

Business from technology



Printed Intelligence and Applications

Dr. Raimo Korhonen

Technology manager

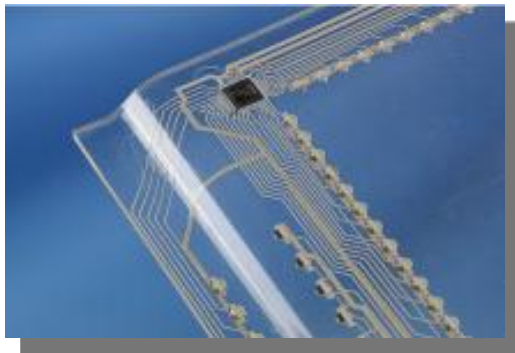
Printed Functional Solutions Knowledge Center

Microtechnologies and Electronics

VTT

Email: Raimo.Korhonen@vtt.fi

Tel.: +358-40-7030052



Outline

- 1 Introduction to VTT
- 2 Printed Intelligence Technologies
- 3 World-class infrastructure
- 4 Devices, Systems Integration and Applications
- 5 Commercialization
- 6 Conclusions



VTT GROUP IN BRIEF

Read more at:
www.vtt.fi

Turnover 307 M€ (2011) • Personnel 3,187 (31.12.2011)



Customer sectors

- Biotechnology, pharmaceutical and food industries
- Electronics
- Energy
- ICT
- Real estate and construction
- Machines and vehicles
- Services and logistics
- Forest industry
- Process industry and environment



Focus areas of research

- Applied materials
- Bio- and chemical processes
- Energy
- Information and communication technologies
- Industrial systems management
- Microtechnologies and electronics
- Services and the built environment
- Business research



VTT's operations

- Research and Development
- Strategic Research
- Business Solutions
- Business Development
- Group Services

VTT's companies

- VTT Expert Services Ltd (incl. Labtium Ltd, Enas Ltd)
- VTT Ventures Ltd
- VTT International Ltd (incl. VTT Brasil LTDA)
- VTT Memsfab Ltd

Main Offering in Microtechnologies and Electronics



VTT Printed Intelligence in brief

Personnel ~100 (1.1.2013)



Key customer sectors

- Consumer packaging
- Medical and diagnostics
- Consumer electronics
- Construction and energy
- Materials and processes

Key customer offering

- Contract R&D
- Pilot production trials
- IPR out-licensing and sales
- Foresight and roadmaps



Key research areas

- Organic devices
- Inorganic devices
- Printed optoelectronics
- Biobased power sources
- Biobased indicators
- Bio- and microsystems
- Integrated solutions
- Large-area manufacturing
- Pilot manufacturing



Program evolution

- Project mode late 90's
- R&D program 2006-
- Commercialization 2010-
- Pilot Factory 2012

R2R infrastructure

- Laboratories
- R2R printing lines
- R2R evaporation unit
- R2R laser machinery
- R2R hybrid integration

Business from technology

Printed Intelligence Technologies

Printed Intelligence Is Based on...

- fluid processable materials technology
- large area high-volume printing like mass-manufacturing methods
- functionality from electronics, biotechnology, chemistry, optics, optoelectronics, etc. integrated as devices and systems

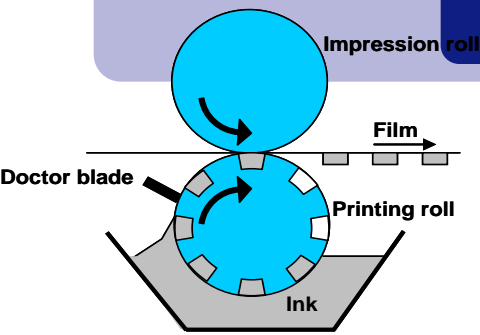


**Generic,
enabling
technologies**

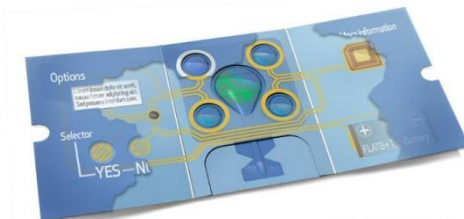
***Patterning, devices, integration, systems-on-foil, embedding
'electronics' into products***

R2R to hybrid processes & production equipment

Materials



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



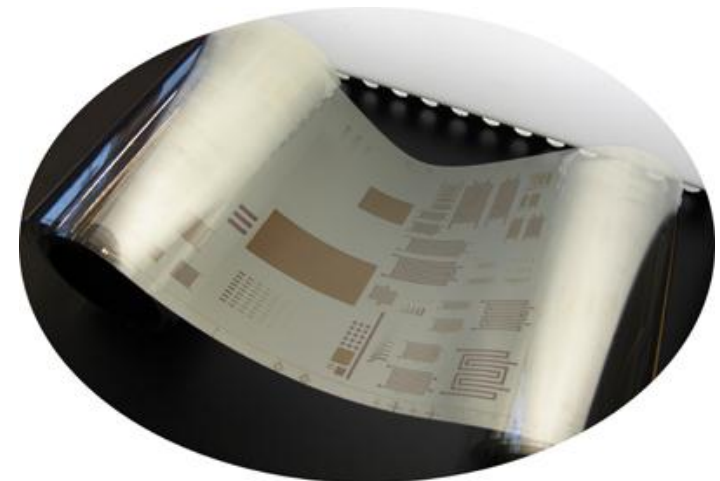
Materials

New uses for existing materials

New advanced materials in liquid phase:

- conductive polymers and particulate inks
- organic and inorganic semiconductors
- nano-materials (nanotubes, low melting Ag, etc)
- bioactive materials

High volume disposable applications demand biodegradable materials



Generic,
enabling
technologies

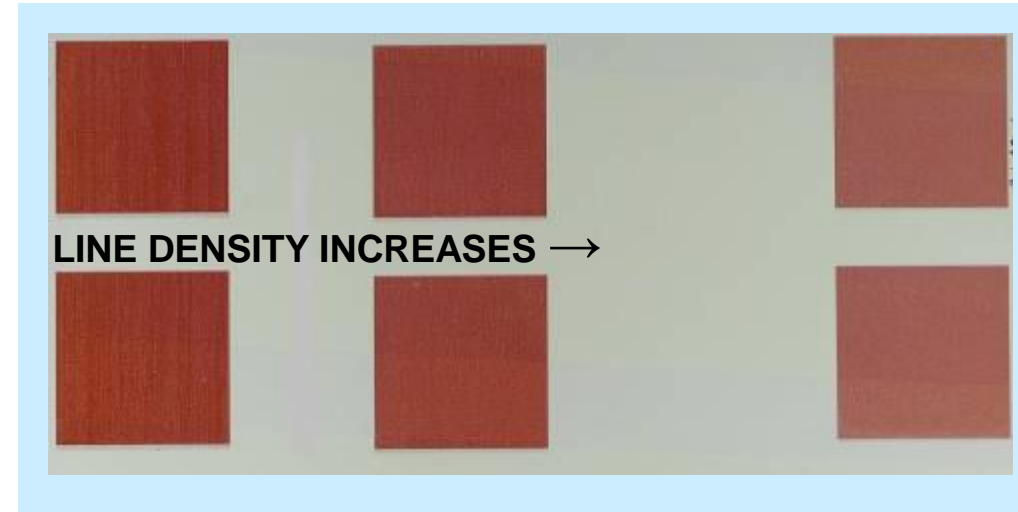
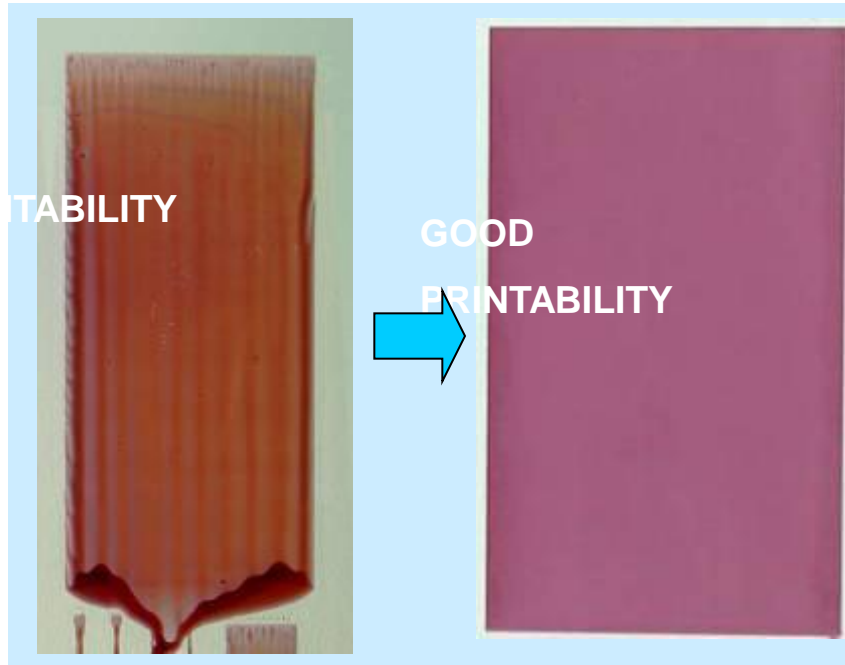
*Components, circuits, integration-on-web, systems-on-foil,
embedding 'electronics from inks' into products*

R2R to hybrid processes & production equipment

Materials

***A major share of current
printed intelligence R&D
activity and money is in the
development of materials***

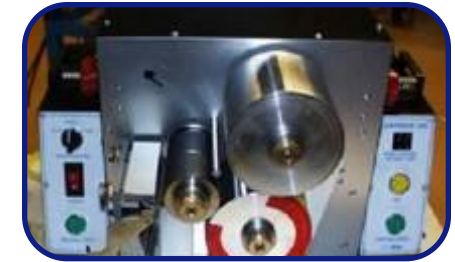
Ink formulation printability vs. performance

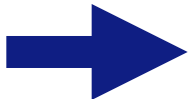


- Ink formulation optimization - solvent mixtures, total concentration, ratio
- Printing unit parameters – eg in gravure cell depth, line density, cell volume
- Printing parameters - printing speed, nip pressure, doctoring angle

