Inkjet Printed Quantitative Indicators

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Abstract

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 this way remaining shelf-life can also 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 quantitative indicator applications are developed, are described.

Introduction

The general trends in packaging production, such as shorter delivery times, larger selections and smaller product quantities, give an impetus to develop package production and packaging logistics. It is also important to develop packages so that they have better product information, a more visible trademark and a more selling appearance. More precise product specifications, better product traceability and brand protection are today required by consumers and the authorities. The number of packages will increase also in information societies

New functional characteristics can be created to the customer packages in order to create value-added in the package itself by utilising the latest digital printing techniques. This means, for example, that personalised and up-to-date consumer information, announcements and advertisements can be as an integrated part of a package. Also totally new kinds of logistic and anti-counterfeit systems, based on the potentiality of digital printing methods, coding and detection systems, and information networks, can be developed for the optimisation of the delivery chain. Brand protection, safety and features ensuring authenticity are important features of packages. VTT has developed new methods for protection, safety and authenticity purposes. One of the developed technologies is the inkjet printed quantitative indicators.

Improving information, traceability, safety and brand protection of packages

One way to add more information for packages is to use different kinds of coding systems for compressing data into a more dense form. These methods can be optical, like visual bar codes or electronic, like RFID tags. Usually these methods can also be used for brand protection and/or theft prevention of packages. The most commonly used linear bar code system is the Universal Product Code (UPC) which is one of the most successful standards ever developed. Originally this code was meant to benefit the retail trade, but over the years its use has also become common among raw material producers, manufacturers, wholesalers, distribution companies and consumers. This code makes it possible to control many activities of product supply chains and to track and identify products all over the world. The downside of the UPC bar code is that it carries only a limited amount of information, usually only twelve characters. For this reason, the normal bar code cannot include real information, but it is a link to a data base where the information is stored.

A two dimensional bar code can act as an independent data base. In this case, information can be read wherever a suitable scanning device for the code can be found. The other benefits of two dimensional bar codes are small physical size, scalability, big capacity of data storage and high data density, good correctness of information and high durability. Two dimensional bar codes can be attached to packages by using stickers or printing them straight onto the packages by means of an inkjet printer.

Two dimensional bar codes are usually used in the manufacturing sector, because more information, even over one thousand alphanumerical characters, can be included in the code. Every 2D code includes an independent data base with total freedom of transportation. This is a great benefit compared to a landline network, because the information can be downloaded wherever the product is. Moreover, special encryption technologies can be used, if the information is confidential. So, encrypted 2D code can be used for the confirmation of genuineness of product. Multi-level confirmation technologies can also be added to the 2D bar codes to ensure that the code will be read right.

Another developing coding system is Radio Frequency Identification (RFID). This technology allows information loaded onto a tag to be transferred wirelessly and without optical contact between a tagged product and an electronic reader. RFID tags use radio antennas which transmit information over a short range. Active tags include batteries so that they can actively send data over longer distances. Passive tags need power from the reader to be activated and to transmit data. Compared to optical bar codes, RFID tags can carry much more information. The biggest benefit of electronic tags is that they make continuous identification, tracking and communication of products possible, when they are connected to a reader network. Because products can be continuously tracked, RFID tags are also used for theft prevention.

The downside of RFID tags is that their price is much higher than the price of printed 2D codes. This means, that RFID tags can't be used in inexpensive consumer products. Because of this reason, we believe, that 2D bar codes will be actively used also in the future. For example, 2D bar code can act as a back up for a RFID.

Two-dimensional bar codes can be decoded by a reading device that has a two-dimensional image sensor. The reading device interprets the coded information into text, sound or video – i.e. to the sensible format for humans. A mobile phone with an integrated digital camera can be used as a reading device for two-dimensional bar codes. The basic idea is to take a picture of the two dimensional bar code. The decoding software installed into the camera phone decodes the information in the bar code and returns to the user the stored information. Anyone equipped with a camera phone can read the information in the code anywhere at anytime.

Two-dimensional bar codes can also be printed with an invisible ink. These invisible codes can be decoded with the mobile phone when using IR or UV light source for making the code visible during imaging. The advantage of invisible two dimensional bar codes is that they can be printed on some graphics depending on the ink used since the bar codes only become visible when needed.

Nowadays, inkjet is the dominant technology when a printing device needs to integrated into packaging line to print small amount of information with very high speed. This information can be for example “best before” dates or information for batch identification like 2D codes. Inkjet devices integrated into packaging line can also be used to print visible or invisible indicators.

