Printed smart card as gift voucher (figures: PolyIC)

Interaction with the User

Printed Smart Objects. Radio-activated displays on thin, flexible plastic films are currently the most important innovation in the field of printed electronics. Such devices can be produced inexpensively in large quantities using modern roll-to-roll processes. They enhance optically attractive, interactive applications, such as product marketing, brand protection and product authentication, as well as games.

KLAUS LUDWIG
HENNING ROST

The idea of printing electronic circuits as easily as printing a newspaper is increasingly fascinating both research teams and the manufacturing industry.

Now that plastic-based organic semiconductors and organic conductors, known as "functional polymers", are industrially available, novel devices, production processes and therefore also innovative new applications are feasible. It is thus possible to combine electronics with almost any industrial product, since printed electronics are produced in the form of thin, flexible films on plastic substrates, and can therefore be used on almost any packaging or tickets.

Translated from Kunststoffe 6/2011, pp. 72–75
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE110763

The above-mentioned functional polymers provide enormous advantages for roll-to-roll production processes, since many of them can be printed from solution, as "electronic ink", so to speak. Consequently, this new form of electronics can be produced with modern, fast printing methods. As a result, electronic applications are becoming available inexpensively in large volumes [1].

Using fast roll-to-roll processes, PolyIC GmbH & Co KG, Fürth, Germany, a member of the Kurz Group, produces flexible, inexpensive electronic parts, such as

- RFID tags (PolyID [2] product line),
- transparent conductive films (PolyTC [3] product line), and
- printed smart objects (PolyLogo product line).

The term "printed smart objects" means a combination of various printed electronic components, such as input elements (switches), displays, energy sources

Fig. 1. Printed interactive optical labels (smart labels) from the roll

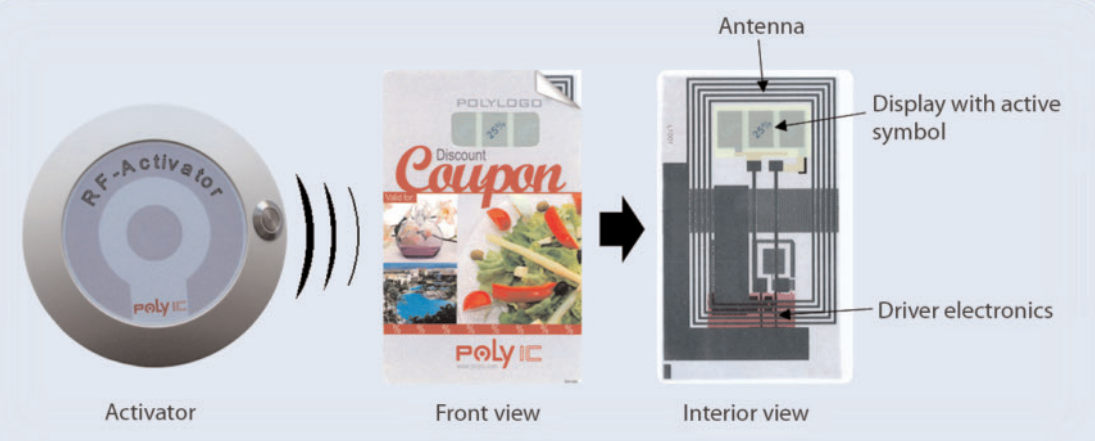

Fig. 2. A radio-activated display consists of a thin flexible display (centre top and top right) with receiver circuit (right) and an activation unit (left)

(e. g. batteries and solar cells), sensors, and control electronics. These individual components can be used to achieve a wide range of new applications. Thus, for example, by combining a printed battery with a logic circuit, an input element and a display, it is possible to construct disposable sensors, games or information displays.

One of PolyIC's first products in the PolyLogo series is a radio-activated display that absorbs energy from radio waves to switch on a display element with predefined information. The product name for radio-activated displays at PolyIC is PolyLogo-RAD.

The PolyIC production process results in a roll that contains the individual smart objects rolled up on a substrate base **(Fig. 1)**. The devices on the roll can then be laminated in cards or packages using standard conversion methods. The above-mentioned low thickness and high flexibility of the smart objects is a big advantage for integrating them into, e. g., entry tickets or vouchers **(Title photo)**.