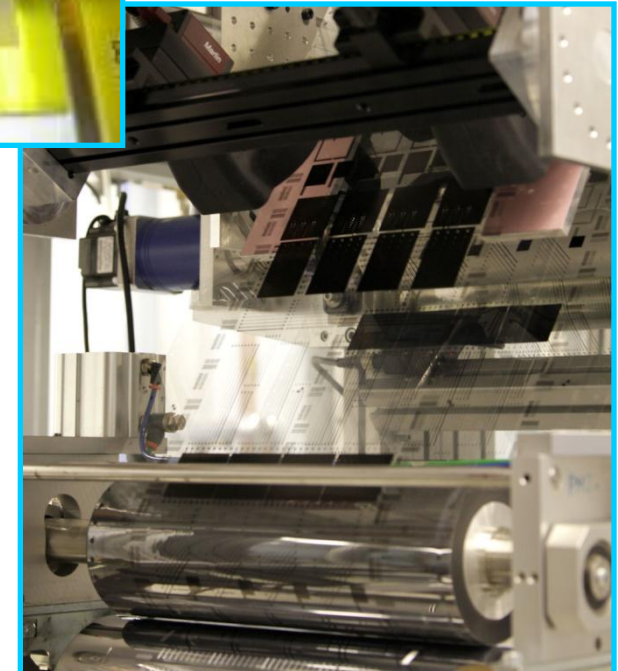
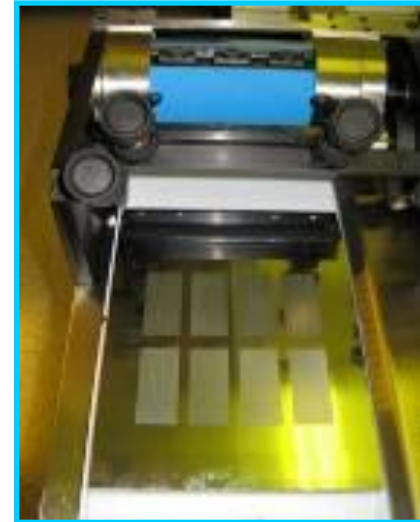
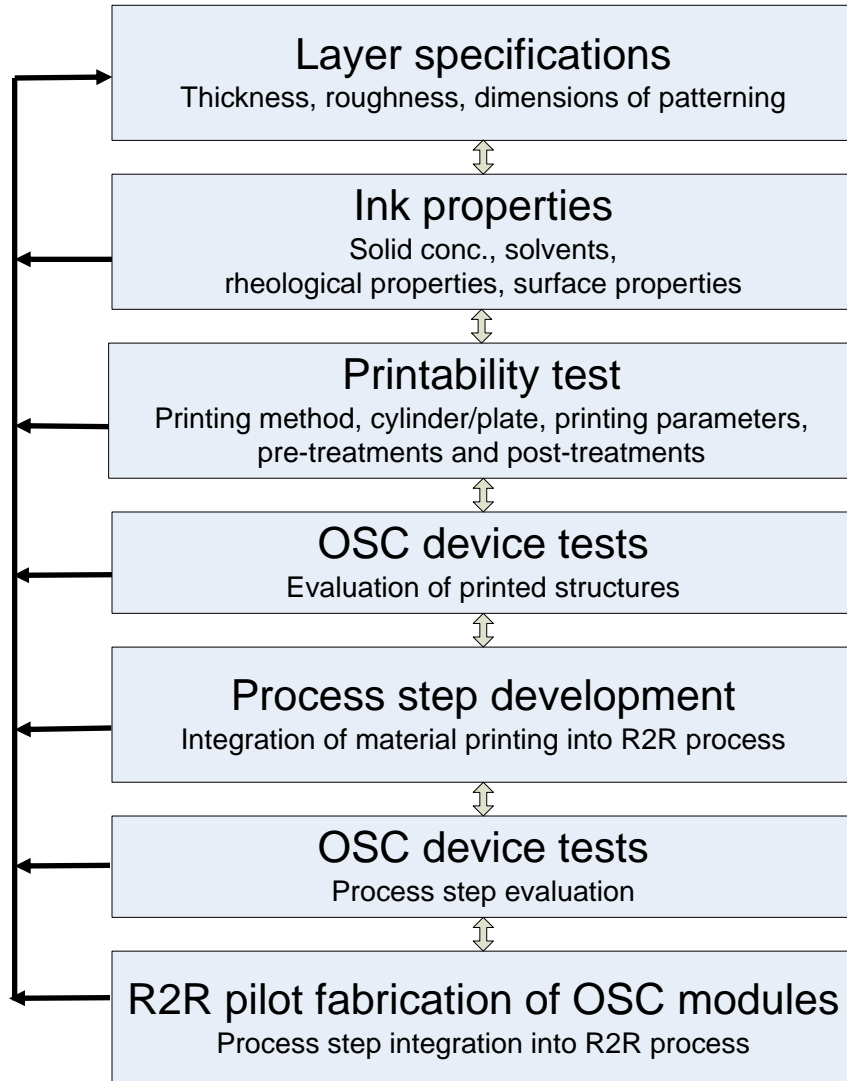
High Volume Cost Effective Production with Roll-to-Roll Processes

- R2R Gravure-, flexo-, and screen-printing
- R2R hot-embossing
- Ink-jet for individualization
- R2R Laser processing
- R2R Lift-off
- R2R etching

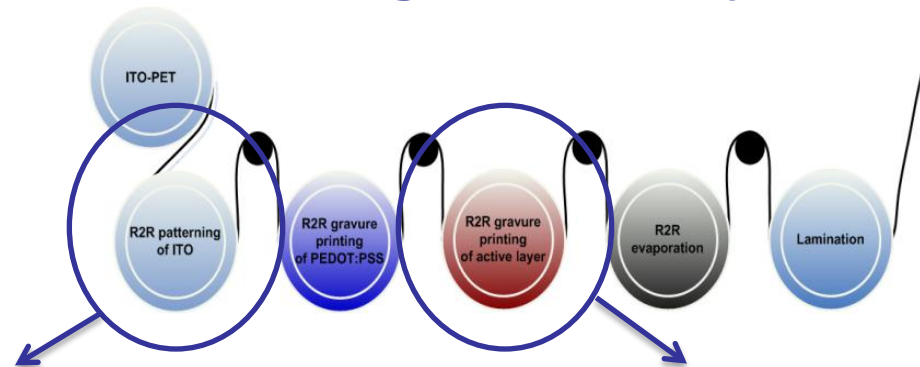


- 
- *Functional ink formulation*
 - *Development of the printing tools*
 - *On-line characterization*
 - *Pilot scale production*

Process step development in printing - Case OSC



R2R printing of OPV layers



Video of R2R rotary screen printing of etching paste for ITO

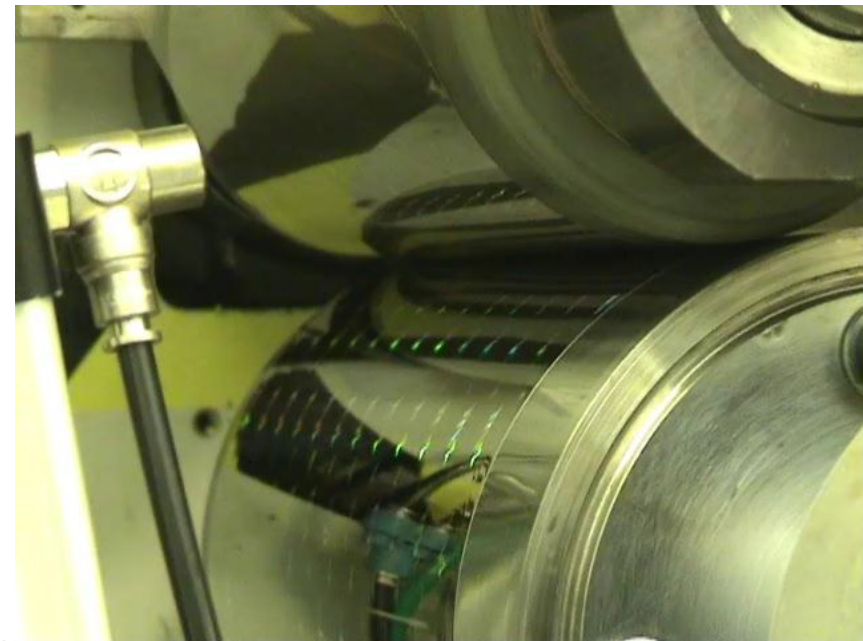
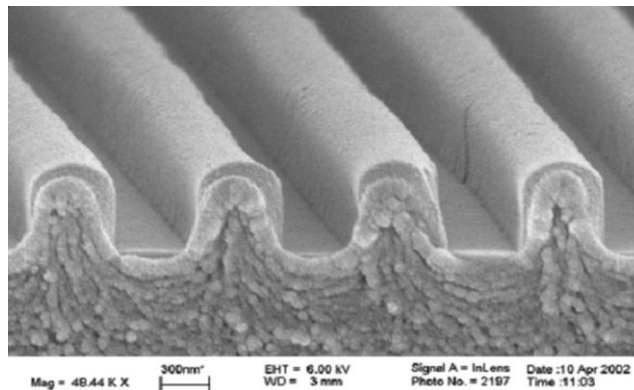
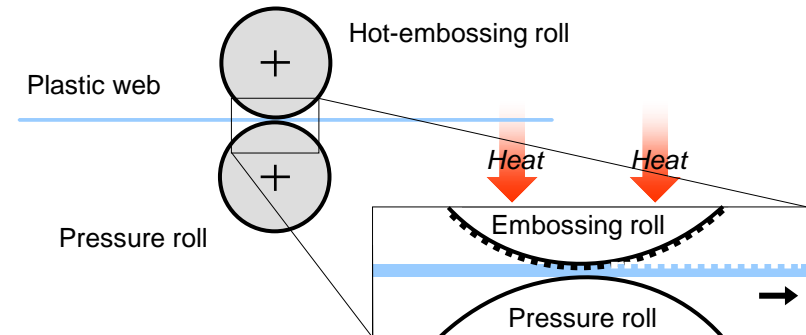


Video of R2R gravure printing of photoactive layer



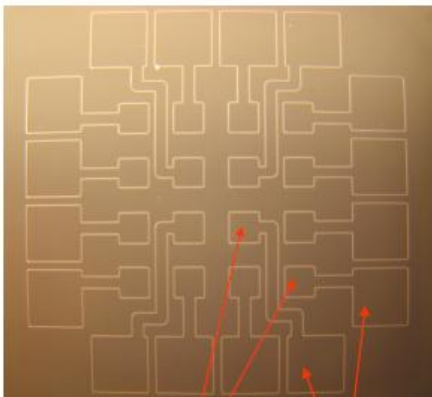
Hot-embossing - thermal nanoimprinting lithography

- Mechanical structures are embossed under pressure and heat on plastic web
- Embossing cylinder
 - Ni-shim
 - Laser or e-beam fabricated
- Features sizes
 - Horizontal: ~100 nm at minimum
 - Vertical: <50 nm - 50 μm

