



Invest in Sweden

Intelligent Packaging

Roadmap 2005-2010

Contents

- 1 Executive summary 2
- 2 Background and Methodology 4
 - 2.1 The assignment..... 4
 - 2.2 The intelligent packaging area 4
- 3 Line of development..... 7
 - 3.1 Progress of society..... 7
 - 3.2 Technology platform..... 9
 - 3.3 Applications..... 12
 - 3.4 Swedish players on the world map 14
 - 3.5 Regulative trends 16
 - 3.6 The packaging area in relation to electronics industry and environment 17
- 4 Technology and Industry Trends in a 3-5 year Perspective..... 19
 - 4.1 Technology trends..... 19
 - 4.2 Industry trends 25
- 5 Competitive advantages/disadvantages of the Swedish industry regarding intelligent packaging 29
 - 5.1 SWOT analysis 29
 - 5.2 Strengths..... 29
 - 5.3 Weaknesses..... 29
 - 5.4 Opportunities..... 29
 - 5.5 Threats 29
- 6 Conclusions..... 31

1 Executive summary

This roadmap within the intelligent packaging area was developed during November 2005 by the Swedish research institute Acreo AB¹ under commission from Invest in Sweden Agency (ISA). The roadmap describes the development within the area. Particularly focus is on paper electronics, packaging applications, RFID and the Swedish operators positioning on the market. It is written with a time horizon from today and through year 2010.

The changing population demography requires rationalized health care. Seeking compliance through packaging can achieve a number of aims, including assisting medical providers in explaining the optimal prescribed regimen; make the patient feels like a true participant in their own therapy, simplifying administration of medication, providing the means by which patient and medication interact, creating a permanent, continuous intervention that demands little involvement by the doctor or pharmacist.

In a world with continuously increasing population and ending resources environmental and recycling issues are believed to meet increased interest from legislation and intelligent packages is expected to play an important role in order to conform to regulations.

The ability to convince a potential buyer to use a given product has always been heavily influenced by product packaging and its message. The challenge continues to be, finding new and innovative ways to get its message across to buyers, in a world where product price reduction and pressures to lower packaging manufacturing costs are a brutal reality due to the globalization. As a result, the packaging market continues to race toward finding more new and innovative ways to get its message across. Although still in the conceptual phase, intelligent packaging is believed to be the new generation in product packaging.

Another aspect of globalization is the increasing problem with counterfeited products including drugs as well as high value brand products. RFID technique has been identified as a reliable and available solution to grant authentication.

Implementation of intelligent packages has already begun in terms of demands for RFID tags on pallets and cases by some international US based merchants but in order to reach item level tagging, RFID tag cost need to be reduced.

Existing technology for RFID is based on Si chip. Despite continuously decreasing chip costs and increased performance, new low cost alternatives will be needed to target item level RFID tagging. Low cost electronics for item level applications do not only include RFID tags. Organic electronics can also add value in terms of completely new functionality that can not be realized in silicon, e.g. sensors, actuators and biofunctions. Displays based on non silicon technology even shows better performance in contrast and color.

¹ Main contributors to this report are Professor Mats Robertsson, PhD Petronella Norberg, PhD Tommi Remonen, PhD Göran Gustafsson and MSc Magnus Svensson

For the time horizon of this report Si chip based RFID will be the dominating technology in the logistic part of the supply chain but in long run organic chip will be developed and be competitive to Si chip performance for niche applications and Si chip based will be for advanced applications in a transition phase before organic electronics matures.

Sweden has large packaging companies and world-beating communication (especially wireless communication) and IT industry and research. Organic electronics was established as research area in the mid eighties and continue to hold a strong position. Swedish paper and pulp companies supported the worlds first presented paper electronic project that early established printed electronics functions for packaging applications

2 Background and Methodology

2.1 The assignment

The content in this report is compiled by the total expertise within Acreo² and their personal contacts to external colleagues.

Intelligent packaging in this report refers to packaging with added electronic functions. I.e. functions that can sense, monitor and activate changes in a package's contents, locate the package in real time anywhere in the supply chain or interact with an observer and provide information on any changes visually there and then on the packaging, or via special readers and software.

Paper electronics is defined as cellulose fiber based carriers for electronic components.

Please note that "electronics packaging" is the term for packaging and interconnection of electronic circuits, chips, components, often including e.g. printed circuit boards, connectors etc whereas "packaging" of e.g. electronics correspond to the traditional view of packaging, including physical protection, marketing, information about the content/product inside the package etc.

RFID – Radio Frequency Identification, The term covers technologies in which small data-carrying devices are interrogated with readers at 100 Hz-10 GHz. Both chip and chipless technologies are available today.

The purpose of this road map is to support a dialogue with potential investors in Sweden and others to whom the estimated development of the intelligent packaging is described and related to Swedish actors and the nation's competitive advantage. It also shows in what way Swedish technology and Swedish actors may be of importance.

2.2 The intelligent packaging area

A recent report on the packaging industry based on facts by end of year 2004, World Packaging Companies 2005/6³ estimates the total packaging market to US\$ 400 billion. Europe represents 32% of the total market.

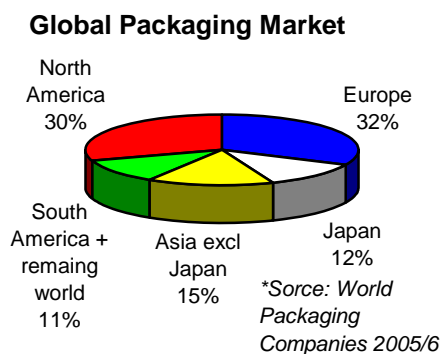


Figure 1. Global packaging market by geography.

² Main contributors to this report are Professor Mats Robertsson, PhD Petronella Norberg, PhD Tommi Remonen, PhD Göran Gustafsson and MSc Magnus Svensson

³ World Packaging Companies 2005/6 is written and edited by Industry Statistics Ltd in cooperation with Polygon Media Ltd and the magazine Packaging Today, the report can be ordered from www.worldpackagingcompanies.com

World Packaging Companies 2005/6 is based on the situation by the end of 2004. Since this statistics was put together several merges and other changes in the packaging industry has taken place or been announced. E.g. the announced proposal for a merge between the Jefferson Smurfit group and Kappa Packaging that, according to the companies themselves will create a leader in paper-based packaging, also the announced efficiency enhancement program within SCA's packaging division that probably will have a negative influence of the company position on the top 20 list.

Adding intelligence, as defined in chapter 2.1, can be done either by post manufacturing attachment or by incorporation of the labelling in the packaging manufacturing process. By today, in mass production, mostly static information in passive components has been added inline manufacturing. A few example of dynamic information exist, e.g. time-temp indicator and battery test. The first is an example of an added value that shows the status of the content; such a sensor could either be integrated within the package manufacturing process or post labeled. In comparison the battery tester is an example where the package is a part of the product and the adding of intelligence to the package must therefore be incorporated into the package manufacturing process.

RFID is a relatively old technology that for at least a decade has been forecasted to in three years time dramatically influence the supply chain management. Lately the technology has started to conquer warehouse and logistic parts of the supply chain. The RFID technology was long considered to be equal to the intelligent package but despite long time marketing, issues to be addressed to implement use of RFID on a consumer packaging level in the supply chain still remains. Such issues include reducing tag cost and on a consumer packaging level development of tags to be recyclable together with the tagged item without influencing quality of recycled goods.

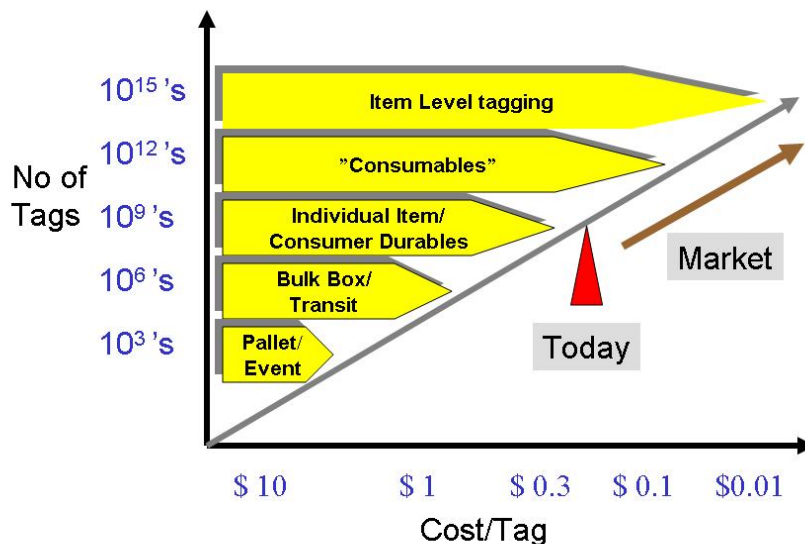


Figure 2. Lowered RFID-tag price – new & expanding markets. Simple Si tags are down to US\$0.18 per tag⁴

⁴ Source: Pack Rep. Issue: vol. 38, no. 6, June 2005, pp20-22 (In German)

The delay of RFID implementation together with extensive research and fast development in areas such as low cost electronics and displays has opened for a wider definition of intelligent packaging. In addition, the packaging industry is targeting organic and flexible electronic devices with increased interest.

