Printed polymer electronics

Alexander Knobloch; PolyIC GmbH & Co. KG; Fürth, Germany

Abstract

Printed electronics can enable very large numbers of new microelectronic products in a cost-efficient way, such as RFID tags and smart objects. Soluble semi-conducting materials are necessary to enable a mass production process on an extremely thin, flexible film.

Results of multi-bit circuits and RFID transponder with poly-(3-hexylthiophene) as p-type semiconductor fabricated completely from roll-to-roll in mass production processes are shown. Process inspection and optimization is a key to successful development. A testing machine capable of electrically measuring kilometers of printed electronics is presented. A yield of 98.5% working polymer field effect transistors within specifications was obtained.

Introduction

Organic or polymer materials with semiconducting or conducting properties open new prospects for fabrication of microelectronic circuits. Many of them can be processed in solution and thus traditional printing processes can be applied. Considerable advantages are high production volumes with even one single machine and a very efficient process, which gives a cost advantage compared to traditional microelectronic circuits. Especially integration and bonding can be identified as cost drivers for conventional microelectronics.

However, printed electronics won't compete with the performance level of Si circuits. The prospect is to enable a sufficient performance in high volumes at low cost on places where there is no electronics today. With the availability of organic semiconductors and conductors, completely new setups and applications can be realized. This will bring electronics closer to everyday products, as they can be produced as thin films on polymer substrates and simply applied on packages.

Technology

Results of printed electronics fabricated from roll-to-roll are presented. At the actual stage of development several kilometers of printed electronics are produced each week. The web speed of each single machine of the fabrication chain is higher than 30 m/min. Thus high volumes can be produced easily and no further upscaling will be necessary. Polymer field effect transistors, capacities, diodes as well as vias and tracks are printed in a top gate set-up. Electrodes with a resolution of 15 µm (channel length and width) and homogeneous layers between 50 and 500 nm are produced. Polymer rectifiers working at 13.56 MHz, multi-bit transponder circuits with Manchester protocol and complete RFID TAGs including the HF antenna were fabricated. These results were based on poly-(3-hexylthiophene) as p-type semiconductor material with a charge carrier mobility of $\mu \approx 0.02$ cm2/Vs. The polymeric devices are very stable and show high electrical performance and lifetime.

Fast roll-to-roll testing of devices and circuits is essential for the development of printed electronics. For process inspection and optimization a testing machine capable of electrically measuring kilometers of printed electronics was built. The web width is several centimeters and a testing speed of up to 30 m/min on a continuous moving web was achieved. Thousands of PFETs were measured and 98.5% of the devices were within the specifications.

First Products

First printed electronics products and prototypes were presented in 2007/08. For example, printed organic radio-frequency transponders were successfully tested at the MEDIA-TECH Expo in May 2008 (Frankfurt, Germany) by the Printed Smart Labels (PRISMA) project [1]. These products have reduced complexities in comparison to silicon-based RFID chips. Recently demonstrators with unique signals like the oscillation of a clock signal or the simple appearance of a display logo were presented. This applications target brand protection, anti-counterfeiting, product authentication, and presence control.

References

[1] Homepage of PRISMA Project: www.prisma-project.de.

Author Biography

Alexander Knobloch studied physics in Erlangen and received his doctor's degree from University of Erlangen for his work on printing of polymer microelectronic circuits at Siemens Corporate Technology. With the foundation of PolyIC in November 2003 he joined the Technology department of the company. He is developing the production process of printed RFID systems as Group Leader Product & Process.