Benefits of inkjet printing for printed electronics

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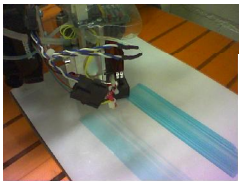
Liisa Hakola
VTT Information Technology

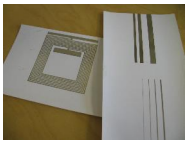
AGENDA

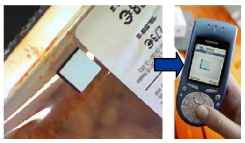
- Printed functionality
- Using inkjet printing for making electronics
- Inks, substrates and printers for inkjet printed electronics
- Inkjet printed electronics at VTT Information Technology
- Conclusions
  - Is inkjet meeting the need for increased accuracy, mass manufacture and cost effectiviness?

Printed functionality

- Optics
- Electronics
- Optical codes
- Reactive inks
- Flexible displays
- Diagnostics
- Food quality indicators







Using inkjet printing as a manufacturing method

MANUFACTURING (at least partially, low-cost devices)

- electronics: passive components, circuit manufacturing
- MEMS devices
- displays
- RFID components
- solar cells
- optics: micro lenses
- diagnostics: DNA synthesis, medical research and development
- medical science: dosing, sorting, DNA and tissue preparation, laser surgery
- CTP plate making
- smell generation

SUITABLE JETTING MATERIALS

- solders and epoxies
- optical polymers
- conductive and semi-conductive polymers
- metal particles and metal nano-particles
- transparent conductors
- dielectric and resistor materials
- ferrite materials
- reagents
- optical absorbents
- biomedical materials

Why inkjet printing?

- Digital non-impact printing method, additive
- All kinds of substrates
  - Rigid or flexible substrates
  - Rough or smooth surfaces, 3D surfaces
- Accurate, high resolution, high speed
- Possibility for mass customisation
- Low material consumption
- Inks for all kinds of applications
  - Printing inks
  - Functional inks

Inkjet for printing electronics compared to other printing technologies

Inkjet

- Customisation
- Printing speed increasing (currently around 1 m/s)
- Substrate independent
- Ink development challenging
- Easy to integrate with existing production lines
- Not many commercial inks available yet

Conventional printing methods
(flexography, gravure, screen printing, offset)

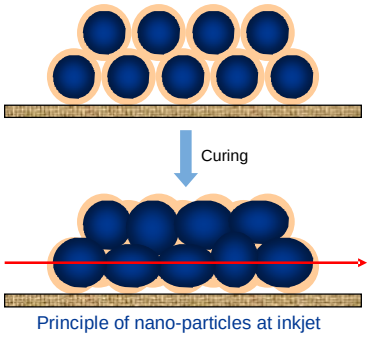
- Constant image content
- Mass manufacturing with high speed (around 20 m/s)
- Not all substrates suitable
- Ink development not so challenging
- Integration requires space and changes in existing production lines
- Many commercial inks available

Inkjet technologies for printed electronics

	Continuous Inkjet	Thermal Inkjet	Piezoelectric Inkjet
Principle	Continuous drop formation. Electrodes guide image forming drops to substrate and other drops for re-circulation.	Drop-on-demand: drops generated only when needed. Heater generates a bubble that forces an ink drop out of the nozzle orifice.	Drop-on-demand. Piezoelectric crystal generates a pressure pulse that forces an ink drop out of the nozzle orifice.
Benefits	High speed.		Only acoustic pressure affecting ink during drop formation → choice of ink chemistries. Durable printheads.
Drawbacks	Ink re-circulation not preferred with often sensitive and expensive inks → ink waste. Large drops → low resolution.	Ink sedimentation. Low speed. Short printhead lifetime. Ink exposed to high temperature (even 300°C) during drop formation.	Nozzle drying.

Technologies enabling inkjet printed electronics

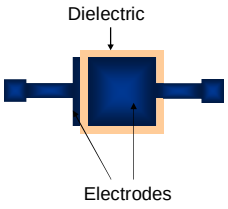
- Nano technology
  - nano-particles enable small particles required in inkjet inks
- Conductive polymers
  - conductive materials suitable for ink components
- Development of inkjet printheads
  - increasing speed, jetting reliability and accuracy
  - decreasing drop size



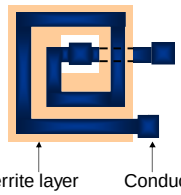
Principle of nano-particles at inkjet printed metal layers