Traditionally, labels and packages aimed at supporting the consumer product packaging market have been largely driven by 4-color printing technology. The challenge continues to be, finding new and innovative ways to get its message across to buyers, in a world where product price reduction and pressures to lower packaging manufacturing costs are a constant and brutal reality. Mechanical solutions currently offered, are limited in their ability to provide improved and innovative functionality.

The European label industry includes approximately 2,500 small to mid-size label printing companies. Part of the problem is that packaging customers are large and sophisticated corporations having limited resources at their disposal when it comes to package labeling. As a consequence, these companies, brand owners and retailers having to rely on what is currently available on the market since they do not possess the means to develop either own packages or labeling.

Finally, due to the fragmentation, the European label industry itself has limited resources to develop new technologies for the market, which is why this market advances slowly.

RFID technology is expected to result in up to 20 times faster supply and reduce costs by up to 15%. Implementation of RFID is also expected to be boosted by the European Union's (EU) new traceability directive for the production and transport of foodstuffs. The industry's doubts about the cost benefits of workflow integrated auto-identification are likely to be resolved by the development of polymer based printable RFID systems.

3 Line of development

It is impossible to predict the future. With knowledge on history and state of the art one can, however, identify trends and possible future routes and directions. This does not only include forecasting of technology development and possible applications. Impacts on environment, economy and social aspects are also to be considered. Politics has become more international and the situation in Sweden must be analyzed from a global perspective. Teknisk Framsyn is a national project, in which the conditions for economical and technical growth in Sweden are analyzed. Forecasts can be downloaded from <http://www.tekniskframsyn.nu/>.

3.1 Progress of society

Intelligent packaging concepts are being developed to meet existing and potential demand from three main sources: product manufacturers, retailers and consumers. At the manufacturer and retail levels intelligent packaging concepts are being developed to reduce costs and add to product and fascia value. In terms of reducing costs, developments in intelligent packaging may enable the real-time linking of merchandise, data and customers throughout the supply chain, providing improved visibility, traceability and full accountability of product movements. Benefits include lower product shrinkage, more advanced inventory control and improved delivery schedules.

Intelligent packaging concepts may also enable more efficient verification of box contents and reconciliation with purchase orders. Improved picking and packing productivity, throughput, utilization of capital equipment and accuracy are also possible, as well as reduced labor hour requirements.

With respect to adding value, intelligent packaging concepts may enable manufacturers to enhance their products and brands through better communication of product value and integrity, improved consumer acceptance of brand proposition combined with product customization and interactive features.

The idea to tag and track all items around us ("The internet of things") has been met with resistance. People react strongly to RFID tagging as an intrusion on their privacy – someone is secretly monitoring their actions. A visible display coupled to an RFID tag could show whether the tag is working and what signal is sent to the reader. This can considerably decrease the customers feeling of privacy intrusion. In addition, as consumers do not have reader equipment available to them, a visible RFID output could give them added value and thus increase the acceptance of RFID from the consumer's perspective.

The impact of regulation and legislation concerning product safety, and the improvements offered by intelligent packaging to producers, distributors, and retailers in the supply chain and logistics management are further factors that can be assessed in the business case.

Legislation in many nations already requires the sorting of household waste. With increasing population and limited resources in the world the creation of a sustainable society will include recycling of products in the supply chain. The regulation and legislation in the recycling area will most probably increase around the world.

Radio frequency identification (RFID) offers the potential to automate the sorting processes involved in recycling. Automated sorting would remove the need for sorting by consumers thus increasing recycling levels and allowing greater reuse of undamaged materials.

By using intelligent packaging retailers may add value to their fascias through improved consumer confidence in, and perceptions related to, the fascias in which they shop, enabled by improved tracking and tracing, time/temperature indication and shelf-life indications. Such features may be appreciated and increasingly demanded by consumers in the light of issues such as product recalls, food terrorism and food scares.

The use of intelligent packaging technologies comes at a cost and an application of such a technology must be justified by a benefit analysis. Counterfeited products have been estimated to 7%, by year 2004 and rapidly increasing, of the global product market by value. Thus the need for brand security and product authentication is real and increasing especially in the group of premium products where an extra cost easily can be motivated.

Out of the total confiscation of fake products by the Swedish Custom Department last year 32% were Coca-Cola products.

The counterfeiting of currency and consumer products are common problems that plague governments and manufacturers around the world, but the counterfeiting of medications is a particularly insidious practice. In case of drugs, counterfeiters do not only defraud consumers, they also deny ill patients the therapies that can alleviate suffering and save lives. In some countries the counterfeiting of drugs is endemic – with some patients having a better chance of getting a fake medicine than a real one. In many more countries, counterfeit drugs are common. In a report⁵ from 2004 US FDA (Food and drug administration) has identified RFID as a reliable and available technology to grant authentication. In the report FDA forecast RFID tagging of all pallets and cases and most packages of pharmaceuticals by end of year 2007.

The health care area is further emphasized by the increasing age of the population. Costs for health care are likely to escalate rapidly. Taking the demographic situation into consideration is not obvious how future health care will be financed. Tomorrow's patients will put higher demands on health care and they are likely to have economical resources at their disposal.

The changing population demography is a challenge for several countries – Sweden included – but there may also be commercial opportunities in the increased needs for health care, pharmaceuticals and diagnostics. Health care must be rationalized. Administration and information is to be handled in a more efficient way. Also, through point-of-care treatments, patients can perform testing and analyses at home. There are today self-testing devices for glucose, pregnancy, ovulation, protrombine complex and nitrate. Point of care analyses are used in a vast number of applications within clinical chemistry and micro biology. Such methods may cut down on costs and provide increased flexibility for the patient. We believe that point-of-care systems for self-diagnostics will increase the need for low-cost disposable systems for test and analysis. Naturally, this is a most interesting field of applications for intelligent packaging.

⁵ Combating counterfeit drugs, Food and Drug Administration, February 2004

3.2 Technology platform

Printed electronics moves forward but challenges remain: recent trends in printed electronics technology⁶. According to the author the development of printed electronic products has now reached the early stages of full commercialization, but a number of major technological and economical problems remain. Initially, the market for low cost printed electronic displays could be worth as much as US\$1bn/y, and could ultimately reach US\$300bn. As many as 1bn radio frequency identification (RFID) tags will be produced in 2005, 95% of which will have printed antennae and by 2010, 30% of almost 60bn RFID tags will be entirely printed, and by 2015 virtually all the 1tn tags manufacture will be printed.

Other electronic products that will be printed include billboards, posters, color advertisements, patient-compliance pharmaceutical packs, and electronic games and timers. Researchers have printed conductors, semiconductors, and dielectrics with off-the-shelf thermal inkjet pens and printers, but there is much work to do on refining the process. M-real, Finland, has developed a process for printing electronic devices on paper substrates using polyaniline as a conductor. This technique can be used to add RFID devices, tamper sensors, and temperature sensors. The major problem for producers of printed electronics is to balance the cost and performance of devices, particularly in the case of more complex products that demand the high resolution achievable only by inkjet printing.

The area of smart, active, sensing and communicating packages has got very much attention lately, nearest "a hype" today, see e.g. info from PIRA (www.pira.co.uk) and IDTECHEX (www.idtechex.com/), organizations that frequently arrange conferences in the area.

RFID

RFID as a technology has existed since the 1940's and has for many years been predicted to have a breakthrough in the supply chain. During the past year the technology has gained much attention through demands from the international giants Metro, Tesco and Wall-Mart on their suppliers to include RFID tagging on all deliveries.

Technically the RFID system consists of five components: transponder (or the tag), reader, writer/decoder, software and the application software. An excellent survey of the technology could be The RFID Handbook⁷.

