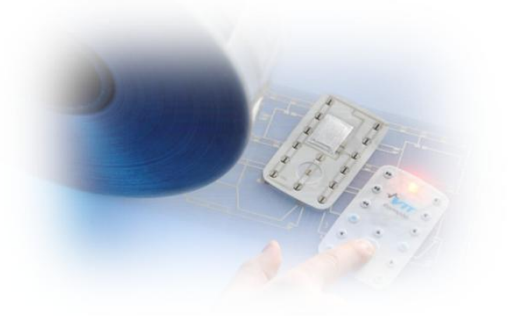
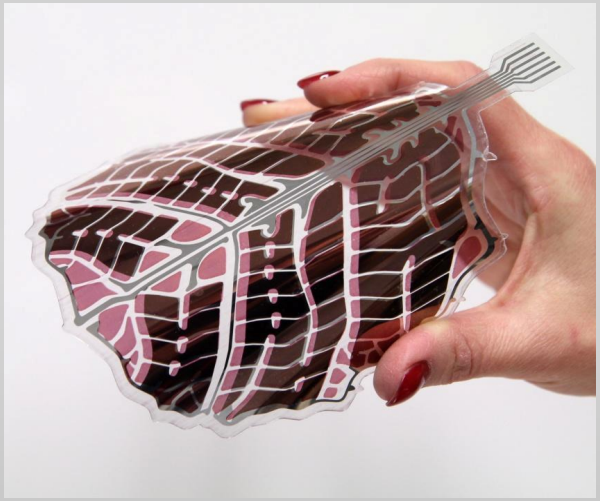
Future Prospects of Printed Intelligence Applications



Prof., Dr. Harri Kopola
VP Research
Knowledge Intensive Products and Services
VTT Technical Research Centre of Finland Ltd.
Email: Harri.Kopola@vtt.fi
Tel.: +358-40-5574867

Iarigai'2015, Sept. 7, 2015, Helsinki

Outline



VTT – Technology for business

VTT Technical Research Centre of Finland Ltd is the leading research and technology company in the Nordic countries. We provide expert services for our domestic and international customers and partners, and for both private and public sectors. We use 4,000,000 hours of brainpower a year to develop new technological solutions.

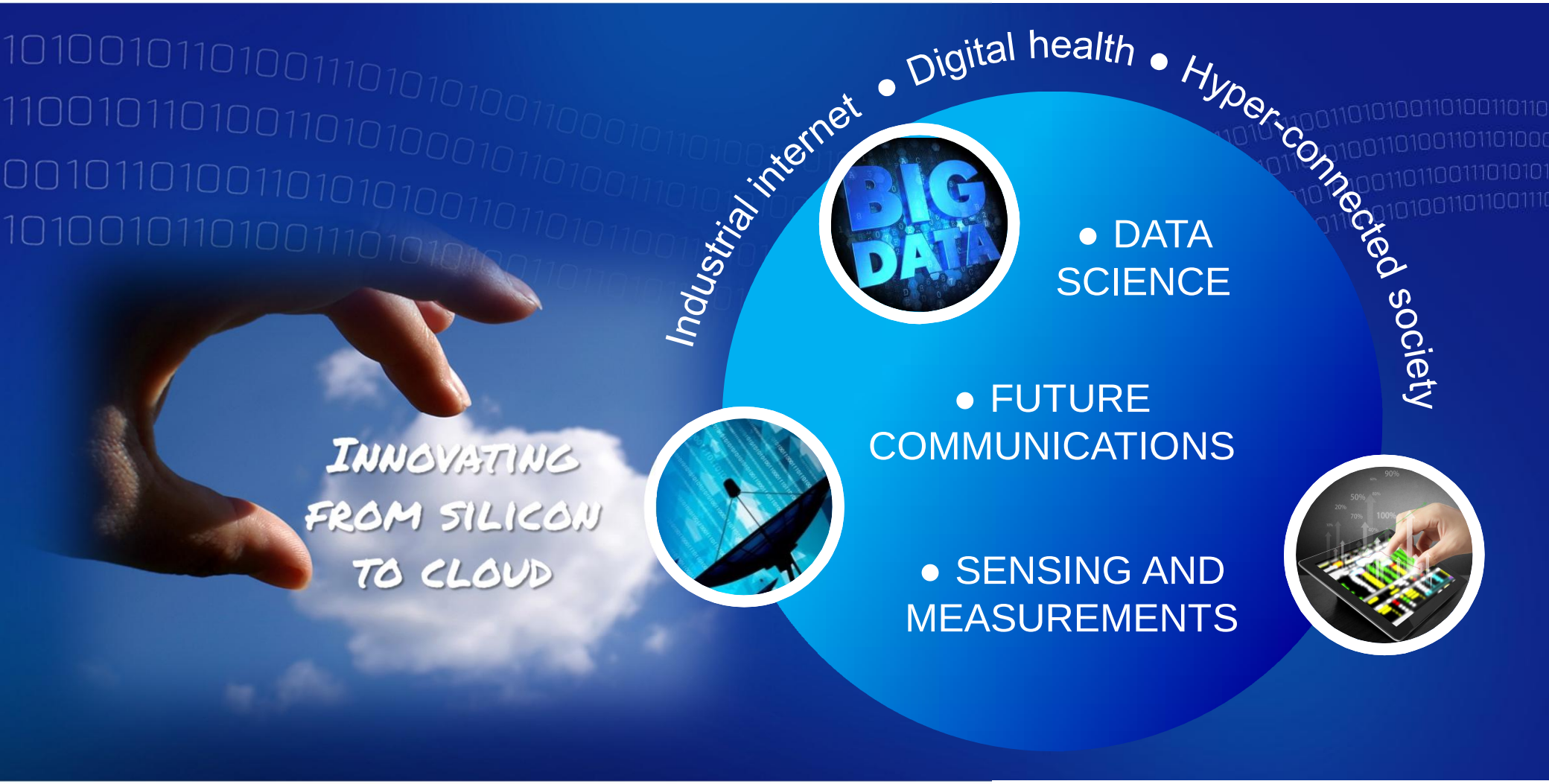
We develop new smart technologies, profitable solutions and innovative services. We cooperate with our customers to produce technology for business and build success and well-being for the benefit of society.

VTT is a non-profit organisation and a crucial part of Finland's innovation eco-system. VTT operates under the mandate of the Ministry of Employment and the Economy.

- Turnover 277 M€ (2014 VTT Group),
- Personnel 2,600 (1.1.2015 VTT Group)
- Business Areas
  - Knowledge Intensive Products and Services
  - Smart Industry and Energy Systems
  - Solutions for Natural Resources and Environment

*) Source: Roles, effectiveness, and impact of VTT, VTT & Technopolis Group, 2013.

