

# Printed Intelligence

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## ABSTRACT

Printed intelligence offers new ways to enhance paper and board products. In this paper, this technology is defined, its core properties are pointed out as well as its implications for printed media. VTT's activities are described and the business potential of various printed intelligence applications is discussed. Finally, the paper stresses that use of fibre-based and other biodegradable materials is fundamental also in printed intelligence for ensuring a sustainable development.

## 1. INTRODUCTION

The primary function of printing has been and continues to be the delivery of data and information for visual inspection and further interpretation by humans or in special cases machines. New printable materials, print production processes and camera phones are now paving the way for expanding the role of printing toward printed intelligence.

Printed intelligence is not to be confused with printed electronics. While both development streams have very similar visions, and can actively draw on each other, their respective targets and development steps are different. The *printing of electronics* aims at production of electronic devices and components for ubiquitous computing, large area displays and high-volume, low-cost electronics, whereas *printed intelligence* focuses on new functionalities of everyday high volume printable items. A closely related term is **printed functionality**, whose taxonomy is depicted in Figure 1 [1].

**Hybrid media** can broadly be seen to be synonymous to cross media, i.e. the combinations of communication channels, content and user interfaces. However, here we use it here in a more specific sense to mean the convergence between fibers based products (paper and board) and electronic media, most notably mobile phones [2]. A typical application is imaging and interpreting a printed 2-dimensional visual code with a camera phone

and connecting the phone to the web site, whose address is expressed in the code (Figure 2).

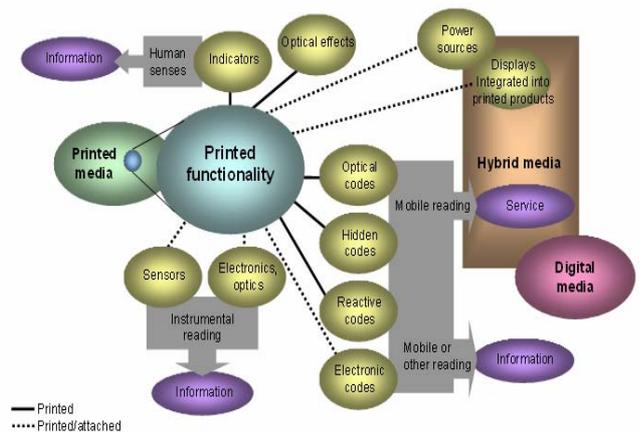


Figure 1. Taxonomy of printed functionality and hybrid media. Printed means that every part of the certain component is made by using printing methods. Printed/attached means that some parts of the component can be done by other means.



Figure 2. An example of a hybrid media application. A camera phone is used for imaging a two-dimensional barcode for accessing a website

Printed intelligence must adhere to the expectations and demands within the printing and packaging industries in terms of high production throughput, fractional added costs per print item, as well as minimal or no impact on environment and human health.

## 2. TECHNOLOGICAL CORNER STONES TO PRINTED INTELLIGENCE

Technologically printed intelligence is based on the application of fluid processable materials onto flexible substrates [3].

Printed intelligence utilizes high throughput and cost efficient manufacturing processes, like continuously running roll-to-roll printing, digital printing, hot embossing, lacquering, coating, laser processing and their combinations.

Such cost efficient manufacturing process know-how is integrated with biotechnology, chemistry, optics, optoelectronics and electronics or their combinations to produce new 'printable' materials and process tooling. These printed intelligent components include e.g. optical/electronic codes and tags, indicators, sensors, bioactive materials, dynamic large area user interfaces, power sources, OLED displays and active opto-electronic devices.

These *intelligent* functions carry out actions on/in the printed item itself, and/or as a part of wider system that can include e.g. external power and computing sources, reading devices and supporting information systems.

### 3. APPLICATIONS BEYOND TODAY'S WORLD OF PRINTING

The application areas for printed intelligence include - but are by no means limited to - hybrid media, smart and active packaging, security devices, disposable sensors, diagnostic devices and functional wallpaper.

Hybrid media is an example of how printed products are becoming integrated into the smart environments and information systems around us. In these environments, printed products are helping us to access and use digital content and services. Thus, the consumption of printed products will become increasingly engaging, entertaining and informative. Printed intelligence will also bring added safety as the products sense the environment around us, content within packages, or just simply verify authenticity of the product. Intelligent printed items will also help save lives and promote health through point-of-care diagnostics and other applications for health care

Printed intelligence will expand printed matter beyond its current application areas.

### 4. RESEARCH AT VTT

VTT's hybrid media research dates back to 1991, when the concept of using a wireless pointing device for calling up additional information from print was presented [4]. This idea was realized and patented several years later in the LINKER system, where a marked word or symbol in

the print was recognized with a handheld device and linked to corresponding web pages [5], [6].

In 1999, VTT started research in printed electronics and optics and their applications. In August 2006, VTT established the "Center for Printed Intelligence" (CPI) as a strategic initiative to contribute to the more effective exploitation of research results for the generation of applications and profitable business [3].

