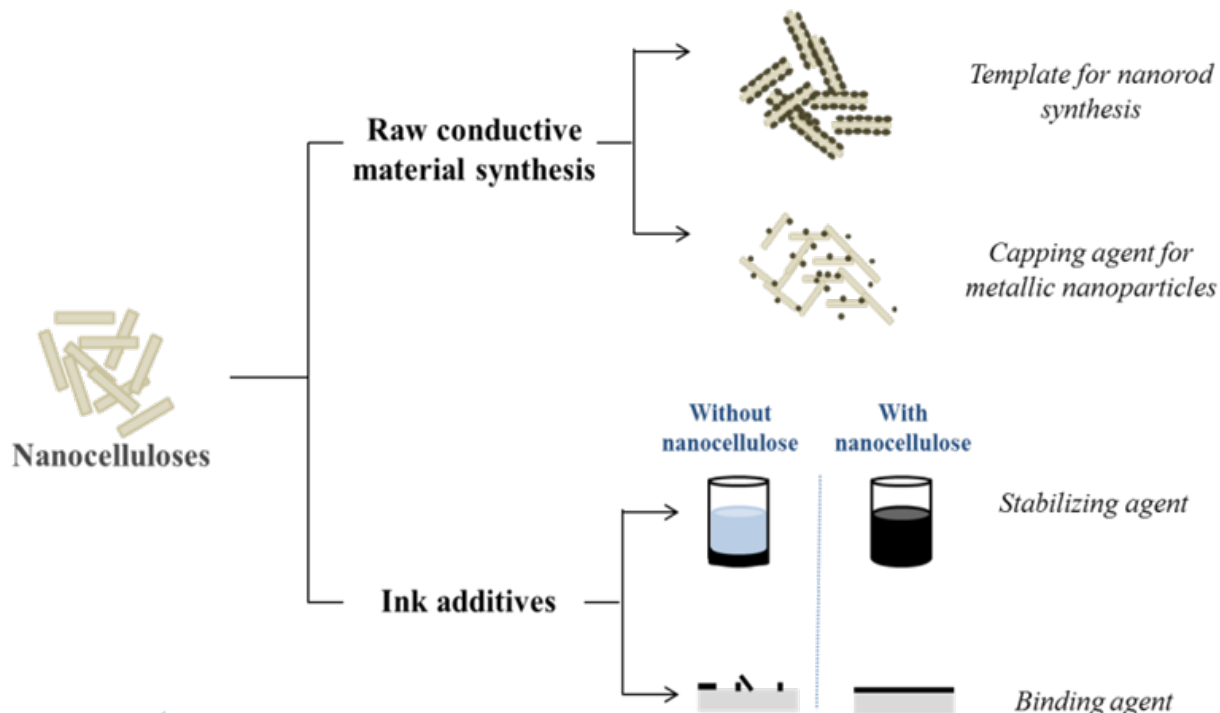
- anthocyanins from grape skins, cabbage or lichen - pH indicators
- myoglobin in agarose gel for hydrogen sulfide detection - freshness indicators
- curcumin, amaranth, anthocyanin extracts from plants and fruits for carbon dioxide detection - freshness indicators
- leuco-riboflavin for oxygen detection - integrity indicator