Knowledge Intensive Products and Services



VTT Printed Intelligence in brief

Personnel about 100

Key customer sectors
- Consumer packaging
- Medical and diagnostics
- Consumer electronics
- Construction and energy
- Materials and processes

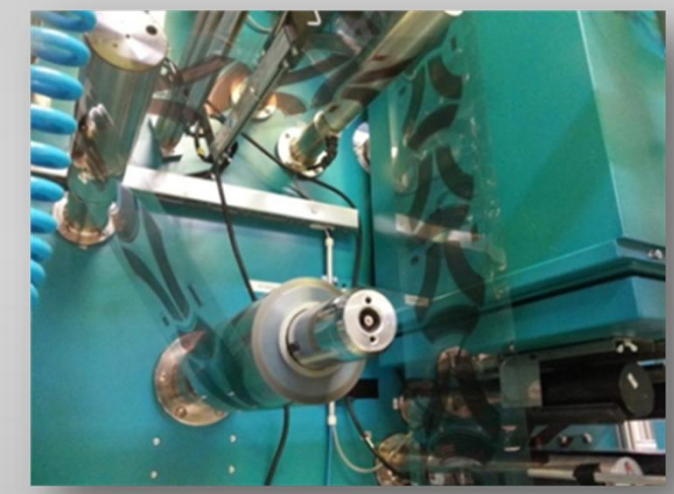
Key customer offering
- Contract R&D
- Pilot production trials
- IPR out-licensing and sales
- Foresight and roadmaps

Key research areas
- Printed photovoltaics,
- Printed organic LEDs
- Printed transistors
- Printed sensors
- Printed indicators
- Printed powersources
- Bio- and microsystems
- Hybrid solutions combining printed and other devices
- Nanoparticles and functional inks
- Systems design and pilot manufacturing

Program evolution
- Project mode late 90's
- R&D program 2006-
- Commercialization 2010-
- Pilot Factory 2012
- Pilot Reactor 2013

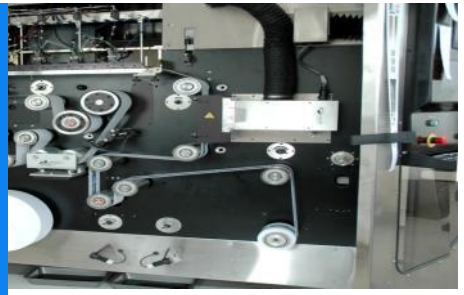
R2R infrastructure
- Laboratories
- R2R printing lines
- R2R evaporation unit
- R2R laser machinery
- R2R hybrid integration

Outline



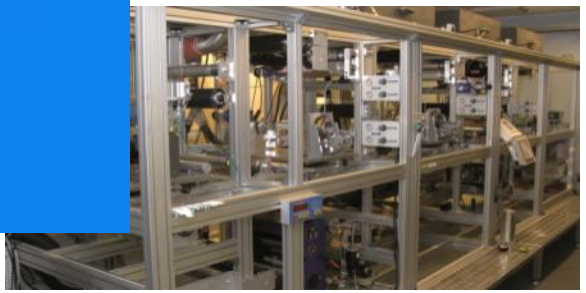
Roll-to-roll manufacturing

VTT
Pilot Factory



roll-to-roll ink-jet

PICO – in-air roll-to-roll pilot line



ROKO – in-air roll-to-roll pilot line

Injection moulding

R2R assembly and bonding

06/09/2015MAXI – In-air roll-to-roll pilot line

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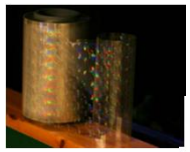
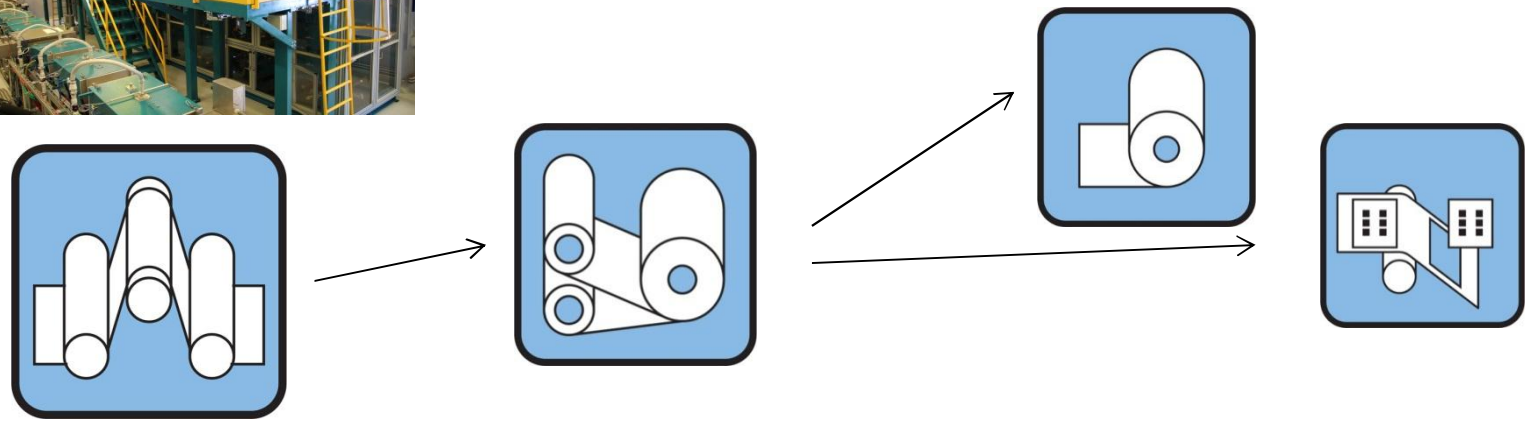
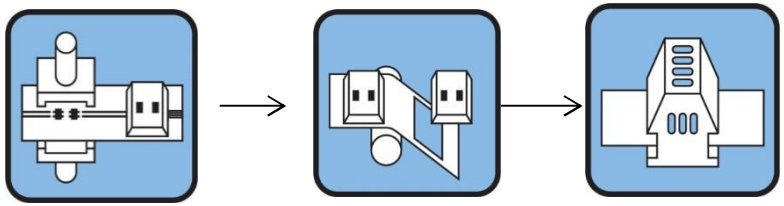
System Integration

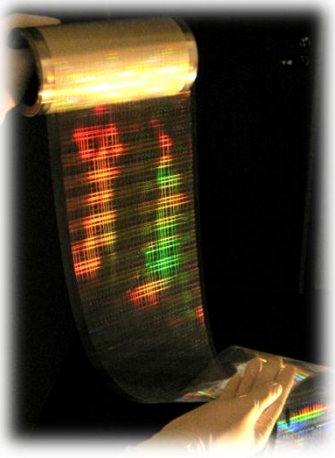
R2R and Hybrid Integration + Injection Molding







Examples of R2R manufactured opto & electronic components



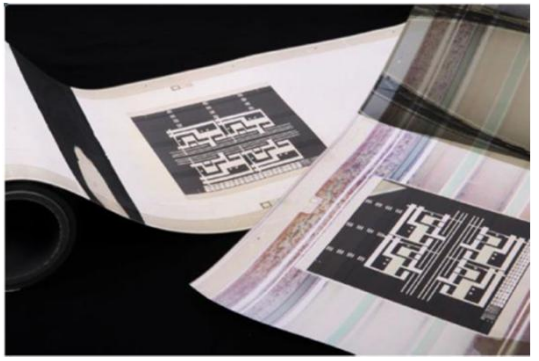
R2R imprinted diffractive optics

R2R printed transparent OLEDs

R2R printed OPV modules

R2R printed PANI batteries

R2R printed WORM memories



Fully R2R processed OTFTs

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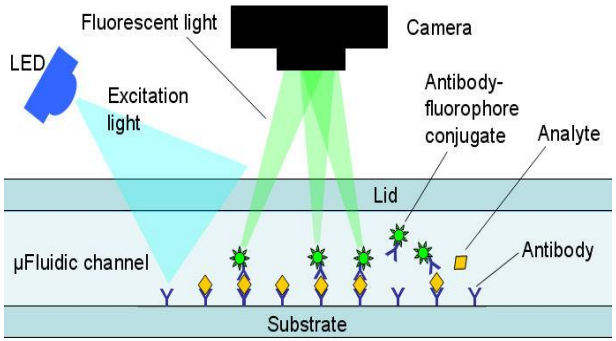
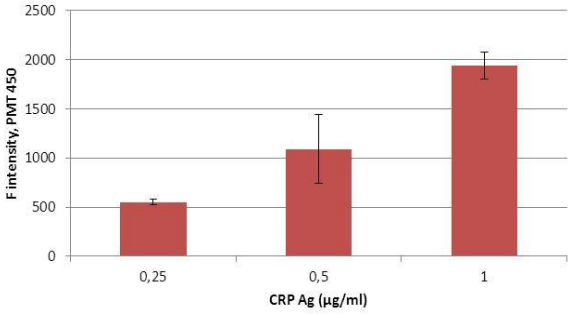
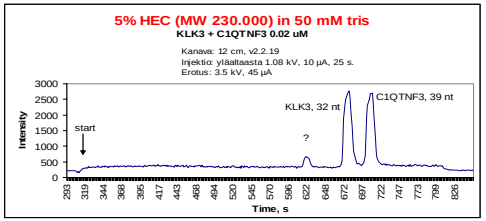
Microfluidic Platforms for Health and Wellness Applications