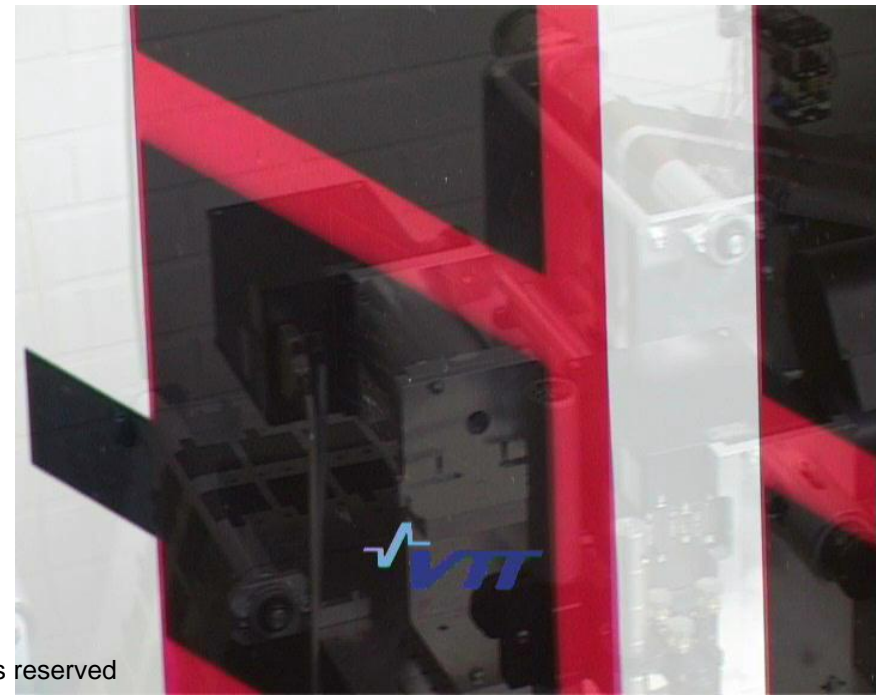


R2R laser processing

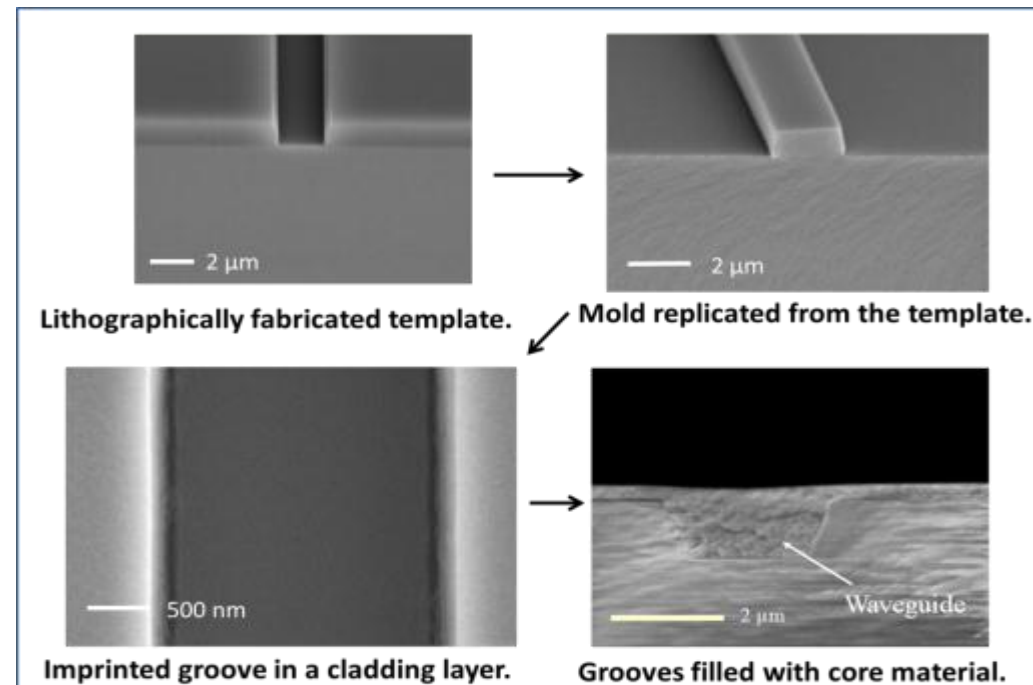
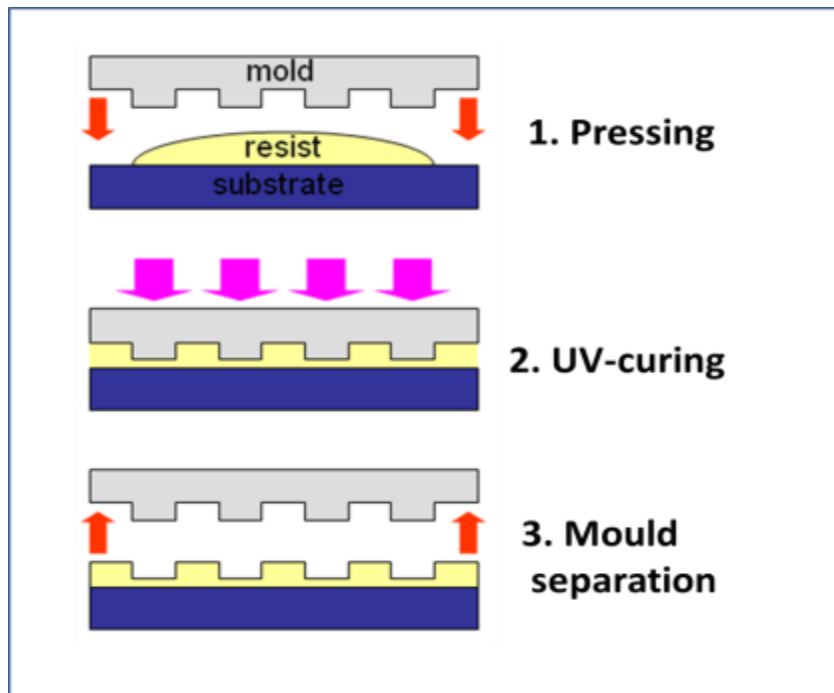
- Integration of novel laser processing techniques to R2R environment - Lumera Rapid picosecond ablation laser
- Applications:
 - Cold ablation
 - Cutting
 - Via drilling
 - Sintering
 - Patterning
 - Lamination



R2R laser processed (4 m/min) Al (12 nm)
electrode structures on flexible substrate



Waveguide fabrication by UV-nanoimprinting



Electrical sintering of printed nanoparticle structures

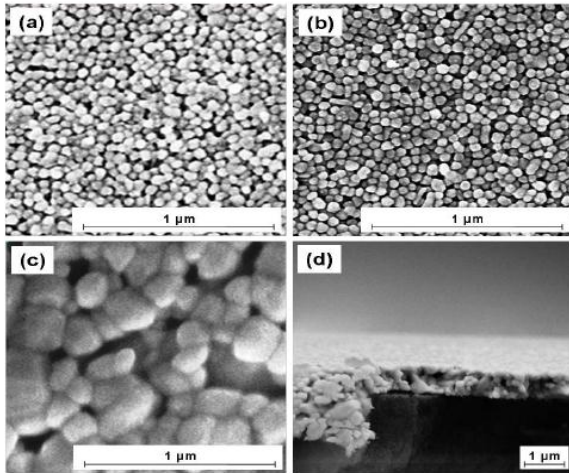
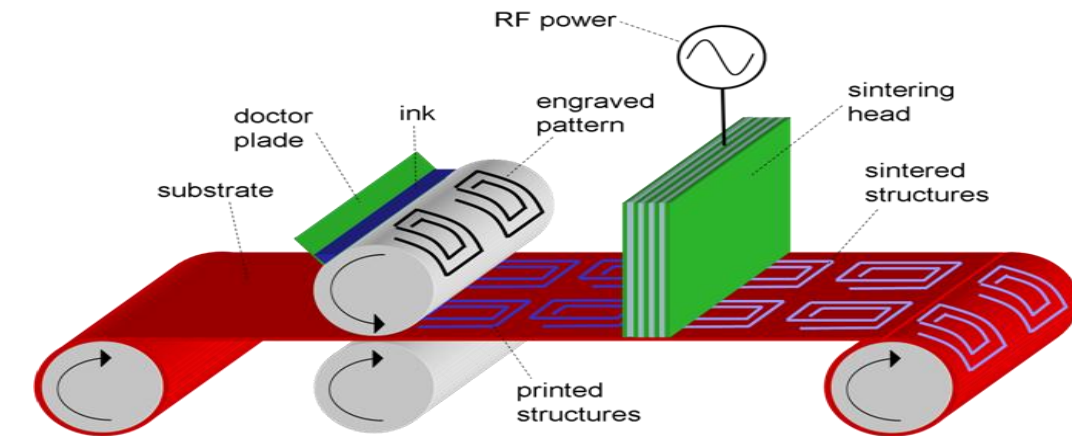


FIG. 3: SEM images of printed nanoparticle ink tracks: (a) unsintered sample, (b) thermally sintered in oven at 120 °C, (c) electrically sintered and (d) cross-sectional view of electrically sintered sample.

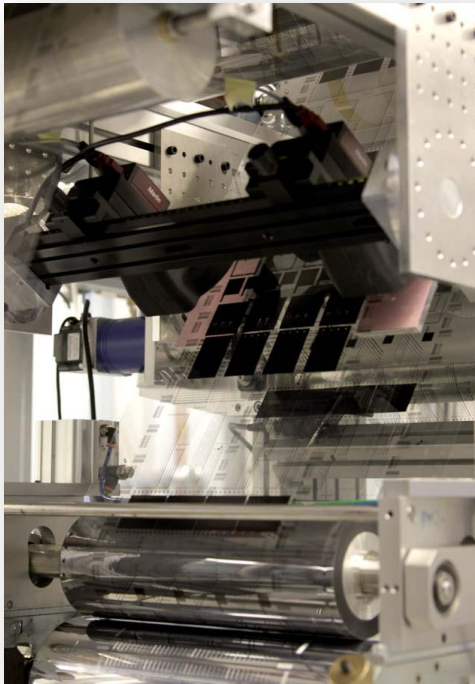
Ag grain growth during the process

- Applications, conductor grids in:
 - OPV, CIGS and DSSC
 - OLED lighting panels and displays
 - Fast (few μ s) sintering
 - Low substrate thermal load
- Patents pending

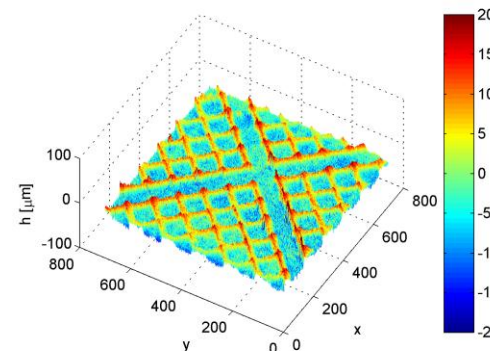
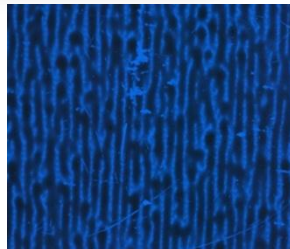
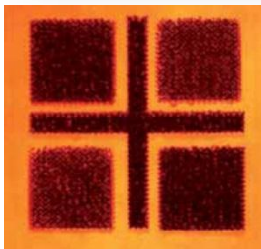


R2R AC implementation

In-line printing quality measurement system



- Novel on-line measurement and characterization techniques
- Improving the quality, runnability and productivity of the R2R process
- For measurement of interlayer alignment of multilayer printed structures
- For visible, semitransparent or transparent layers
- Surface topography measurements



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Infrastructures

ROLL-TO-ROLL PILOT FACILITIES AT VTT



PICO 2003

- ✓ 2 gravure printing units
- ✓ Hot embossing unit
- ✓ Corona unit
- ✓ Lamination unit
- ✓ Drying units (air, UV, IR)
- ✓ Max. web width 200mm
- ✓ Max. web velocity 100 m/min



ROKO 2007

- ✓ 4 interchangeable printing units
 - ✓ forward and reverse gravure, rotary screen and flexography
- ✓ Corona/plasma pretreatment
- ✓ Lamination unit
- ✓ Drying units (air, UV, IR)
- ✓ Web width 300mm
- ✓ Max. web velocity 10m/min



