# Printed Technologies for Intelligent Packaging Applications and their impact on printed electronics market

*S. Nomikos[1], A. Politis[1], D.Renieri[1], M. K. Tsigonias[1,2] and N.K. Kakizis[2],*
**1. Faculty of Graphic Arts Technology, Athens Technological Educational Institute, Ag. Spyridonos, 12210, Egaleo, Athens, Greece**
**2. Micro-porous Materials and Membranes for Environmental Applications Laboratory, Institute of Physical Chemistry, National Centre for Scientific Research ''Demokritos'', Terma Patriarchou Grigoriou & Neapoleos, 15310, Ag. Paraskevi, Athens, Greece**

## Abstract

*Printed technologies have proved their functionality in the process processing and presentation of information on paper and other substrates. Hence, recently, there has been a lot of scientific research on printed electronics and RFID technology, which, create the framework for the potential development of smart and intelligent packaging applications.*

*The purpose of the present paper is to investigate the degree of development of printing technologies applied for Intelligent Packaging Applications and their impact on printed electronics market. Furthermore, the existing situation of the traditional processes and workflows of packaging printing in relation with the development of innovative applications regarding the integration of digital information on to the package is examined, in conjunction with the changes possibly required in existing packaging production and the flow of the supply chain.*

## Keywords

*Packaging printing, smart and intelligent packaging, printed electronics.*

## 1. Introduction

Developments in new technologies in packaging and, in particular, the integration of digital information on the packaging substrate, appear as an emerging issue for the packaging printing production. Recent developments in various fields and industry sectors including electronics, information technology-IT, materials and processes lead to new applications in packaging which are described as "intelligent", "smart" or "active". These developments concern in particular new materials (printed organic materials such as organic polymers) and tagging applications (such as RFID applications).

Numerous studies reveal that although packaging will continue to be printed on a substrate (paper, board, polymer, aluminum or on a multilayer substrate), new types of information carriers (as those mentioned above) are to be embedded in and/or on packaging. As a result, packaging – the substrate - which will continue to be printed and processed as usual, is changing, with regard to the types and structure of information to be transferred on the packaging material - substrate. Therefore, the package becomes a *physical* carrier of both printed and electronic information. Such new forms of packaging could be defined as "hybrid" packaging.

The objective of this scientific paper is to explore the existing situation of the traditional processes and workflows of packaging printing in relation with the development of innovative applications regarding the integration of digital information on to the package. Furthermore, it is intended to examine the implications of these developments in the printed electronics market mainly regarding the potential changes in supply chain and the retail business.

## 2. Methodological approach

This paper has been based on literature study, focusing on the investigation of printed electronics market and technologies and the way they will affect the supply chain and the retail.

## 3. Background and literature review

### *3.1 Structure of packaging*

Packaging is about 2 % of the GNP in the developed countries. The volume of the packaging industry is about 345 million euros, and about one third of this is in Europe. As Juhola (2002) points out, packages will remain and their proportion will clearly increase in the Information Society. Increasing e-commerce will also serve to augment the number of packages. The packaging itself will carry more and more information, for consumer, for parcel tracking, becoming more and more an important communication media (Juhola 2002).

Data from various sourses reveal that all packaging subcategories seem to increase continuously. Tables 1 and 2 show the increasing rates of packaging production and Packaging type segmentation.

**Table 1. Basic packaging categories: Percentage of annual increase 2001-2005 in the USA. Source: Graphic arts marketing information service, USA 2004.**

| Basic Packaging Categories | Percentage of Annual Increase 2001-2005 |
|---|---|
| Flexible Packaging | 4,5% |
| Labels | 4,5% |
| Corrugated-paperboard Packaging | 3,5% |
| Paper – Board Boxes | 2,5% |

**Table 2: Packaging type segmentation in 2002 (worldwide packaging production). Source: HUEBER/ Flexo und Tiefdruck Journal/ 3-2004**

| Packaging type | Percentage (%) |
|---|---|
| Corrugated board | 33% |
| Flexible packaging | 19% |
| Folding carton / board boxes | 11% |
| Paper bags | 10% |
| Labels | 9% |
| Cans | 5% |
| Other forms and types of packaging | 13% |

