Low-cost all-polymer integrated circuits for low-end high-volume identification applications

Europe is front runner in applied research on conducting and semi-conducting organic materials for applications in microelectronics and optoelectronics devices. Breakthroughs were realised in the University of Cambridge with the invention of the polymer light-emitting diode, and in the CNRS Laboratoire des Matériaux Moleculaires with the fabrication of high mobility organic field effect transistors. Philips and Covion have shown the industrial feasibility of polymeric light emitting diodes for applications in segmented displays.

Organic semi-conducting materials have much lower charge carrier mobility than their inorganic counterparts, such as Silicon and Gallium Arsenide. Consequently, these materials are not suitable for high-performance, high-speed data handling or computational purposes. Instead, their main application domain will be in relatively simple mass-produced, low-end, low-cost, circuits. ***Electronic barcode devices*** *for identification (for example in supermarkets or for airport luggage management),* ***flexible displays*** *for personal computers or dashboards, and* ***electronic paper*** *are some of the potential application areas.*

The Market

Amongst these potential application areas, the most immediate one is in ***electronic tagging***, for services like product identification, supply chain management, parcel transport, anti-counterfeiting, ticketing, and so on. Electronic tagging devices are ***'smart labels'*** that are read out from a distance through a radio-frequency connection. The market, some 50 million smart labels per year, is presently served by silicon based microelectronics devices. Their high cost prevents penetration in a low-end segment where there is a strong demand for (perhaps disposable) ***flexible*** smart labels with limited technical performance. ***Polymer electronics is positioned to satisfy this demand: in-between conventional paper barcodes and high-end silicon devices.*** The market may be expected to grow to some 2 billion labels per year by 2004.

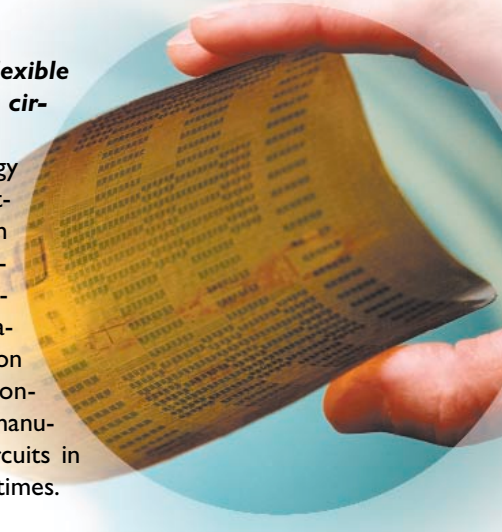
Innovations

The project has realised a number of crucial milestones along the development path towards an industrial plastic electronics technology. ***The project has resulted in 7 patent applications.***

Some highlights are:

- ***Chemical synthesis of the precursor polymer polythienylene-vinylene (PTV).***
  A laboratory process for the synthesis of PTV has been scaled-up to an industrially viable process, yielding kilograms of material. A record value for the mobility for disordered semi-conductors of 5 10^{-3} cm^2 / Vs has been achieved.

- ***Reduction of environmental impact.***
  The project has succeeded to replace the toxic solvent meta-cresol with an aqueous formulation of PEDOT. The chemical composition of polymer devices makes them more suited to standard disposal (combustion or landfill) than their silicon counterparts.



- ***An architecture for flexible polymeric integrated circuits.***
  An industrial technology for polymeric integrated circuits on 150 mm flexible foils was developed. The photochemical process allows feature sizes in the micron range. Vertical interconnect structures allow manufacture of complex circuits in acceptable processing times.

- ***A demonstrator "smart label".***
  A 48-bit code-generator, using 2.5-micron design rule and comprising more than 200 2-Input NAND gates, was demonstrated.

- ***A demonstrator active matrix liquid crystal display.***
  A small 256 grey level active matrix liquid crystal display, driven by polymer transistors, was developed*. This is a major step towards "electronic paper".