MAXI 2012

- ✓ 4 interchangeable printing unit slots
 - ✓ forward and reverse gravure, rotary screen, flexography
- ✓ Slot die coating
- ✓ Hot embossing/thermal nanoimprinting unit
- ✓ Plasma substrate treatment unit
- ✓ Lamination unit
- ✓ Rotary die cut unit
- ✓ Drying units (air, UV)
- ✓ Automatic registration system
- ✓ Max. web width 300mm
- ✓ Max. web velocity 30m/min

ROLL-TO-ROLL PILOT FACILITIES AT VTT



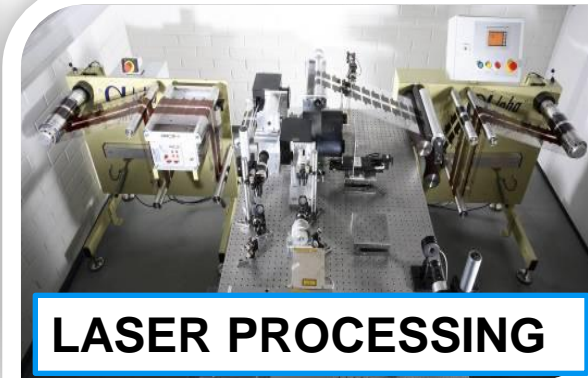
NICO 2011

- ✓ NITROGEN ATMOSPHERE
- ✓ 2 interchangeable printing unit slots
 - ✓ forward gravure, rotary screen
- ✓ Lamination unit
- ✓ Drying units (IR)
- ✓ Manual registration system
- ✓ Printing, curing and lamination made in nitrogen atmosphere (O_2 level $<1\%$)
- ✓ Max. web width 300mm
- ✓ Max. web velocity 20m/min



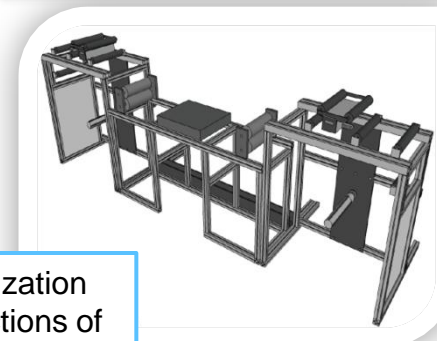
R2R EVAPORATOR

- ✓ Thin film metal evaporation
 - ✓ Ag, Al, Au, Ca..
- ✓ 5 thermal evaporation sources
- ✓ Max. web width 320 mm
- ✓ Max. web velocity 2 m/min



LASER PROCESSING

- ✓ Different laser systems available for R2R testing of various applications
- ✓ Ps-Fs-ablation, IR-diode, CO₂, NdYAG, fiber lasers



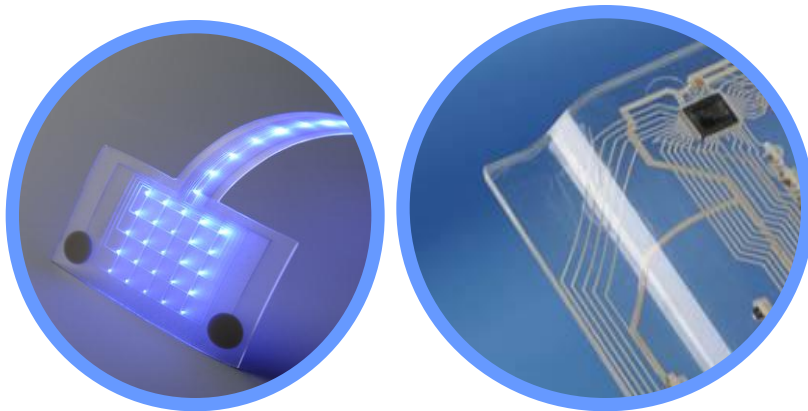
Under installation: R2R characterization equipment for testing electrical functions of printed components.

Up-scaling- Ramp-up of Hybrid pilot production environment



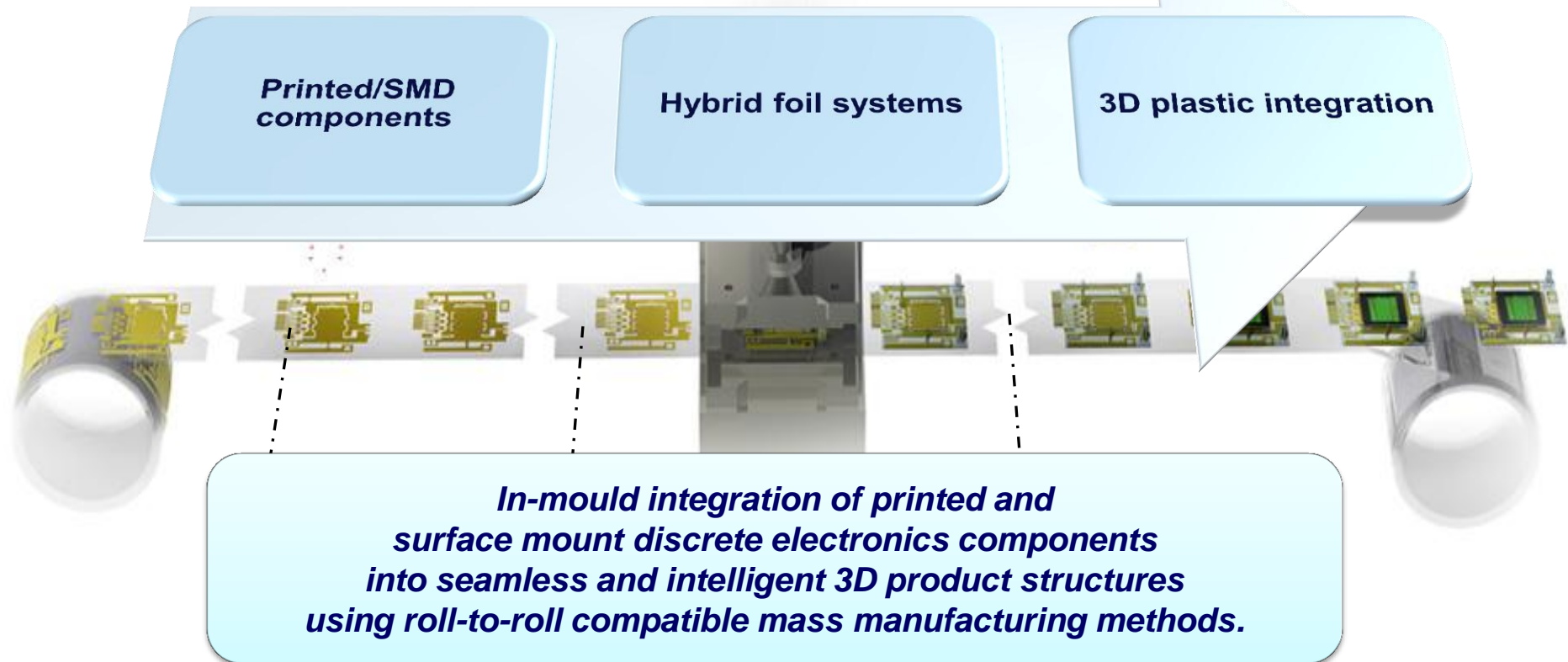
Printed Hybrid Systems Pilot Fab 2011-2013

- Making products from printed roll(s)
- Assembling SMD components, chips and modules to R2R produced roll
- 3D products with foil over-moulding



→ plastic integrated freeform intelligent products

Hybrid in-mould intelligence technology concept



Integrated functionalities:

**Sensors & Sensor arrays • User feedback • Processing & Communication •
Power supplies & Storage • Antennas & Wiring**

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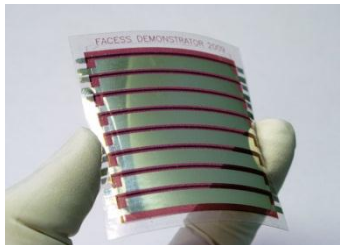


Devices, Systems Integration and Applications

Printed Intelligence Component Examples at VTT

- Printed components can be integrated on web, sheet or foil to form printed systems
 - Organic solar cells
 - OLED displays and signage
 - Indicators and sensors
 - Printed biofuel cells
 - Memory devices: WORM, FeRAM
 - Printed organic transistor circuits, multilayer electronic circuits
 - Holographs
 - Electrical and optical codes

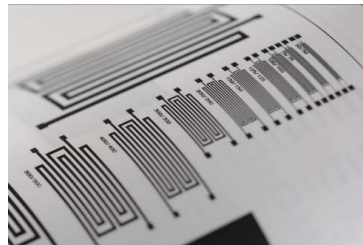
Optical codes for linking physical and digital media



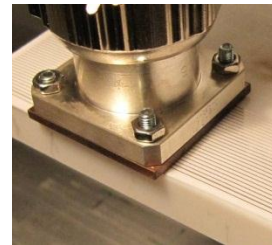
Gravure printed organic solar cells



Printed disposable biofuel cell



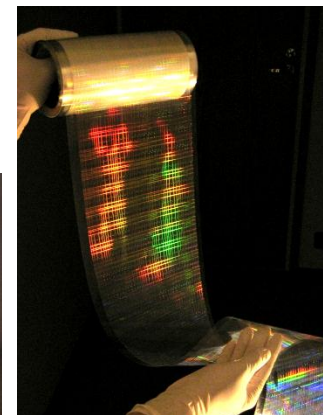
Passive electrical components



Processing tools for nanoparticle sintering

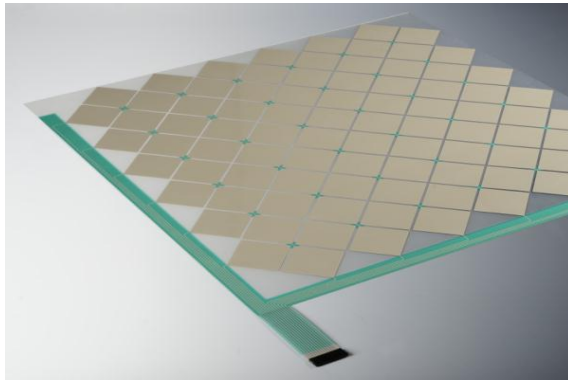


OLED signage

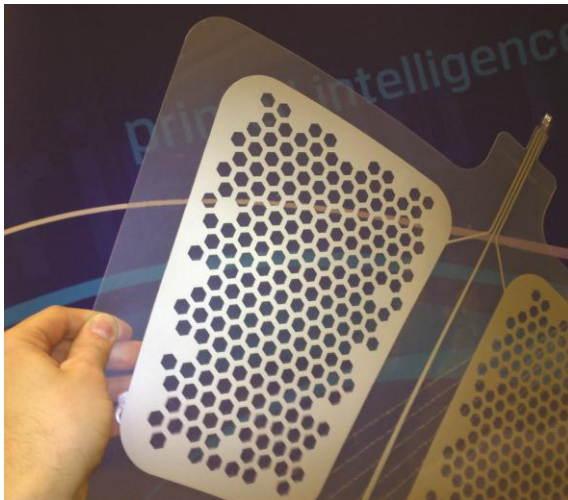


Optical effects for packaging

Printed wide-area capacitive and resistive sensors



Printed wide-area sensor matrix



Printed capacitive sensor

The advantages of VTT's wide-area sensing technology include:

- Thin and flexible form factor
- Compatibility with standard communications protocols such as NFC, RFID and ZigBee
- Integration into surfaces with printed graphics and different textures, enabling attractive user experiences
- The use of hybrid combinations of various sensing and communication technologies

Examples of the short-term application potential of integrated sensor systems include:

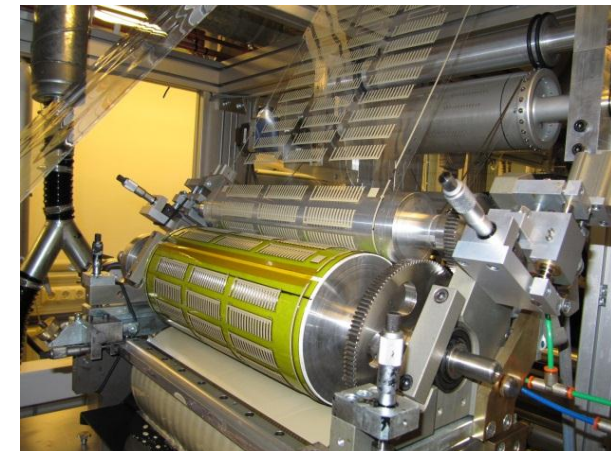
- Gaming and entertainment applications
- Interactive graphical products such as posters with user interfaces
- Indoor or structural monitoring in buildings

Printed memories

- Application areas for printed memories range from simple data-carrying cards to programmable RFID tags

The advantages of VTT's roll-to-roll printed WORM memory technology include:

- Low cost per bit of memory, achieved via minimal usage of nano-particle ink
- Low-voltage programmability enabling applications that utilise printed batteries
- Flexibility and integration possibilities for various substrates
- Demonstrated data retention times of months



Printed power sources

Examples of printed power sources developed by VTT comprise:

- Enzymatic biofuel cell
- Carbon based supercapacitor
- Polyaniline battery

There is remarkable potential for printed power sources in, for example:

- Package-integrated functionality
- Disposable electronics-containing products, such as 'smart' patches and drug delivery systems in medicine and cosmetics
- Advanced inventory and luggage tracking, active brochures, and other information-carrying materials (e.g. active RFID tags).



Active paper and printed diagnostics



Fluid control patterns on paper



Microfluidic channels on plastics



Printable reaction chemistries

- Fluid control platforms on paper and plastic substrates
- Versatile application opportunities in the field of rapid diagnostics
 - Easy and fun monitoring of personal and environmental well-being
 - Point-of-care diagnostic products
 - First application opportunities in consumer advertising

Clean Card® PRO– Orion Diagnostica Oy

Clean Card® PRO is a new-generation hygiene test for monitoring the effectiveness of cleaning of surfaces which come into contact with food. The test detects protein residues, the presence of which indicates inadequate cleaning.

Features

- simple procedure: moisten - wipe – interpret
- colour change indicates an unclean surface
- result in only 30 seconds
- facilitates immediate corrective action
- no special training required
- no expensive equipment needed



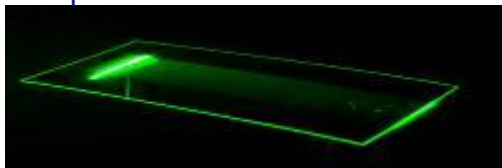
**Finnish Chemical Industry Association
Innovation Prize 2010
for Orion Diagnostica and VTT**

VTT has helped several customer companies to develop new products based on VTT's expertise on Printed Intelligence. For example, Orion Diagnostica Oy and VTT jointly transferred old swabs and reagent bottles based hygiene monitoring system to a new-generation, fast and easy to use integrated test device, which can e.g. help to focus the use of dip slide testing in a cost efficient way.

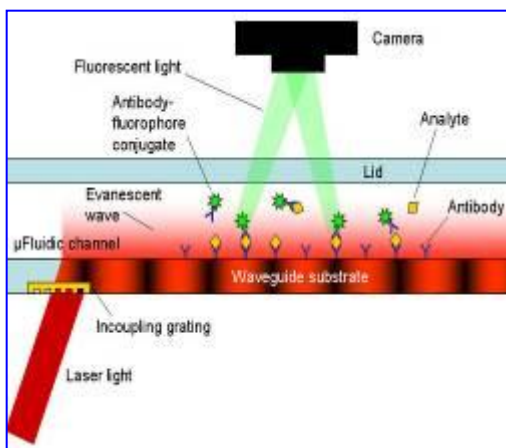
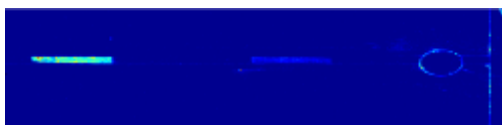
Biosensors

Low-cost disposable biosensor platform

R2R manufactured optical components



Detection using fluorescently labeled antibodies



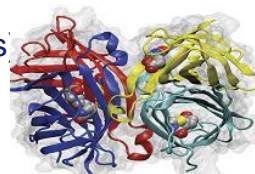
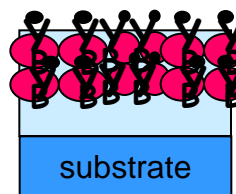
Development of a bioactive sensor surface

Chimeric avidin (ChiAVD) :

Most stable protein fold known

Uniform bioactive sensor component

Bioactive binding components (e.g. antibodies) coupled to the surface via biotin



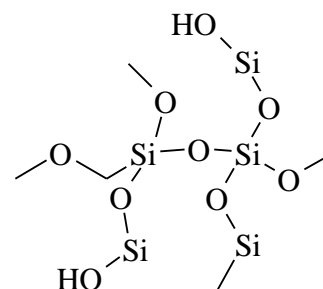
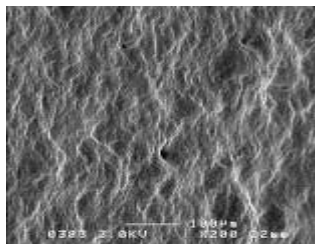
Sol-gels:

Printable sol-gels to be used as medium for the prolonged stability of doped chimeric avidin.

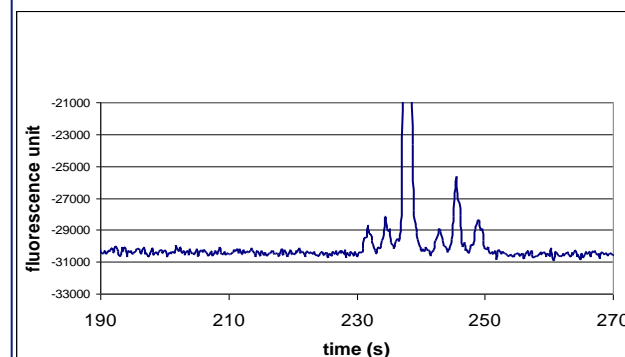
Covalent immobilization:

of ChiAVD

with functionalized polymeric substrate materials



Capillary electrophoresis on disposable plastic chips



TRAC-on-Chip analysis of six selected mRNAs from totRNA (5 µg) extracted from VCap cells.

Enabling technologies – Printed optoelectronic components

Examples of applications for printed OPV modules:

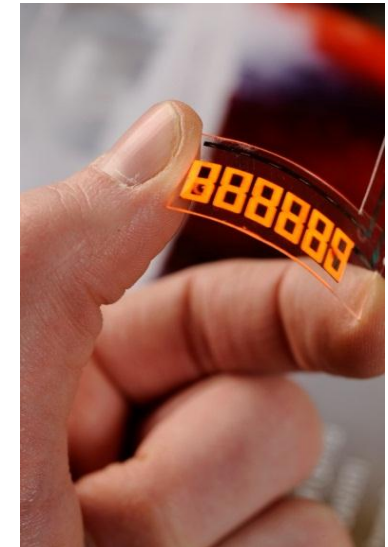
- Smart cards
- Wireless sensors
- Interior design products
- Reflective-type displays
- Mobile consumer electronics

Examples of applications for printed OLED elements:

- Interactive packaging and point-of-sale products
- Smart cards and smart labels
- Consumer electronics and interior design products



Printed OPV foil



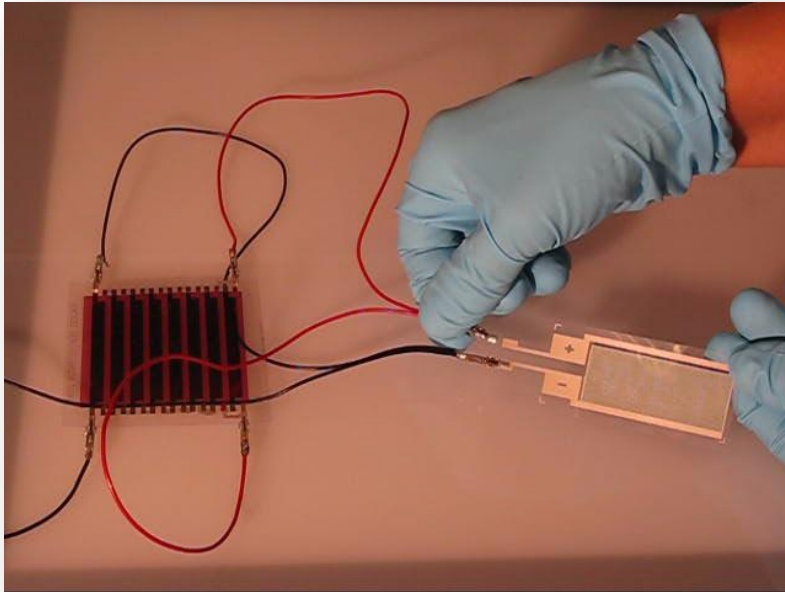
Printed OLED display

The competitiveness of VTT's roll-to-roll printed OPV and OLED technologies stems from a combination of:

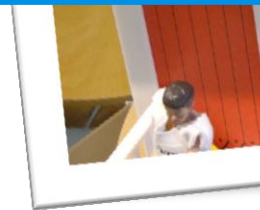
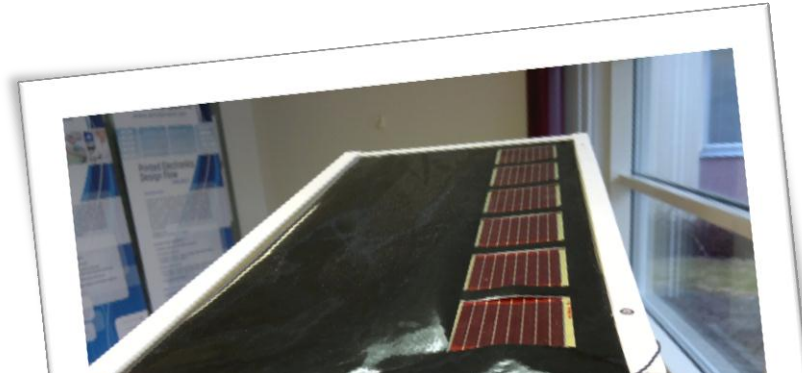
- Flexible, thinness, lightweight
- Transparency
- Freedom of design – size, shape, colour
- Low-cost production structure