Semiconductor components are constantly produced with improved performance and at lower costs. But there are reasonable doubts that the components needed for full implementation of intelligent packages on consumables will ever be low enough using traditional production technologies, see also Figure 2. With the realization of the first printed polymer transistor, the way towards new and inexpensive electronics is paved. Two of the pioneers are PolyIC and OrganicID.

⁶ Ink World, vol. 11, no,7, July 2005, Part 1 of 2, pp18-19

⁷ The RFID handbook, Klaus Finkensteller

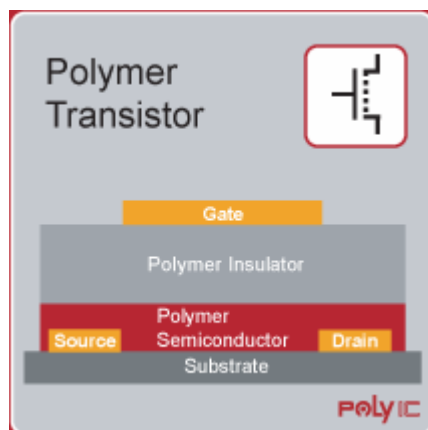


Figure 3. Schematic of polymer transistor. Figure from PolyIC home page.

The EU supported PolyApply project aims to replace barcodes with printed RFID labels costing EUR0.01 each, compared with the EUR0.15-0.18 cost of silicon tags. Members of the Copaco association are working with software and electronics firms such as SAP and Siemens to develop complementary hardware and software solutions for the management of the production process. In addition, the Copaco Group has set up an Actionteam Product and Brand Protection/RFID project to study the cost benefits of available technologies, the development of new solutions, risk analyses and implementation. According to a Capgemini survey the industry is concerned about data protection issues and would like to see tags deactivated after sale⁸.

Electronic paper

Electronic paper is a relatively new concept and the “paper” is actually made of organic electronics. The basic idea behind electronic paper is that it is a reusable display device, allowing the storage of visual content on a 'page' of plastic paper (e.g. e-book). This technology is at its very early stages. In table 1 some interesting actors in the areas of polymer, printed electronics and display together with their technology and applications are listed.

	Substrate	Technology	Device
Philips	Plastic, Flexible (glass)	FETs, electrowetting	Display, Circuits
Infineon	Plastic, Flexible	Nanotubes, FETs	Circuits, Memory
E-ink	Plastic, glass	Electrophoretic microencapsules	Active display cells
Siemens	Plastic, glass	FET, Electrochromic displays, solar cells	Active display cells
TFE	On chip	Organic memories - silicon chips hybrid	RAM Memories
Acreo	Paper, Flexible	Electrochemical	Display, Circuits
Power Paper	Plastic	Thin film electrolytes	Battery
Brunel	Paper, Plastic	Offset printed conducting lines	Non-active circuitry
MIT	Plastic, glass, etc. etc.	Almost everything	All?

⁸ Source: Pack Rep., Issue: vol. 38, no. 6, June 2005, pp 20-22 (In German)

Gyricon	Plastic, glass	Rotation of spheres	Active display cells
Motorola/ International Paper	Plastic tags/foils attached to paper packages	Silicon chips together with Carbon paste antennas	Active RFID circuitry
Murel	Plastic, Glass	Electrochromism	Active display cells
CDT	Plastic, Glass	Light emission, photovoltaic	Display
Plastic Logic	Plastic, Flexible	Solution based, direct write	Circuits
Aveso	Paper, Plastic	Electrochromism	Display
Toppan			Display, Circuits

Table 1. Actors in the areas of polymer, printed electronics and display together with their technology and applications

Paper electronics

Paper Electronics as a topic was defined and established in Sweden in the PAELLA project⁹ that was conducted during the years 1999-2002. The project constituted a marriage between newly developed electronic materials and established techniques used in paper conversion. Using materials such as conducting polymers, inks and pastes and techniques such as inkjet printing, screen printing and lamination, electronics is applied directly onto the surface of paper or paper products.

Using cellulose fiber based materials as substrates for electronic devices is a challenge since the performance of electronics mostly will be compared with state of the art performance, i.e. silicon semiconductors. If paper electronics would compete with silicon on a performance level long time and huge financial resources would be needed. On the other hand using state of the art technology for paper electronics and aiming for simple applications there are new markets to be conquered if the functionality can be reached at low costs.

In a longer perspective, naturally more complex systems are targeted.

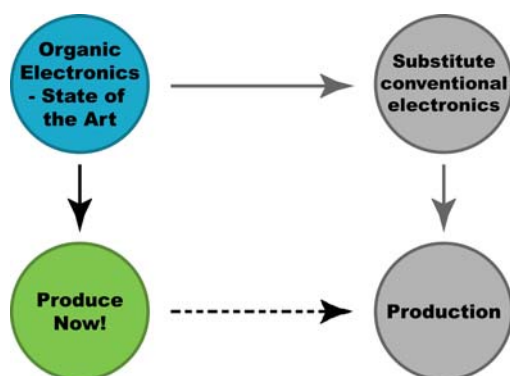


Figure 4. Future directions for paper electronics. Use existing technology for simple applications and immediate production or the competition case with the goal to replace conventional electronics.

⁹ www.acreo.se/paella, partners: Acreo AB, ITAB Elektronik, AGFA-Gevaert, M-Real, SCA, Stora-Enso, Tetrapak, Vinnova

3.3 Applications

In almost all the applications listed below intelligence may be achieved in two principally different ways. Either the intelligence can be integrated during manufacturing or it can be attached to the package post manufacturing.

The benefits of RFID over other technologies, such as barcode reading, include the ability to read data without line of sight to the code, combined with the ability to store and retrieve very large amounts of data. RFID systems in hospitals provide healthcare workers entering a patient's room with the ability to check instantly if a drug could be administered without the need to scan the drug and patient's bracelet manually.

The pharmaceutical industry is confident that RFID technology will find a major role in primary and secondary packaging identification, tracking and anti-counterfeiting, within a few years. It is confident that new coding industry regulations, along with coding, marking and labeling technologies will be continuously developed to increase the applicability of RFID to the healthcare environment.

Rapidly expanding pharmaceutical applications for increased functionality include security and safe use. Integrated use of intelligent functionality, currently achieved using mechanical solutions is also on the rise. Intelligent and smart packaging is a practical approach to ensuring patient compliance with their medications and providing the means by which the confusion felt by patients about the functions of and reasons for their medications can be overcome. Seeking compliance through packaging can achieve a number of aims, including assisting medical providers in explaining the optimal prescribed regimen, ensuring that the patient feels like a true participant in their own therapy, simplifying the administration of medication for the patient, providing the means by which patient and medication interact, creating a permanent, continuous intervention that demands little involvement by the doctor or pharmacist.

The ability to convince a potential buyer to use a given product has always been heavily influenced by product packaging and its message. Intense competition for product dominance on store shelves is causing the market to look at new and more aggressive ways to steer buyer's attention toward their product. As a result, the packaging market continues to race toward finding more new and innovative ways to get its message across. Although still in the conceptual phase, intelligent packaging is said to be the next generation in product packaging.

Applications calling for interaction between the product and its package include toys and games, representing yet another area with growth potential. Interactive communication between the consumer and the product rank high on the list of desires, in several market segments.

Ultimately RFID is likely to be included in most products' packaging. RFID tags enable the unique identification of each pack, allowing access to information on the packaging materials. RFID enables monitoring of the numbers of recycled smart packages. Some products such as computers contain components which can be reused following identification through RFID. RFID can also assist in identifying packaging which requires careful disposal such as that for single use medical equipment.

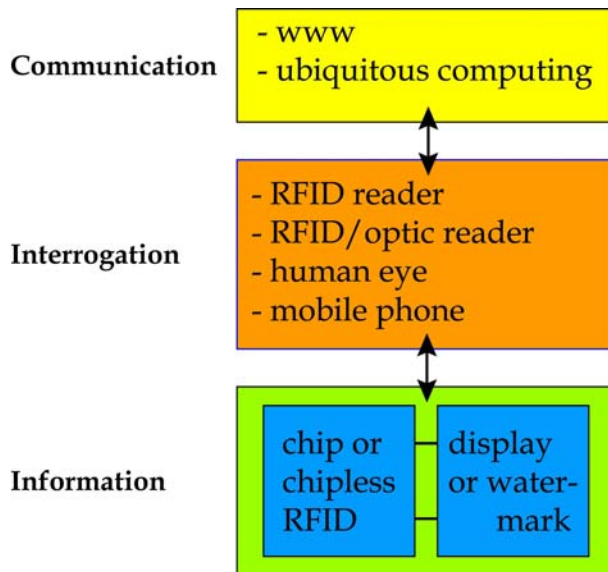


Figure 5. Possible readout technologies (middle) to be combined with chip or chipless RFID systems with optical functions such as displays or watermarks. The reader output can be used for ubiquitous computing (top).

