Inkjet Printing For Making Fine Conductors and Multi-Layer Electronics

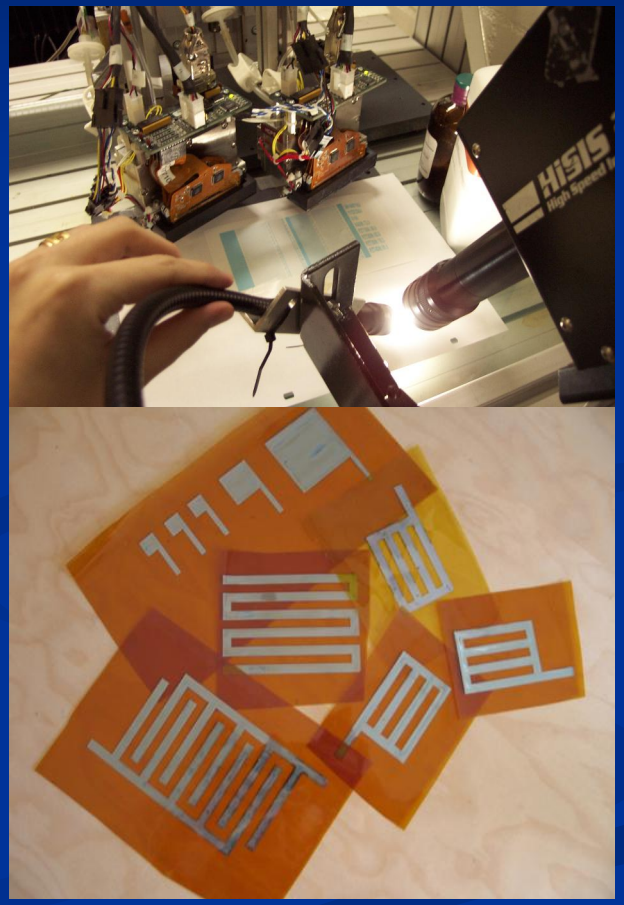
Liisa Hakola, Research Scientist
VTT – Technical Research Centre of Finland

e|5: UV & EB Technology Expo & Conference
April 24th, 2006

RADTECH
THE ASSOCIATION FOR UV&EB TECHNOLOGY

Outline

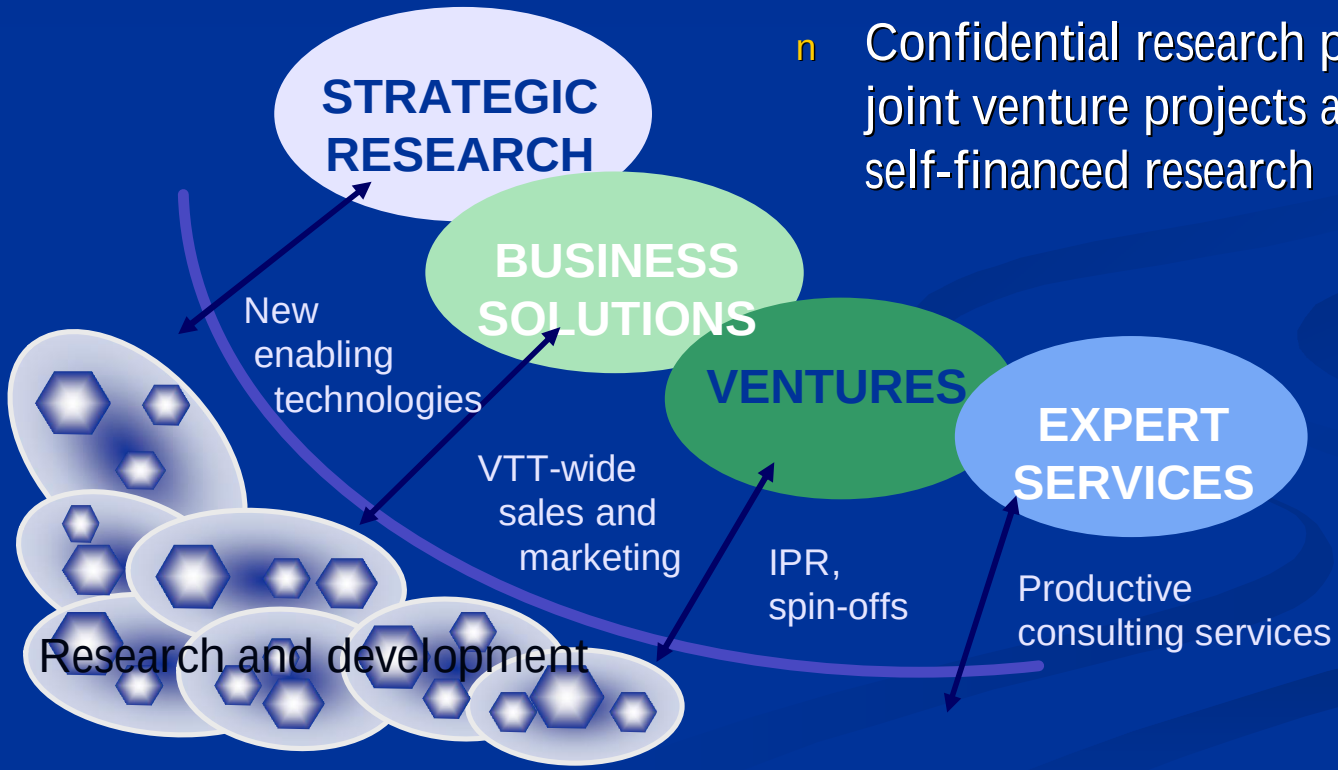
1. VTT overview
2. Inkjet technology
3. Inkjet for making printed electronics
4. Inkjet printing conductors
5. Inkjet printing multi-layer electronics
6. Summary