At present, protective oxygen-free atmosphere is commonly used in food packages to protect the packed product from spoilage. Because of this, oxygen sensitive indicators can be used inside the package to signal, if the package is intact or not. Different indicators, based on different reactions, have been developed for this purpose. Also indicators, which show directly changes in microbiological quality of the food product, can be used. The most important thing is that there is a reliable and unambiguous correlation of the sensor indication with the product quality. The change should also be easy to understand and irreversible. Some of these indicators are already commercially available, but not in general use. One reason for this is that the price of indicators is too high for common, inexpensive consumer products. If these indicators could be printed directly into package utilising inkjet technology, the price of indicator would be considerably lower. is the inkjet printed quantitative indicators.

As mentioned, one of the most important application areas of mobile phone readable optical indicators is checking the freshness of food supplies. VTT has patented an invention, which 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 colour 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 inkjet 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 theink 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 the printing of big surfaces is advantageous and dependable. Also the formation of in situ layering and three-dimensional structures is possible.

The inkjet technology has also 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, inkjet is very inexpensive in respect of costs.

A quantitative indicator and a camera phone as a thermometer

The aim of the project called INDICA was to build an illustrative and easy-to-use demonstrator, which clarifies the basic principles of quantitative indicators for the parties interested in the utilisation of the technology. To carry this out, a special, reversible heat indicator was developed based on thermochromic inks. Camera phone software was also built for the interpretation of the indicator.

The principle of a quantitative indicator is shown in Figure 1. The data included in a 2D code is used in the interpretation of colour change in the indicator and based on these numeric values a mobile phone, equipped with special software, will give information, instructions or warnings to the user. The indicator can monitor for example temperature, relative humidity, UV radiation etc. It can also be used in checking the freshness of food supplies. The active indicator material must of course be tailored separately for each individual application. There is also a colour calibration field in the indicator, so that the effects of varying illumination in different places can be taken into account.

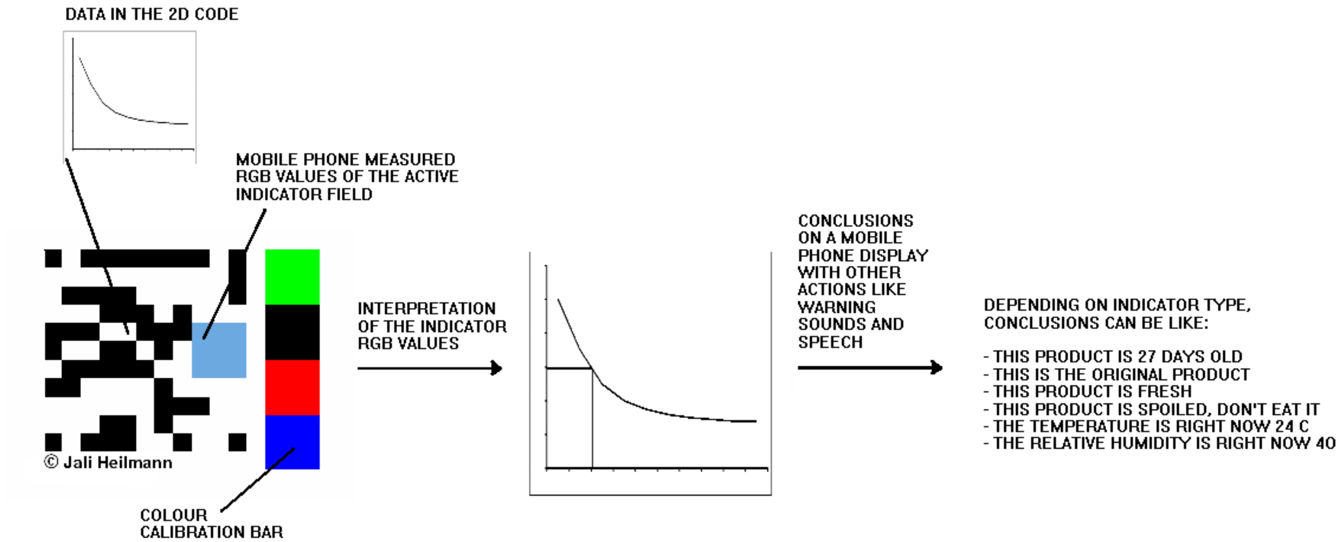

Figure 1. The principle of quantitative indicator. The 2D barcode consisting information on interpretation function of RGB values including threshold values characterising the particular level of indicator colour performance (for example product quality). The colour calibration bar is used to compensate the effects of different lighting conditions

The final indicator mobile phone system can be seen in Figure 2. There is an indicator field in the business card, which changes its colour when heated. The temperature area of this indicator is 23-45 ^{o}C. In ordinary room temperature the colour of the indicator is purple, but it becomes more transparent when heated. The indicator is totally transparent in the 45 ^{o}C temperature.

The action of the demonstrator can be shown, for example, by pushing the indicator against a hot coffee mug. When heated the indicator becomes transparent. When the indicator field starts to cool down, frames can be taken with a camera phone and special mobile phone software translates the colour values into temperature, which can be seen in the display of the mobile phone.

Figure 2. A quantitative indicator as a camera phone readable thermometer.