An initial stage of RFID use in waste recycling is in waste carrying vehicles. Further stages in RFID tagging are of industrial and household waste containers, followed by the tagging of hazardous chemicals containers and large scale tagging of consumer packaging. RFID is presently assisting UK councils in meeting recycling objectives set by Chancellor of the Exchequer Gordon Brown.

The pharmaceutical and healthcare packaging industry continues to promote, supporting the brand message, building efficacy and integrity, reducing errors and providing a complete solution to the problem of compliance. The objectives of what may be termed Electronic Compliance Packaging include compliance, doctor/patient interaction and information flow, brand loyalty, product differentiation, and persistence in terms of prescription renewals.

Device	Functionality	Example of application area
Time temperature indicator	Historical temperature information and/or abuse temperature	Transportation and storage of cold food stuff
Oxygen indicator	Leakage information	Food stuff stored at reduced oxygen atmosphere or under vacuum
Carbon dioxide indicator	Gas concentration information	Food stuff packaged in modified atmosphere
Color indicator	Temperature information within food stuff	Stored food stuff, modified atmosphere
Putrefaction indicator	Microbiological status information	Fresh meat, chicken, fish
Security indicator	Broken package information	Baby food

Table 2. Example of sensor components/applications and technology used.

3.4 Swedish players on the world map

According to the report “World Packaging Companies 2005/6”, also previously referred to, the world’s largest packaging company is the Swedish Tetra Pak. Three other Swedish companies or companies with strong connection to Sweden are SCA who ends up on 15th place and the Finish-Swedish company Stora Enso on place 19. Rexam who has large Swedish representation in the top management as an effect of the merge with PLM 1999 is the 9th largest packaging company.

In the report “Inspiration for Innovation” from Teknisk Framsyn eleven fields, in which Sweden is believed to have the best pre-conditions, are identified. Two of them *Interactive Technology* (including electronic paper) and *Functional Materials* are essential for the development of - and the third *Health Care Technology* is a potential application area for intelligent packaging described in this roadmap.

The broad and long research tradition in the fields of organic and polymer electronics together with today’s industrial approaches in Sweden supports the establishing of a national centre. The Centre of Organic Informatics (COIN) shall act in the field of organic and polymer electronics related to the application aspects of informatics – information processing, displaying, storage and sensing.

Recently the Swedish web site RFIDnews¹⁰ was launched. RFIDnews shall deliver news and valuable contact information within the RFID area.

University research

In Sweden, research of utilizing polymers and organic molecules for electronic applications has been progressing since the mid eighties. Initially, the focus was directed towards reaching high conductivity in the polymers aiming at applications such as novel conductors. At 1990 the scientists started to study the different aspects of including the polymers and molecules as the active material in electronic devices. Today the outcome of this effort has resulted in that transistors, light emitting diodes (LED), solar cells, photo diodes and other fundamental components can be realized in organic materials.

Ongoing research in the field is performed primarily at Linköping University, Chalmers University of Technology and at the Royal Institute of Technology. The research activity covers material synthesis, theoretical studies, fundamental material characterization, electronic components and the device system aspects together with manufacturing issues.

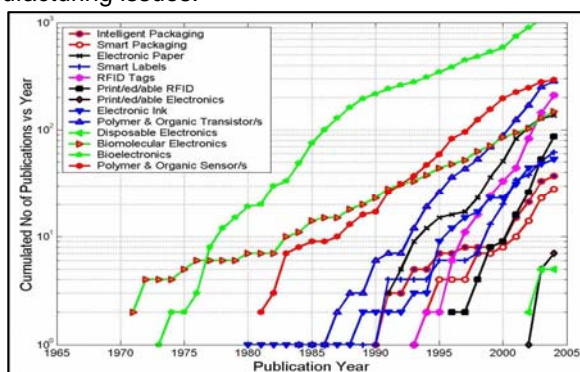


Figure 6. Cumulated No of Publications for communicative packaging related topics¹¹

¹⁰ www.rfidnews.se, produced by Trade Promotion Förlag AB

¹¹ INSPEC and COMPENDEX data bases searched, M. Robertsson, Acreo

The research activities at Mitthögskolan, which in general are well connected to the Swedish forest- and paper industry, are through the Electronic Design Division coordinating a multidisciplinary research project under the name *Electronic Systems for Sensible Things that Communicate* (STC) sponsored by the KK-foundation. The project focus on the development of new technology for intelligent products that have an electronic identity, are sensing their environment and communicates in an intelligent way with the surrounding world.

Lately KTH, Royal institute of Technology, has launched a professorship in Media Electronics where the technology integration oriented research should build a bridge between paper and packaging research and IT and electronics research.

Institutes

STFI/Packforsk is a research institute covering the value chains from the raw material to print and media, to packaging and to bio-based energy and chemicals. They are establishing innovative new technologies in the fields of "opto-active paper" and "new functions integrated within the paper". They are currently setting up innovation support by acting as technology enablers, establishing contact with customers and modifying new technology according to their demands.

Acreo AB is a research institute, several development projects of organic and polymer electronics are being carried out in close collaboration with industry.

IMEGO are developing biosensors and chemical sensors for use in the fields of e.g. biotechnology, medical diagnostics and food stuff.

Industry

With no imagination that all existing products or projects are listed this chapter highlights some interesting implemented or announced RFID or other intelligent packaging activities in Sweden.

Tetra Pak has presented chilled carton packages (Tetra Brik, Tetra Top and Tetra Rex) with included thermo chromic inks that become visible only at certain temperatures. Also demonstrated was indicators/sensors that work as temperature abuse indicators and automatic identification, involving radio frequency identification (RFID). In the converting process a penguin and snowflake were printed onto Tetra Brik aseptic cartons using thermo chromic inks. No color could be seen at ambient temperature, but when the carton was placed in the refrigerator and the product reached 5 deg C, the penguin and snowflake would appear, together with a message Perfect to Drink.

Skane Dairy was the first dairy to use Time Temperature Biosensor System from Bioett, Sweden. The system combines biotechnology with RF electronics, measuring the accumulated temperate load and also offering a cost efficient management tool.

Sensible Solutions Sweden is responding to earlier findings, that printed moisture sensors for adult nappies would be attractive to the packaging industry once the cost was reduced, by developing a prototype system for the elderly care nappy market that costs approximately US\$0.03/sensor. The company, which is a spin off of Mid Sweden University's electronics design division, is developing a printed sensor which is integrated into radio frequency identification (RF1D) label. The sensor detects moisture and sends a discreet alarm to

a portable personal alarm, watch or service centre. The sensor can also be adapted to record, time, temperature, acid levels or the blood sugar levels of diabetic patients. At present the cost of the sensors is prohibitive for all except the more expensive applications but the approach is regarded as having considerable potential for future development. The university has also been working in collaboration with SCA Packaging Research to produce cost effective sensors for the packaging industry.

- Other uses include that by Swedish waste collection company Ragn-Sells in recording containers of industrial waste as they are emptied.
- Strålfors is in cooperation with SAS and Lufhansa developing RFID solutions for luggage handling.
- Partnertech is a contract manufacturer with a track record of producing readers for intelligent labels.
- ITAB works on shop equipment such as check-outs and entrance systems.
- Gateway in Motala provides security solutions to retailers, super markets and libraries world wide.
- IBM has opened a Nordic knowledge centre for e-tagging based on RFID in Västerås.
- Example of other companies working with intelligent packaging are Cypak, Cerbo, Beab, Addmarkable, Stora Enso M-Real and SCA and many more.

3.5 Regulative trends

The reduction of unwanted emissions from industry, households and transports are most likely to be regulated in some way even if the well known Kyoto agreement have been neglected by some countries. Many indirect contributions to positive environmental effects are within reach, for example such a conceptually simple idea as a further developed packaging modularization can reduce more of the unwanted emissions from the transport sector than improved motor and fuel technology¹².

Many end-use segments are under legislation that will influence the direction of intelligent packing development. E.g. the regulation (EC) No 1935/2004. The regulation authorizes the placing on the market of two types of packaging which act "intelligently" in contact with foodstuffs, either providing information on the quality (freshness) of the product or preserving it for longer by introducing favorable chemical modifications. Previous legislation states that food contact materials should not trigger any chemical reactions which might change the food's taste, appearance, texture or smell or alter its chemical composition.

