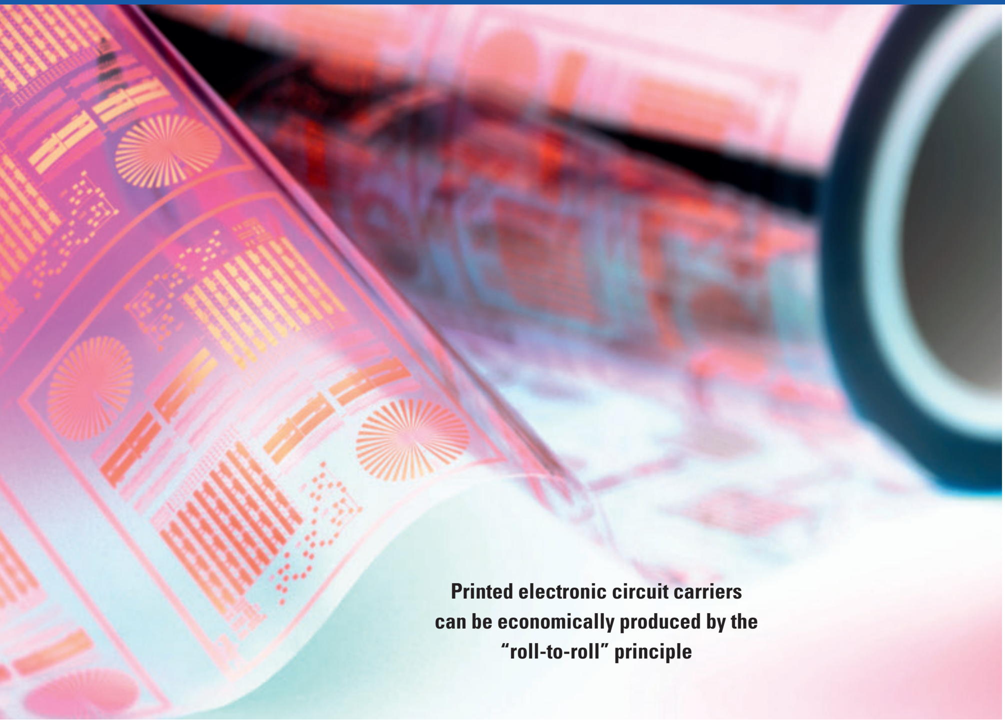

Printed electronic circuit carriers can be economically produced by the "roll-to-roll" principle

Conductive Films. Applications such as displays, touch sensors and ultra-thin heating elements contain flexible, optically transparent films with highly electrically conductive coatings. The conductive material normally used for these coatings today is ITO (indium-tin-oxide). However, this material has to be patterned before use in what is generally a time-consuming and costly process. A newly developed process now offers an economic alternative with better functional characteristics.

Invisible Helpers

JASMIN WÖRLE
HENNING ROST

Printed electronics **(Title picture)** is a general term used to denote electronic components or assemblies that are wholly or partly produced by printing methods. For this purpose, electronic functional materials [1], normally based on special plastics, are used instead of printing inks. By employing modern, high-volume printing methods, production costs are considerably reduced. The possibility of printing large, flexible substrates with new functional materials is opening up applications for printed electronics in areas where conventional (inorganic) electronics have had limited or no access. Thanks to printed electronics, new developments are emerging, for example in applications such as RFID (Radio Frequency Identification) tags [2], displays and solar cells.

Translated from Kunststoffe 4/2010, pp. 82–85
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE110369

PolyIC GmbH & Co. KG, a joint venture between Siemens AG and Leonhard Kurz Stiftung & Co. KG, headquartered in Fürth, Germany, is an industry leader in the development of printed electronics. The principle of printed electronics involves using printing processes to apply electrically conductive, semi-conducting and also insulating materials in several superimposed layers on a polyester film (generally produced from polyethylene terephthalate, PET). Printing is carried out according to a precisely specified design in order to create electrical components and circuits. These are then used in applications such as RFID tags. Here, printed electronics makes it possible to produce low-cost RFID tags for new mass applications. The new technology is also being used in display elements and complex systems known as smart objects.

Printed RFID tags consist of a combination of different individual components. The great advantage of the newly developed technology for producing printed RFID tags is that all the necessary components for integrated circuits can be created through the same layer structure. The production of all the components for the RFID tag can therefore be carried out on a flexible substrate using the "roll-to-roll" principle and requires only a few printing steps. On this basis, it is possible to mass-produce low-cost products. For successful "roll-to-roll" development of printed electronics, many different requirements have to be met in terms of materials, processes, design and testing. All the materials used must have adequate functionality and offer long-term security of supply in high volume (kilogram scale) at low prices.