Printed OPV demonstrators

Electrochromic display driven by printed OPV module under indoor lighting

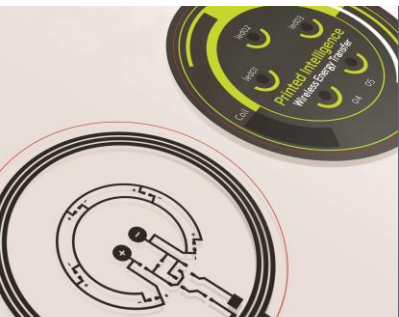


“BIPV” – dollhouse’s LED lighting powered via printed OPV

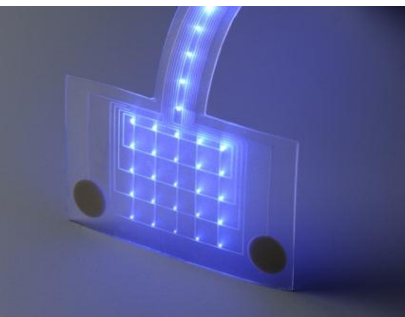


Hybrid integration

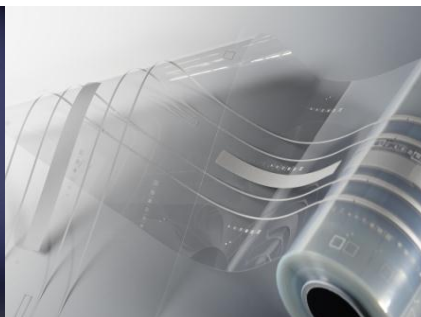
- VTT is developing a hybrid integration technology that enables seamless integration of novel optical, electrical, and mechanical features into 3D plastic products.
- Hybrid integration technology as part of a product design enables:
 - Lower product complexity
 - Reduced product volume
 - Seamless integration
 - Design freedom



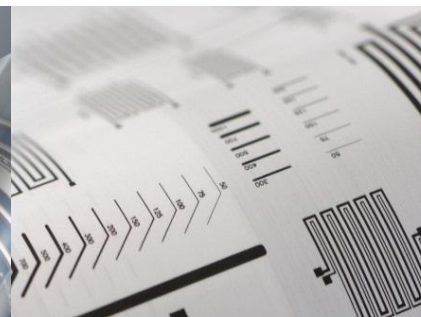
Wireless power



Hybrid integration



Printed conductors



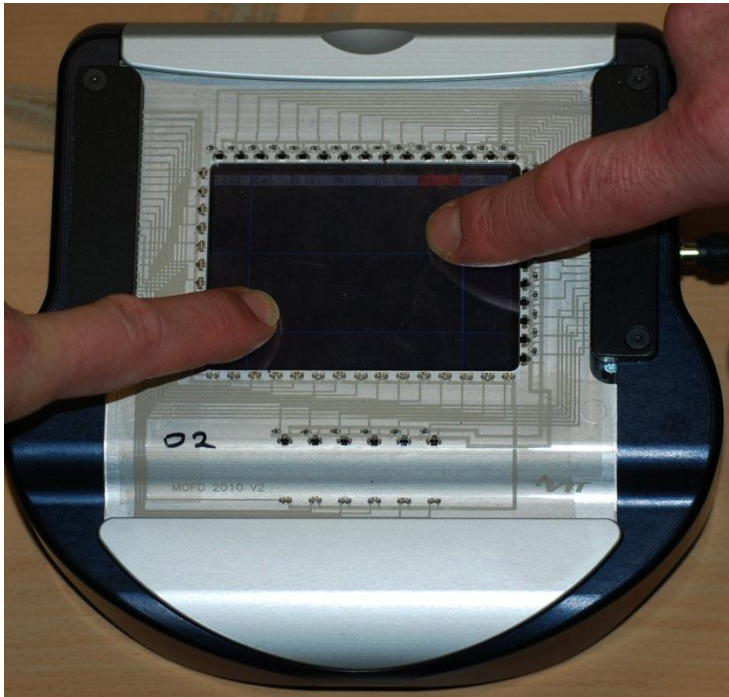
Embedded Electronics



Embedded Software

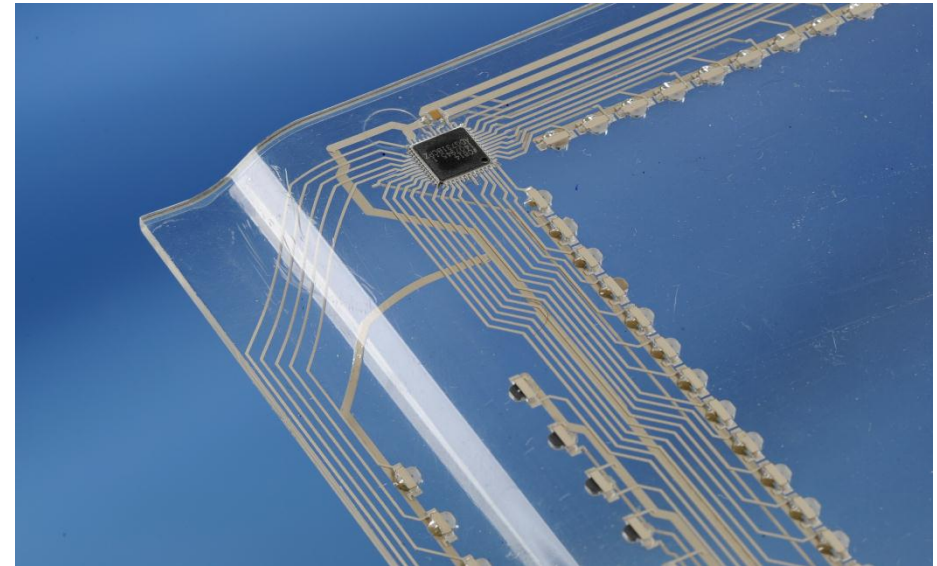
Towards new embedded user interfaces

Case: Over-moulded optical touch screen



Over-moulded touch screen demonstrator with multi-touch functionality

Commercialisation by spinoff TactoTek

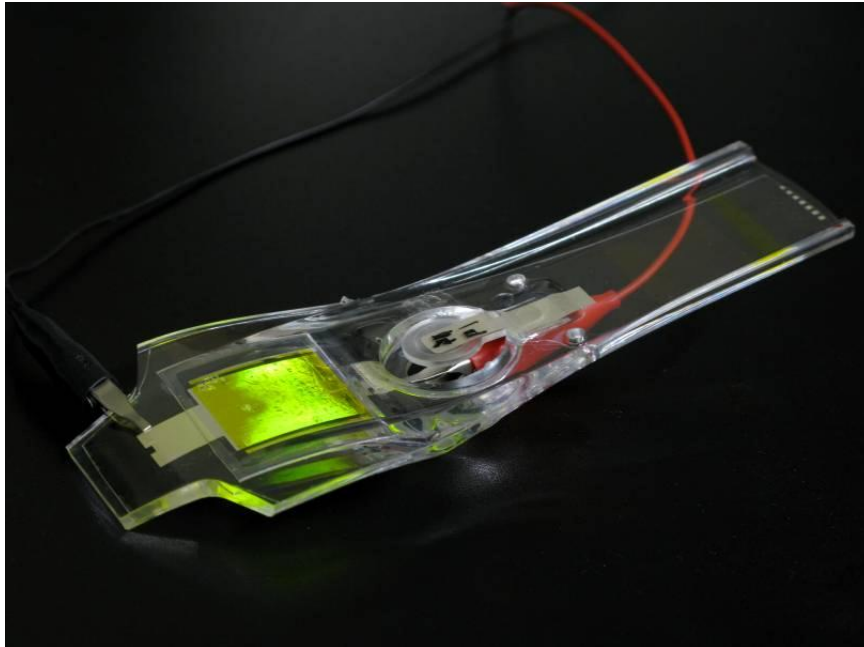


3D forms can be implemented in moulding process, even though touch components can be assembled in planar structure.

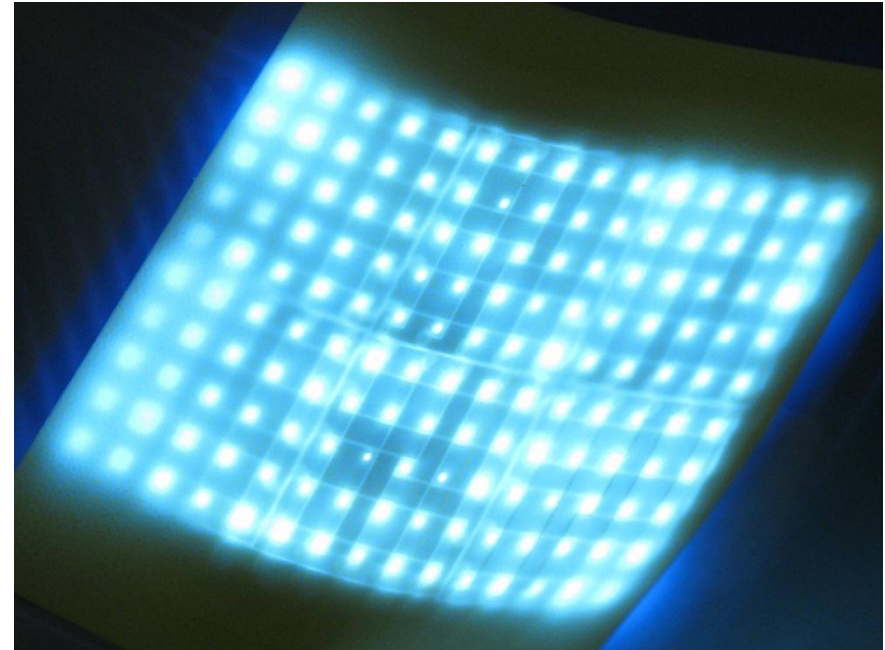
Advantage:

- Easily integrated - new shapes, designs and ways to interact
- Compactness and robustness
- Scaling up to large-area UI

Flexibility and sustainability in lighting



Flexible Roll-to-Roll printed OLED foil embedded into 3-D mechanical structure by foil over-moulding



Flexible illumination elements by embedding LED bare chips in multilayer laminated plastic structures

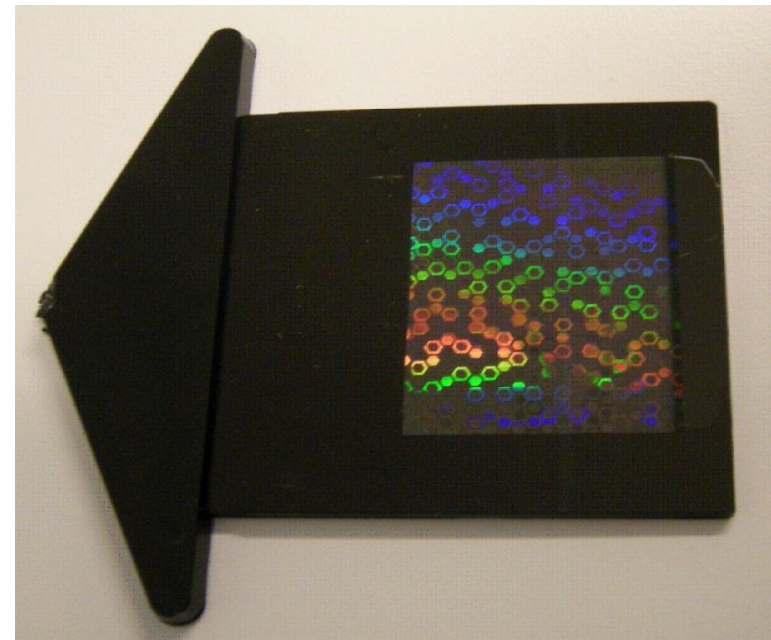
Advantage:

- ✦ Thin, flexible, all size and shapes
- ✦ Easily integrated - new shapes and designs
- ✦ Environmentally friendly

More appealing, desirable and eye-catching Printed functional films embedded into consumer packaged goods and packaging



LED lights can be integrated on consumer products



Hot embossed holographic film injection moulded into plastic.