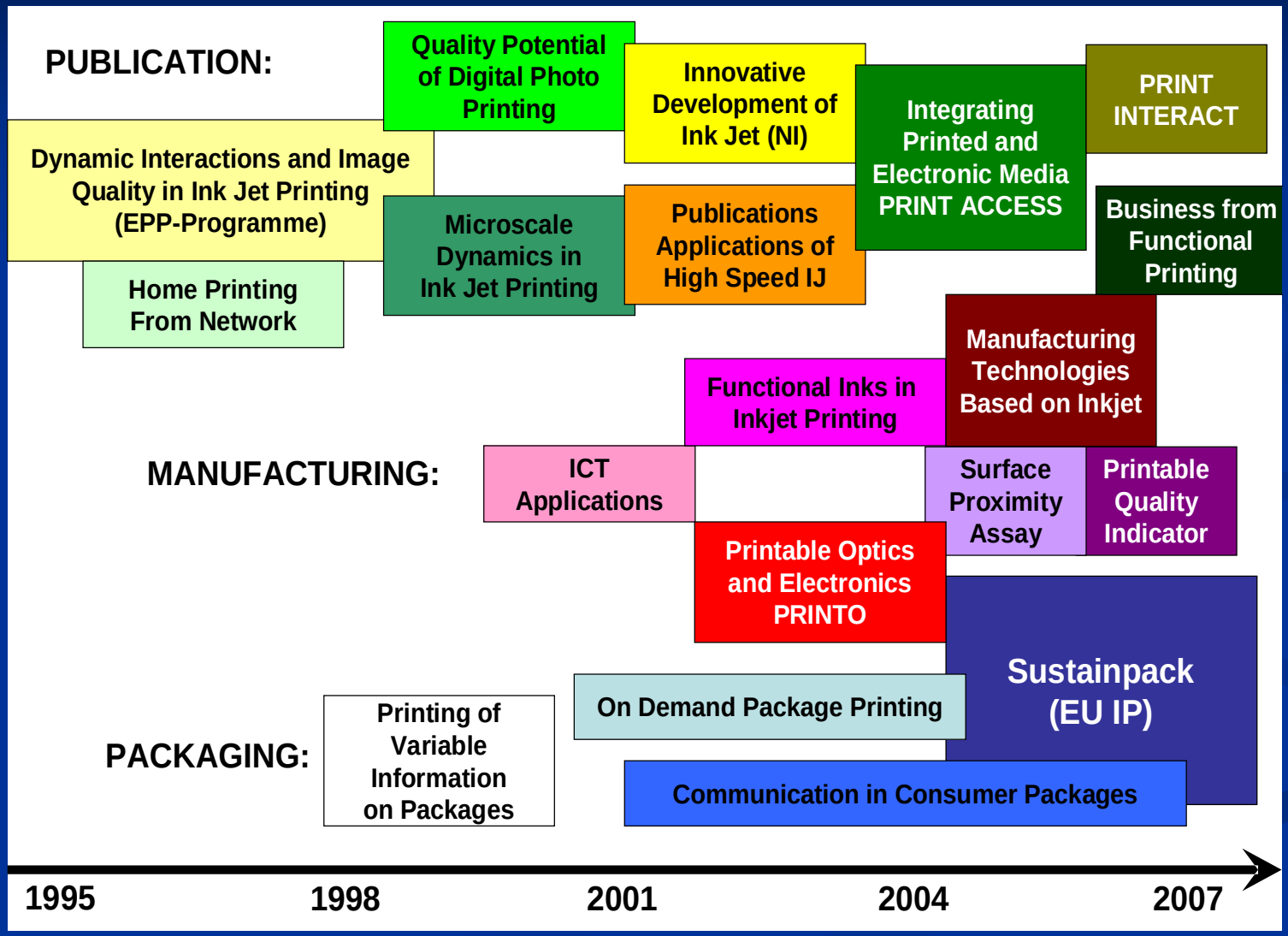
VTT – Technical Research Centre of Finland