In the selection of suitable processes, production speed is an important parameter, which must go hand in hand with

Contact

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

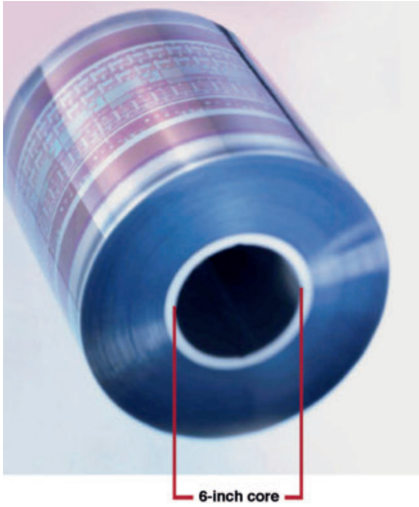

Fig. 1. Production roll printed by the "roll-to-roll" process

Process details	
Typical roll length	2–5 km
Printing speed	> 30 m/min
Substrate thickness	50 µm
Metal layer thickness	20–80 nm
Polymer layer thickness	50–500 nm
Roll weight	50–200 kg
Roll area	1,000–3,000 m^2
Development capacity	1 roll per week
Production capacity	much more

Table 1. Process parameters for a "roll-to-roll" process

low drying temperatures and short drying times. Furthermore, only non-toxic, non-explosive materials and solvents may be used in these processes.

The "Roll-to-Roll" Process

The process parameters for a printed production roll are shown in **Table 1** and **Figure 1.** Above all, a high production speed of > 30 m/min and the possibility of achieving long production runs with the printing processes used are key to serving the printed electronics market – especially in the RFID sector.

For the development of RFID tags, organic field effect transistors (OFETs) with high functionality are required, which can be influenced in particular by high resolution, i. e. small structure size, of the lower electrode level (source and drain electrodes). Over the last few years, PolyIC has succeeded in developing a new process for electrode production, which makes it possible to produce high-resolution, thin conductor tracks by a large-scale "roll-to-roll" operation **(Fig. 2)**. This technology for the production of conductive layers on PET substrates is also an alternative to previously used ITO (indium-tin-oxide) technology. By producing high-resolution structures in µm scale on thin flexible PET films (the typical resolution is 15 µm), not only sufficient conductivity but also sufficient layer transparency can be achieved.

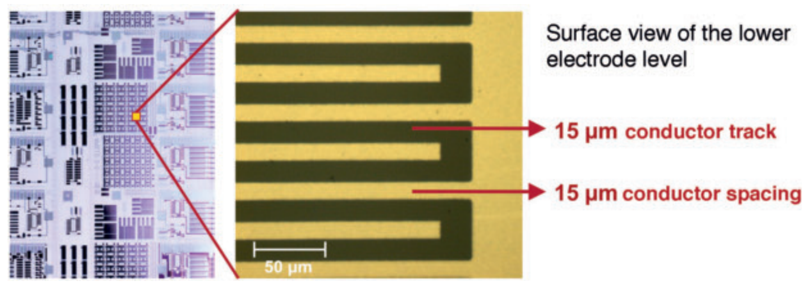

Fig. 2. Results of the PolyIC production process: high-resolution structures on a flexible substrate

Transparency and conductivity can be tailored to specific customer requirements by adjusting the area occupancy ratio of the conductive material (width and density of the conductive structures per square meter of PET film). The conductive materials used are metals, which, depending on the application, can be applied over the total film length and width or as an individual layout pattern. **Figure 3** shows, by way of example, a layout pattern for a transparent, conductive coating.

More Economic Film Coating

Bearing in mind the scarcity of resources, particularly as regards the world's indium reserves, the need to develop new technologies for the production of conductive layers is becoming increasingly urgent. Numerous research and development centers are engaged in the search for alternatives. While there are various projects concerned with new inorganic materials such as zinc oxide (ZnO) and carbon nanotubes (CNT), many companies are also focusing on the development of new polymers as a printable replacement for ITO coatings. The general public know polymers as non-conductive materials. But there is a special class of polymers, referred to as intrinsically conductive polymers, whose conductivity lies between that of semi-conductors and metal, i. e. in the range 10^2 to 10^3 S/cm [3]. A good example of an intrinsically conductive polymer is the PEDOT/PSS (poly(3,4-ethylenedioxythiophene) / polystyrenesulfonate) system.

