Inkjet printed indicators

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Abstract

Inkjet is an exceptionally versatile printing technology, which application areas vary from inexpensive desktop printers for home printing to photo-quality wide format printers for graphic arts applications and ultra-high-speed digital printing machines for transactional and book printing. Because inkjet is a digital method – where liquid drops are generated from a print head driven by computer controlled electronic signals – very small amounts of material can be added and aligned precisely. Inkjet is also the only non-contact printing method, because there is no interaction between the print head and printing substrate during printing. This means that topography of printing substrate or shape of a printed object isn't as critical as it is in other printing methods, which often require relatively planar, smooth and durable printing surfaces. These two features make the inkjet technology especially appealing also for manufacturing applications. VTT has worked with inkjet technology more than a decade in the areas of publication and packaging production. In the end of last decade, we got interested in developing manufacturing methods based on inkjet. One of our goals has been the development of inkjet printed quality indicators.

Optical indicators are based on active compounds, which undergo a definite colour chance depending on changes in exposure conditions. Indicators are used to monitor, for example, food product quality in real time and also remaining shelf-life can this way be better estimated. VTT has developed and patented special ultra-low-cost ink jet printable indicator systems for example in checking the freshness of food supplies. VTT has also developed indicator monitoring systems based on emerging camera phone technology. In this paper, the technologies and the operational environment, in which the new camera phone based indicator applications are developed, are described.

Introduction

The original function of packaging was to protect the product. Today, however, packages have to meet increasingly rigorous requirements. This is especially true of consumer packaging, where one of the main purposes of the package is to market and sell the product. Because of this, packaging is nowadays an integral part of the trademark. Moreover, due to the requirements of the authorities and consumers, packages need to contain precise product and safety information. In the future, packages will become an increasingly important medium of communication. There is also the tempting possibility to use consumer packages as a medium for advertisements.

Manufacturers want to trace their products more accurately and pack shorter series and smaller quantities for different user groups, language areas, etc. The number of packages will increase also in information societies. Future packages will thus be much more multifunctional, informative and demand-driven than they at present. This is why packaging industry companies are interested in all R&D activities that pave the way for future ways of doing business.

Nowadays, an increasingly important task of packaging is to provide greater brand protection, because forgers usually try to falsify the package rather than the product itself. Forgery is estimated to affect over 300 billion dollars of goods annually, which is about 10% of total world trade. The European Union has estimated that as many as 100,000 workplaces have been lost through forgery. Moreover, some forgeries (e.g. pharmaceuticals or spare parts for airplanes) can threaten the health and safety of consumers. Up to 50-60% of medicines can be bogus in some parts of Africa.

Intelligent packaging research

Four VTT-wide themes were launched at the beginning of 2002, one of them was Intelligent Products and Systems. The Intelligent Products and Systems theme was aimed to make synergetic use of new technologies to develop intelligent products and systems which can be applied in future societal and business concepts.

From a holistic perspective, intelligent products/systems have the following features:

- They continuously monitor or perceive their status and environment (awareness)
- They react and adapt to environmental and operational conditions
- They maintain optimal performance in varying circumstances, also in unexpected cases
- They actively communicate with the user, the environment or other products and systems
- Many of these properties result from long evolution in living organisms => in the future, machines will imitate nature (biomimetics) and will be smart or intelligent
- A "smart" system adapts to expected situations in a predictable manner. An "intelligent" system is able adapt to unexpected situations as well (reasoning and learning)

One of the projects in the theme was Active, Communicative Packaging, where the aim was to achieve innovations that will lead to applications that ultimately serve consumers. The main purpose was to develop and integrate active, communicative packaging with an effective logistical system for sensitive and demanding products. The purpose was to develop packages that will give the product the required protection without additives. They will deliver information about the product (its condition and history in every phase of the logistical chain) and control the progress of packages, thus decreasing losses and mistakes. Packages will communicate topical information about the characteristics, usage and state of the product to consumers and consignees in entertaining ways. The idea was to increase the efficiency of the logistical chain while decreasing the use of packaging materials and packaging waste.

New functional characteristics can be created for customer packages in order to create value-added in the package itself (advertising, consumer information and education; edutainment, infotainment, etc.). Value-added can also be created for the packed product (prevention of damage, freshness) or to produce savings for consumers (less waste, no overpacking) and/or suppliers (brand protection, traceability, theft protection, optimisation of the supply chain).

Research and experimental studies for coding and optical and electrical detection systems were carried out in purpose to outline the possibilities of logistical as well as anti-counterfeit systems based on camera phone readable ink jet printed indicators, which can be used for example in checking the freshness of food supplies. It has been predicted that about one billion mobile phones will be sold in the world in year 2007 – and that 90% of these phones will be equipped with a digital camera. So the emerging camera phone technology will be in everyday use for most people in the near future and this development will offer great prospects for the services based on these technology. One of the most potential application area of this multi-billion dollar industry of the future is the packaging products, because these items are extensively used in everybody's everyday life.