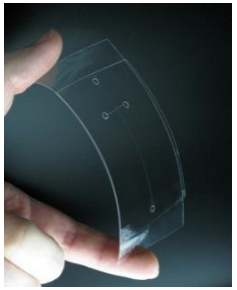
Fully Integrated immunoassay chip



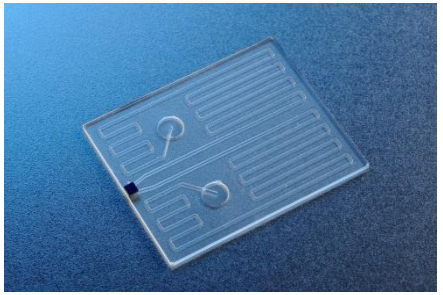


Capillary electrophoresis

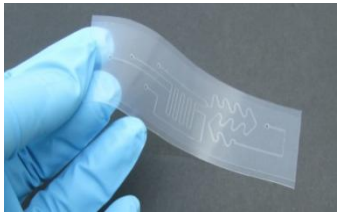


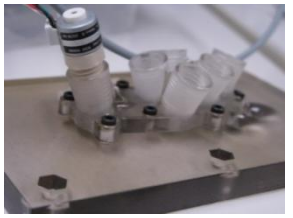


Chip-to-polymer hybrid microfluidics for miniaturized sampling

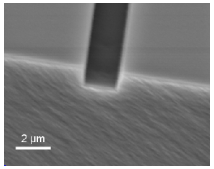


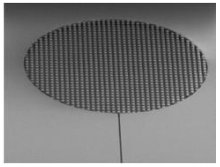
Enzyme activity measurement

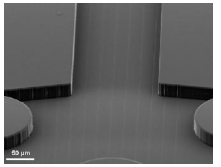




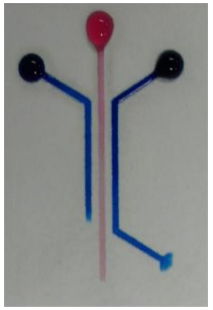
Polymeric Optofluidic platforms

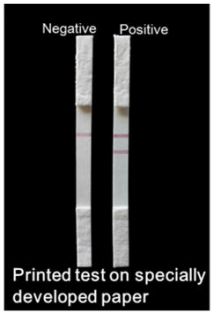


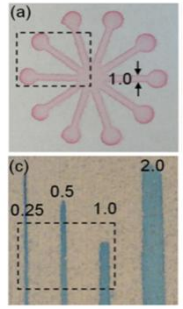




Paper based Rapid Diagnostics







Printed Functionalities on Flexible Polymer Chips

Mass Manufacturing
- Roll-to-Roll printing techniques
- Flexible substrates
- Compatible materials, *e.g.*, PMMA, COC, COP, PC, CA
- Large printing area enabling fabrication of multiple chips simultaneously

Fluidics
- Channels
- Capillary pumps
- Mixers
- Reaction chambers
- Blister packs for liquid storage

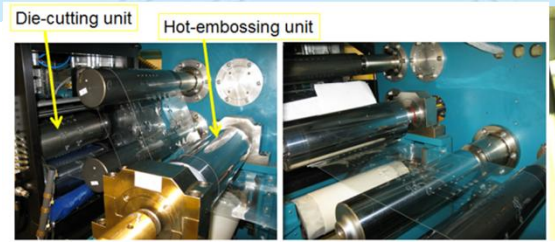
Chemistry
- Surface modifications
- Hydrophobic/-philic surfaces

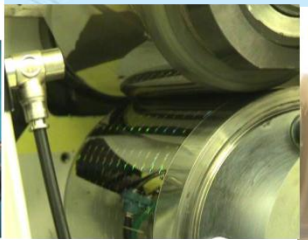
Electronics and optics
- OLED light sources
- Batteries
- Connectors
- Antennas
- Electrodes

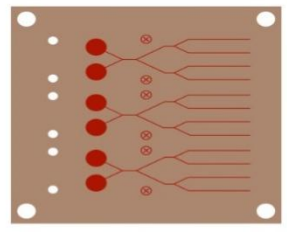
Detection
- Sensing surfaces
- Qualitative/quantitative

Biomolecules
- Immobilization
- Ink-jet printing in lab- and pilot-scale
- Dispensing

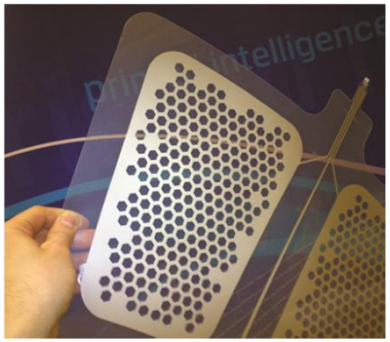
R2R technologies enable high volume manufacturing of disposable lab-on-chip devices



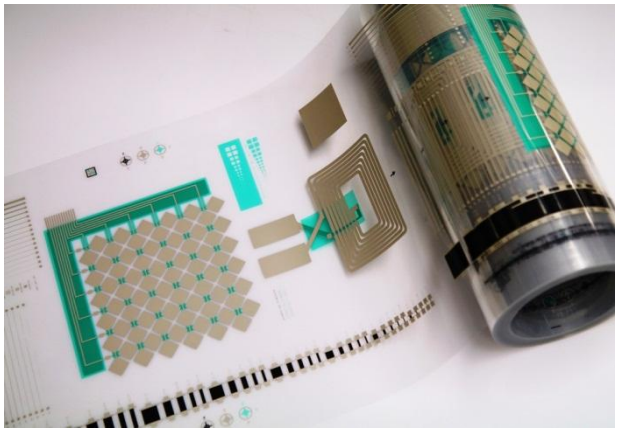


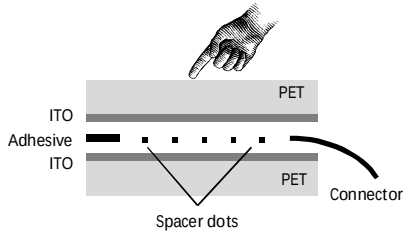



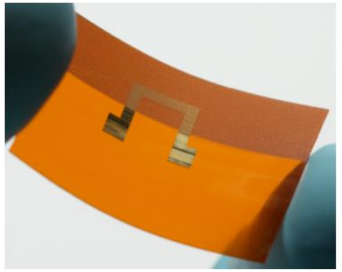

Roll-to-Roll Printed Flexible Sensors



- R2R manufactured Capacitive Proximity Sensor Device
- R2R Manufactured Capacitive Moisture Sensor Device
- R2R manufactured Resistive Touch Sensor Device
- Gravure Printed Resistive Gas Sensor Device