The new regulation also deals with traceability of foodstuff.

The relevance of RFID to industry, commerce and services where items and data are handled points to the need for appropriate standards. Where standards are harmonized or structured as international standards the opportunities relating to global trade can be significantly increased. The process of standardization as far as RFID is concerned at international level is expected to be led by the International Organization for Standardization (ISO). It is developing a range of standards which will benefit the take-up of RFID in the future. They are expected to embrace four types.

- Technology standards: dealing with the technological features, such as the air interface communications format and data exchange protocols that have to be agreed to ensure

¹² Prof. G Jönsson, Lund, personal communication

compatibility or interoperability in systems produced by different manufacturers or systems providers.

- Application standards: dealing with agreements on the way or ways in which technology or systems are to be used in particular applications to ensure consistent usage in a specified manner.
- The application standard may incorporate the data standard, or refer to an external data standard.
- Data standards: dealing with the agreements on the way data is structured for compatibility and interoperability requirements.

However, there is not a monopoly situation for ISO, there are other players on the “standardization” arena. Royal Philips Electronics of the Netherlands and Dallas-based Texas Instruments issued a joint press release announcing their efforts to test that GEN 2 products conform to the new specification. According to the release, the collaboration "is aimed at ensuring interoperability and accelerating market deployment of Gen 2 products, such as labels, hardware and system solutions, to offer multiple sourcing for implementations of RFID throughout the world."

The GEN 2 standard, ratified by EPCglobal last December, is considered a critical element in the furtherance of RFID's adoption in the supply chain. Vendors of RFID supply chain-focused software and hardware have been working since December to ready GEN 2-compliant products, and it is widely expected that in a very near future (months), the industry will see a flurry of product releases and upgrades touting new GEN 2 capabilities.

In Sweden EPC Global is represented by EAN Sweden.

3.6 The packaging area in relation to electronics industry and environment

When treating the subject “communicative packaging”, including packages, media, communication systems, logistic systems, raw materials, technologies and processes for paper and board manufacturing and printing processes it is adequate to start the discussion on a global level with a long time horizon where also the discussion relates to the electronics industry and to environmental aspects.

The global turnover of the packaging industry is estimated to be over US\$ 400 billion, a significant part of the "Gross Global Product" (GGP) and an essential factor for the food supply chain, product marketing, product sales and logistics. The consumer market dominate the global packaging market with 70% whereas industrial packaging applications are behind the remaining 30%¹³.

The global electronic market is the largest industry sector in the world estimated to US\$ 1000 billion. Divided in segments the hardware, i.e. microelectronics (~chip) and electronic packaging (everything but chip in the hardware) is approximately 25% or US\$250 billion yearly. Remaining 75% includes software, systems and internet shopping & internet application.

The growing interest in RFID technology is maybe at present building the first bridge between packaging industry and electronics industry. The drivers for this are mainly expected to be commercial since the packaging and logistics industry is believed to have much to gain in implementation of electronics and communication technology. To a large extent the increased cooperation is also affected by national and international legislation, since packages are so strongly connected to the flow of goods and general flow of

¹³ Reardon, Corey M., **Source:** *Paper, Film and Foil Converter*, v 77, n 2, February, 2003, p CL3

“mass”. The global society is increasingly aware of questions related to minimal resource usage and sustainability. Different kinds of security and authenticity aspects are also becoming more important. A dramatically increased cooperation is expected during the next decades.

Increased cooperation is not only expected to be limited to the case where the packaging industry is a “customer” to relatively established electronics and IT but also a cooperation between state-of-art research within electronics & IT, ranging from system and architecture level to details in software applications as well as production and processes.

4 Technology and Industry Trends in a 3-5 year Perspective

It should be noted that historically, companies offering system solutions, often with high complexity mostly difficult to counterfeit, have been success stories with high profit margins while volume production has been outsourced to low cost countries and subcontractors continuously suffering from lower margins and toughest global competition.

4.1 Technology trends

ABI Research's report *Printed and Organic Electronic* from 2004¹⁴ forecast that the technologies for IC, Antenna and LED Opportunities in Displays, RFID, Photovoltaics and Batteries could become commercially available from 2008-2010. Organic and printed electronics have the potential to make radio frequency identification (RFID) tags less costly and antennae more effective, as well as enabling new applications, cheaper components and added value capabilities.

The effective cost of an RFID tag needs to be evaluated in the context of overall business processes and benefits as well as tag costs. Although production costs are expected to decline as the technology is taken up more widely, some industry experts predict that even simple tags will never fall to US\$0.05. Tags may be passive, active or semi-active. Passive tags have no internal power source and rely on the radio frequency energy from the reader to activate the transmission of their identity. Some passive tags are encoded once only but others can be recoded for reuse. Active tags have more complexity, contain their own power source and can transmit signals over greater distances. Passive tags with a 12 byte tag code, such as those mandated by Wal-Mart¹⁵, currently cost about US\$0.22 in quantities of 100,000. Active tags range from a few US\$ to a few hundred US\$ each. Data can be rewritten dynamically on the more sophisticated, active tags which enables them to be reused many times. Even simple, passive tags can be recycled. When reuse is taken into the equation, the effective cost/tag falls dramatically.

There are great expectations that RFID will replace barcode tagging at the item level. Several advantages over barcodes exist: more data can be stored, data can be rewritten, line-of-sight is not required when reading, and tags are less fragile and less ugly, just to mention a few. One obvious advantage with barcodes is their low cost. Another important feature is that the barcode can be read without reader equipment. This is possible since the encoded 13 digit number is written in digits along with the code. RFID technologies offer no corresponding possibility. However, in many situations it is desirable to make electronically stored information visible. This can for instance be an identity or some status information, such as a sensor output.

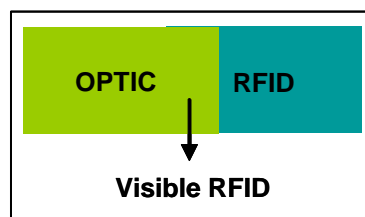


Figure 7. "Visible RFID" as the outcome of joining optics and RFID.

¹⁴ www.abiresearch.com

¹⁵ Wal-Mart press release March 2005 as presented by <http://www.smartlabelsusa.com>

Combining the best from the radio frequency and the visual domains into “Visible RFID”, new concepts can be developed. Widening of the technology field will open for new RFID applications. Several highly interesting benefits can be achieved.

Increased security. A display or a security print (“watermark”) that is updated according to information in an RFID tag can be difficult to copy. Such a solution increases security and may find use in anti-counterfeiting systems and security paper applications. E.g. a combination of RFID, visible information, encryption and push buttons create possibilities for very sophisticated security solutions.

Localized accessible information. Visible information on a display is accessible by any observer at any time. If, for instance, the status of a product requires action to be taken, this can be communicated at once whereas it may be too late to wait for someone with a reader to notice. Visible information may thus decrease the need for readers in a system. This lowers cost. It is also possible to distinguish between information accessible by any observer (even the consumer) and information accessible only by people with readers. This increases security.

Visible RFID aims to develop RF/optic concepts. Both chip and chipless RFID concepts will be considered and combined with display and watermark functions.

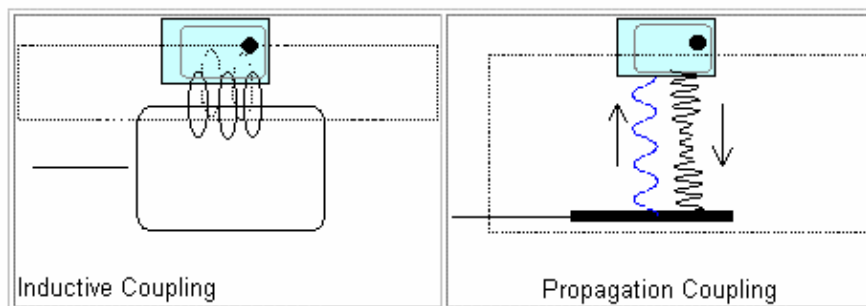


Figure 8. Coupling principles for RFID tags. Left, near field and right far field.

Teknisk Framsyn [www.tekniskframsyn.nu] has identified 100 future technology and knowledge areas in 11 clusters. Below the cluster with relevance to packaging technologies are listed.