NANOCELLULOSE IN INKS

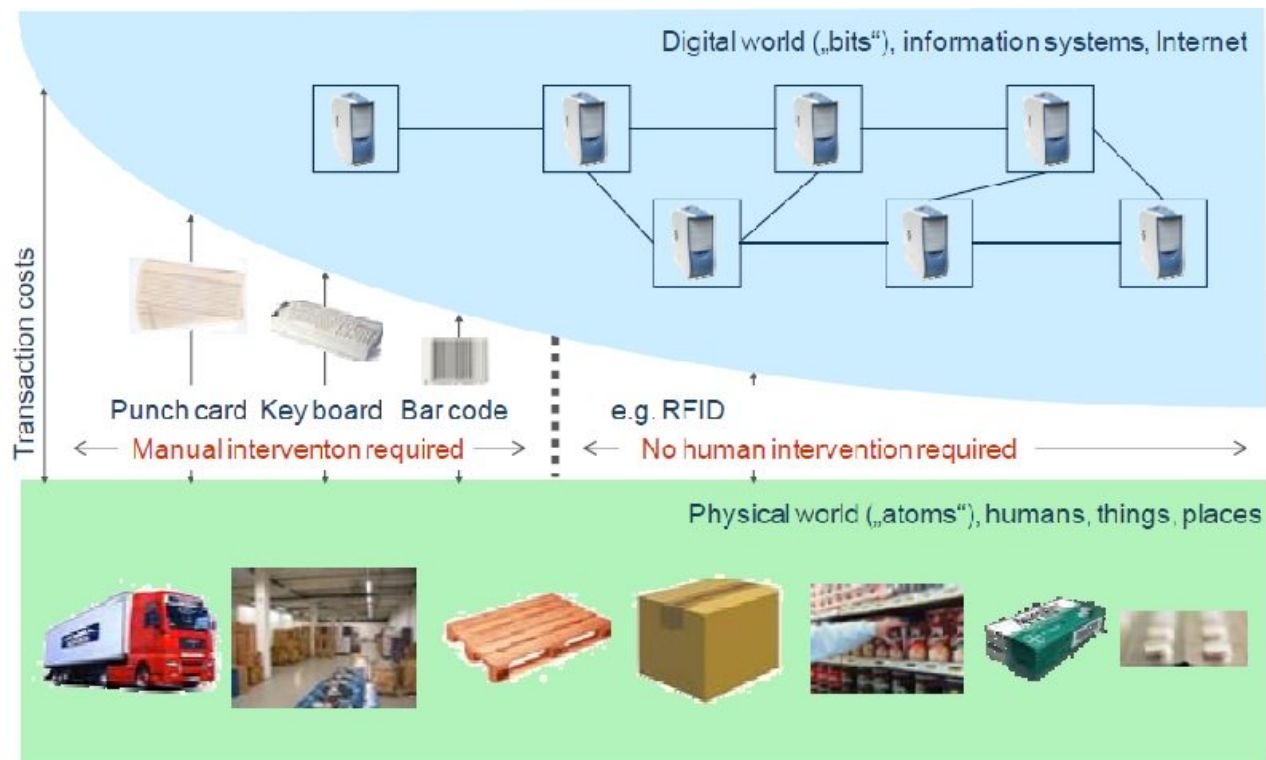
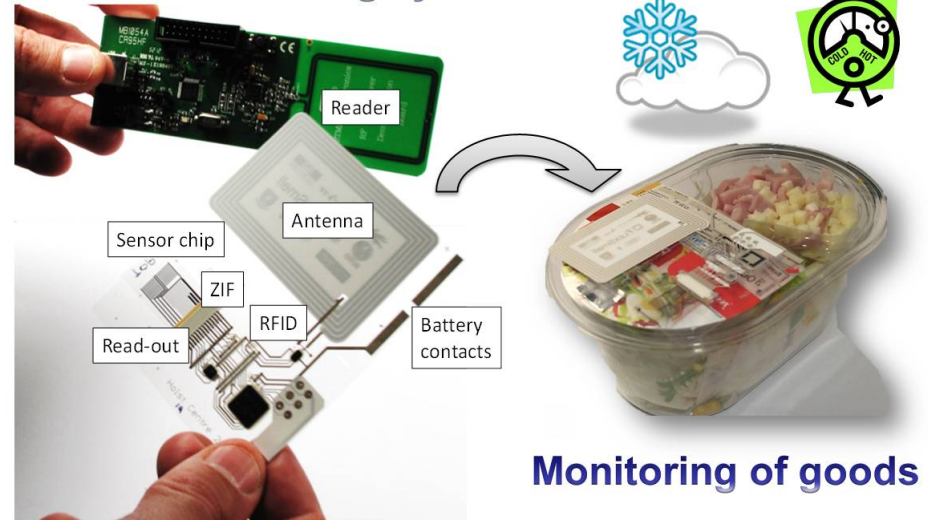
Use:

1. in functional conductive inks:
 - capping agent in the synthesis of metallic particles
 - in ink formulation as dispersing and stabilizing agent or binding agent
2. as a substrate in printed electronics.