Inkjet printed electronic components

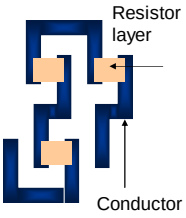
CAPACITOR



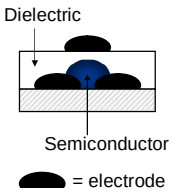
INDUCTOR



RESISTOR

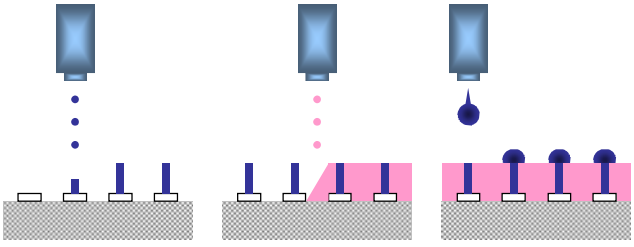


TRANSISTOR



Applications for inkjet printing in printed electronics

- Direct printing of electronic components
- Several printheads easily integrated
  - all parts of an electronic component can be inkjet printed
- Hybrid printing with conventional printing methods
  - inkjet for customisation
- Layering of printed material for improving performance and making 3D structures



Investing in inkjet printed electronics

INKJET PRINTING

- ink prices
  - conductive polymers ~ 400 €/kg
  - metal particle inks ~ 5000-10 000 €/kg
- ink consumption ~ 1 g/m^2 with one ink layer
  - conductive polymers 0.4 €/m^2
  - metal particles inks 5-10 €/m^2
- printers cheaper than presses

CONVENTIONAL PRINTING

- Ink prices
  - conductive polymers ~ 400 €/kg
  - metal particle inks ~ 2000-20 000 €/kg
- ink consumption ~ 2 g/m^2 *
  - conductive polymers 0.8 €/m^2
  - metal particle inks 4-40 €/m^2
- plate making, pre-press and set-up add costs

*Juhola, H., Linna, H., Tepponen, T. *Printing (in Finnish). 1988. 239 p.*

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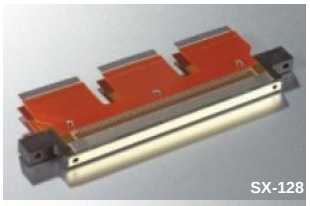
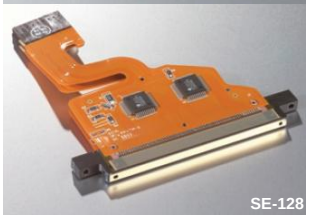
Printheads for inkjet printed electronics

- Dimatix (Spectra) manufactures inkjet printheads designed for material deposition e.g. printed electronics
- SX-128
  - drop size 10 pl (27 µm diameter)
  - for fluids with pH as low as 1.5 such as conductive polymers
  - every nozzle can be controlled individually
- Other printheads also suitable for making printed electronics
  - SE-128 with 30 pl drop size
  - Nova AAA with 80 pl drop size





Printers for inkjet printed electronics

2000

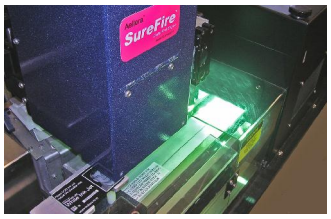
2005

Litrex

- Piezoelectric inkjet printers for making OLED and LCD displays
  - Layering light emitting or conducting materials
- Printers suitable for clean room environment
- From 20 cm × 20 cm printing area to 2 m × 2 m
- Product development, research, prototype manufacturing

Other printers

- Printers based on Dimatix printheads have potential in printed electronics



Aellora SureFire™ print engine
•can be integrated to a production line
•300-1200 dpi
•up to 65 cm/s

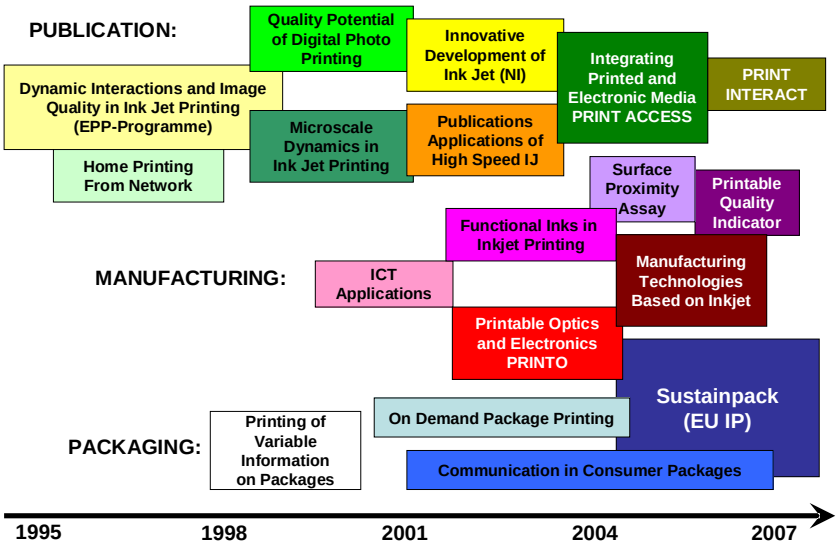
Impika
•MatJet for making printed electronics
•can be integrated into a production line
•600 dpi
•maximum speed 1 m/s

