

# Printed Intelligence- Applications and Technologies; Low cost diagnostics

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Business from technology

**NANOPHOTONICS-PRINTED OPTOELECTRONICS,**  
Oulu 07.05.09

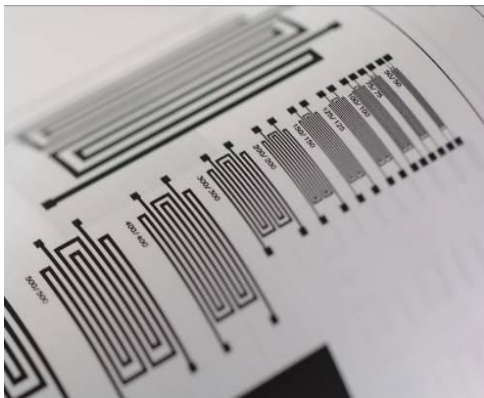
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# PRINTED INTELLIGENCE

## *Starting idea*

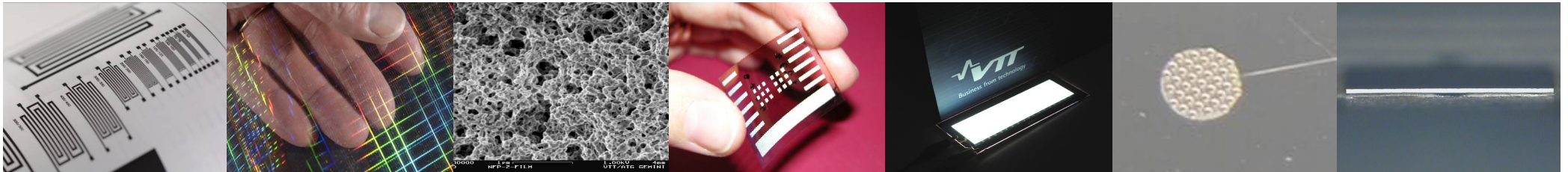
- New technology driven innovation at the cross sections of the paper and electronics industries:
  - ⇒ manufacture electronic components utilizing roll-to-roll production techniques (***printed electronics***)
  - ⇒ printing of new functionalities into high volume low cost packaging and printed media applications (***printed functionality***)



## PRINTED INTELLIGENCE

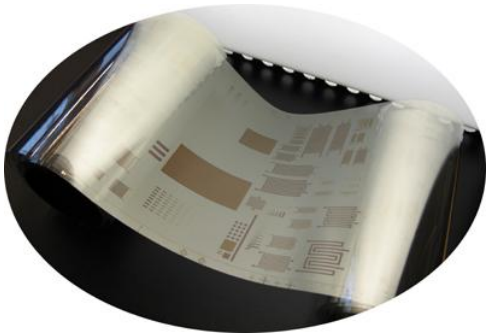
- Printed intelligence are *components* and *systems* which:

**extend the functions of printed matter** beyond traditional visually interpreted text and graphics

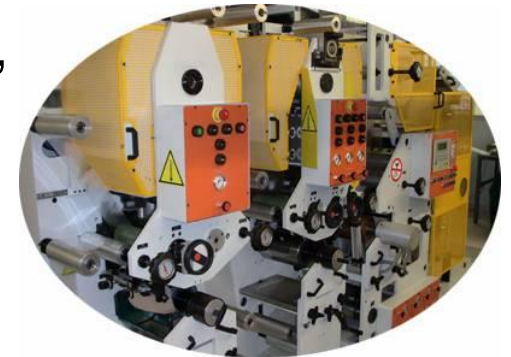


- The functions perform actions
  - on/in the printed item (functional product)
  - as a part of wider system (e.g. external power & computing sources, reading devices, supporting information systems)

## PRINTED INTELLIGENCE IS BASED ON



- electronics, biotechnology, chemistry, optics, optoelectronics
- fluid processable materials technology
- large area high-volume printing like mass-manufacturing methods



