Printed Electronics – from Vision to First Products

RFID SysTech 2007, Duisburg

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Printing meets Electronics Industry

Quelle: MAN

Quelle: Infineon

Printed Electronics

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PolyIC – The chip printers

Printed electronics make

- Thin and flexible
- Inexpensive and simple
- Pervasive and disposable

Electronics come true

Challenges
Parameters to achieve high performance and reliable printed electronics

- Often simplified to
  - single parameters (e.g. mobility or channel length)
  - simple functionality (e.g. transistor performance)

- Optimization of single parameters influence the whole system

  - Complex system of about 40 parameters
    - to be measured, managed and optimized
Four Dimensions of controlled parameters

- Logics
- Physics
- Chemistry/Materials
- Geometrics
Four Dimensions of controlled parameters

Logics
- Basic Components
- Circuit concepts
- Circuit Modeling and Simulation

Physics
Influence of
- Channel length + width
- Capacities (e.g. overlap)
- Interfaces
- Ambient conditions (Temperature, Oxygen, Humidity)

Chemical/Material
- Mobility, Work function
- Contact resistance
- Regioregularity, Mol-weight
- Adequate solvents

Geometric
- Dimensions
- Layer Thickness (conductor, semi-conductor, dielectric)
Next level of complexity - Printing

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Geometrics
- Dimensions
- Layer Thickness
  (conductor, semi-conductor, dielectric)

Printing
- Process
- Formulation
- Throughput
- Scale-Up
- Quality Control

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Understanding and Optimizing a model for Printed Electronics

- Target of PolyIC
  - Understand the parameters and their influence
  - Build a system model
  - Optimize the model for future circuits
  - Extend the model to printing processes

- Progress
  - Performance
  - Components per Circuit
  - Milestones to Application: Approaching Printed RFID
Parameters are identified and developed for the 1st generation of products

**Logics developed**
- Simulation and Modeling Software developed
- Polymer based circuits for RFID tags demonstrated (125kHz, 13.56 MHz, 8Bit@7.5cm)

**Physical Parameters identified**
- Lifetime >> several month
- Survived 85/85/85 test
- Circuits work at LowVoltage (10-20V)

**Chemistry / Materials identified**
- Identified 1st Generation Material Set
  - Polythiophen
  - Polyester
- conducting and insulating materials

**Geometrical parameters achieved**
- < 20µ channel
- Overlaps
- Layer thickness
- Registration
Parameters are identified and developed for the 1st generation of products

- Combined, continuous Roll2Roll Processes (Min. 20m/min)
- First methods for Quality Control established (inline / optical / electrical)
The Fabrication of Polymer ICs at PolyIC

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| Results             | Development of Chip Design and Materials                                  | Identify & Test Formulation for     | Low cost high volume Product$     |
|---------------------|----------------------------------------------------------------------------| Printing Process                    |                                  |
| Speed               | Development of Chip Design and Materials                                  | Fast Circuits & Rectifiers          |                                  |
| Yield               | High Yield & Stability                                                    | High Yield & Stability              |                                  |
| Stability           | RFID Demonstrators                                                        | Stability                            |                                  |

| Goal                | Development of Chip Design and Materials                                  | Identify & Test Formulation for     | Low cost high volume Product$     |
|---------------------|----------------------------------------------------------------------------| Printing Process                    |                                  |

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The chip printers

Milestones to Application: Approaching printed RFID

- Q4.2004: 125kHz 1Bit RFID
- Q3.2005: First 13.56MHz RFID
- Q3.2006: First printed circuits for 13MHz Tags (RF, Ring Oscillator)
- 13.56 MHz Printed RFID

Demonstrator

Roll-to Roll Printed
PolyIC presents Miles of printed MHz Tags

- Prototype
  13.56 MHz RF Tags
  - full flexible and thin
  - Roll-to-Roll manufactured with adapted printing processes
  - High Speed (up to 20m/min)

- Roll-to-Roll printed logic circuits
  - Ring Oscillators
    (needed for 13.56MHz RFID Tags)

- First demonstration and show at OEC06
  Sep 25-27, Frankfurt
Polymer 8-Bit 13.56 MHz RFID-Tag with 7.5 cm reading distance

Inductive coupled RFID Tag with 13.56 MHz rectifier, clock generator, counter, multiplexer, 8-bit ROM and modulator:

- 16 Bit: 8 protocol & 8 data bits: 00000000-10111011
- ~0.1 s read time
- 7.5 cm reading distance
- measured 3 month after fabrication

All layers and devices are made of polymers except antenna, tracks and electrodes

Reader operating with only 1.2 W power supply (allowed 2 W)
Polymer 64-Bit 13.56 MHz RFID-Tag with 3 cm reading distance, inductive coupled

**Detail:**
- 64 Data bit followed by 64 "Zero" - bits
- Bit width: 6.5ms → 420ms @ -16V for 64-bit
- Bit width: 8ms → 520ms @ -14V for 64-bit
- Chip area ~ 35mm²
- Supply voltage min. -14V
- Reader / RFID distance ~ 3cm
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Electronics come true

Applications
Printed Electronics open new markets

- Barcode
- RFID Tag
- Item Level Tagging
- Smart Objects
- Consumer Electronics

System costs, approx. (€)

- $10^{-2}$
- $10^{-1}$
- $10^{0}$
- $10^{1}$
- $10^{2}$

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Why Printed RFID?

Content Verification
- Check if a box contains a product

Electronic Authentication
- Check if a product is a counterfeit

Tracking & Tracing
- Track a product through the supply chain from production to the retail store

Inventory Control
- Acquire product data automatically without human interaction
Our two product line trademarks: PolyID™ and PolyLogo™

- RFID
  PolyIC – product line PolyID:
  ![RFID Chip](image)

- Smart Objects and Display
  PolyIC – product line PolyLogo:
  ![Display Chip](image)
Our long term target applications: PolyID™: EPC – PolyLogo™: Smart Cards

EPC™ (Electronic Product Code)
- Applications
  - Item Level Tagging
  - Supply chain
  - Inventory Control

Smart card / Intelligent sensor
- Applications
  - Single use sensors
  - Combined optical / RFID function
  - smart package
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