Development work of optical indicator systems is continued in a project called SustainPack, which is an EU sponsored research project on "Innovation and Sustainable Development in the Fibre Based Packaging Value Chain", which started in 2004. SustainPack is a pull-driven project, focusing on customer and downstream supply chain needs in order to identify and prioritize research requirements and to integrate other key themes such as sustainability, European competitiveness, legislation and policy.

Cardboard is a versatile packaging material because of its strength, printability and sustainability. However, the requirements imposed on packaging nowadays go beyond its physical ability to protect the product. Qualities such as barrier against gases, fastening by seals, excellent print results and information provision are now almost common practice for conventional plastics. The next step is to develop new innovative solutions to incorporate this range of qualities into renewable raw materials.

The work program for SustainPack is structured around a series of six sub-projects. VTT is actively involved in two sub-projects. In the first sub-project we will determine the market needs and therefore provide direction for the applied research projects. The success of SustainPack will be confirmed through a series of demonstration projects with industry partners delivering commercially and technically viable packaging solutions. In the second sub-project we will develop one- and two-way communicative packaging technologies.

Research environment

The inkjet research environment of VTT Information Technology is based on an up-to-date industrial piezoelectric printing system manufactured by FujiDimatix and a xy-table manufactured by iTi. A laboratory-scale testing environment for the high-speed imaging of inkjet drops is also integrated with the printer system. The impact, spreading, absorption and drying of the ink droplets on the samples can be observed in this testing environment on a time scale of microseconds up to several minutes. Our approach in the inkjet research is that all the printheads and printing systems are production-scale devices, so that the results obtained within the environment can be up-scaled to industrial production.

***Figure 1**. FujiDimatix inkjet printing system integrated with xy-table manufactured by iTi.*

Food quality indicators

One application area of mobile phone readable optical indicators is checking the freshness of food supplies. VTT's patented invention relates to a method non-damaging the package for noticing a change caused by a leakage, the oxygen content and/or deterioration of a product in the package by attaching an indicator to the packaging material using the inkjet technique, which indicator indicates by changing its color a change in the conditions of the package. The system relates also to a method for locating the package using the inkjet technique by means of an identifier formed by the indicator attached to the package. The identifier included in the indicator enables the identification and locating of the packages included in the same batch, and if desired, also the sorting of the products based on this information.

The problem with the earlier indicators in the market is that it is not possible to manufacture and attach them in conjunction with the packaging of the product on a packaging line, instead the indicator is manufactured separately prior to the packaging phase. So the indicators must be stored prior to attaching them to the package as used conventional manufacturing techniques comprise complicated processes which cannot be used on the packaging line of the product. Moreover, the manufacturing, handling and specifically the storage of indicators in which the indicator colour mixture has been put on a separate substrate, such as e.g. an adhesive label or foil, is difficult as they tend to react with the factor that causes the change, e.g. with the oxygen of air.

The objective of the developed indicators is to overcome these disadvantages. One specific objective of the invention is to disclose a novel and simple method for attaching the indicator directly to the packaging material in conjunction with the packaging on the packaging line. Moreover, the method enables the manufacturing of an individual, product-specific indicator on the packaging line.

In the test series, the indicator was attached using the ink jet technique, directly to the surface of the packaging material just before sealing the package and it was noticed that the use of the ink jet technique is very well suitable for putting the indicator colour mixture in the packaging material. The inkjet printing, is a contactless, additive method in which the desired amount of the

material to be printed is transferred into the desired spots of the packaging material by computer control. In the method it is possible to print several different materials simultaneously from several nozzles. The indicator to be attached to the surface of the packaging material is operative when printing, or is brought into working order after the printing.

The technique has the advantage that it is more flexible than the methods in which the layering and embossing are performed using various impression surfaces or masks. For example, the material is transferred only the desired amount to the desired points. The technique in question consumes very little material. The digitality further enables e.g. fast manufacturing of prototypes of electronics systems and small series. As the ink jet printing is a contactless method, the printing head can be freely moved in relation to the printing platform. This enables printing also on non-planar surfaces. The method enables an exact adjustment, but also the printing of big surfaces is advantageous and dependable. Also the formation of in situ layering and three-dimensional structures is possible.

The ink jet technology has the advantage that it is an environmentally friendly manufacturing method. No toxic solvents are used in the method, and the generation of waste is very low. The method is considerably more environmentally friendly than multi-phased evaporation, etching and coating methods. Moreover, ink jet is very inexpensive in respect of costs.

