Printed Electronics for Flexible Applications

Dietmar Zipperer; PolyIC GmbH & Co. KG; Fürth, Germany

Abstract

The application of roll-to-roll printing processes for the fabrication of polymer electronics on flexible films enables the mass production of low-cost electronic circuits and components. Being produced by the successive application of thin layered functional structures on flexible polyester film, the products end up being thin and flexible themselves.

Example applications are discussed, all manufactured in roll-to-roll printing processes. A 13.56 MHz radio frequency rectifier was combined with an electrochromic display into a "smart object" that reveals the display information when brought into an electromagnetic field of an activator unit. Transparent conductive films on flexible substrates were realized by a high resolution roll-to-roll production process with structure sizes down to 10µm. They are suitable to replace indium tin oxide in applications such as touch screen displays.

Introduction

Printed electronics is a platform technology which uses printing methods to produce electronic components and integrated circuits. Compared to conventional printing, where different colors are used to form colorful images, printed electronics involves the printing of dissimilar conductive inks, e.g. conductive, semiconductive, insulating and ferroelectric materials, in a multilayer setup. Organic semiconductors, mainly soluble polymers, play a special role. They enable the control of electrical current flow in diodes and transistors, as silicon does in conventional electronics. Compared with silicon technology the performance level of printed electronics is lower, due to higher integration density and charge mobility attained in silicon technology. The benefits of printed electronics are high speed and high volume production at low cost, and their character of leading to thin and flexible products.

Technology

One promising application of printed electronics in the long term is radio frequency identification (RFID). The feasibility of RFID tags based on the polymer p-type semiconductor poly(3-hexylthiophene) has been proven by a 64-bit RFID tag manufactured using clean-room techniques [1]. Printed circuits, on the other hand, currently show a lower level of complexity and lower performance figures like switching speed or packing density. State of the art in the field of printed electronics are roll-to-roll printed, fully operational polymer RFID chips containing 4 bits of information transmitted by Manchester encoding and supplied by 13.56 MHz rectifiers [2,3].

Besides RFID being one of the driving forces for printed electronics, many other applications emerge using the same technology, which we call the printed electronics platform. The high resolution process, for example, creates electrodes for transistor circuits that are so fine that they cannot be resolved by the human eye. The use of this process to produce metal grids on flexible polyester film enables transparent conductive films [3,4,5], which evolved into a separate product line PolyTC within the last year. It is a suitable replacement for indium tin oxide (ITO).

A promising application is to combine several printed electronic components into one product: e.g. energy sources like antennas with radio-frequency-rectifiers, batteries, solar cells combined with logic circuits, sensors, memory, and output devices like displays. This sort of combination is often referred to as "smart objects", because they connect goods and objects with information.

Printed Smart Objects

One of the first printed smart objects available is a radio-activated display called PolyLogo-RAD [6]. It combines an antenna with resonant circuit and radio-frequency rectifier, and an electrochromic display element. In an inactive state the predefined information on the display is not visible. When being exposed to an electromagnetic field at 13.56MHz the predefined symbol in the display is revealed. The antenna absorbs energy, which is turned into DC voltage by the rectifier to supply the display element the latter thus turning visible, as shown in figure 1. After being removed from the electromagnetic field the displayed information vanishes and can be repeatedly reactivated.

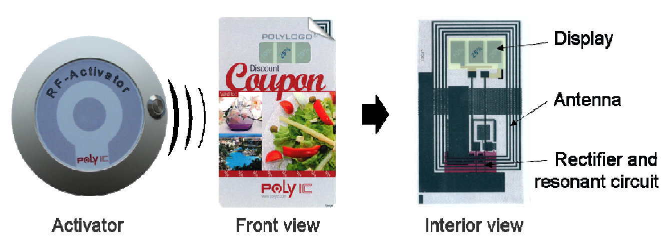

***Figure 1** A radio activated display based on a radio frequency rectifier and a electrochrome display. The display information is revealed when being activated in the electromagnetic field of the activator unit.*

In electrochromic displays a special phenomenon is utilized. Certain conjugated polymers undergo a color change when being oxidized and reduced, which is a reversible process depending on the voltage applied. In PolyLogo-RAD the electrochromic system viologen (figure 2) is used. Viologens are the different redox states of the salt bipyridyl [7]. It was developed by the company NTera Ltd. as "NanoChromics" display. The setup consists of two electrodes, a layer of electrochromic material and an electrolyte layer, which can be printed by conventional roll-to-roll printing methods, such as screen printing. This process can easily be integrated with the polymer rectifier circuit manufactured with the roll-to-roll printed electronics layer stack for RFID tags [3]. The rectifier delivers enough voltage and energy to switch a display area of 1cm² within less than 1 second.