### *3.2 Smart and intelligent packaging - RFID*

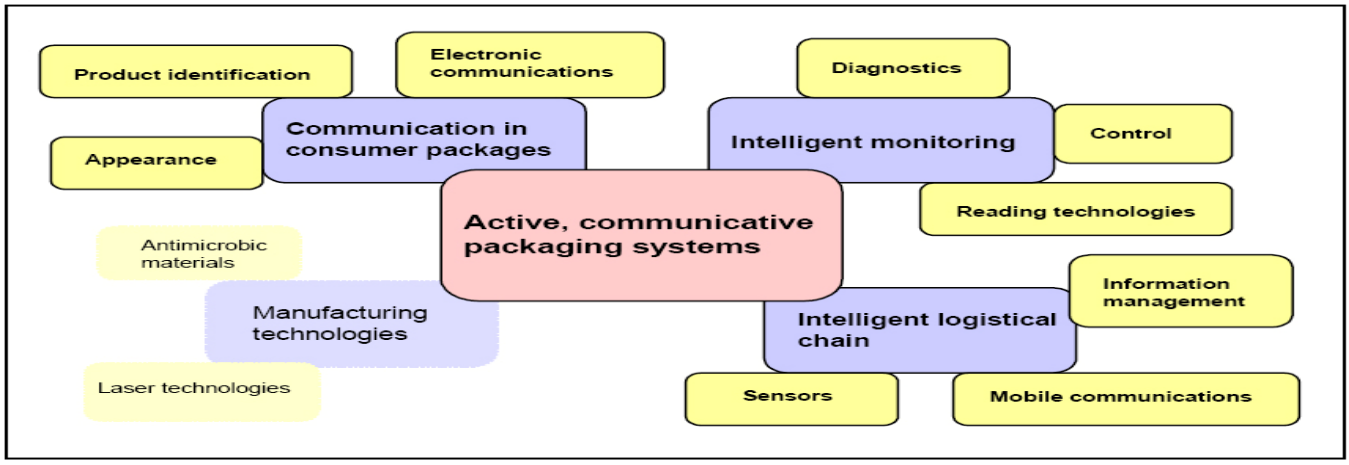
According to IDTechEx (2005), recent developments and applications on packaging show that not only human readable printed information, but also machine readable data needs to be incorporated in the packaging. Such data can be in the form of sounds, or smells, or other perceptions (for instance weight- some products such as fruit become lighter as they get older, and the juices inside them evaporate) (IDTechEx, 2005). These various perceptions and transformations or changes of conditions can be traced by sensors that compare the "printed" descriptions with the actual data from handling / scanning the package.

A convergence of emerging technologies that rely on new materials (such as printed polymers) and tagging applications (such as RFID and EAS systems) are leading to new concepts of "intelligent", "smart" or "active" packaging (Nomikos and Politis, 2005).

**In addition,** RFID can be defined as an automated identification technology, being not simply a bar code replacement. RFID has greater identification and functional capabilities than bar codes, such as reading through obstacles and in hostile environments, and can carry sensors, and read/write memories possible. As such it can lead to active communication (MIT, 2004).

Packaging lies in a quite strong relation with the supply chain, being subjected to changes and developments caused within the more generic field of the supply chain. Within this context, smart and intelligent applications for packaging are emerging from this more generic context of the supply chain. Packaging as the means for serving the supply chain, is affected by these developments. An important issue is the involvement of various sectors in the development of smart packaging applications; these include among others the informatics, electronics and material development sectors. A good example can be shown in Figure 1:

***Figure 1**. Technology map of Active, Communicative Packaging Systems. Source: VTT Information Technology, Finland*




### *3.3 Which drivers for change for smart packaging?*

The application of smart packaging elements causes changes in management attitudes. As Lindner (2005) points out, there is an amount of works to be done for the efficient application of smart elements in packaging; these are:

a) Materials optimization, materials compatibility, device modelling, inkjet architecture.
b) Benefits to ink jet printing electronics
c) Low-cost atmospheric processing.
d) Compatible with variety of substrates
e) Reduced materials costs.
f) Reduced environmental impact.
g) Large area processing.
h) Alignment during deposition.
i) Direct control of composition, gradients (Lindner, 2005)

According to IDTechEX (2005), all types of packaging can become smart. The intelligent –smart packaging is part of a communication system, whose heart is the desired information and knowledge about the product. It is made up of autogenous parts (chip, antenna, battery), which can collaborate partially or globally and create a group of collaborations, resulting in the creation of an RFID system (IDTechEx, 2005).