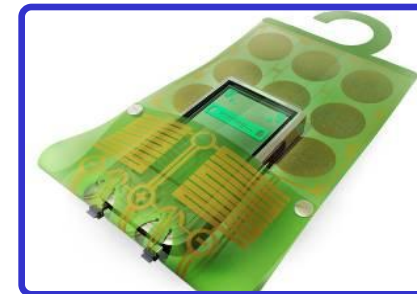
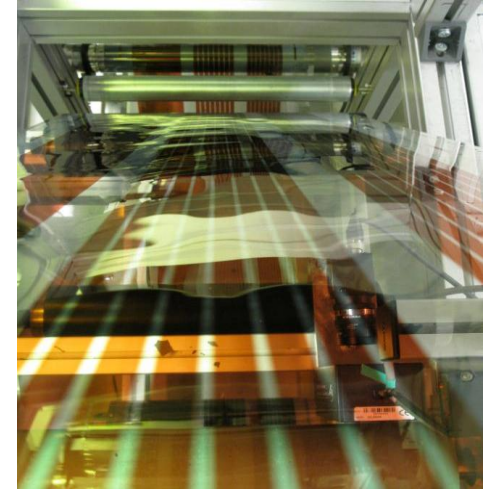
Business from technology

Commercialization

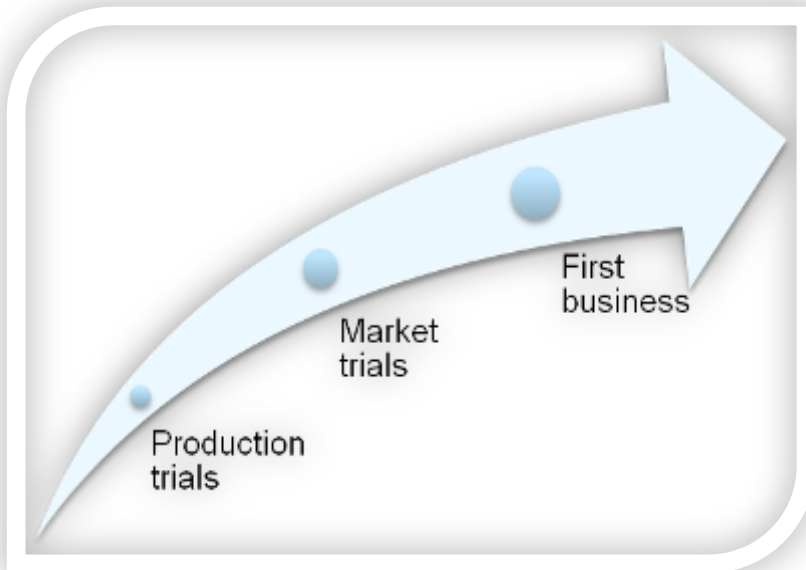
VTT Printed intelligence commercialization program

Started 2010

- From "roll-to-roll" to...
"roll-to-product"
- Successfully introduce technologies from lab to early market trials and commercial adoption.
 - More proof of enabling technology
 - More proof of product
 - More proof of cash in-flow
 - Developments in supporting infrastructure



PrintoCent



- Centre for business development in the area of Printed Intelligence.
- Offers a world-class pilot production environment based on Printed Intelligence processes.
- Brings together complementary players across the value chain - ranging from technology providers to customers.
- Customer Affiliate Programs.





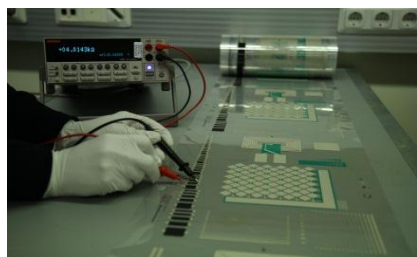
R2R printed Aluminium ink



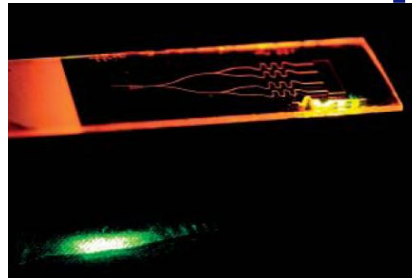
R2R processed OPV foil



Hot embossed microfluidistics



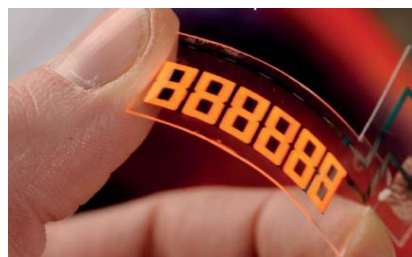
Printed passive components



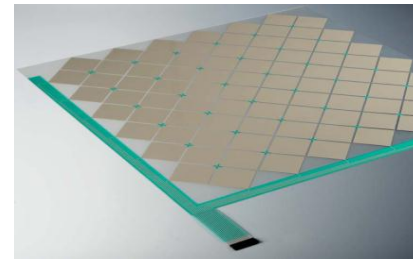
Opto-fluidic sensor with light source



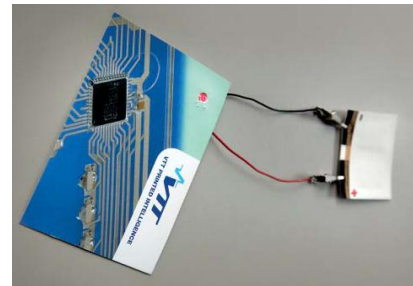
OLED element



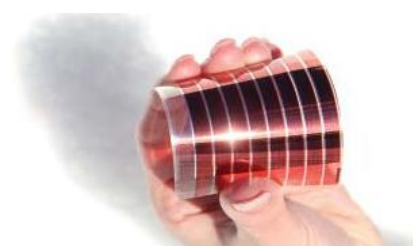
7-segment OLED display



Wide area sensor matrix



Biobattery



Solar energy module



In-mould OLED element



Active paper



Printed low-cost indicators



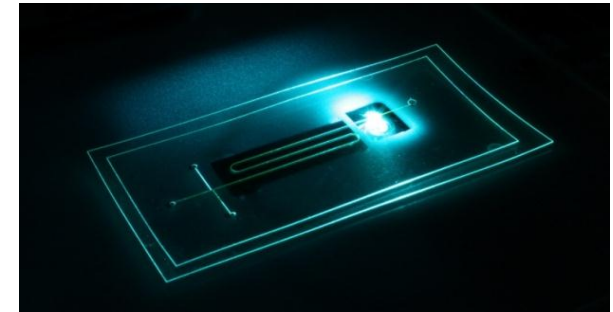
Printed memory (WORM)

R&D towards demos and products

PrintoCent

8 new start up companies founded 2010 – 2011

- MK Fluidics (Biodiagnostics, Oulu)
- FocalSpec (Optical instrumentation, Oulu)
- Nanordic (Nanomaterials, Oulu)
- Spektikor (Printed biosensing – e.g. disposable heartbeat monitor, Oulu)
- Iscent (Hot embossed decorative products, Tampere)
- TactoTek (Optical Touch Screens, Oulu)
- Global Innovation Network (Rapid diagnostics: Production and systems, Oulu)
- KeepLoop (Mobile phone microscope, Tampere & Oulu)

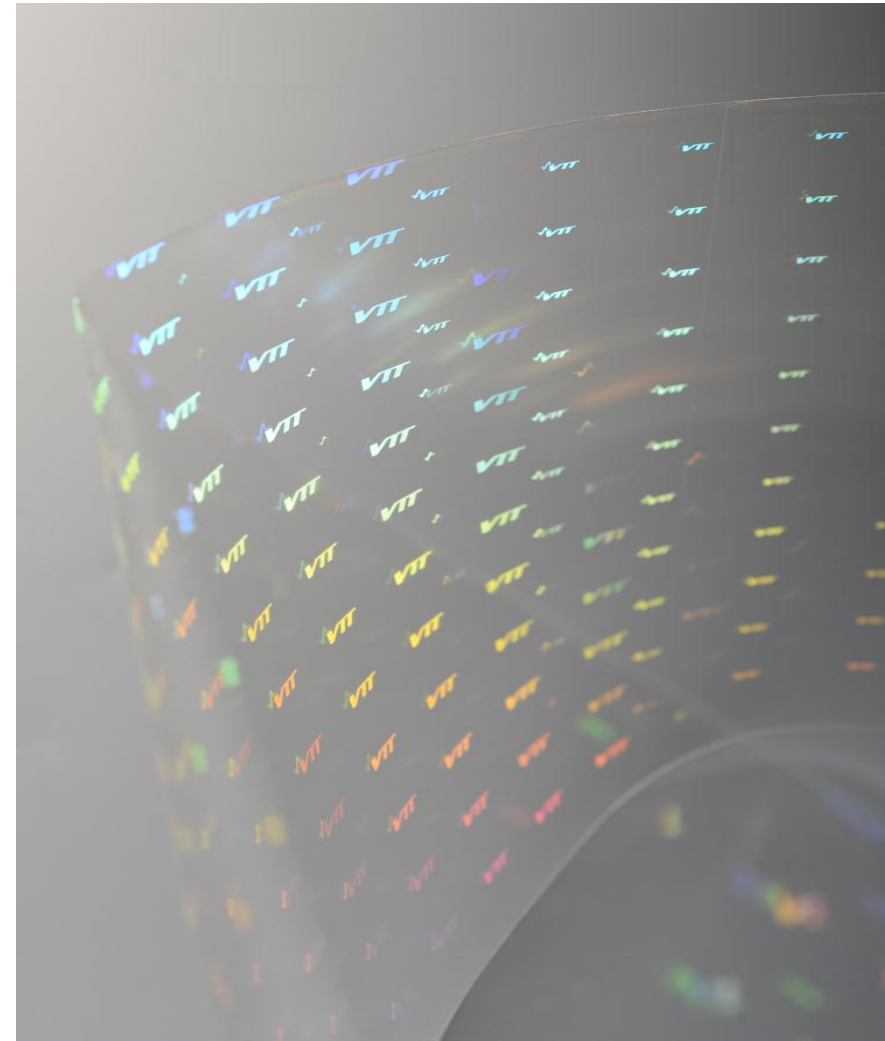


More companies in a pipeline

- Takomo – PrintoCent: PÄLLI –training: 2010-> Spektikor, 2011-> Detemex established 23.3.2012, additionally 2 ideas/teams are looking for first round funding

Entrepreneurial activity – Decorative light scattering films

- VTT spin-off Iscent Ltd
- Offers decorative and ecological light scattering films for paper and plastic based products
- Based on roll-to-roll hot embossing technology developed by VTT
- For more information visit:
www.iscent.fi