1. **Larger complex systems** (e.g. logistics, transportation & communication systems and traceability systems)
2. **Mechanical systems and structures** (indirect)
3. **Interactive technology** (e.g. printed electronics with info and interaction: visually, optically, electromagnetically or direct touch, etc)
4. **Functional materials** (almost per definition, paper and packaging materials can be refined by integration or addition of functional materials on structures, surfaces etc)
5. **Environment and life cycle** (sorting and recycling), logistic aid (energy and time saving technology and systems to record and control material flow)
6. **Mobile energy** (Printed low cost solar energy collection and storage)
7. **Solid energy systems** (large area paper solar cells?)
8. **Security and brand protection**, (authentication etc, alerting systems e.g. sensors integrated on traffic signs)
9. **Sustainable food production** (sensors, info/displays integrated into packaging)

10. **Available IT** (IT & IT-interactivity through smart papers & packaging, large area displays, communication, things that sense and communicate)
11. **Health business** (Information, drug packaging, single use sensors/analysis equipment etc)

Even if the scope of this report is the development direction in a 3-5 year perspective it might be necessary to raise the question on what the final goal in a longer perspective might be in order to find the direction for the near future. The following different “what if” questions are examples that can be used as basis for creating scenarios:

- What if everything (every package) sense, store, think and communicate?
- What if hybrid solutions between traditional silicon electronics and printed organic electronics at any time give the optimal functionality?
- What if we had sensor and info loggers on all packages in the logistic chain logging measured data and events?

Things (packages) That Sense, Store, Think & Communicate (TTSSTC)

Description

This far out “ultimate” vision or scenario for electronics on or in a package embraces extremely much and can in this context only be commented briefly. This device should or could be a label or a printed area and should act as a computer with add-on sensors and communication devices. It needs to have power supply, either as a battery, a fuel cell, a device for harvesting of energy from light, electro-magnetic radiation, movements, temperature gradients etc. It should communicate both on demand and spontaneously with “things” around. It should be able to participate in arbitrary mainly wireless ad hoc networks, i.e. an extended internet including “things and packages”. It should have on demand visually readable output.

If or when “TTSSTC’s will be available at non-prohibitive cost for packages and other “items or things” they may have a substantial influence on peoples life and possibilities to find more sustainable ways of organizing societies from global to local level. They will be the prerequisite for e.g. global optimization of mass-flows and transportation by - in a global internet systems context - collecting “complete” information about how packages “feel”, what they experience, where they are etc. Packages that “think” also means a lot of perhaps simple but still vastly distributed intelligence that can support with decisions based on what they experience of inputs from sensors and other input devices.

Demands

The demands are tremendous on technologies, systems and infrastructure. Today the nearest starting point for this device may be today’s mobile phones. To adopt electronics - preferably printed organic electronics with ultra-low cost potential fulfilling a reasonable specification - is a major challenge since all the classical elements of electronics need to be there. These elements are; conductors, resistors, coils, memories, logic devices with thousands to millions of transistors, display units, antennas and last but not least adequate energy supply. Major inventions need to be made regarding e.g. speed of printed organic electronics or finding ways around the speed limitations of organic electronics.

If we aim at printed electronics, the complexity also makes processing and production a multi-sequence task introducing requirements of high speed “zero fault” production in every step. Also process and material compatibility is crucial, for example it is not a priori given that “needed” functional organic materials can be

processed sequentially on top of each other. An important task is to find short processing routes where a processing step and involved materials can fulfill many tasks simultaneously.

“Hybrids Forever” (HyFo)

Description

This vision or scenario for electronics on or in a package brings up the everlasting discussion about “monolithic” technology solutions and “hybrid solutions”. Here the “Hybrids forever” scenario stands for the idea that printed organic electronics will almost always be complemented with discrete silicon-chips, at least for more demanding applications. Thus this scenario is more of an evolution path of today’s “electronic packaging and assembly” towards applications in the packaging area, but with “elements” of printed organic electronics or at least printed conductors and passive elements. The scenario is unspecific and covers broad application areas. The most pronounced example today that fall under this heading is the RFID-development.

These “HyFo” devices should or could be packaged as a label or attached to many different surfaces or integrated into structures (i.e.: like today’s “smart cards”).

If or when “HyFo’s” will be available at non-prohibitive cost for packages and other “items or things” they may have a substantial influence on people’s life and possibilities to find more sustainable ways of organizing societies from global to local level, just as “TTSSTC’s” above. Actually it is likely that the most advanced “TTSSTC”-devices at any time will be of “HyFo”-type and that the same functionality later may be achievable and exchanged with non-silicon chip based technologies. From the performance point of view, “HyFo”-devices will be extremely difficult to beat by technologies relying only on low cost printed organic electronics. Today’s target for RFID-tags, US\$0.05 per tag is likely to be the lower cost limit for “HyFo’s” in the future that can be foreseen (5 years?).

Demands

The challenges are partly new, since hybrids of printed organic electronics and silicon-electronics do not really exist today. The assembly step is still very costly per item in comparison to the anticipations regarding printed organic electronic components.

Thus, ultra low cost mounting methods of grain-sized Si-chips at printing speeds (100 m/min) compatible with roll-to-roll printing of organic electronics is one essential key. Co-design of Si-chips and organic electronics is another area to be mastered in addition to what has been mentioned for the TTSSTC-scenario above.

“Sensor & Info Logger” (SIL)

Description

The “sensor and info logger” scenario is very specific, it deals with a printed use once organic electronics (ultra-) low cost device that should be able to log sensor data versus time autonomously for a shorter period of time corresponding to transport times for worldwide transports of goods (max time \approx month). Temperature and relative humidity sensors are primary targets. Readout of data could preferably be via RFID-antennas or from a simple display unit that could be read by e.g. a mobile phone camera or a barcode reader or a “naked eye”. It should be possible to write data wireless and associate that data with time data. The device has “printed energy” integrated, i.e. a printed battery. The organic electronics device includes logics, memory and a clock or timer unit. It targets a very low cost level that can’t realistically be reached with Si-chip alternatives or hybrid alternatives.

If or when “SIL’s will be available at targeted cost for e.g. fresh tomato packages they will be the prerequisite for optimization of the logistic chain by giving possibilities for tracking the time temperature humidity history of every single package as well as check-point-time data.

Demands

The specific novel challenges includes; a printed clock or timer, printed ultra low cost batteries, the integration of needed base components into a working device and a high speed roll-to-roll process for: printed transistors, printed memories, printed clock/timer etc.

Concluding remarks

Major efforts within rather novel technology areas are needed before any of the scenarios can be realized. Much of the work needed deals with the complex integration and co-design of different basic printed organic components to get functional devices. This type of work has only recently started at some R&D labs in the world, including Acreo and associated Linköping University. Hybrid-approaches where Si-chips and printed organic electronics are combined are so far quite neglected but considered to be important.

Some necessary “building blocks”, e.g. a printed clock or timer have hardly been demonstrated yet.

The table below brings up some not yet solved major issues (obstacles, problems, killer criteria) needed to be addressed before it is possible to realize the scenarios. Many of these are common especially for the TTSSTC scenario and the HyFo-scenario.

	Technology	System	Security	Material	Substrate	Sustainability
TTSSTC	Energy supply, e.g. Printed rechargeable battery + energy harvesting RF-antennas	Ad hoc networks	Many complex issues about security and integrity!	Organic semiconductors with higher mobility for diodes and transistors to work at high frequencies	Label with printed organic electronics put on any substrate	Exchange of often employed Ag-pastes, Organic conductors with sufficiently low resistivity
	Printed low cost organic memories, compatible with printed transistor circuits	Readers/writers/ interfaces to e.g. internet	Visual output verifying security and integrity	Organic semiconductors with low resistivity for electrical interconnects	Printed organic electronics on card board with prepared surface	Exchange of often employed Ag-pastes, Patterned Aluminum – foils?
	Speed and size of transistors and circuits, printed rectifier for up to ≈ 2.5 GHz	General systems and systems optimization		Material systems for self assembly of miniaturized circuits	Organic electronics integrated in paper laminate	Organic and inorganic electronic inks – recyclable or separable in paper-processes?
	Very Complex Integration	Dedicated systems development for e.g.: item & mass-flow tracking		Materials for “bio-sensing” and bio-interfaces	Organic electronics integrated on or in cellulose fiber	Reduction or elimination of organic solvents – suspensions etc in water?
	Cost	Global communication and computing capacity		Materials for printed battery		Bio-degradability? Possibility to burn used materials with harmless emissions?