## 4. Market trends and developments in packaging in relation with smart and intelligent applications

Regarding future developments in packaging, on one hand, general packaging production trends, such as shorter delivery times, larger selections and smaller product quantities, are setting higher and higher demands on package production and packaging logistics. On the other hand, developing communication and printing technologies are providing new tools for solving problems, boosting production and giving value addition to packages. An increasingly important task for packaging is to improve brand protection, because forgers usually try to falsify the package rather than the product itself (VTT, 2002).

Methods such as visible or invisible printed bar codes and electronic RFID tags can be effectively used for brand protection and theft prevention. This can be implemented with the development of “smart” or “intelligent” systems. According to VTT, a “smart” system adapts to expected situations in a predictable manner. An “intelligent” system is able to adapt to unexpected situations, such as reasoning and learning (VTT, 2002).

In addition, data derived from a joint Pira International and IDTechEx conference (2005) show that «packaging is changing; ten years from now packaging won't just be able to do a lot more, it will be expected to». According to statements from the conference intelligent and smart packaging comes at this crucial time when key players are working together to make intelligent packaging a commercially viable, cost-effective catalyst for change» (PIRA and IDTechEx, 2005).

Furthermore, as it can be derived from OEA (Organics Electronics Association), intelligent packaging is an integration of display, logic, keys, sensors, memory, power supply and speakers. As a result, organic electronics are defined as electronics based on organic materials and polymers. Various studies estimate that their global market until 2015 will reach a market volume of 30 Billion USD. As they are thin, flexible and lightweight, they can be printed with the traditional printing methods of flexible substrates (offset, gravure, flexography, ink-jet and laser printing processes (Hecker, 2006).

**Regarding the characteristics of printing processes for printed electronics,** it is interesting to see the dimensions for good printing results as they are illustrated in Table 3:

**Table 3. Dimentions for good printing results**

| Printing method | Viscosity (Pas) | Layer thickness (μm) | Feature size (μm) | Registration (μm) | Throughout ($m^2$/s) |
|---|---|---|---|---|---|
| Gravure printing | 0.01 – 0.2 | < 0.1 - 8 | 75 | > 20 | 3 – 60 |
| Flexography printing | 0.05 – 0.5 | 0.04 – 2.5 | 80 | < 200 | 3 – 30 |
| Offset printing | 5 – 100 | 0.5 - 2 | 10 – 50 | >10 | 3 – 30 |
| Screen printing | 0.5 – 50 | 0.015 - 100 | 20 – 100 | > 25 | 2 – 3 |
| Ink Jet printing | 0.001 – 0.04 | 0.05 - 20 | 20 – 50 | 5 - 20 | 0.01 – 0.5 |

Sources: G.E. Jabbour et al (2001), A. huebler et al (2002), M. Bergsmann et al (2003), T. Kawahara et al (2003), A. Blayo et al (2005), A. Maaninen et al (2005), H. Sirringhaus et al (2006), M. Schr dner et al (2006), Y. Xia et al (2006)

Furthermore, in Table 4 the global market for smart packaging devices is illustrated, up to the year 2014:

**Table 4. Global market for electronic smart packaging devices 2004 to 2014 in billions of units**

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EAS | 5.0 | 5.5 | 6.2 | 7.1 | 7.9 | 8.5 | 8.9 | 9.5 | 10.0 | 10.5 | 11.1 |
| RFID | 0.8 | 1.4 | 1.8 | 3.0 | 5.0 | 6.0 | 7.0 | 12.0 | 25.0 | 35.0 | 100.0 |
| Other | 0.5 | 0.6 | 1.0 | 2.0 | 3.0 | 4.3 | 5.6 | 8.4 | 11.2 | 23.1 | 50.0 |
| Total | 6.0 | 7.1 | 9.0 | 12.1 | 15.9 | 18.8 | 21.5 | 29.9 | 46.2 | 68.6 | 161.1 |