**Generic,  
enabling  
technologies**

***Components, circuits, integration-on-web, systems-on-foil,  
embedding 'electronics from inks' into products***

***R2R to hybrid processes & production equipment***

***Materials***

+ possible interconnections of printed systems to wider IS/IT-systems

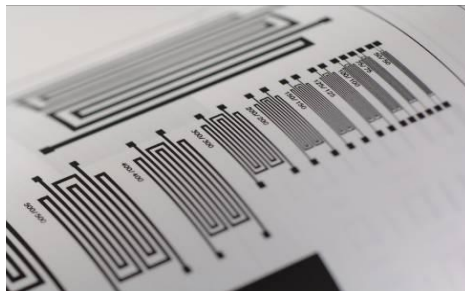
## COMPONENT EXAMPLES

- **Component categories:**
  - passive electrical and optical
  - active electronic and optoelectronic
  - sensors and indicators
- **Components can be integrated on web, sheet or foil to printed systems**
  - OLED displays and signage
  - printed organic transistor circuits, multilayer electronic circuits
  - memory devices
  - solar cells, miniaturized fuel cells ... etc.



*Gravure printed organic solar cells*

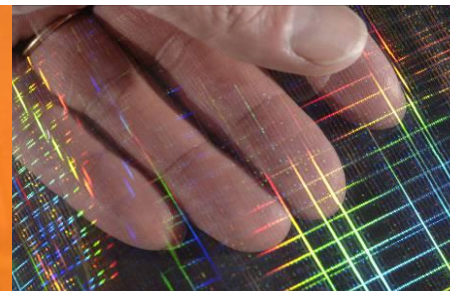
*Printed disposable fuel cell*



*Passive electrical components*



*Printed organic light emitting device (OLED)*



*Holographics produced directly into packaging materials without stickers or laminations*



*Printed electrical code and reader*

*(Nicanti authentication solution)*



*Optical codes for linking physical and digital media*

## VTT Center for Printed Intelligence

technology | applications | business

- **is a growth oriented strategic VTT initiative**

➔ 55 person years per year in 2006

➔ 100 person years / 2009

- **combines multidisciplinary know-how of VTT:**  
electronics, optics, biotechnology, nanotechnology,  
chemistry, printing, P&P, process automation
- **has a strong established partnership network to  
research and industry**
- **strongly orientated towards applications and  
business**