Applications range from games, marketing, brand protection to product authentication. Being thin and flexible such smart objects can be processed into tickets and packaging, or being distributed as insert in newspapers and magazines. Their information is only revealed when the user holds the card or package close to a particular activation unit, located for example at the point of sale.

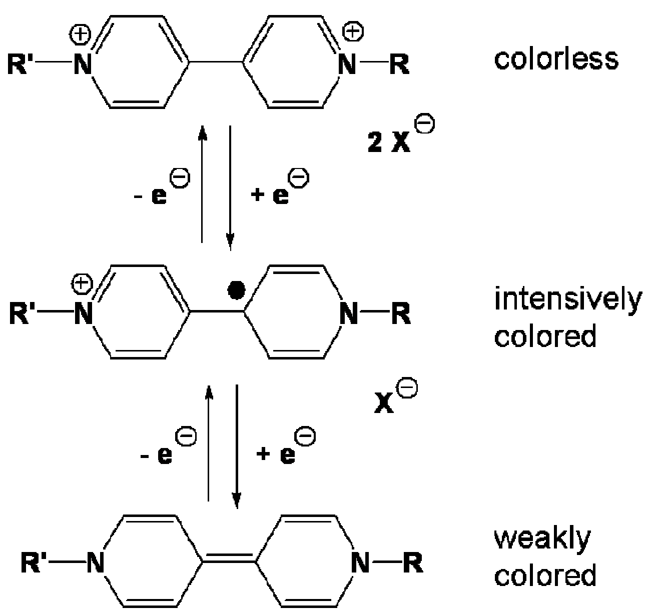

Figure 2 The redox states of the bipyridyl salt (viologen) permit electrochromic displays that reversibly switch to different colors when a voltage is applied.

Transparent Conductive Films

The high resolution roll-to-roll process to print bottom electrodes of transistor circuits enables structure sizes down to 10µm [3]. Beyond a resolution of 50µm even opaque metal structures are not resolved by the human eye and appear transparent. A fine metal grid that only occupies a fraction <10% of the surface thus appears transparent and still provides electrical conductivity to the substrate. The transmittance as well as the conductivity or sheet resistance can be tailored by design. With a sheet resistance between 2 ohm/square and 100ohm/square and a transmittance of up to 95% across the whole visible wavelength range PolyTC films show lower sheet resistance (that means higher conductivity) at higher transmittance than alternative transparent conductors like indium tin oxide (ITO). Furthermore, PolyTC films are thin and flexible, whereas ITO is a rigid material.

These properties make PolyTC an ideal replacement in many fields where ITO is used today. Application examples are resistive and capacitive touch sensors and displays, EMI (electromagnetic interference) and ESD (electrostatic discharge) shielding as well as electrodes for displays and photovoltaics.

Conclusion

Printed electronics is a platform technology to produce thin and flexible products using roll-to-roll printing methods. A radio activated display, PolyLogo-RAD, based on a 13.56 MHz radio frequency rectifier and an electrochromic display was demonstrated. Transparent conductive films PolyTC based on finely structured metal tracks down to a resolution of 10µm show high transmittance of up to 95% at low sheet resistances down to 2 ohm/square.

References

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Author Biography

Dietmar Zipperer studied physics at the University of York, UK and the University of Erlangen-Nuremberg, Germany, where he received a PhD for his work on polymer rectifiers in 2004.

He has worked for Siemens Corporate Technology, Erlangen, before he joined PolyIC at the formation of the company. He works as senior research scientist on the electrical characterization of printed electronics.