- Impartial and multidisciplinary expert organisation

- 2,900 employees
- Turnover 220 million €, 5000 customers
- Confidential research projects, joint venture projects and strategic, self-financed research



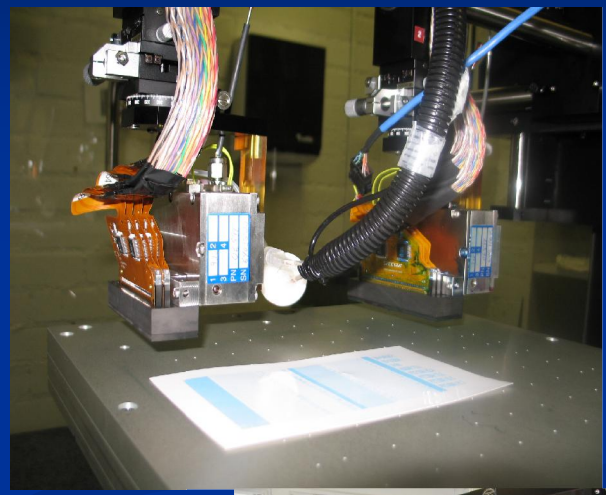
Digital Printing Research at VTT 1995-2007

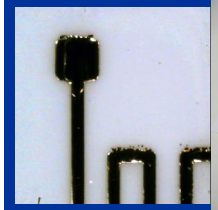


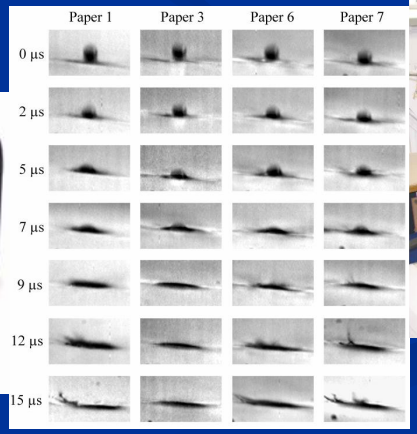
Inkjet research environment at VTT

- State-of-the-art, industrial, piezo electric inkjet printheads → research results upscalable for production