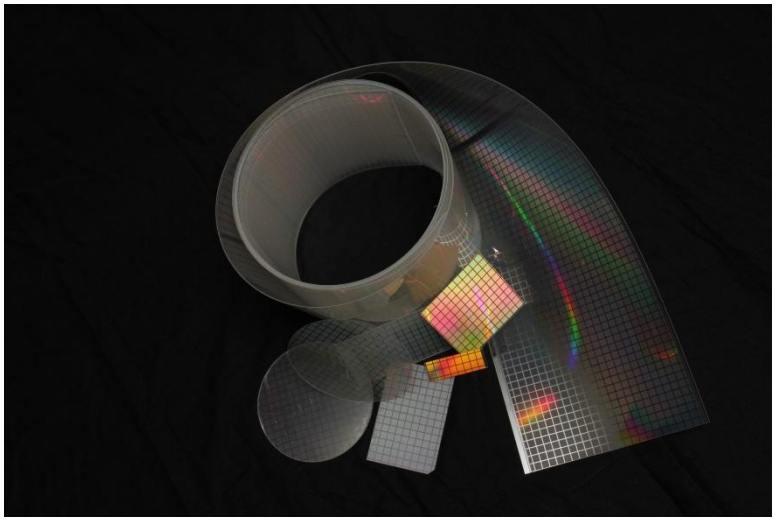




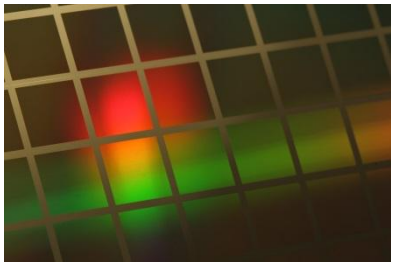


Micro and nanophotonic chemical sensors

- Micro and nanophotonic chemical sensors by the use of roll-to-roll printing
- Results of FP7 project PHOTOSENS (www.photosens.eu)
- Including free-form SERS sensor, roll-to-roll printed waveguide sensor and Photonic Crystal sensor.



Nanoimprinted roll of substrate showing continuous SERS array



Nanoimprinted roll of substrate showing and cut out 96 well plate (gold coated)

SEVENTH FRAMEWORK PROGRAMME

PHOTOSENS

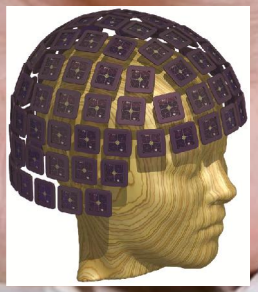
Outline

Opportunities for Advanced Services and Products

- Solving Societal Challenges – Health & Wellness
- Internet-of-Things Solutions
- Industrial Productivity







VTT creating paper-thin products from roll-to-roll printing and hybrid integration

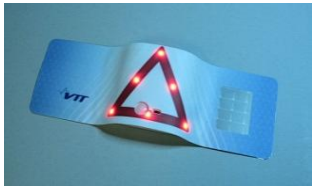
- Design freedom - new form factors- arbitrary shapes, any size, decorative design
- Large area product architectures
- Turn any surface to smart User Interface
- Flexible Signage and lighting

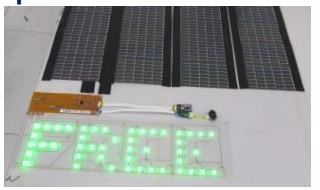
- Lower product complexity-seamless integration
- Reduced product volume, thickness and weight


2 m x 0.2 m flexible LED luminaire


Electrochromic display poster with OPV


NFC powered blink ‘n’ link card


Intelligent warning sign



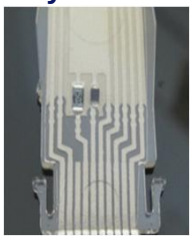
Autonomous road sign


Disposable cholesterol sensor

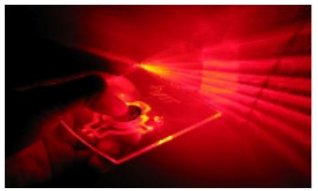

Voting card with flex battery


Disposable healthcare sensor

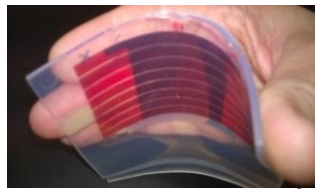

Over-moulded LED strips


Connector structure


Over-moulded OLED


Battery compartment


LEDs, touch, optics


Over-moulded OPV

Skin Treatment Patch

Cosmetics or Medication Purposes

- More speed to skin care routine at home: VTT has developed quick and easy-to-use beauty patch for galvanic skin care.
- Patch represents a new, tested mechanism to enhance skin permeability
- The required microampere-scale current is produced by a printed bio power source that uses glucose as fuel
- Patch can be used with a versatile range of cosmetics.

VTT's galvanic skin treatment patch

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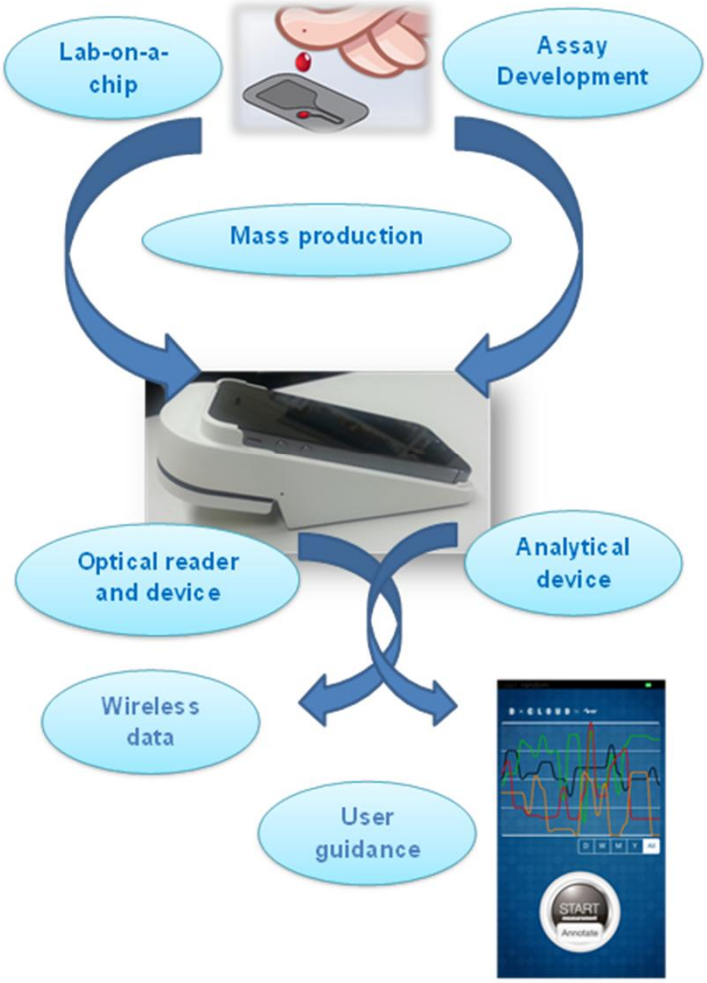
Mobile Health and Wellness Monitoring System

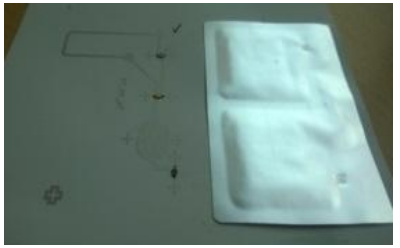
From test Chip to Cloud Service

- VTT's one-stop shop for creating new diagnostic solutions for the customers:
  - reagent development
  - development of analytical devices
  - personal health solutions (ICT)