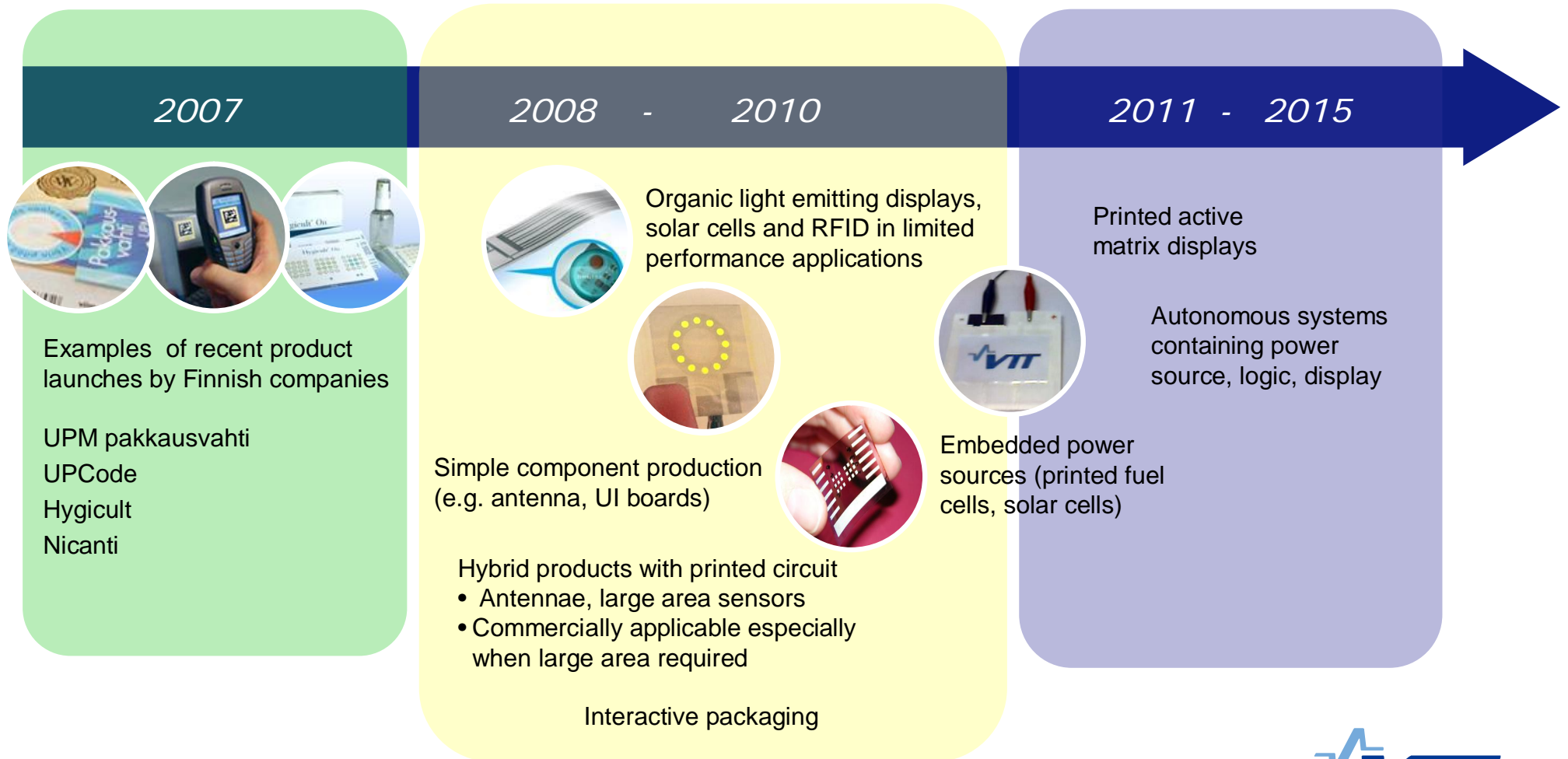
➔ **Vision**  
A globally leading  
innovation center  
in the emerging  
printed intelligence  
markets



For more information see <http://cpi.vtt.fi>

# PRINTED INTELLIGENCE TECHNOLOGY TIMELINES

## “technology ready in-lab”



## PRINTED INTELLIGENCE AN EMERGING MARKET

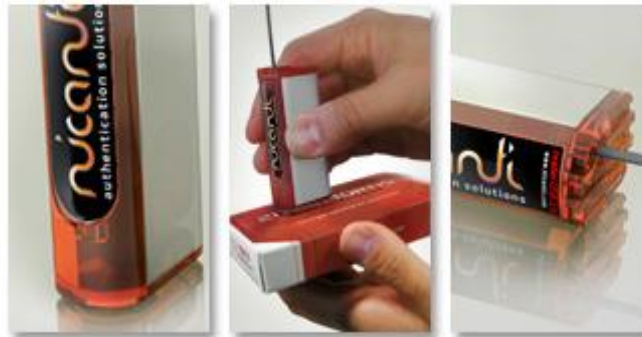
- Printed intelligence is a new emerging market.
- There is roughly a decade of R&D efforts to date in this space but the market is still in its early stages of commercialization. First end-market applications based on printed intelligence technologies, for example, in displays, hybrid media, brand authentication and diagnostics, have already been brought to market.



- *Printed intelligence* is not yet identified in market reports but elements of this can be found in “printed electronics” and “disposable electronics” reports.

## Case: NICANTI

- Nicanti Oy (est. 2007) is commercializing an electrical coding and reading technology initially for product authentication purposes.
- Codes based on almost transparent inks with electrical properties, which are read with special handheld reader.