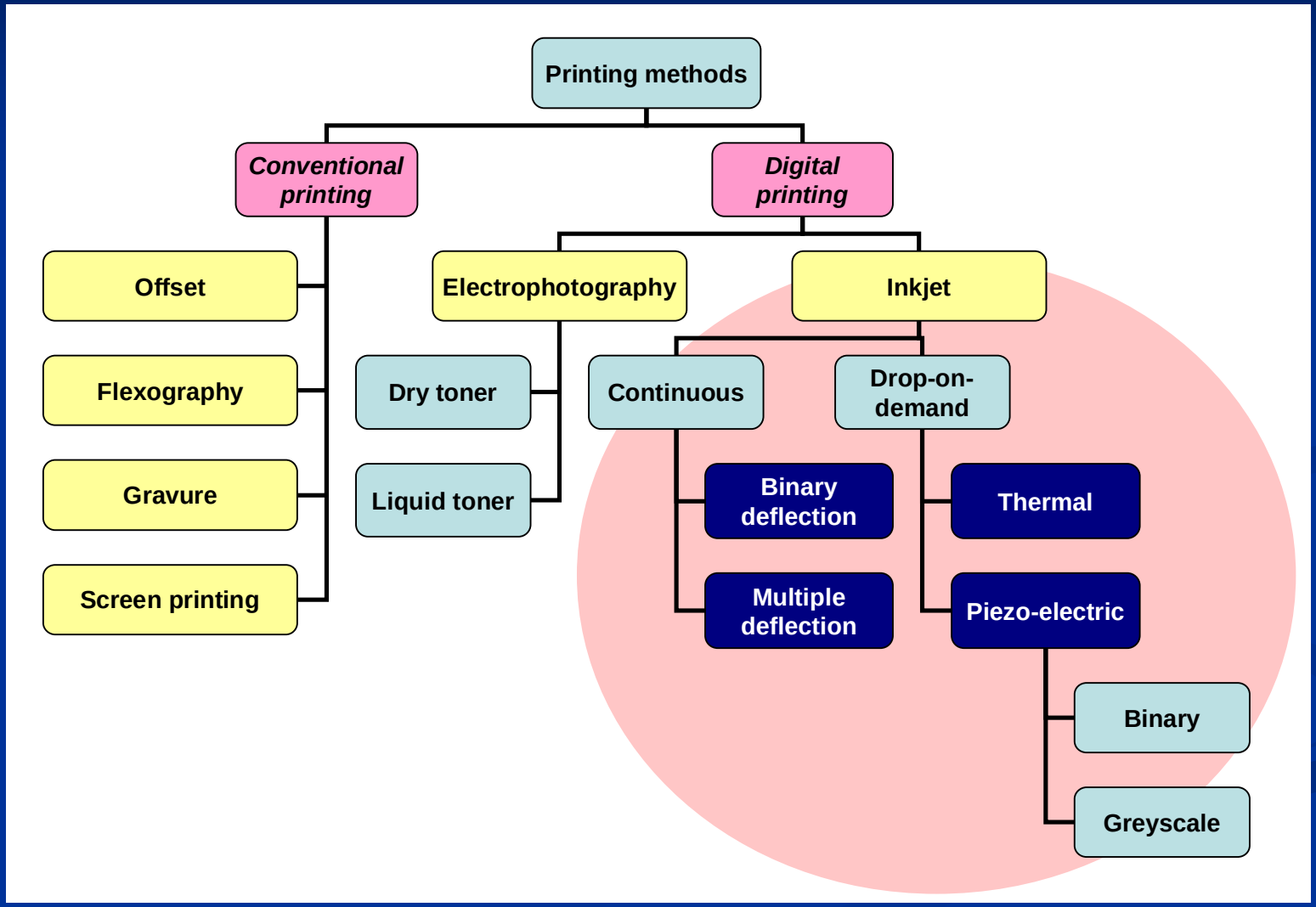
Water-, oil- and solvent-based inks
UV-curable inks
Hot melt inks and waxes
Conductive and dielectric inks
Biochemical and diagnostic fluids
Indicator fluids







Printing methods



Inkjet printing compared to other printing technologies

Inkjet

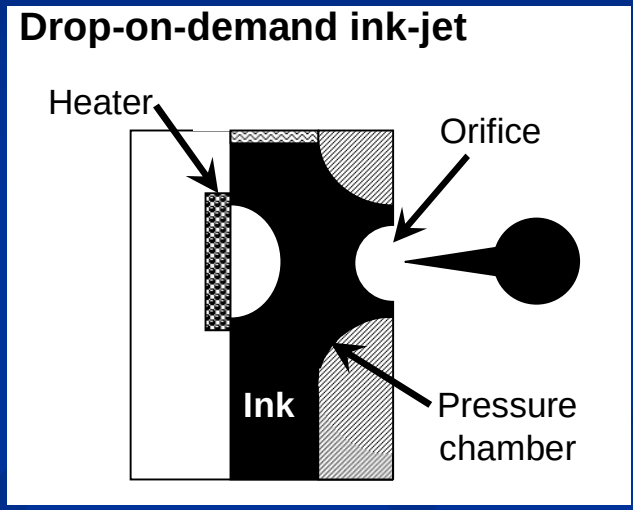
- Customisation, small series
- Printing speed increasing (currently around 1 m/s)
- Substrate independent
- Ink development challenging
- Easy to integrate with existing production lines