In comparison with these alternative material systems, the new technology developed by PolyIC for the production of transparent conductive layers on films offers key advantages in relation to transparency and conductivity **(Fig. 4).** The graph makes clear that the PolyIC product can be considered as an alternative to an ITO coating. **Table 2** summarizes the significant technical parameters of the films with a conductive coating:

As already mentioned, the currently used ITO-coated films are to be replaced with a newly developed alternative. The →

! Polyethylenedioxythiophene (PEDOT)

On account of their structure, polythiophenes are classed as electrical semi-conducting polymers. Such polymers can be changed into an electrically conductive form by oxidation. One important polythiophene derivative is polyethylenedioxythiophene (PEDOT). Thin films of the doped, i. e. oxidized form (PEDOT/PSS), are characterized by high thermal, photochemical and hydrolytic stability and transparency in the visible range of the spectrum. PEDOT/PSS is used as an anode coating in organic light-emitting diodes.

Conductive and antistatic, transparent coatings for a wide range of different purposes can be produced as follows: a suspension of the polymer as gel particles in water with polystyrene sulfonate (PSS) as the doping agent is applied to the substrate. Film formation takes place during physical drying.

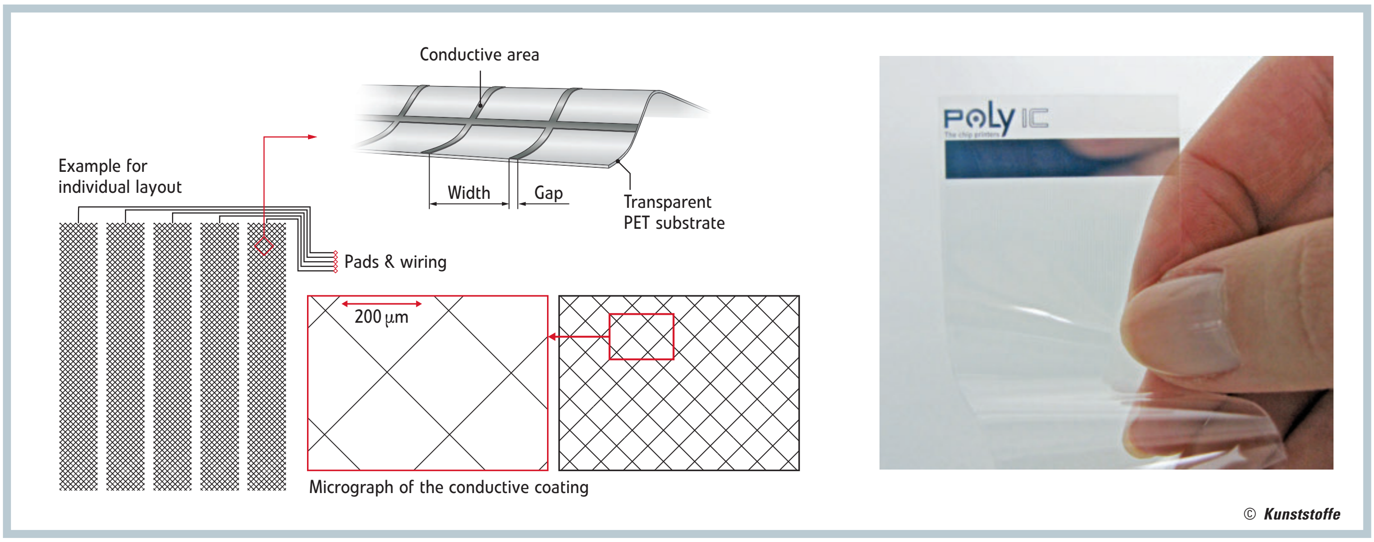

Fig. 3. Layout pattern for a transparent, conductive coating: details of an individual layout (left), pattern (right)

materials being considered are transparent film carriers (preferably PET) with high-resolution, conductive structures. The conductive structures developed by PolyIC have a resolution of 15 µm. They do not need to be transparent themselves, since the necessary light transmission is achieved by the high-resolution structuring. This means that the conductive structure occupies only a fraction of the surface (< 10 %), which allows light-impermeable but highly conductive materials such as silver or copper to be used. Through careful adjustment of the process parameters, resistivity values of 0.4 to 1 ohm/sq can be achieved with the conductive materials used. The conductivity of the transparent area can therefore be individually adjusted to typical values of ITO films, for example. Above all, the consistently high transparency achievable over a wide wavelength range is another advantage of this new technology. **Figure 5** compares the wavelength-independent transparency of the conductive layers of PolyIC film with that of the substrate used and of commercially available ITO-coated film.