[www.nicanti.com](http://www.nicanti.com)

- Printed invisible codes:
  - do not visually disturb other graphics
  - printed with standard printing processes over large areas
  - low cost of tags, suitable for very high volume applications
  - virtually impossible to copy

# Pioneering R2R pilot manufacturing machinery for printed electronics and intelligence



**3 printing unit pilot line,  
2003, Oulu**

*Gravure, hot-embossing,  
lamination*

*20 cm web*

*100 m/min max.*



**4 printing unit pilot line,  
2007, Oulu**

*Gravure, reverse gravure, flexo,  
rotary screen, lamination*

*Printing units in register*

*30 cm web*

*10 m/min max*

*Inert atmosphere printing*



**Coating pilot line, 2008,  
Espoo**

*Roll coating, spray coating*

*Single process components can  
be connected as desired*

*Coating width 500 mm (adjustable  
between 200...500 mm)*

*3...90 m/min*

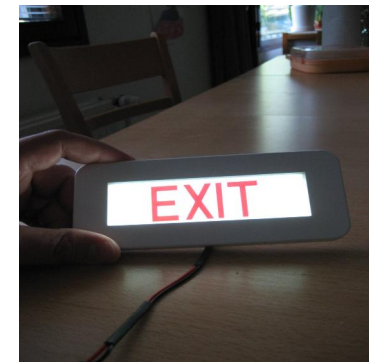
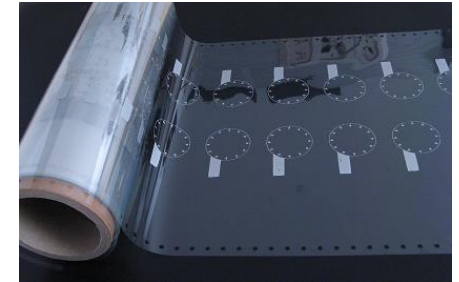
*Substrate 40...300 g/m<sup>2</sup>*

*Coat weight 0.1...400 g/m<sup>2</sup>*



## Results: R&D, most important

- **Generic technologies, materials and manufacturing processes**
  - Printed materials; conductive Al-ink, biocompatible ink, organic semiconductor material for transistor application, nanoparticulate inks
  - Manufacturing processes and machinery; advanced registration control, web handling and quality measurements for pilot machines. R2R laser processing environment. Electric sintering evaluated as a new manufacturing method.
  - All-R2R printed flexible OLED demonstrator ( 1st in the world) and >30 cm<sup>2</sup> OLED lighting element printed on glass - EXIT-sign.
  - R2R-manufacturing/printing technologies for printed organic solar cell, printed transistor, printed memory, large area MEMS-display and printed biofuel cell



## Results: R&D, most important continues

- **Consumer packaged goods**

- Heat activated oxygen indicator, pat.pend.
- Humidity indicators demonstrated, pat.pend.
- evaluation of a time-temperature indicator
- License; printed oxygen indicator for Japanese market