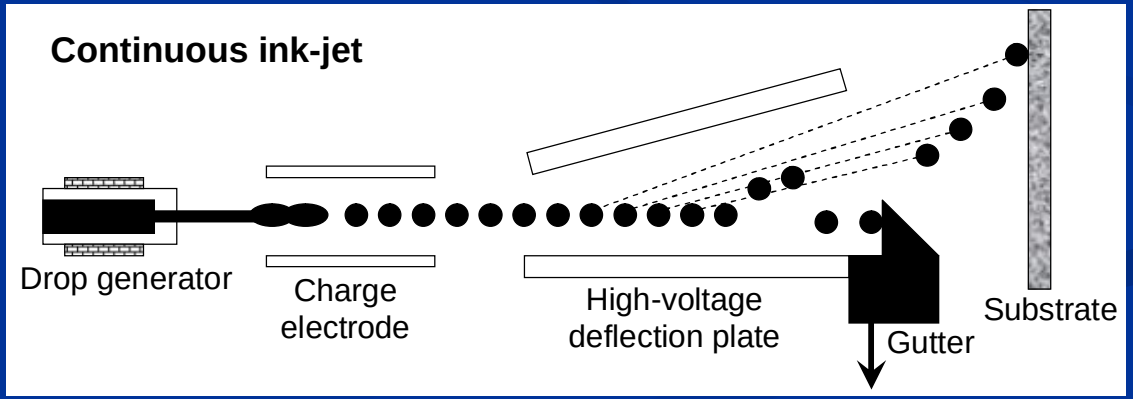
Conventional printing methods

- No variable data, large volumes
- 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

Inkjet printing technology

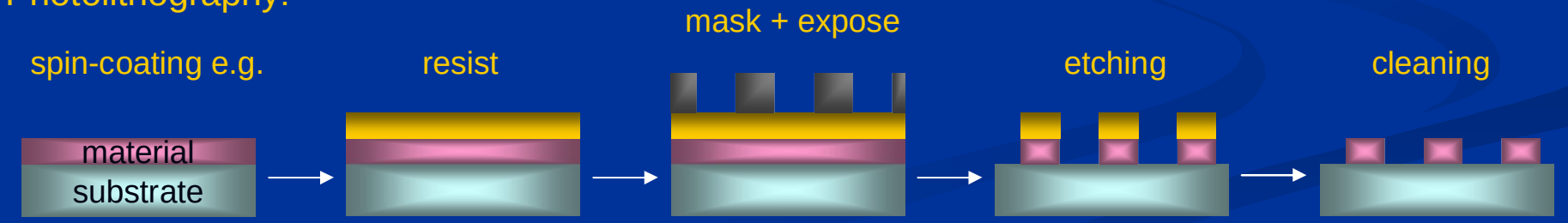
- Digital non-impact printing method, additive
- Substrate independent
- Accurate, high resolution, high speed
- Possibility for mass customisation
- Low material consumption
- Inks for all kinds of applications





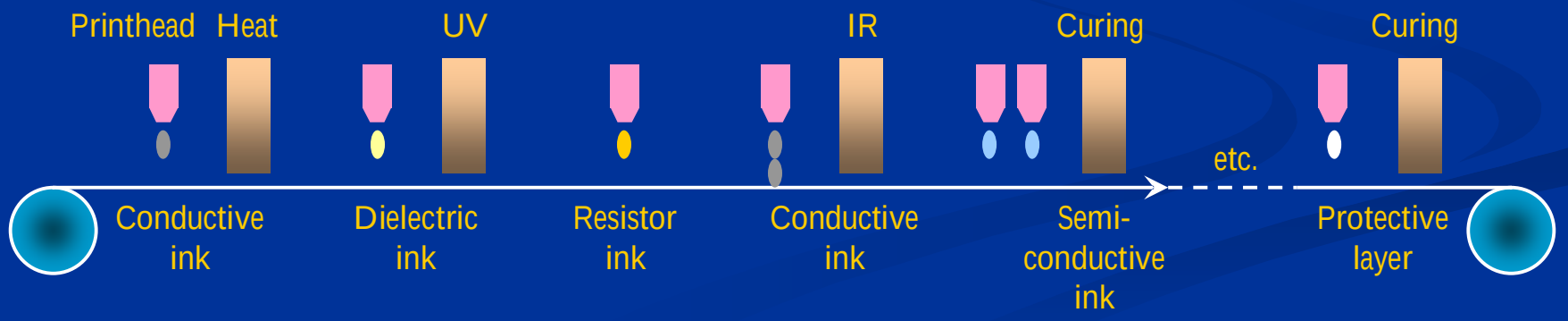
Benefits of inkjet printing in printed electronics