Compared with conventional ITO films, the conductive, transparent structures of the PolyIC films offer advantages such as:

- Production of customer-specific, individualized layouts,
- elimination of costly structuring processes,

Properties		Typical values
Transparency (400–800 nm wavelength)		High transparency over the entire wavelength range
Gloss [60°]		90–120 %
Conductor resistance		Adjustable from 0.4–1 ohm/sq
Minimal structure size	Conductor width	Min. 15 µm
	Conductor length	Min. 15 µm
Film thickness (mainly the substrate)		36–100 µm
Substrate		PET
Conductive material		Metals (Ag, Cu)
Supply form		Roll

Table 2. Significant, technical properties of PolyIC films with a conductive coating

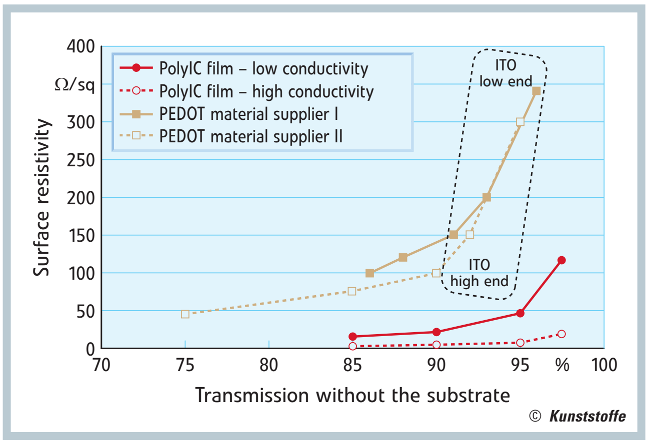

Fig. 4. PolyIC technology: transparency and conductivity as compared with alternative materials

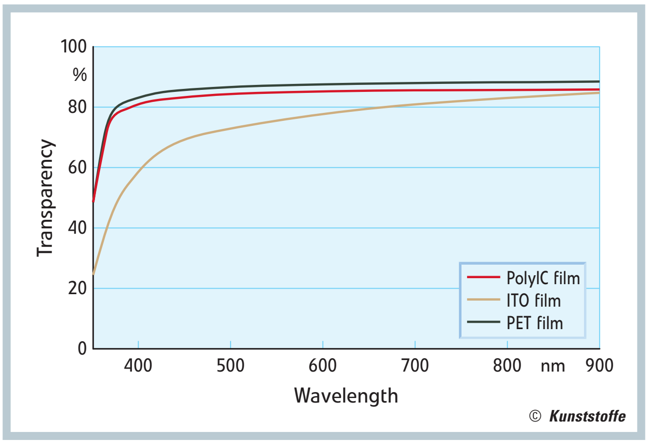

Fig. 5. Transparency of the PolyIC conductive coating as compared with ITO films

- high transparency over a wide wavelength range from 400 to 800 nm,
- individualized conductivity and surface resistivity,
- use of thin, lightweight, flexible PET substrates,
- low-cost product through roll-to-roll mass production.

Conclusion

Both the cost factor and scarce global ITO reserves mean that new technologies are needed to meet the requirements of a continually growing market – especially for displays and touchscreens. Through the use of a "roll to roll" mass production process, conductive films can be produced in large quantities and so cost less than the ITO films previously used. The new technology for transparent, conductive layers developed by PolyIC may therefore be considered an attractive alternative to ITO films. ■

! Indium-tin-oxide (ITO)

Indium-tin-oxide (ITO) is transparent in the visible range and at the same time electrically conductive. It is suitable for the prevention of electrostatic charging, can be used as a thermistor or as a contacting material for electric panels, and reflects infrared radiation. The ITO layer is characterized by resistance per square area (ohm/sq). The layer thickness determines optical behavior. As a highly refractive material, ITO is highly reflective. Additional adapting layers can reduce the reflection.

REFERENCES

1 Rost, H.: Off the Reel. Kunststoffe international 97 (2007) 5, pp. 60–63, PE103881

2 Rost, H. et al.: On the Way to Printed Electronics. Kunststoffe international 98 (2008) 6, pp. 60–64, PE104275

3 Rost, H.: From Polymer Transistor to Printed Electronics. Kunststoffe international 98 (2008) 6, p. 214 (Summary), PE103333

THE AUTHORS

DR. JASMIN WÖRLE, born in 1975, is employed as a group manager at PolyIC GmbH & Co. KG, Fürth, Germany.

DR. HENNING ROST, born in 1966, works as a project manager at PolyIC.