- **Bioactive paper and diagnostics**

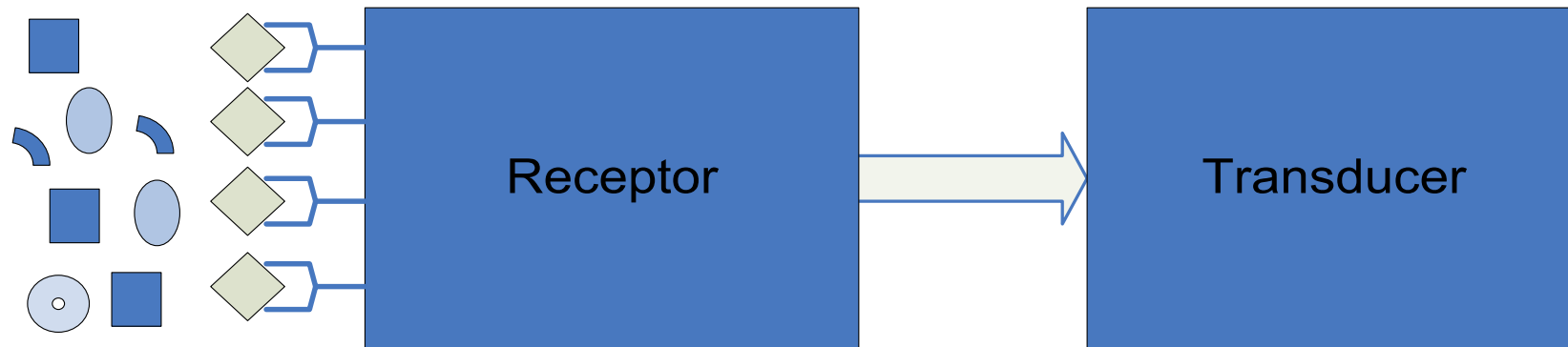
- Initiated a remarkable national bioactive paper joint project and network collaboration to Canadian Sentinel-network
- Disposable biosensor platform, 2 pat.pending
- Printed filter and indicator demonstrators



- **Media and ICT applications**

- Optical and electrical code based ICT/hybridmedia applications
- Printed electric sensor, indicator and RFID solutions, ink-jet interconnection technologies

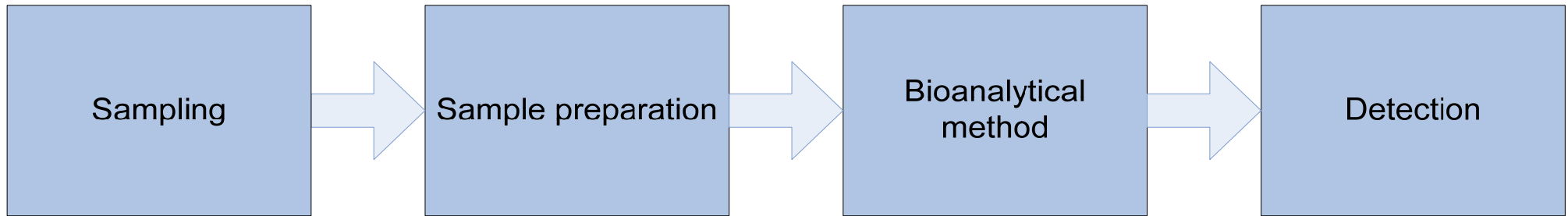
## BIOSENSOR



- Polymer
- Enzyme
- Antibody
- Micro-organism
- Cell
- Tissue

- Potentiometric
- Amperometric
- Capacitive
- Optical
- Thermal
- Acoustic
- Resonator

# Bioanalytics



Lysing  
Dilution/concentration

DNA/RNA  
PCR  
ELISA  
Immunoassay  
Competitive/non-competitive

Electrical  
Optical  
Mass  
Acoustic  
Thermal



<http://www.pelikantechnologies.com>

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# Development needs and trends - bioanalytics

KITS & plate readers

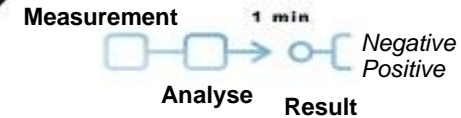
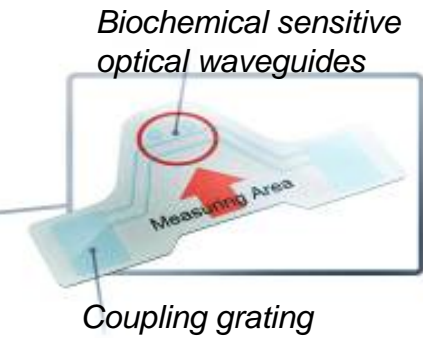


## Bioanalytics today

- Analysis time -> hours - days
- Trained personnel
- Single analyte
- Sample treatment separately
- Laboratory analysis (centralised)
- Culturing
- Si/glass microfluidics
- High cost – low volume