	Technology	System	Security	Material	Substrate	Sustainability
HyFo	Energy supply, e.g.: Printed Rechargeable Battery + energy harvesting RF-antennas	Ad hoc networks	Many complex issues about security and integrity!	Organic semiconductors with low resistivity for electrical interconnects	Label with printed organic electronics and Si-chip(s) put on any substrate	Exchange of often employed Ag (Metal-)pastes for chip-mounting, Organic conductors with sufficiently low resistivity
	Printed low cost organic memories, compatible with Si-chips or memory integrated in Si-chip?	Readers/writers/ interfaces to e.g. internet	Visual output verifying security and integrity	Material systems for self assembly of miniaturized circuits	Printed organic electronics on card board with prepared surface	Exchange of often employed Ag-pastes, Patterned Aluminum – foils?
	Very Complex Integration	General systems and systems optimization		Materials for “bio-sensing” and bio-interfaces	Organic electronics or Si-chip integrated in paper laminate	Organic and inorganic electronic inks plus Si-chips – recyclable or separable in paper-processes?
	Cost	Dedicated systems development for e.g.: item & mass-flow tracking		Materials for printed battery	Organic electronics integrated on or in cellulose fiber	Reduction or elimination of organic solvents – suspensions etc in water?
		Global communication and computing capacity				Bio-degradability? Possibility to burn used materials with harmless emissions?
SIL	Energy supply, i.e.: Printed low cost Battery	Readers/writers/ interfaces to e.g. RFID-readers/interrigators, mobile phone cameras and barcode readers	Not primary important	Organic semiconductors with low resistivity for electrical interconnects	Label with printed organic electronics put on any substrate	Exchange of often employed Ag-pastes. Organic conductors with sufficiently low resistivity.
	Printed low cost organic memories, compatible with printed organic electronics	General systems and systems optimization		Materials for printed battery	Printed organic electronics on card board with prepared surface	Exchange of often employed Ag-pastes, Patterned Aluminum – foils?
	Printed clock and or time circuit	Dedicated systems development for e.g.: item & mass-flow tracking			Organic electronics integrated in paper laminate	Organic and inorganic electronic inks (battery chemistry) recyclable or separable in paper-processes?
	Printed temp and RH-sensors compatible with readout printed organic electronics				Organic electronics integrated on or in cellulose fiber	Reduction or elimination of organic solvents – suspensions etc in water?

	Technology	System	Security	Material	Substrate	Sustainability
	<i>circuits</i>					
	<i>100% printed organic battery?</i>					Bio-degradability? Possibility to burn used materials with harmless emissions?

Table 3. Not yet solved issues needed to realize the scenarios. Highlighted with yellow are common issues for all three scenarios. Highlighted in green are common issues for TTSSTC and HyFo scenarios and in italic are specific issues for respective scenario.

Another important area is to find materials that show both sufficient basic properties and sufficient process compatibility between different materials and processes. A strong development of organic electronic materials can be noticed at many places in the world why the situation is gradually improving. The materials need also to be compatible with (printing-) processes that are sufficiently fast so they can enable (ultra-) low cost devices.

Sustainability and recycling questions have hardly been treated at all for printed organic electronics.

Property	2005	2007	Market need
Substrate	Semi- flexible plastic	Tyvek, textiles, paper	Flexibility, versatility
Deposition methods	Spin, spray, vapor deposition	Inkjet and printing	High volume manufacturing
Electrical properties	Comparable to amorphous silicon	Comparable to polycrystalline silicon	Performance
Applications	Displays	Clothing, luggage tags	Flexibility at low cost

Table 4. Organic semiconductor technology transitions, to 2007.

4.2 Industry trends

The term "printable electronics" refers to circuitry created out of conductive polymer and nano-metallic inks using a wide variety of printing technologies, old and new. A recently launched report from NanoMarket¹⁶ says that printable electronics offers compelling advantages over more conventional ways of producing electronic circuits. These include the ability to cost-effectively mass produce products that could never be created using the old CMOS paradigm. Example of products to be produced with this novel technology are RFID tags that are inexpensive enough to replace bar codes, roll-up displays or smart packaging that will allow companies to enhance their offerings and product lines. The report notes that ink-jet printing offers the potential to create specialized circuits in very small runs that will address the semiconductor industry's urgent need to reduce prototyping costs. Lastly, printable electronics will also enable companies to create new forms of consumer products embedded with intelligence or other features that will enhance revenue possibilities. All of this can be done with relatively modest up-front investments.

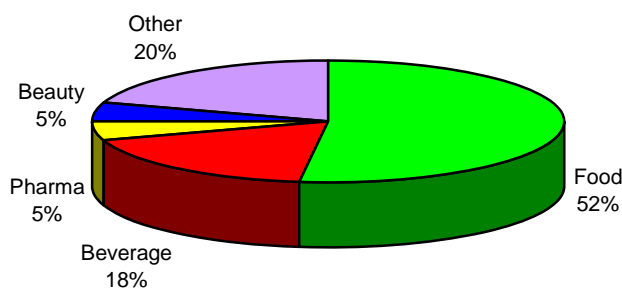
¹⁶ Printable electronics: Roadmaps, Markets and Opportunities. NanoMarket, www.nanomarkets.net

NanoMarkets' new report claims that printable electronics will generate estimated revenues of over US\$7 billion in 2010, driven by demand for printable displays, RFIDs, photovoltaic, computer memory and other printable products. Areas with the largest growth opportunities include printable displays, which NanoMarkets projects to be a market worth over \$3 billion in 2010, printable RFIDs which will be worth \$2.2 billion, and computer memory and photovoltaic which will achieve more modest, yet significant, market opportunities of almost \$770 million and \$580 million respectively.

The packaging industry can be seen as "the common denominator" between all industry branches. The IT-industry can be said to bring the "global village" together with digital information flow whereas the packaging industry bring the "global village" together with flows of food, raw materials and products. Note that the flow of money (the "imaginary part" of the flow of real matter and services) is taken care of very carefully with great accuracy and in highly developed and integrated systems whereas the packaging area and packages that actually carries the "real values" of food and products is in comparison primitively treated today, often with large losses as a consequence and definitely without utilizing the full potential of the packaging medium. Smart and communicative packaging systems can be utilized for various optimization purposes, from support of e.g. local systems for logistics to general resource management and optimization on a global level.

Presumably a number of business ideas can be built on using packages as communication links that also communicates information about product- and mass-flows.

Global market by end-use



Source: Consumer Packaging report 2005/6[16]

Segment	CAGR 05-09
Food	4.7
Beverage	4.2
Pharma	7.1
Beauty	4.5
Other	4.9
Total	4.8

Table 5. Expected annual growth per segment 2005-2009¹⁷. CAGR (Compound annual growth rate).

Figure 9. Global packaging market by end-use application.

RFID on pallets and cases are a reality by some pilots. E.g. Wal-Mart's mandate to top suppliers came into effect on 1 January 2005, and although some suppliers marginally missed the deadline, by the end of January the required radio frequency identification (RFID) systems were in place in 104 Wal-Mart stores, 35 Sam's clubs and three distribution centers. 129 suppliers are now live with RFID for Wal-Mart. By the end of February 2005, stores using RFID had received 23,753 tagged pallets and 663,912 tagged cases. The read RFID data is made available to suppliers through Wal-Mart's Retail Link extranet website. Information screens have been installed at some stores to explain Electronic Product Code (EPC). Tag failure rate has improved considerably, while at case level, read rates have exceeded 90% for cases on carts, 95% on conveyors in distribution centers and 98% in trash compactors in the back room of stores. Read rates of

¹⁷ Consumer packaging report 2005/6, Rexam PLC, www.rexam.com

tags on individual cases on fully loaded pallets have been low, but suppliers are working to resolve this. Wal-Mart intends to have RFID in 12 distribution centers and 600 stores in the USA by October 2005, with the next top 200 suppliers mandated to be compliant by January 2006. The retailer is also working on tracking recalls¹⁵.

As other pilots have also shown, using RFID to increase sales by reducing stock outs shows an excellent payback. Now, Wal-Mart claim a 16% reduction in out-of-stocks using RFID¹⁸.

PolyIC, a joint venture between Siemens AG and Leonard Kurz GmbH, have claimed the development of the world's fastest organic circuit and working RFID tags based on polymer organic semiconductors as prototypes. The tags are based on radio frequency of 125 kHz. The target of PolyIC is to reach the 13.56 MHz standard.