Mode of Operation of Radio-activated Displays

In discussing the function of a radio-activated display, we will focus on PolyLogo-RAD below. The PolyLogo-RAD system consists of a thin flexible display with receiver circuit and an activation unit **(Fig. 2)**.

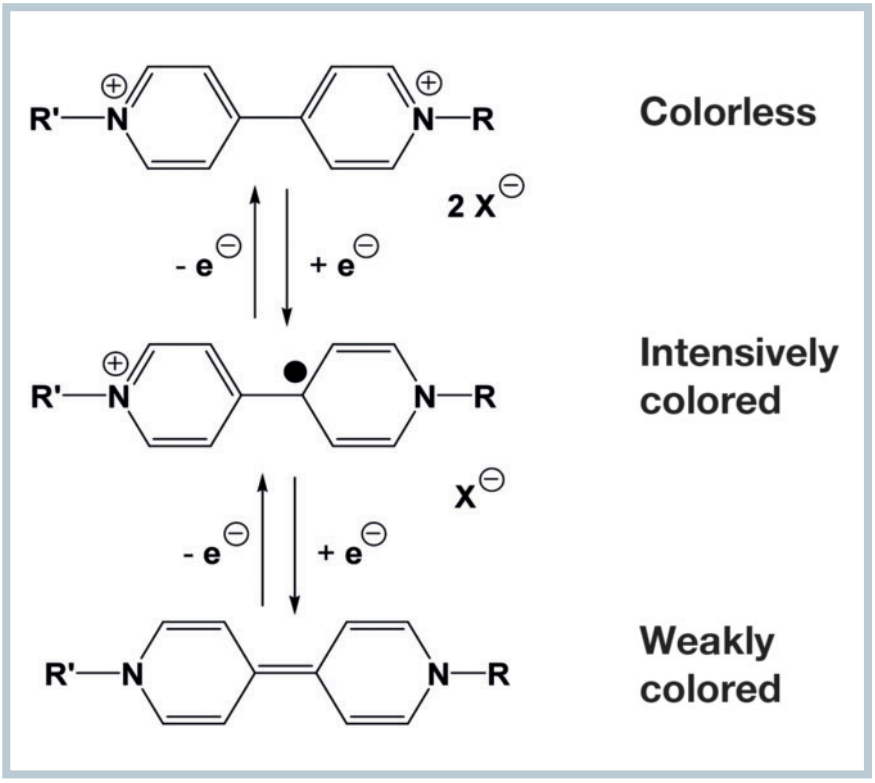

Fig. 3. The redox stages of bipyridyls (viologens) permit electrochromic displays that reversibly change to different colors

From a technical point of view, a radio-activated PolyLogo-RAD label consists of an antenna on a plastic substrate, printed organic driver electronics and an electrochromic display **(see Fig. 2)**. In an inactive state, the information on the display is not visible. The energy required to display the information is transmitted from an activation unit by radio waves at a typical RFID frequency of 13.56 MHz. The emitted radio waves are received by a resonance circuit, consisting of an antenna and printed capacitor, and rectified by a printed rectifier [2]. This allows the printed display to be supplied with the required energy. When the display element is then connected up, predefined information becomes visible, for example in the form of a symbol or logo. If the PolyLogo-RAD is taken out of the radio field, the displayed information is quickly erased and can be repeatedly reactivated.

It is obvious that the printed displays are a very important component of PolyLogo devices, since they are responsible for active communication with the consumer. In principle, there are various technologies that can be used, such as electrophoretic or electrochromic displays.

Electrochromic Systems as Display Elements

For PolyLogo-RAD labels, electrochromic displays are preferably used, as they can be ideally integrated in the roll-to-roll production process. In the application of this electrochromic display, the phenomenon is utilized that the material's optical properties can change when an electric field or an electric current is applied. For example, certain conjugated polymers [3] can be reversibly oxidized and reduced. According to the polarity, certain electrically charged states (radical cations and →

Fig. 4. Radio-activated smart tickets provide automatic admission

Fig. 5. Radio-activated playing cards give an answer immediately

Fig. 6. A previously undisclosed discount or prize is shown by radio-activated prize draw tickets

dications) are generated that have strong differences in their absorption behavior. An electrochromic polymer that is well known to the experts is, for example, the PEDOT/PSS system, i.e. poly(3,4-ethylenedioxythiophene)/poly(styrene sulfonate), which can be switched between weak light blue and deep dark blue by changing its oxidation state [4].