## MULTIANALYTE SENSOR

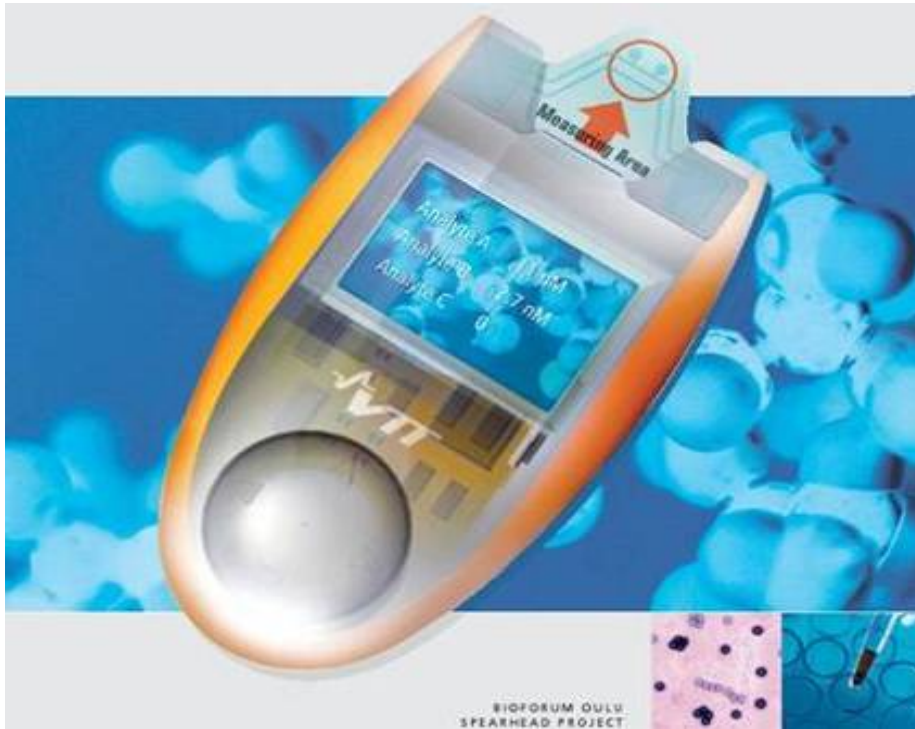


## Future trend

- Analysis time -> minutes
- Easy to use
- Multi analyte
- Sample treatment integrated on chip
- Point-of-care analysis (decentralised) -> Home Care
- Biomolecular diagnostics
- Polymer microfluidics
- Low cost – high volume



## Rapid diagnostics markets



### Point-of-care diagnostics applications:

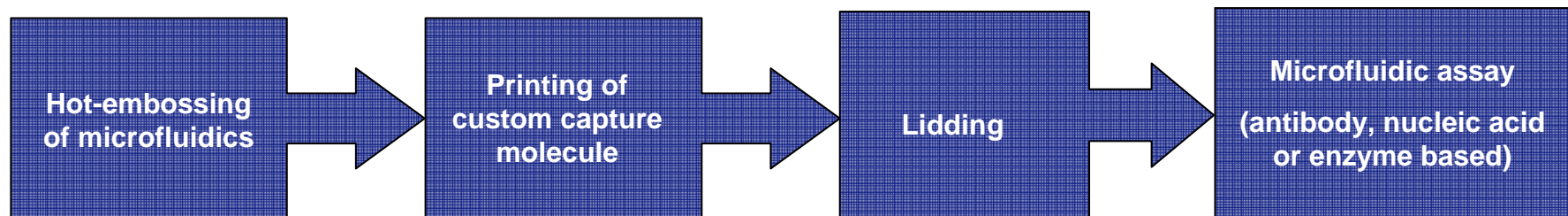
- Drug screening (abuse and overdose)
- Cardiac markers (heart attack)
- Infectious diseases (pathogen identification; genotyping of HIV)
- Blood lipids (cholesterol, triglycerides, and lipoproteins HDL, LDL and their ratios)
- Tumor markers (including biomarkers)