The components of the indicator can be mixed before attaching the indicator to the surface of the packaging material, or alternatively, the components of the indicator can be attached to the surface of the packaging material by steps. After attaching to the packaging material, the indicator can be activated and/or its activating can be accelerated by momentarily subjecting it to conditions that cause and/or accelerate activation. The conditions can be reached e.g. by heat and/or light energy and/or by some other energy or technique suitable for the activation of an indicator.

The indicator attached to a packaging material can react to the oxygen from outside, indicating the ageing of the package. The indicator also reacts through leakage to the oxygen passed into the package. Further, the indicator can function as a deterioration indicator through an indirect mechanism. In that case, the compounds created in the deterioration of the product, can cause the discolouration of the indicator through a suitably selected catalyst, e.g. an enzyme, or through the change in the pH. The susceptibility of the indicator can be so adjusted that no separate, active oxygen remover is needed inside the package. The indicator to be printed can be protected from direct contact with the packaged product using a separately printable protective layer, e.g. a lacquer layer.

The composition of the indicator colour mixture is selected according to the product to be packed from indicator colours and colour mixtures generally known in the field. A binding agent is necessary when printing an indicator on a non-absorbing substrate such as a plastic surface. The binding agent can be selected according to the substrate to be printed and to suit the printer.

The locating of the package is performed by means of the indicator, which is made the identifier individualising the package. The identifier formed by the indicator can be any identifier generally used in the packaging field, such as a two-or three-dimensional identifier. It can further be a compound bar identifier in which a linear, two-or three-dimensional bar identifier has been combined to form one symbol. The identifier can comprise e.g. the batch number and manufacturing time of the product.

The identifier can be read by any automatic reading technique, like a mobile phone camera. The read information included in the identifier can be transmitted by connecting the detection head to a computer, or by using wireless data transfer technologies. Moreover, by means of the identifier, the product data of the package are retrieved from a database, by means of which it is possible to locate the packages included in the same batch with the package. Finally, a sorting decision is made, as the other packages are concerned, i.e. for example, with deteriorated foodstuffs, the packages included in the same batch are recalled.

During the research a software that detects a specially designed indicator that has black frames in the two edges of the indicator was developed. The black borders help the software to find the square and also tell the right orientation it. The software automatically detects the square and takes a picture of it. After this the software automatically calculates the RGB colour coordinates and gives these values to the user. The program can also tell to the user that how much the colour differs from the original colour of the indicator. The system can also give an alarm, if the difference is too big and food is spoiled. The system can also detect squares that are at an angle.

One of the most challenging aspects of the development work has been the development of the right materials to be used in the optical codes. In some cases materials can be selected and unsuitable ones eliminated due to their chemical and physical properties, but in most cases the only reliable way to test the materials is to arrange printing tests. This created many challenges, because bioactive materials used in indicators needed special attention, because in many cases they jammed the printer heads or other parts of the printing system. Another challenge was to keep the sensitive bio-based materials active before, during and after the printing.

***Figure 2**. VTT's internationally patented inkjet printed food quality indicator system. A consumer can check the freshness of a food product by taking a picture of an inkjet printed food quality indicator. After the frame is taken, the mobile phone software automatically interprets the colour information and informs the user of the status of the product.*

An example of an indicator

The objective of the test was to indicate the discolouration of a printed indicator colour by the action of oxygen. The following indicator colouring agent was prepared:

- 25 ml methylene blue/water-solution (10 mg methylene blue/1 ml water)
- 25 ml Na2SO3 (water-solution, 50 mg Na2SO3/1 ml water)

- 10 ml polyethylene glycol 400

The mixture was heated to be boiling and was cooled to room temperature. Lacquer (Sicpa 1100, pH 6.2) was mixed into the mixture in relation 1:1. The freshly prepared indicator colour mixture was put into the cartridge of an ink jet printer and printed using the inkjet printer onto a corona treated bright polyethylene foil. The printed colour was light right after the printing, but got blue by the action of oxygen in 2 hours.

Conclusions

In this article, some areas of VTT's optical indicator and mobile phone research were covered. But the applications of optical indicators and camera phone technologies are practically unlimited. So at the moment we are only at the beginning.

References

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Author Biography

Jali Heilmann (MSc.) is a Senior Research Scientist at VTT. In his Master of Science thesis, he developed new research methods for color electrophotography and he is also very well acquainted with other digital printing technologies, especially ink jet printing. His current research activities also incorporate technical solutions, uses and appliances for smart packages, printed electronics, electronic book technology and other new information carriers like flexible displays. He has also worked as a Visiting Scholar at the University of California, Berkeley between August 2003 and September 2004.