- Direct write of electronic components and circuits
  - less manufacturing steps
  - less material waste
  - cost savings
  - shorter turnaround times → small series and customisation



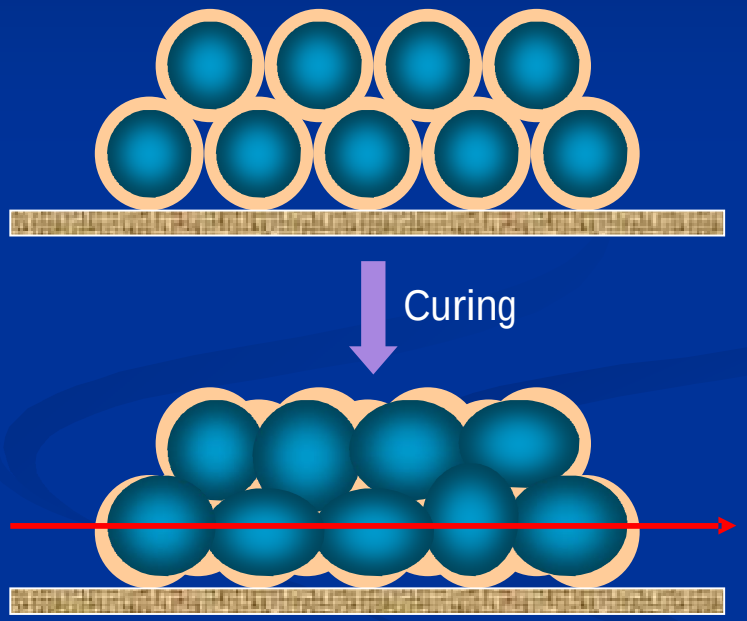
Application areas for inkjet printed electronics

- Not meant to replace traditional manufacturing methods
- Low-cost devices
- Low performance, single-use, disposable devices
- New application areas
- New features to printed products
- Hybrid printing → inkjet for customisation
- Multiple material deposition with several printheads
- Layering of materials → 3D structures



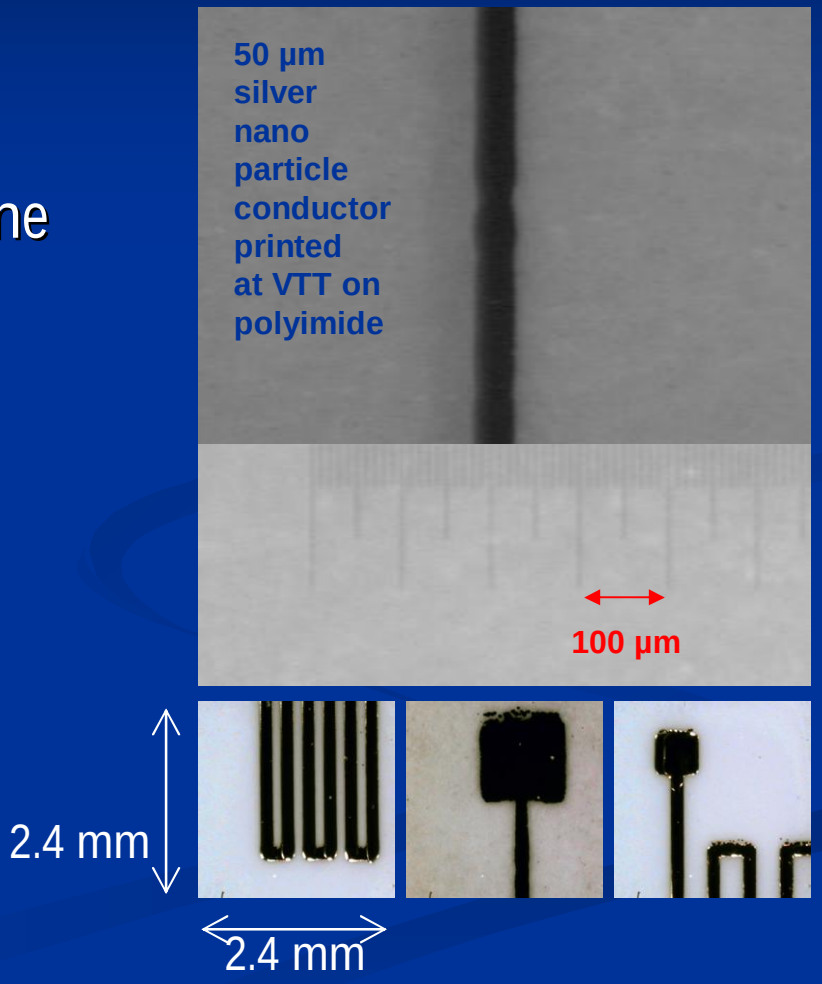
Nano-particle inks for making conductors