Visible RFID available today can be exemplified by KSW's "Indicator RFID" and M-Real's "Hide" concept. In the KSW concept a 13.56 MHz chip tag with a sensor is combined with a display element. The display is used to visualize the status of the sensor. A reader is thus not needed to get information from the tag. If the display indicates "over limit" one can decide to read the tag and get more detailed information.

In M-Real's "Hide" concept, an image printed on specialty paper forms the electronically readable RFID signal/pattern. A higher level of security is provided since a special substrate and special inks are needed to realize the RFID tag. The signal detected is coupled to information in the visible printed image.

VTT developed an information-communication concept in which data carriers such as 2D barcodes are combined with a mobile phone camera, "every-mans-reader". Using this technology software and solution providers within the mobile phone area can now explore a completely new field for ubiquitous computing e.g. for games or logistic control.

Intelligent packaging can assist manufacturers, brand owners, distributors, retailers, consumers and regulatory authorities in resolving their respective issues. However, an increasingly major issue in performance/cost analysis is the broad range of solutions offered at widely varying costs to all involved in the supply chain. It is increasingly difficult for interested parties to differentiate between those technologies that offer truly effective solutions and those that are easily replicated, or fail to satisfy all or part of the needs of participants within the supply/logistic partnership.

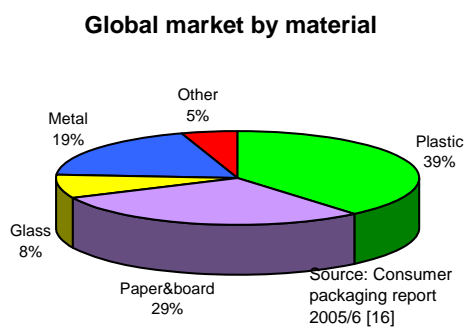


Figure 10. Global packaging market by material.

Material	CAGR 05-09
Plastic	5.9
Metal	3.1
Glass	2
Paper&Board	5.3
Other	3.6
Total	4.8

Table 6. Expected annual growth by material, 2005-2009¹⁷⁾

¹⁸ Wal-Mart press release October 2005 as presented by <http://www.smartlabelsusa.com>

A report from Pira¹⁹ forecast a dramatic growth in adoption of intelligent packaging in the food and drinks industry is. Between 2004 and 2006, adoption of intelligent packaging should at least double. By 2008, around 50 % of the packaging industry encompassing food and drink is expected to incorporate intelligent technologies into packaging. Product manufacturers and retailers are expected to push growth as they aim to add value and reduce costs. Consumers are expected to pull growth as they increasingly demand product of greater and added value.

When it comes to the integration of flexible electronic displays traditional printing technology and present mechanical solutions are not considered feasible. By comparison, conventional electronic systems used in labeling of consumer goods do not currently include electronic elements needed to support a message display. The integration of flexible electronic display solutions will require that electronic circuitry be implemented in packaging and successfully merged with the manufacturing process. Current markets views are that this would be both costly and complicated to implement.

Therefore, the market is actively seeking simpler and more effective solutions, although there are no feasible solutions available on the market today.

¹⁹ Low-cost Smart Packaging in Food and Drinks, Pira International Ltd, 2004

5 Competitive advantages/disadvantages of the Swedish industry regarding intelligent packaging

5.1 SWOT analysis

This SWAT (Strengths, Weaknesses, Opportunities, Threats) analysis is performed from an industrial growth possibilities perspective.

5.2 Strengths

- Strong and competent forest- and paper industry (e.g. SCA, Stora Enso, Korsnäs, Billerud).
- The number one company in packaging (Tetra Pak).
- World-beating forest- and paper research (STFI-Packforsk, KTH, MH, KaU).
- High quality fiber raw material and a developed sustainable environmental policy.
- World-beating communication- and IT Industry. (Ericsson...).
- Globally present furniture industry with world-beating concept in production, logistics and sales (IKEA).
- Strong mail order companies could be embryo to globally competitive e-business companies.
- World-beating communication- IT- and electronics research (KTH, Stockholm-Kista).

5.3 Weaknesses

- Awareness and knowledge about future possibilities available with IT- and electronics within the forest- and paper industry.
- Forest- and paper research has been successful but shows little inclination to change.
- Lack of visions, ambitions and ideas outside core competence.
- Lack of venture capital outside core competence.

5.4 Opportunities

- Potential for cooperation between forest-, paper- and packaging industry and IT and electronics industry.
- Potential to use system solutions generated by new communication products (e.g. 3G, 4G, broad band, FTTX).
- Potential cooperation between forest-, paper- and packaging research and IT- and electronics research (e.g. co design of systems, software, hardware).
- Potential to take advantage of the strong development within organic electronics and printed electronics.
- Restructuring of business concepts, companies to change their position within the supply chain (e.g. Dell transferred from producer of computers to be a producer and retailer).
- Swedish companies to establish world-beating packaging-communication system solution (e.g. taking advantage in the world leading positions from Ericsson and Tetra Pak).
- Environmental and sustainable systems for material flow using packaging as information carrier.

5.5 Threats

- Lower production costs for wood raw material, pulp and paper in low cost countries.

- Lower freight rates make it possible to supply wood raw material, pulp and paper at competitive prices globally no matter where it is produced.
- Continued outsourcing of all large volume manufacturing to countries with lowest production cost (salaries).
- Continued outsourcing of simpler services to countries with lowest salaries.
- Restructuring of business concepts due to globalization and IT.
- Many quick and competent research and market actors in competing countries.
- Strong mandates from global merchants (e.g. Wal-Mart and RFID) that might result in sub optimized (de facto) standard- and technology solutions blocking improvements for long time.

6 Conclusions

Developments of intelligent packaging concepts are driven by meeting existing and potential demands from three main sources: product manufacturer, retailers and consumers. Manufacturers and retailers try to reduce cost and add to product and fascia value. Intelligent packages, in terms of RFID labeled pallets and cases, are already on the market demanded by e.g. Wal-Mart. Initial evaluations by those pilots shows excellent payback, so far mainly due to reduced out-of-stocks. It is therefore no wild guess that the implementations of RFID throughout the supply chain will continue.

Other driving forces for implementation of RFID are counterfeits and legislation. In the case of counterfeits RFID has been evaluated to be an efficient way to reveal fake products. Legislation, e.g. EU regulation on traceability of food stuff, or expected legislation within the recycling area where automated sorting is supposed to increase recycling level and allowing greater reuse of undamaged materials as well as identification of packaging which requires careful disposal are other examples.

However the technologies offered today are too expensive to reach item level tagging and we will therefore see increased efforts in development of low cost RFID tags presumably using printing techniques.

Manufacturers always struggle to enhance their products and brands. Adding value to a product may be achieved by the development of packages that can sense monitor and activate changes in a package's contents or interact with an observer and provide information on any changes visually there and then on the packaging. Such features may be appreciated and increasingly demanded by consumers in the light of issues such as product recalls, food terrorism and food scares.

Due to the increasing age of population health care must be rationalized and development of intelligent packages is one way to increase self testing and analysis at home.

Many above listed features may be achieved using Si chip based solutions but most likely the cost will remain too high to reach item level. Therefore new solutions, such as the use of organic electronics, are needed while Si chip based RFID solutions are foreseen to dominate in the logistic part of the supply chain (i.e. tags on pallets and cases).

Organic electronics also have advantages over existing technology when it comes to display contrast and color perception and completely new functionality that can not be realized in silicon e.g. sensors, actuators, biofunctions.

Who will develop these new and innovative functions? The European label industry is much diversified and includes approximately 2,500 small to mid size label printing companies, do not have the resources. Packaging companies, who in comparison are large corporations, have lately shown increased interest in targeting organic and flexible electronic devices. However, traditionally they have not been responsible for electronic devices and they have been hesitant to take a product responsibility.

Sweden has large packaging companies and world-beating communication (especially wireless communication) and IT industry and research. Organic electronics was established as research area in the mid eighties. Swedish paper and pulp companies supported the worlds first presented paper electronic project that early established printed electronics functions for packaging applications.

Opportunities for Sweden are foreseen in the potential merge or cooperation between strong industry and research areas such as forest-, paper- and packaging and ICT and electronics. There is also a great potential to take advantage of the strong development within organic electronics and printed electronics so far mainly at university research and institute levels.



Invest in Sweden Agency

PO BOX 90, SE-101 21 STOCKHOLM, SWEDEN • WTC, KLARABERGSVIADUKTEN 70, B6
TEL +46 8 402 78 00 • FAX +46 8 402 78 78 • <http://www.ISA.se> • E-MAIL isa@isa.se