* *Nature, Vol. 414, dec. 2001, 599*

The Project Team

The project team is structured to include the multi-disciplinary competencies necessary for the simultaneous development of a general technology and the push towards the particular first application in identification.

Philips Research plays the central role of the technology developer, bringing in the state-of-the-art competence and facilities for device fabrication – device physics, deposition and patterning.

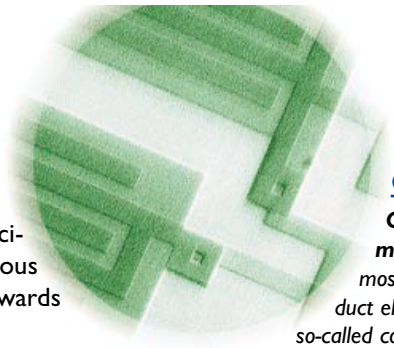
The main exploiting parties are **Philips Semiconductors** – wishing to develop their position of market leaders in radio-frequency identification – and **AGFA** – for whom patterned PEDOT layers present an expansion of their product range in the area of conducting polymers.

Covion is the displays business of Avecia Ltd., one of Europe's largest specialty chemicals companies. Covion plays the key role of up-scaling materials synthesis from laboratory to industrial scale, in accordance with stringent environmental, safety and health constraints.

TNO and the **Limburg's Universitary Centre** took the responsibility for characterisation of materials and devices, as well as for innovative laboratory-scale synthesis methods for the materials.

An application example

A breakthrough in creating the low-cost identification market will be the concept of an electronic barcode transponder linked to the internet. This is an ultra-thin, disposable label containing a polymer chip carrying a unique identification code. It can be read by a "base station", through a radio-frequency link. The chips can be used to connect the world of products (parcels, goods) to the virtual world of the Web. For example cooking recipes could be displayed and downloaded from the producers web site upon scanning the chip on a food package.



Glossary

Organic and semi-conducting organic materials: *organic chemicals (containing mostly carbon and hydrogen), which can conduct electricity. An important class contains the so-called conjugated polymers.*

PTV: *poly-thienylene-vinylene: a semi-conducting conjugated polymer.*

PEDOT: *poly-3,4-ethylene-dioxy-thiophene: a conducting conjugated polymer.*

Interconnects: *the electrical connections between different active layers on an integrated circuit.*

Code-generator: *an integrated circuit that, when prompted, responds with a 1/0 code of a given length.*

2-Input NAND gate: *one of the basic logic elements of integrated circuit technology.*

Active matrix display: *a display in which each pixel is controlled by an individual transistor.*

Low-cost all-polymer integrated circuits for low-end high-volume identification applications

Plastronix
Contract number: G5RD-CT-1999-00011

Start date: 01.01.2000 End date: 31.12.2001
Duration: 24 months
Project cost: 4.17 million euros Funding: 2.20 million euros

Project co-ordinator:
Dago de Leeuw
dago.de.leeuw@philips.com

Philips Research *Eindhoven (NL)*
Corporate research lab
http://www.research.philips.com/

Agfa-Gevaert *Antwerp (B)*
Manufacturer and supplier of photographic and imaging products
http://www.agfa.com/

Covion Organic Semiconductors *Frankfurt (D)*
Developer and supplier of organic semiconductor materials
http://www.covion.com/main/company_profile.asp

TNO *Delft (NL)*
National research organisation
http://www.tno.nl/

Limburgs Universitair Centrum *Diepenbeek (B)*
University
http://www.luc.ac.be/

Philips Semiconductors *Gratkorn (A)*
Manufacturer and supplier of semi-conductors
http://www.semiconductors.philips.com/

Useful links

http://www.cordis.lu/nanotechnology/home.html
http://europa.eu.int/comm/research/growth/
http://www.cordis.lu/growth

growth infodesk: growth@cec.eu.int

Release May 2002

KI-AC-02-002-EN-C