Research projects in printed intelligence at VTT include:

- LINKER, where a prototype for linking Printed content to web pages were developed and Tested by teachers (1995-97).
- PRINTO, which investigated and developed possibilities to fabricate passive and active electrical, optical and optoelectronic elements using roll-to-roll processes (2002-05)
- PRINTACCESS and PRINTINTERACT: convergence of printed and digital media in the printed product through the use of an integrated technology implemented by printing (2003-07)
- TIVIK and HYPERFIT. Multichannel delivery of food product information based on reading EAN codes on packages with a camera phone (2003-07)
- FUNKTIOBISNES: technical innovations and business models for printed functionality (2006-07)
- SUSTAINPACK: innovation and sustainable development in fiber based packaging value chain (2004-08, EC/FP6)
- ROLLED: roll-to-roll manufacturing technology for flexible OLED devices and arbitrary size and shape displays (2004-08, EC/FP6)
- WELFARE: low cost disposable sensor platform for home diagnostics and health care and wellness management systems (2005-09)

### 5. BUSINESS POTENTIAL

Printed intelligence is a technology intensive market in an early stage. However, research and development activity in printed intelligence is increasing and market researchers are forecasting rapid market growth for new printable components.

According to VTT's roadmap of printed functionality [1], the global turnover will grow to 70 Billion € in 2015, about 30 times more than in 2005 (*Figure 3*). OLED displays will retain a significant growth rate 10 years ahead, but will be surpassed by the total sum of materials and manufacturing of other electronic components. Printable sensors will grow rapidly the next years to come, but a slight saturation will take place after 2010.

Hybrid media (here considered also to include electronic paper) has an exponential growth accelerated by the deployment of electronic paper around 2012. Visual indicators on packages have a similar growth curve as hybrid media, but the volume is about the half.

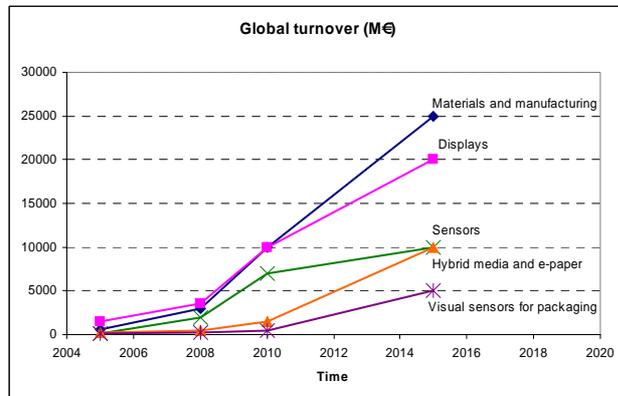


Figure 3. Expected growth of printed functionality in different sectors according to [1].

NanoMarkets [7] has estimated that the biggest growth areas in 2005-2010 in printed electronics will be RFID (cumulative sales 3000 M\$), OLED displays (2900 M\$), backplanes (1700 M\$), memories (900 M€), photovoltaics (850 M\$), smart cards (500 M\$) and sensors (300 M\$). Compared to VTT's forecast, NanoMarkets has estimated that the sensor sector will not be as big. However, NanoMarkets agrees, that OLED displays will be one of the most important areas.

The wide and rapid adoption of mobile phones with embedded cameras has significantly boosted the outlook for hybrid media. While Japan and Korea are forerunners, hybrid media solutions are increasingly adopted in other parts of the world. In Finland, R&D works pursued by VTT and its partners, like UpCode Ltd [8], have led to several commercial hybrid media applications. Recent launchings are in real estate advertising [9], sales catalogues [10], phone catalogues [11] and in newspapers [12].

As venture capital has started to find its way into this sector, new printed intelligence technology companies are emerging to offer printed intelligence components and solutions. Established companies in various fields are evaluating the impacts and possibilities of these new technologies on their businesses. Yet, besides hybrid media, the first commercial success stories are still missing.

Printed functionality, and advances in both optical and electronic reading techniques are expected to improve

usability and increase the role of the printed item in the process. Codes with active components, higher data-capacity, and less visible to the eye are in development.

New printable techniques are being used for security printing and brand protection. Some of these techniques are already expanding towards brand promotion and brand enhancement.

Printed packaging indicators are a promising market, but is still waiting for a killer application helping with the take off.

Printed bio sensing and diagnostics devices are starting to reach the markets.

## 6. IMPACTS AND POSSIBILITIES FOR THE PULP AND PAPER INDUSTRY

The active development and use of fibre based and other biodegradable materials in printed intelligence will be fundamental in ensuring sustainable development while increasing the functionality and performance of printed products.

Printed intelligence introduces new business opportunities for the paper and board industry and their upstream and downstream value chains. While to date, a large portion of printed intelligence developments have focused on the printing and converting stages of the process, interesting developments in coatings and paper substrates themselves will allow for increasingly advanced printed intelligence functionality.

## 7. CONCLUSIONS

Printed matters are given additional functionalities by the application of fluid processable materials onto flexible printable substrates. These printed low-cost and intelligent components enable a large range of new applications, like hybrid media, smart and active packaging, security devices, disposable sensors, diagnostic devices and functional wallpaper. The business volume of printed intelligence is expected to expand exponentially, especially in electronic components, OLED displays and in hybrid media, where the rapid spread of camera phones already is fuelling applications. Fibre-based substrates will be a central material in printed intelligence for ensuring a sustainable environment.

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