A quantitative indicator and a camera phone as a moisture meter

One aim of the EU financed project called SUSTAINPACK was to develop low cost humidity and moisture sensors. From this initial research several different approaches for producing low cost visual indicators were identified. The printing of the dye containing inks for the visual humidity indicators could be successfully carried out with inkjet printing. On the basis of the results it became apparent that the printed indicators require a relative inert printing substrate. In order to broaden the range of substrates that can be used with the indicator a preparatory surface treatment is desirable. The development of inkjet printable, enzyme-based composition responding to cumulative effect of humidity and time was carried out. Finally, the system was realised by tailor-made, Symbia-based colour measurement software implemented in a commercial camera phone. In order to transfer the RGB values to corresponding quality the indicator was combined with a 2D barcode. The code consists of information on interpretation function of RGB values including threshold values characterising the particular level of indicator colour performance, which can be translated into product quality.

In order to explicitly link the colour change of the indicator to product quality, an instrumental measurement of the indicator colour has to be carrier out. The colour changes of two different indicators (B2 and B4) on two moisture levels (RH 0% and RH 85%) were measured using two measurement methods. An optical densitometer was utilised to get exact RGB values of indicators. The use of a mobile phone camera for this purpose was also verified during this work. A Nokia 6630 camera phone with special optics was utilised. The average RGB signal change of the indicators was measured in the mobile phone tests. The measurements time was 50 days.

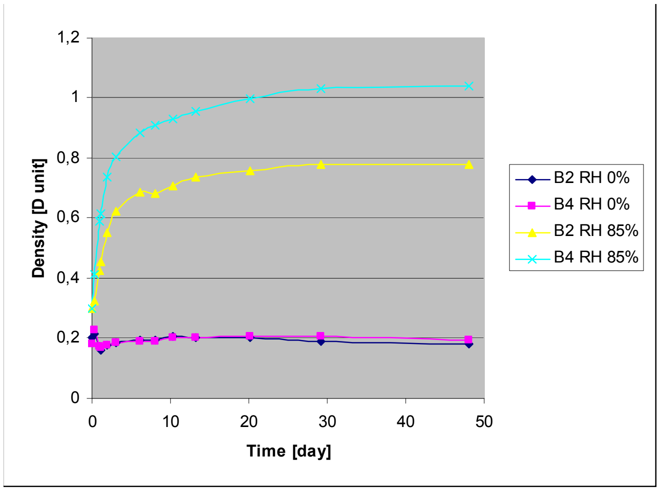

Figure 3. Density of inkjet printed indicators B2 and B4 as a function of time at the moisture levels of 0% and 85%.

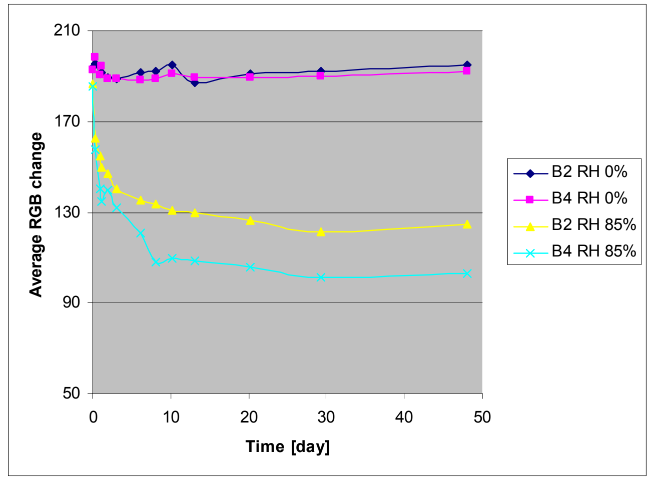

Figure 4. The camera phone measured average RGB change of inkjet printed indicators B2 and B4 as a function of time at the moisture levels of 0% and 85%.

The results of densitometer measurements can be seen in Figure 3. At the moisture level of 85%, both indicators reach their maximum darkness level in a month. In the moisture level of 0%, which means dry conditions, there are no changes in the colour of indicators. The results of camera phone measurements can be seen in Figure 4. Again, in dry conditions, there are no changes in the colour of the indicators. But at the moisture level of 85%, the final darkness level is reached in a month. This proves that mobile phone cameras can be used as a measurement device of optical indicators.

Conclusions

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

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Author Biography

Jali Heilmann (MSc.) is a Senior Research Scientist at VTT Technical Research Center of Finland. In his Master of Science thesis and after graduation, he developed new research methods for colour electrophotography. He has also been dealing with inkjet technology, materials and applications last twelve years. Moreover, his current research activities incorporate technical solutions, uses and appliances for smart packages and publication products, printed electronics, electronic book technology and other new information carriers like flexible displays. He has also worked as a Visiting Scholar in the University of California, Berkeley.