Another interesting electrochromic system is the "viologens", which are based on bipyridylium salts **(Fig. 3)**. They can also be reversibly switched between several different strongly colored states. Ntera Ltd., Philadelphia, PA, USA, already successfully uses this technology in its NanoChromic EC displays [5], which are also used as display elements, for example, in PolyLogo-RAD.

In its simplest form, an electrochromic display element consists of two electrodes, a layer of electrochromic material and an electrolyte layer on a plastic substrate. Note that the upper electrode is generally transparent, so that the user can see the information on the display through this electrode.

The display element switches when a voltage of typically 0.5 to 1 V is applied. As described above, the required d.c. voltage is provided from the printed rectifier as soon as the smart object is held in the field of an activation unit to absorb the required energy. The actual switching operation, i.e. the oxidation or reduction of the electrochromic material with color change takes less than 1 s. The duration of the color state can vary – depending on the material used and the design of the display. The necessary energy for a switching operating is less than 1 mJ for a display area of 1 cm^2.

As mentioned above, such electrochromic display elements can be printed by conventional roll-to-roll printing methods, such as screen printing. The displays manufactured in this way are flexible and have a total thickness of only approx. 20 µm **(see Fig. 1)**.

From Product Marketing to Product Authentication

PolyIC's radio-activated displays permit a novel interactive connection to the user. The user thus obtains a card or package with the integrated display. To obtain the information on the integrated display, which is invisible at first, the user holds the card or package close to a particular activation unit.

The applications are in product marketing, event marketing **(Fig. 4)**, games **(Fig. 5)** or in brand protection and product authentication. In product marketing, PolyLogo cards, for example, can be distributed well beyond the subsequent point of activation, e.g. as an insert in newspapers or magazines. The user is thus motivated to look for a particular store or tradeshow booth to activate the display and access the information. The display can then show, for example, a previously undisclosed discount or prize **(Fig. 6)**. If the scenarios are skillfully chosen, the surprise effect of the active display can combine the elements of a game, marketing and brand protection.

Because of their small size and flexibility, such smart objects can also be processed into tickets in credit card format. This allows innovative marketing campaigns to make use of the potential of printed electronics. Customers can discover the possibilities offered by printed electronics and benefit from their potential. The technology can typically be used, for example, to support tradeshow appearances and publicity or customer loyalty campaigns.

The first field tests with roll-to-roll-produced PolyLogo cards will be the entry into the mass production of radio-activated displays. New product requirements can then be gained from the practical use and integrated into future development work. The functionality of the printed radio-activated display will be extended in the course of development and adapted to the growing possibilities of printed electronics. This opens up a wealth of new applications and markets.

Summary

Interactive optical labels that can be activated by radio waves are an example of innovative printed electronics with high innovation potential. Such smart labels will in future be used in very diverse areas, such as marketing, brand protection and games with high customer benefit. ■

Contact

PolyIC GmbH & Co. KG
D-90763 Fürth
Germany
TEL +49 911 20249-0
→ **www.polyic.com**

REFERENCES

1 Rost, H.: Printed Electronic Circuits: Off the Reel. Kunststoffe international 97 (2007) 5, pp. 60–63, PE103881
2 Rost, H.; Mildner, W.: Latest Advances: On the Way to Printed Electronics. Kunststoffe international 98 (2008) 6, pp. 60–64, PE104275
3 Wörle, J; Rost, H.: Invisible Helpers. Kunststoffe international 100 (2010) 4, pp. 58–61, PE110369
4 Heuer, H.W. et al.: Electrochromic Window Based on Conducting Poly(3, 4-ethylenedioxythiophene)–Poly(styrene sulfonate). Advanced Functional Materials 12 (2) (2002), pp. 89–94
5 Monk, P.M.S. et al.: Electrochromism and Electrochromic Devices. Cambridge University Press 2007

THE AUTHORS

KLAUS LUDWIG, born in 1969, is product manager for the PolyLogo product line at PolyIC GmbH & Co. KG, Fürth.

DR. HENNING ROST, born in 1966, is senior project manager at PolyIC; henning.rost@polyic.com