- Application Example: Dose Coach for MS Disease Medication
  - Measures the medication level from serum sample by immunoassay
  - Asks for symptoms and side effects to evaluate effect of medication
  - Collects data to cloud service



Roll-to-roll processing on paper substrates
Case: Security tag demonstrator



Roll-to-roll process:

1st substrate:

- R2R flexo printing of silver conductors and carbon resistors
- R2R assembly of LEDs and battery

2nd substrate:

- R2R graphics foliation
- Button embossing
- R2R Registration hole perforation
- R2R Button conductor silver flexo printing
- R2R Heat adhesive flexo printing

Final stack:

- R2R heat lamination

Label/shipment ok

Label broken/ shipment opened

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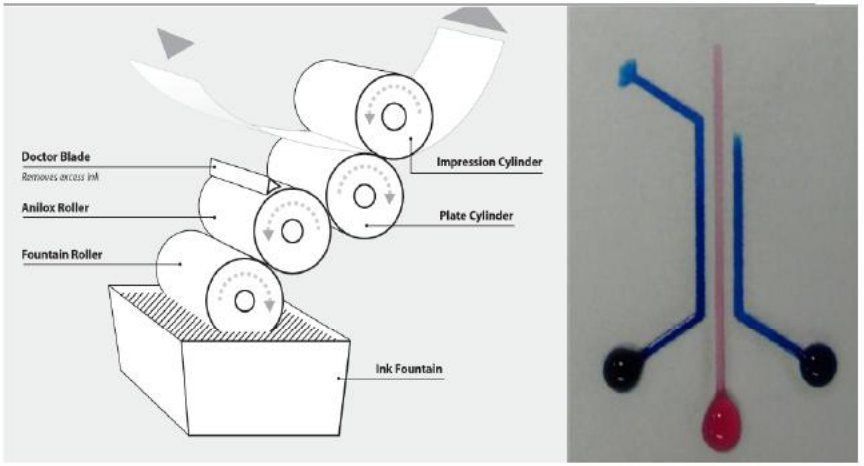
THE ACTIVE PAPER COMPANY

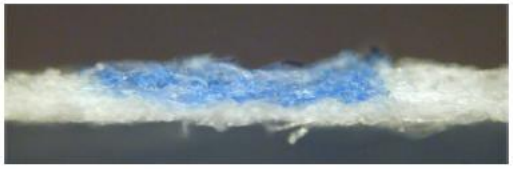
ACTIVE PAPER TECHNOLOGY*

*Patents pending, one granted in Finland

- A drop of liquid activates a controlled color change effect.
- Control of water absorption and flow on a paper substrate.
- By printing hydrophilic and hydrophobic patterns using proprietary materials.
- Standard printing methods and processes can be used!
- Printing of reaction chemistries on Active Paper sheet enables simple sensors based on visual indication!



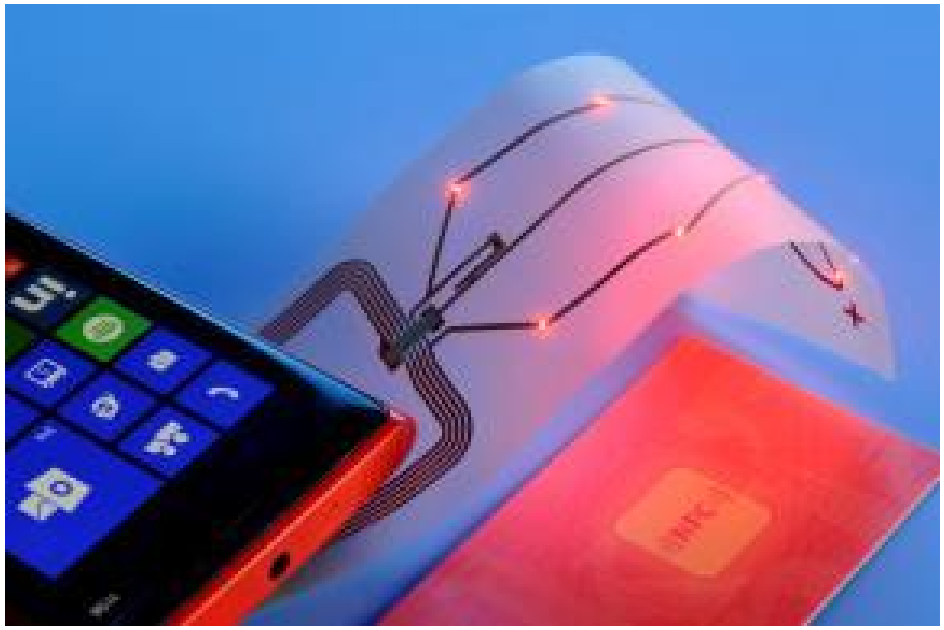
Flexography is the most commonly used method in packaging printing.



www.theactivepaper.com

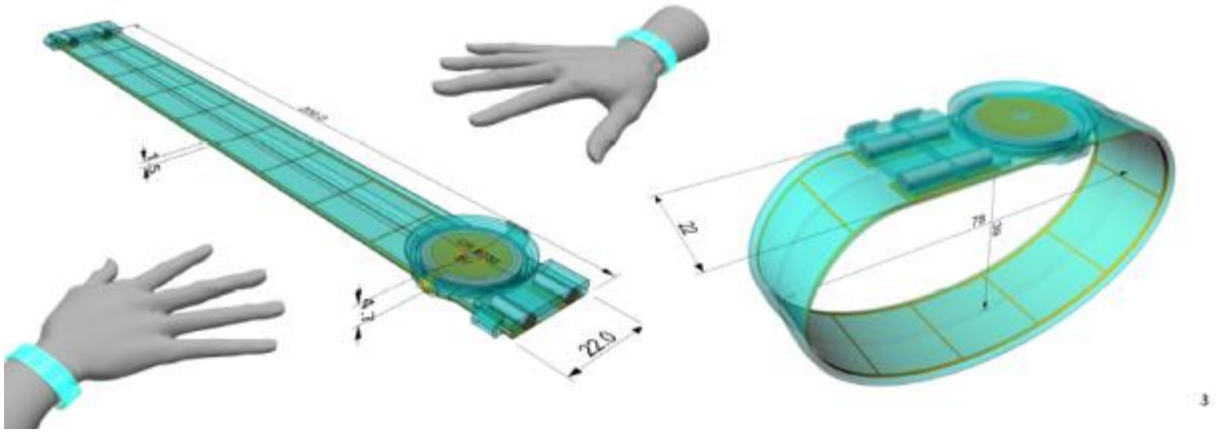
Paper thin wirelessly powered sensors

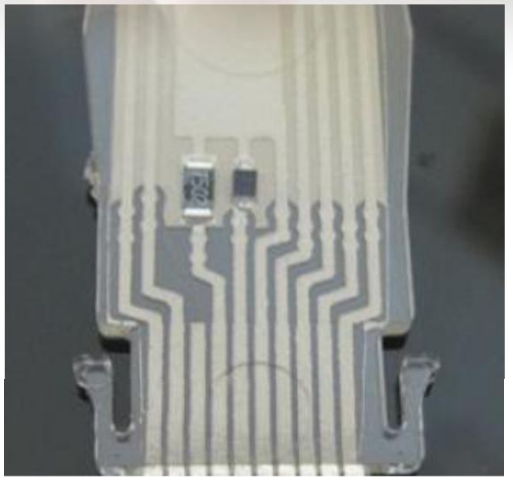
- paper thin wireless powered sensors
- NFC sensors on flex available today for upscaling