*New and cheap measurement sensors and instruments and quick analysis methods are required in many application areas and foremost in point-of-care diagnostics. The development of sensors is aimed at decreasing the cost of individual laboratory tests and reduce the diagnosis time.*



# Technologies for low-cost diagnostics

- **Printed microfluidics** on flexible substrates by hot-embossing.
- Printing and **immobilisation** of biomolecules.
- Development of **printable biocompatible surface materials** which enable long term storage of bioactive molecules on biosensor surfaces and retain their activity in harsh conditions met in printing processes
- Development of **bioanalytical instrumentation** and **optical measurement systems** for life science applications:



- sample handling (e.g. filtering, mixing)
- sample transport

- analyte detection
- antibodies
- recombinant Abs
- enzymes
- biocompatible sol-gels

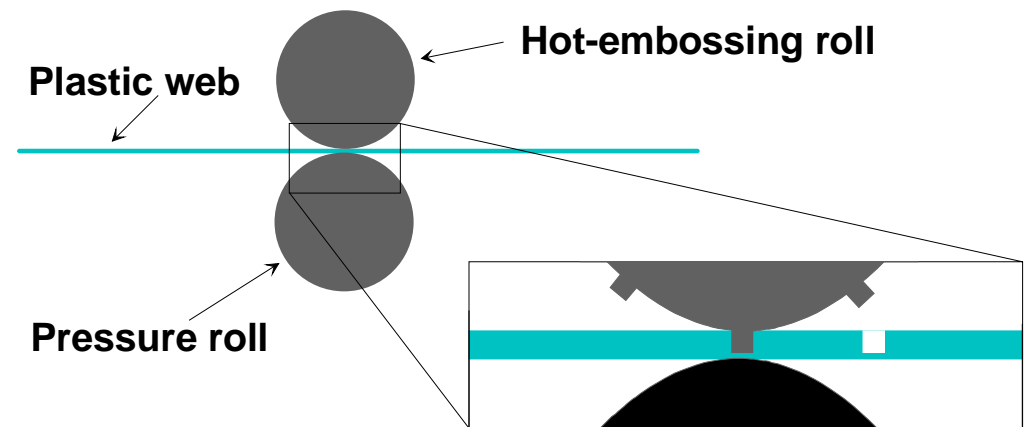
- packaging
- biocompatible lamination
- integrated printed electronics and optics

- sensitive and selective detection methods
- qualitative
- quantitative
- digital output



## R2R hot-embossing principle

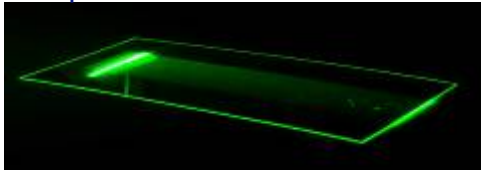
- Mechanical structures are embossed under pressure and heat on thermoplastic (or paper) web.
- Polymer foil is heated over its glass transition temperature  $T_g$  but lower than its melting point  $T_m$ .
- Embossing cylinder material: electroplated Ni shim or laser or e-beam fabricated surface



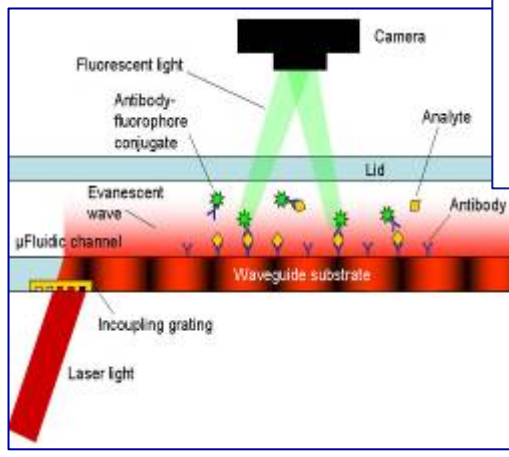
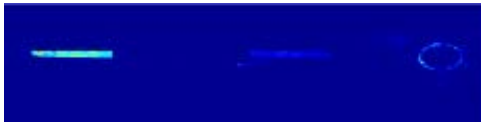
# Current research activities