Mobile microscope

- VTT spin-off KeepLoop Ltd
- Turns your mobile device into a microscope.
- Target customer groups comprise printing industry, security and healthcare professionals.
- For more information visit:
www.keeploop.com



Optical touch screens

- VTT spin-off Tactotek Ltd
- Commercializes optical touch screen technology
- Focuses on low-cost touch panels for the tablet, phone and PC markets.
- For more information visit:
www.tactotek.com



PrintoCent Pilot Factory



Laboratory infrastructure

- Table-top printers
- Research and development
- Proof of concept demonstrators

R2R up-scaling

- Room-sized R2R lines
- Trasfer from lab to R2R
- Process development

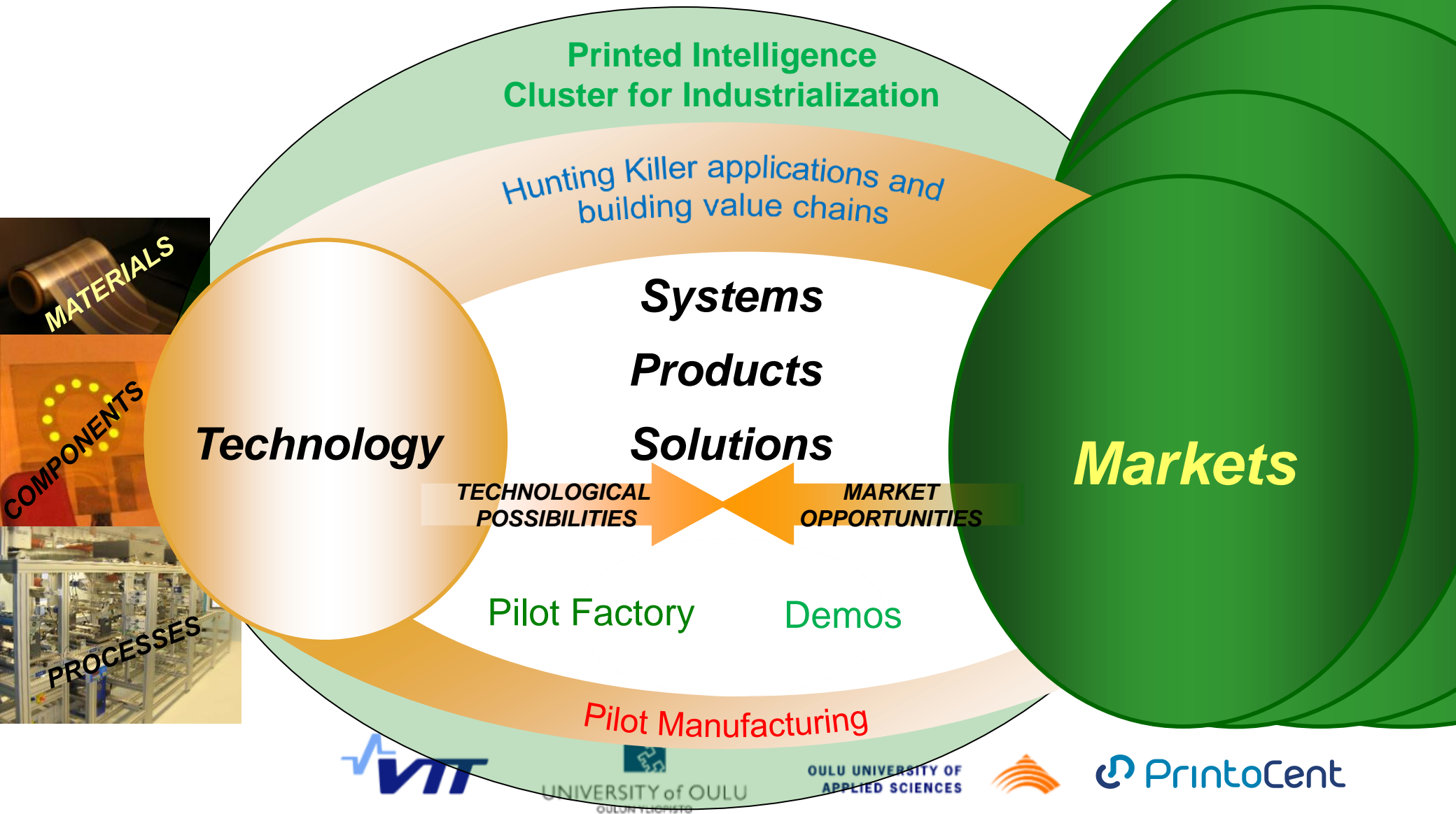
R2R pilot manufacturing

- Hall-sized R2R pilot lines
- **New Hybrid Pilot line**
- Towards pilot manufacturing
- Towards market trials



PrintoCent 2013-2015 – draft

Creating Application Driven Value Chains



Key Features

Ecosystem creation – 50 companies to PrintoCent cluster

- **Target to establish a community for building joint development activities**
- **Offering**
 - **Membership.** Networking, business and project initiation, priority access to PrintoCent Pilot Factory,
 - **Annual training or consultation day.** Based on company needs.
 - **PRINSE-seminar 2014 .** Free for speakers and 50% discount on seminar fee. Every second year.
 - **Annual member meeting.** Status of projects, Workshop on new topics, Research portfolio of founding members
 - **Identification of new project ideas.** Continuous process to establish value chains for joint projects.
- **Yearly membership fee - 1 k€ StartUp & Micro, 3 k€ SME, 6 k€ LSE - 3 year commitment.**

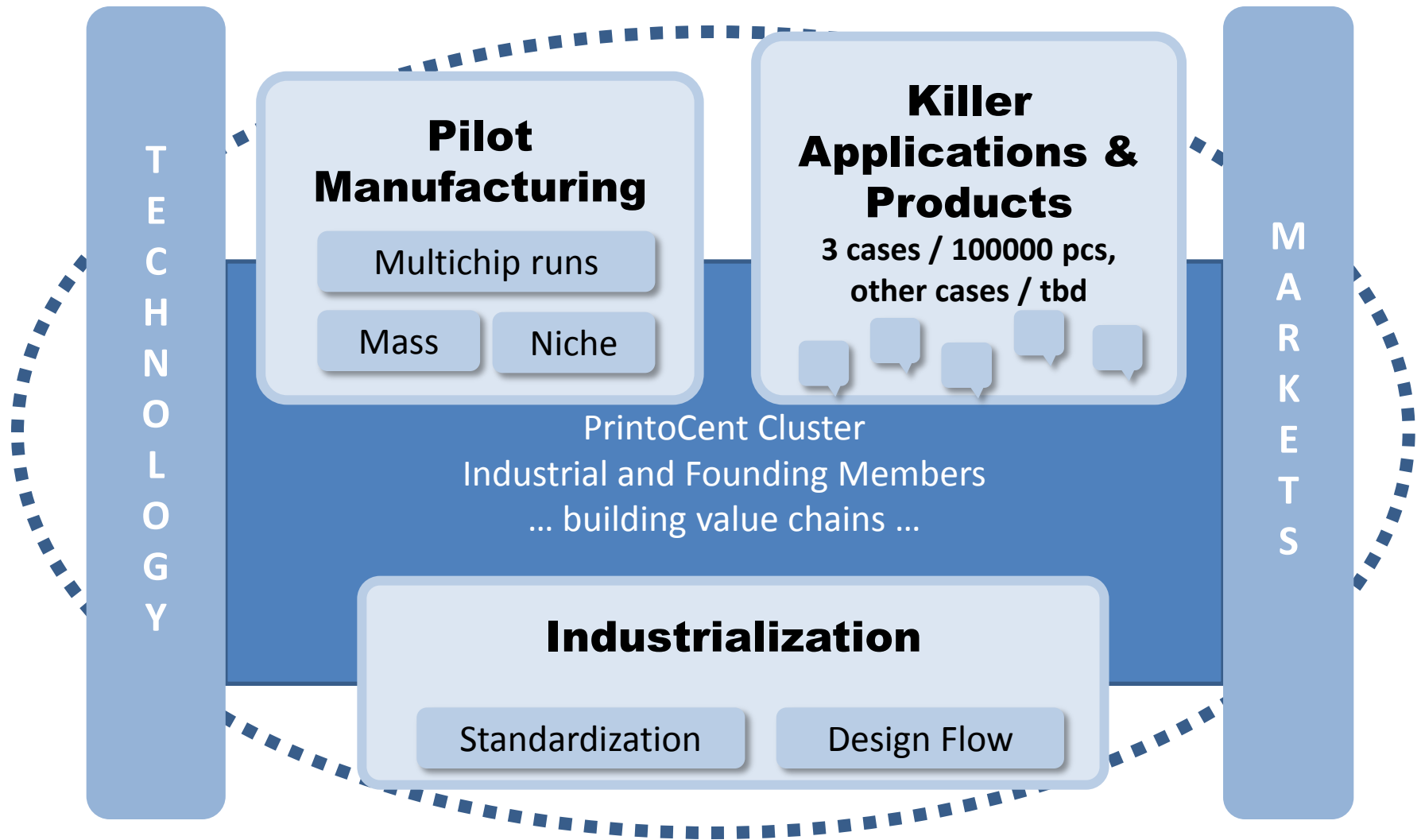
Three programmes creating application driven value chains.

- **Joint projects – sharing the risk**
- **Projects have their own management - the IPR is for the partners of each project.**
- **Programme themes - see next slide**

Note.

Besides PrintoCent activities, the founding members have their own research portfolios and customer projects.

Cluster and the Three programmes



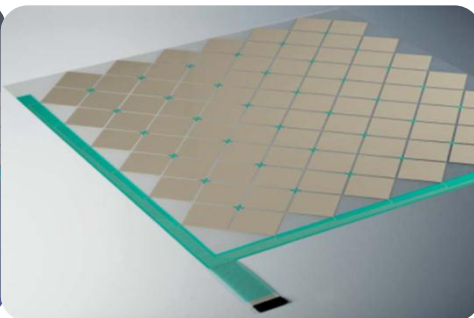
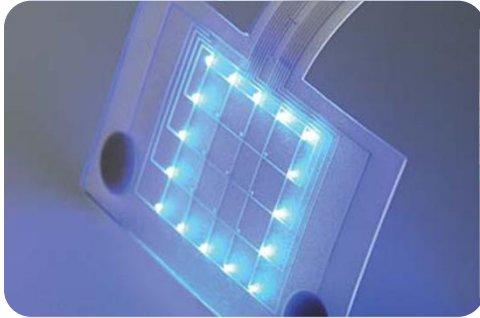


Conclusions

- Printed Intelligence Technology and Components demonstrated
- Roll-to-Roll and Hybrid Integration Pilot Factory available
- Time for intensive System and Product development
- We welcome new Industrial Partners to join our commercialization efforts
 - creating application driven value chains
 - membership in PrintoCent Ecosystem
 - or bilateral co-operation



ACKNOWLEDGEMENTS



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- Research partners & Industrial collaborators
- Co-workers throughout VTT working on developing printed intelligence

More information on www.vttprintedintelligence.fi



Thank you for your attention!

Contact information:

Raimo.Korhonen@vtt.fi





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technology for business
and society**