- applications medical, construction, industry

Plastic overmolded integration



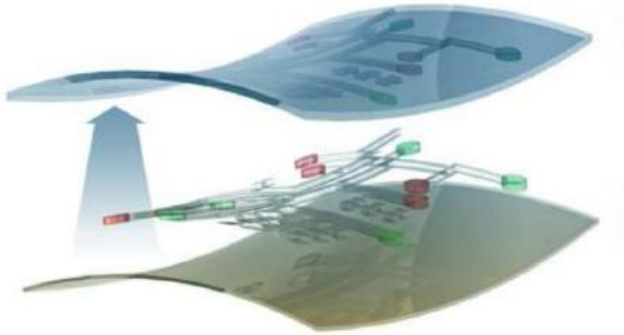


In-moulded connector of flexible health care sensor

**Roll to roll process for electrodes,
circuits, chip integration, overmolded connectors**

Applications:
Fully flex wearable electronics
Flexible medical devices (patches, sensors)

True 3D Encapsulated Electronics



6) Injection mold with an insert
5) Create 3D form
4) SMD components
3) Print membrane circuitry
2) Print decoration
1) Clear flexible film

- Printed flexible membrane circuitry and printed components utilized in combination with standard passive and active electrical components such as sensors, controls and LEDs.
- Novel roll-to-roll manufacturing method incorporating standard mass production equipment and printed electronics.

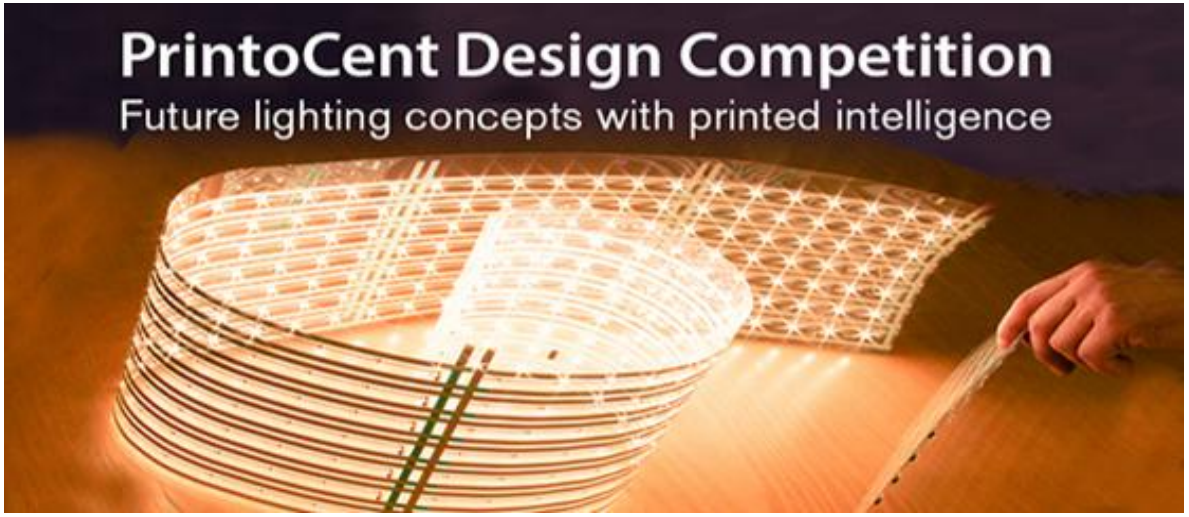
TactoTek **Intelligent Plastic Surfaces. Smart Designs.**

Copyright VTT

Internet of Things Roaming to Hand Towel Dispensers

- The cloud-driven display brings **digital advertising** to places where it has not been possible before.
- Digital display can be installed anywhere – no power cord needed
- **First commercial application**, the display is integrated **into Lindström's towel dispensers**. The advertisement on Smart Lid changes every time a customer pulls the towel or moves a hand in front of the screen
- In Finland alone, Lindström has 100 000 dispensers from which fresh towel is pulled around 350 million times a year

Lindström POSTERFY VTT VTT VENTURES LTD



The Grand Winner
Koistinen Oskari with *Tykky*

The Best Business Potential
Saccardi Samuele with *Eclipse*

The Wildest Idea
Koivuaho Anniina with *Aava*

Honorary mention
Saavalainen Juho with *Adjustable table light*

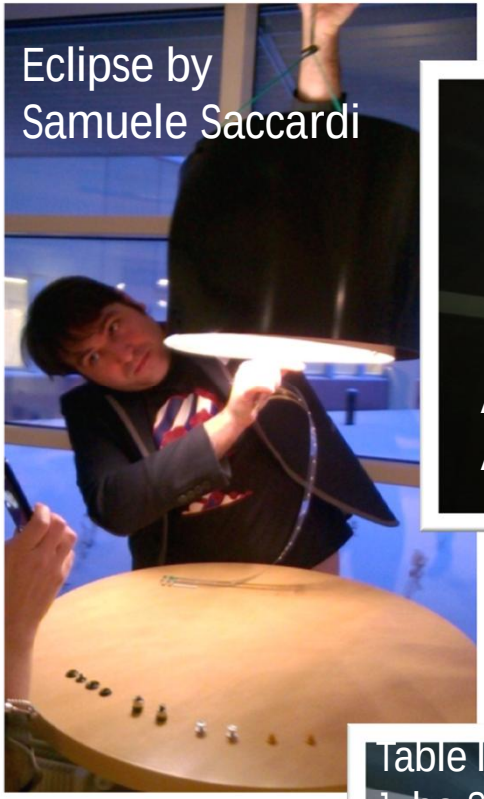
Honorary mention
Laitinen Joona with *Fabian*

To boost awareness around printed intelligence, the 1st **PrintoCent Design Competition** was launched in October 2014

As a result, around 20 open-minded designers and engineers from Finland and Italy challenged themselves with printed intelligence. Their competition works were outstanding!

In January 2015, TOP5 finalist gave presentations on their polished and fine tuned designs for media, jury and various industry audiences and the winners were chosen.


Tykky by
Oskari Koistinen


Eclipse by
Samuele Saccardi


Aava by
Anniina Koivuaho
PrintoCent
www.printocent.net
PrintoCent


Table light by
Juho Saavalainen


Fabian by
Joona Laitinen

Outline

PrintoCent

PrintoCent

Commercializes the research results of the Printed Intelligence and Optical Measurement

2009 -2012

- Established 2009 - VTT led community to create business
  - Goal to >10 M€ programme
- Status 2012 - resources for commercialization and industrialization
  - Pilot Factory and Demonstrators
- Cooperates – excellent network
  - COLAE

2013-2015

- Create Industry Cluster to build Value Chains
  - 50 companies - now 43 omboard
  - 22 start - ups
- Offers unique Design, Develop and Pilot Manufacturing Environments
  - >300 people working
  - Services - companies, research institutes. trainings, student thesis
- Joint projects – 15 M€ programme
  - 3 cases / 100.000 pcs
  - Learning about various Product Concepts
  - Towards Industrial Balanced Competence Building

www.printocent.com

Leverage from the EU

European Union
European Regional Development Fund

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PrintoCent

PrintoCent Industry Cluster Members (43)

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...still some more are welcome!