Jetrion 3025
•printing on production lines
•316×526 dpi
•up to 13 m/min

Commercial inks for inkjet printed electronics

- Silver nano-particle ink from Cabot
  - sheet resistivity of 0.1-0.5 Ω/square achievable
  - plans to produce all kinds of inks for inkjet printed electronics
    - inkjet printed nickel and resistor ink under development
- PEDOT ink from Bayer Chemicals for OLED displays
  - printed layers resistivities of 1000 Ω cm achievable
- Copper inks for high volume customers from CIT Limited (Xennia)
- Ink development for conductive and dielectric inks at several companies on-going

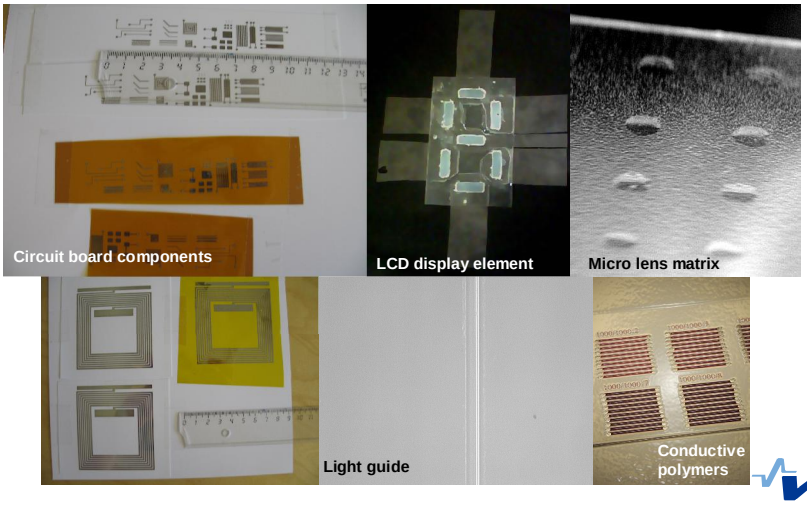
Digital Printing Research at VTT Information Technology 1995-2007



Inkjet research environment at VTT Information Technology

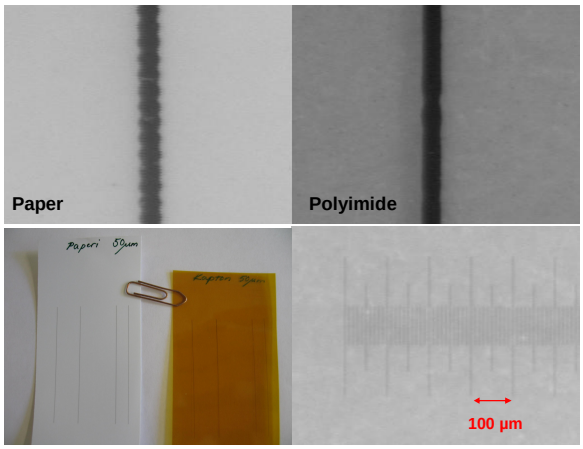
- Inkjet printheads manufactured by Dimatix (Spectra)
- Apollo II printhead support kit for 2-colour printing
- XY Materials Deposition System from iTi
  - possibility for heated substrate
  - 25 cm × 25 cm print area
  - positional repeatability 1.0 µm
- XY table for printing large areas
  - 75 cm × 75 cm print area
- High-speed CCD camera for imaging ink drops during flying, impact, spreading and drying

Inkjet printed electronics and optics at VTT Information Technology



Inkjet printing fine conductors

- 50 µm wide conducting silver lines
  - Dimatix SX-128 printhead with 10 pl drop size
  - Cabot Silver Ink Conductor ink
- 70 µm line width with conductive polymers
  - Dimatix Nova AAA printhead with 80 pl drop size
- Direct printing
  - No surface patterning or pre-treatment



Conclusions

- **Accuracy**
  - Printheads with < 2% drop volume variation, individually adjustable nozzles, 10 pl drop size and ± 10µm spot location available for jetting conductive inks
  - Even 50 µm lines achiveable without substrate pre-treatment
- **Mass manufacture**
  - Printing speeds increasing, currently around 1 m/s
  - Potential for mass customisation
  - Printers available
- **Cost effectiviness**
  - Conductive inks expensive, especially metal particle inks
  - Price reduction expected?

Thank you for your attention!

Liisa Hakola, Research Scientist
VTT Information Technology
P.O.Box 1204, FI-02044 VTT, Finland
tel: +358 20 722 7206, fax: +358 20 722 7066
liisa.hakola@vtt.fi
http://www.vtt.fi/indexe.htm