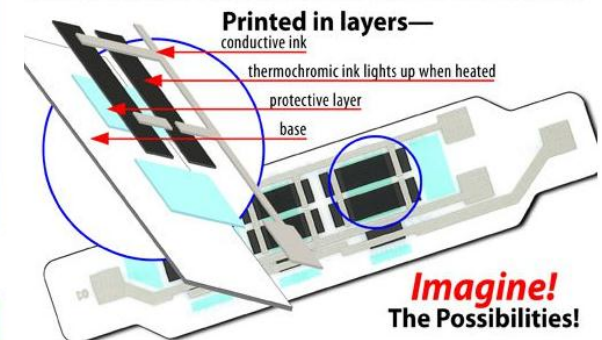


RFID FlexSmell tag system



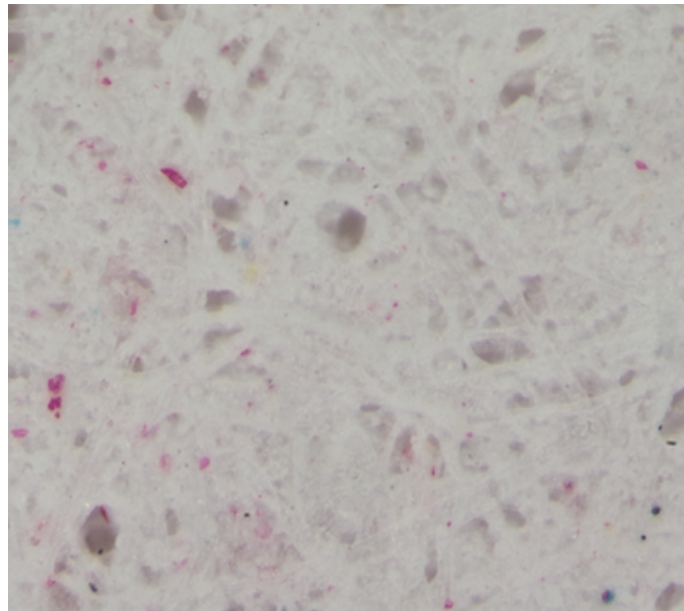
CONDUCTIVE CIRCUITS WITH THERMOGRAPHIC DISPLAY

Conductive and Thermo-chromic Ink



INTELLIGENT PACKAGING

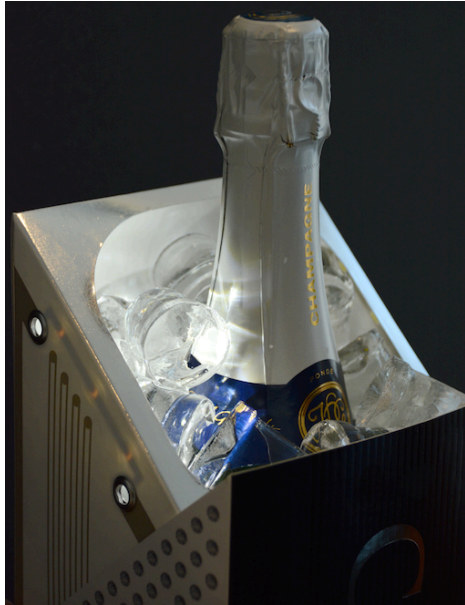
Benefits	Considerations
higher quality, safety of products, anti-counterfeit	price
better management, distribution, traceability	consumers perception and legislative aspects
consumer convenience	technical limitations
reducing the food waste	more unsold products (food)
excellent marketing tool and brand differentiation	recyclability and environmental impact



INTELLIGENT PACKAGING IN ACTINPAK SHOWROOM



INTELLIGENT PACKAGING IN ACTINPAK SHOWROOM



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- <http://pakbec.blogspot.si/2008/08/crise-de-la-listeria-lemballage.html>
- <http://www.telatemp.com/p/470/reversible-humidity-indicator-card-AEC826004NE>
- <http://www.mgc.co.jp/eng/products/abc/ageless/eye.html>
- <http://www.ripesense.co.nz/>
- <https://www.packworld.com/article/food/proteins/smart-label-sensor-gives-superior-results>
- <http://slideplayer.com/slide/4685866/>
- <http://www.tiptemp.com/Products/Time-Temperature-Labels/THGSENo06-Temperature-Label-Monitor-Mark-Model-g860C-50F-10C-48Hrs.html>
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<http://www.idtechex.com/printed-electronics-europe-15/photos.asp>
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<http://www.print-electronic.com/news-media-gallery.html>
<http://www.prelonic.com/technology/printed.html>
<http://blog.drupa.com/de/printed-electronics-for-interactive-packaging/>
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THANK YOU FOR YOUR ATTENTION!



COST Action FP1405

*Active and intelligent fibre-based packaging –
innovation and market introduction
(ActInPak)*

ActInPak is a pan European (COST) network of the leading experts in active and Intelligent packaging of over 50 institutes and universities of 28 different countries. Main goal is to develop a knowledge-based network on sustainable, active and intelligent fibre-based packaging in order to facilitate its introduction on the market.

http://www.cost.eu/COST_Actions/fps/Actions/FP1405

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