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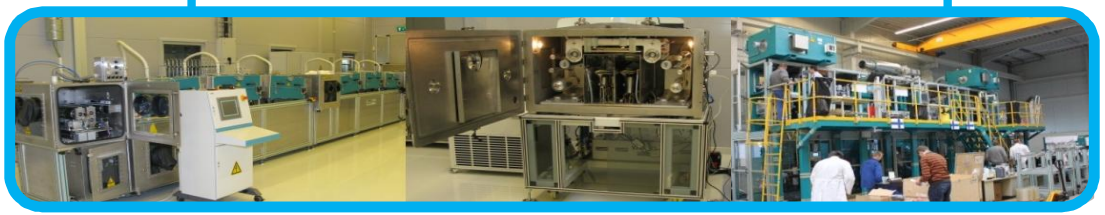
Leverage from the EU
European Union
European Regional Development Fund

PrintoCent

PrintoCent Pilot Factory Concept

- R2R functionality testing
- Component assembly
- Injection moulding

Roll to Product



- Pilot production for components, products and systems
- Multilayer printing in register
- Product testing and characterising

R2R Pilot production

- Ink tuning for R2R process
- R2R printing trials
- Layer and component prototyping and testing
- R2R process development

Up-scale to R2R

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- Material research, development and testing
- Printing tests with different techniques
- Layer and component characterisation
- Application development
- Demonstrator manufacturing

R&D at the research laboratories

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PrintoCent

PrintoCent
Start-Ups founded since 2010

1. MK Fluidics , Machinery, Tools, Diagnostics, Oulu
2. FocalSpec, Optical instrumentation, Oulu
3. *(Lumedy -OLED lighting solutions, Oulu – on hold)*
4. Nanordic, Nanomaterials, Oulu
5. Iscent , Hot embossed decorative products, Tampere-Helsinki
6. TactoTek, Optical Touch Screens, Oulu
7. Ginolis, ex GIN, Rapid diagnostics, Oulu
8. KeepLoop, Mobile phone microscope, Tampere & Oulu
9. Spektikor, Disposable heartbeat monitor, Oulu: CEacceptance 11/2012, NATOcompliance
10. *(Detemex, Disposable diagnostics, Oulu)*
11. Neficon, Development services, Oulu
12. Goodwiller, Disposable Diagnostics, Oulu
13. *(Premisense, home monitoring, Oulu)*
14. MePromation, R2R testing services, Oulu
15. Qlu, Hearing Aid Services and Systems, Oulu
16. The active paper company, Helsinki
17. InstaFe, Oulu
18. Flexbright – Spinout from Neonelektro, Oulu
19. Posterfy - Advertisement, Helsinki
20. MoniDrops - Disposable Diagnostics , Oulu
21. Kala Products , Oulu
22. Movesole , Oulu

Challenge is to identify high quality business cases

- > 0.5 B€ market potential
- Industry interest - channel to market
- Competence - resources to make it

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European Union
Regional Development Fund

PrintoCent

PrintoCent Designer's Handbook

Buy and download from: www.ppe-info.com

www.printocent.com

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PrintoCent

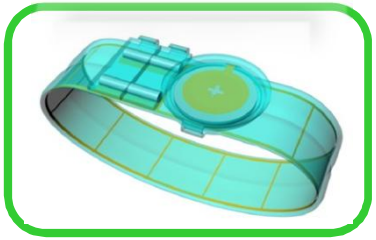
Future Steps on Industrialisation Route 2015 ->

Disposable microfluidics & health batches

Smart flexible lighting & signage

Energy harvesting & storage

Wearable products



- Identified Key Application Areas for Product Concepts
- Pilot Factory Upgrade 2015-2016
  ⇒ Advanced Pilot Manufacturing
- Efficient Ecosystem for Industrialization
- InnoFest 2015, Innovation Competition, June 11-12, Oulu, Finland
- **PRINSE'2016** Printed Intelligence Industrial Seminar, Oulu, Finland **June 7-8, 2016**

Leverage from the EU

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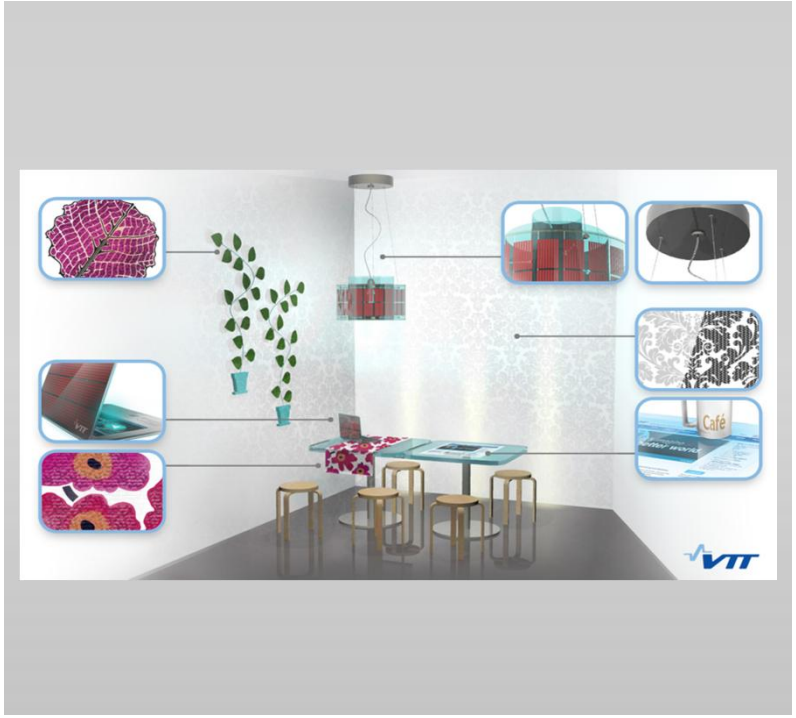
BUSINESS OULU

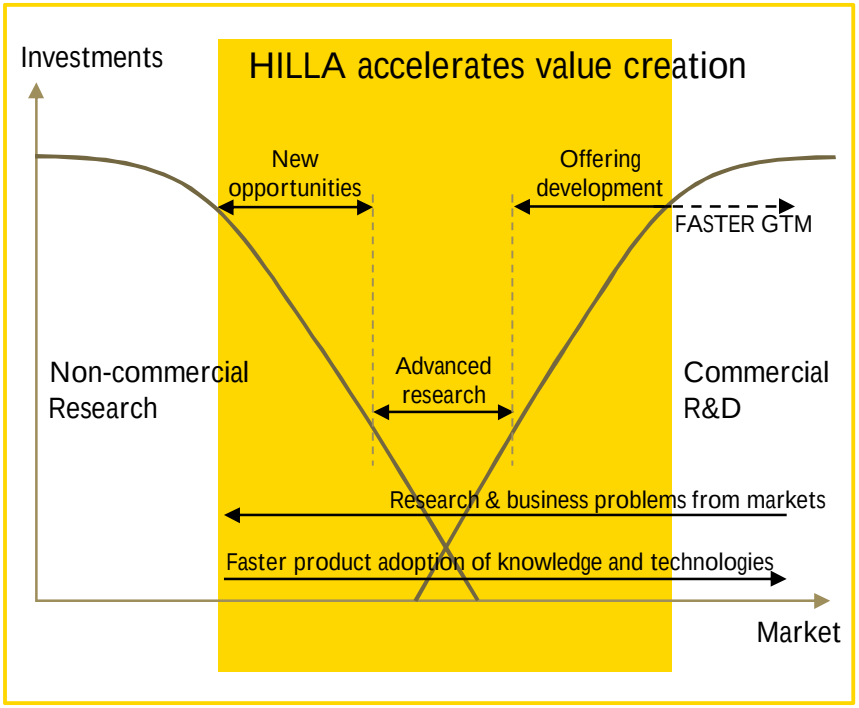
Outline

1. Introduction
2. Enabling technology
3. Towards Products
4. Routes to Industrialization
5. **Integration to Application Areas**
6. Conclusions