## Low-cost disposable biosensor platform

R2R manufactured optical components

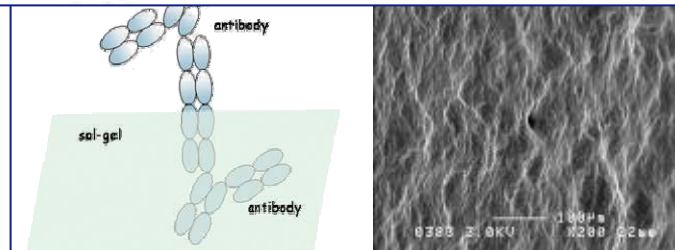


Detection using fluorescently labeled antibodies

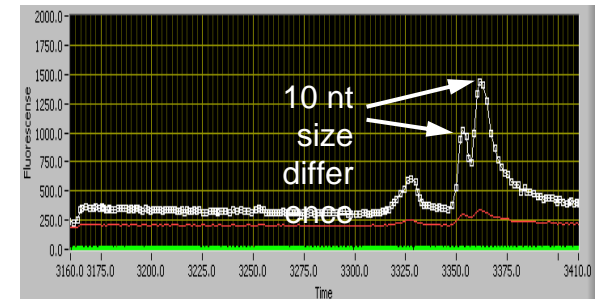
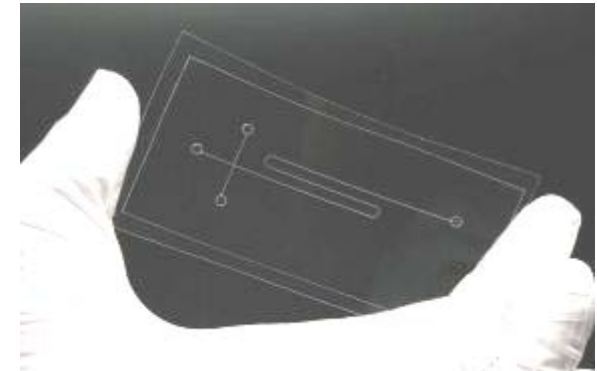


## Enzymatic color reaction on paper

### Integrated all-polymer structure



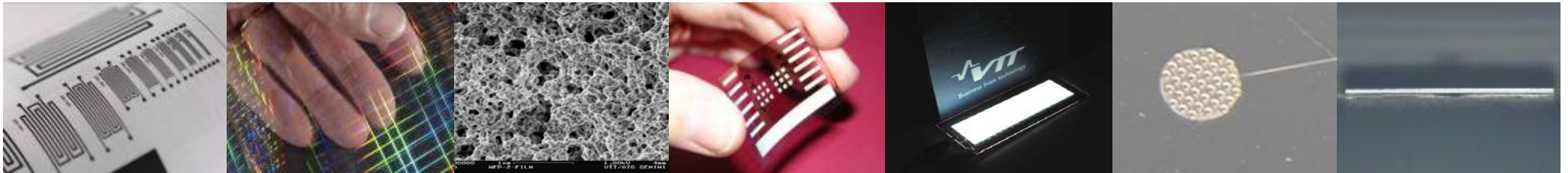
## Capillary electrophoresis on disposable plastic chips



## Conclusions

- Printed intelligence technologies enable new printed functionality in large area high-volume applications
  - Commercial market entries; optical effects, simple diagnostic indicators, hybrid media
  - Ongoing R&D activity on multidisciplinary devices and integration
- Printed intelligence is built on printed components and systems and their interactions with the printed product itself and external systems.
- Advances in materials are a crucial component to achieving the high business potential of printed intelligence consumer applications.
- Printed intelligence technologies are enablers for high volume manufacturing of bioanalytical disposable chips (lab-on-a-chip, biosensor)

# Acknowledgements



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Communication  
Displays



Sensing  
Quality



**New functions for packages ..**

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