Source: ID TechEx

## 5. Discussion

The survey and the literature review has indicated that there is a huge potential market for the so-called “smart” applications. This field is of high interest for many industrial and commercial activities and for a quite diverse range of sectors. Particularly, the IT industry, the electronics, the material science and its developments as well as automation (with the new field of Automatic Identification) seem to be the areas of significant technological

development. Packaging is one of the sectors where the "smart" applications are of significant interest, among the totality of the retail production chain. Smart packaging printing seem to be interesting in this context, only as it concerns the capability of the existing printing methods and processes to print the new substrates or to integrate the smart elements on to the package.

A first result from these findings is that packaging printing production will have to adapt to the new demands of the retail market and industry. Currently, there is a noticeable struggle on the issues of the technology that will be established in the market as the dominating application. RFID seem to take the lead, however, its application are to be currently found in secondary packaging, transport and identification in storages and pallets. Printing of RFIDs, are mainly labels, which are attached as normal labels on to the packages.

Furthermore, RFID is competing with the printed electronics field of development, namely the organic polymers, where the active carrier is the substrate itself. Such a development can be applied at consumer packages offering the possibility for extending smart packaging applications to everyday life within the supply chain of products and goods.

The study revealed that the majority of smart packaging elements (tags, antennas, printed polymers) are thin, flexible and ***printable with all major printing processes***. However, an issue of importance is whether smart packaging applications will be based on the direct printing of these elements on the substrate or will be taking place following various inlay processes (such as laminating or embossing of preprinted tags for example on the printed substrate).

For the time being, the production of smart applications for packaging, seem to be based on labels. However, the other technologies evolve further and, consequently it is not possible to make an accurate prediction on which technology will be the most applicable.

## 6. Conclusions

Only general comments can be stated by the present survey, in particular as it concerns the implications of packaging printing developments for the supply chain and the retail business, which can be summarized below:

All major printing processes will be used in smart packaging applications and allow the implementation of printed electronics. However, technology evolves further, suggesting new substrate, inks and layers, and it is quite possible that printing processes will need to be adapted into new production environments.

Finally, since printing processes evolve further in order to implement smart and intelligent applications on packaging, the market of printed electronics is affected by these developments. In addition, production workflow of packaging printing seems to require changes calling for alterations towards the integration of new/additional processes in the entire design, production and management fields.

## 7. Future study

One significant issue to be further investigated examine further is the suitability of each printing process for the integration of smart packaging applications. Answers are required on the issue of changes that are expected to happen in the traditional packaging printing production towards the integration of smart packaging applications.

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## Author Biography

**Spyridon Nomikos** received his BSc in Graphic Arts Technology from the Technological Educational Institution of Athens and his PhD in Graphic Arts from the University of Aegean. He is teaching in the Graphic Arts Technology Faculty in the TEI of Athens and he is working on the research of the RFID systems.

**Anastasios Politis** received his BSc in Graphic Arts Technology from the Technological Educational Institute of Athens and his PhD in Graphic Arts from the KTH – Royal Institute of Sweden. He is teaching in the Graphic Arts Technology Faculty in the TEI of Athens and he is working on media management, human capital development, innovative technologies and packaging applications.

**Despoina Renieri** is a student in the Graphic Arts Technology faculty of the Technological Educational Institution of Athens and she is working on RFID technologies and their social impact.

**Marios Tsigonias** received his BSc in Graphic Arts Technology from the Technological Educational Institute of Athens and his MSc in Industrial Chemistry (Polymers) from the National University of Athens. He is teaching in the Graphic Arts Technology Faculty in the TEI of Athens and he is working on nanostructured materials and polymers for GA applications in the NCSR Demokritos.

**Nikolas Kakizis** received his BSc. in Mech. Eng. & Comp. Sci., his MSc. in Material Science of advanced Composites and his PhD in Material Science and Sensor Systems Integration from the Univ. of London. He is a Project Manager and Research Coordinator for the NCSR "Demokritos".