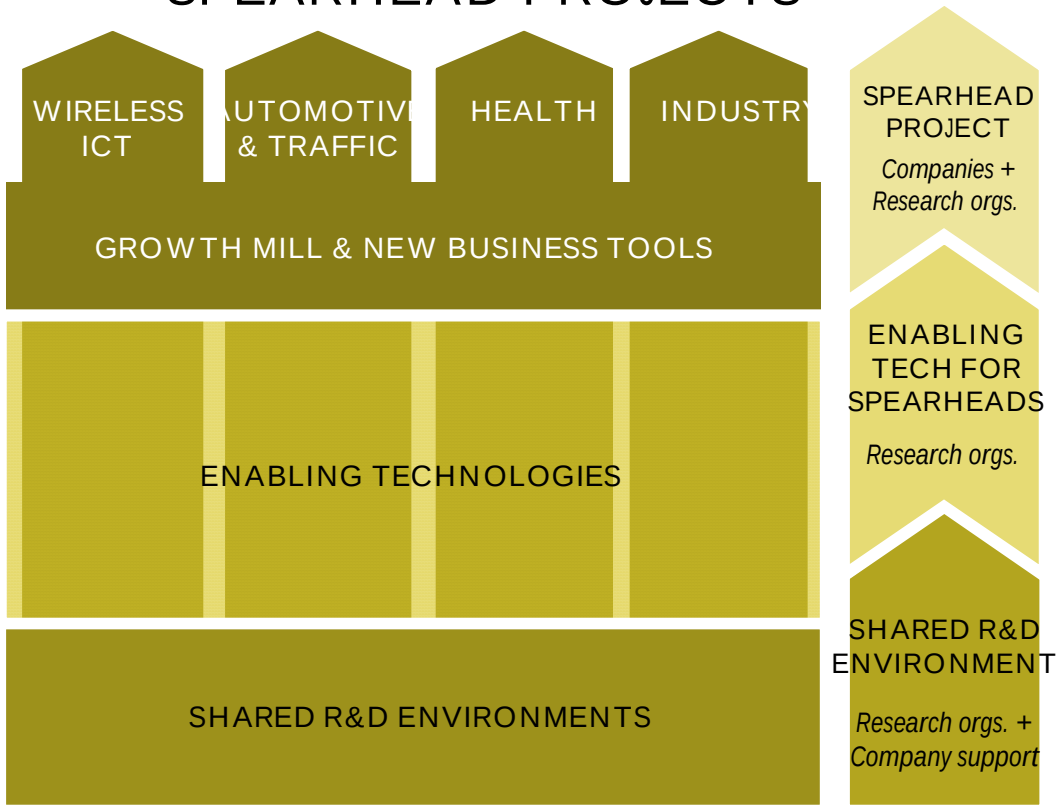


Hilla Program (50M€, 5 years) for Building and Catalysing New Business Spearheads

PILOT NEW MODEL TO BRIDGE RESEARCH TO BUSINESS



COMPANY DRIVEN SPEARHEAD PROJECTS



BUSINESS OULU OAMK

HILLA Northern Gol

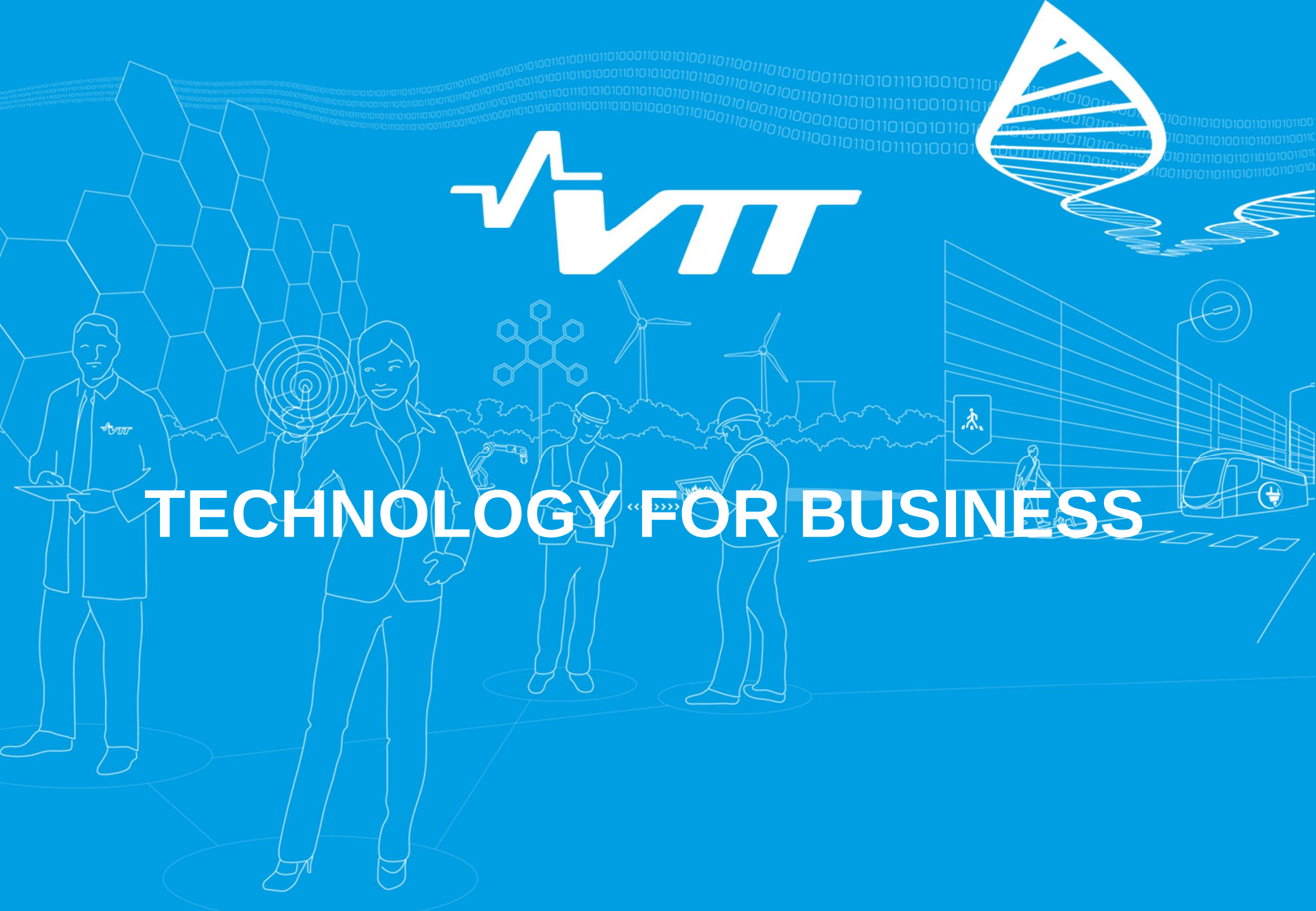
The Naked Approach

User lives “naked”
without gadgets

Nordic perspective to gadget free hyper connected environments

Conclusions

- VTT has demonstrated paper-thin electronic components and systems and pilot applications.
- Design, Development and Pilot Manufacturing Environment
- Towards Industrial Balanced Competence Building
- We welcome new Cooperation Partners to join our research and commercialization efforts creating products and application driven value chains


TECHNOLOGY FOR BUSINESS