- Small particle size and ink stability crucial in inkjet printing
- Nano-particles provide
  - high metal loading with low viscosity
  - ink stability
  - jetting reliability
  - low curing temperature
- Metal nano-particle inks provide printed conductors with low resistance values
  - even in the range of μΩ



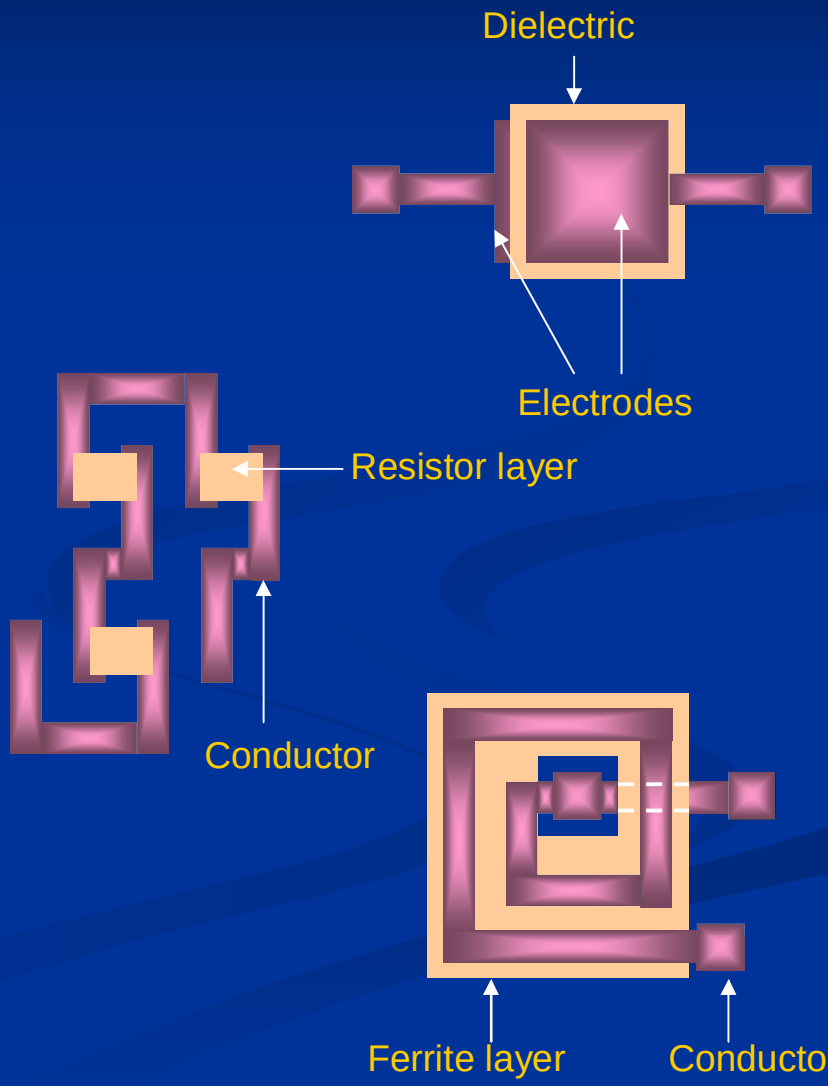
Inkjet printing fine conductors

- Lines as fine as possible and continuous
- Drop size and spreading define line width
- Print resolution defines line continuity
- Substrate pre-treatment or pre-patterning



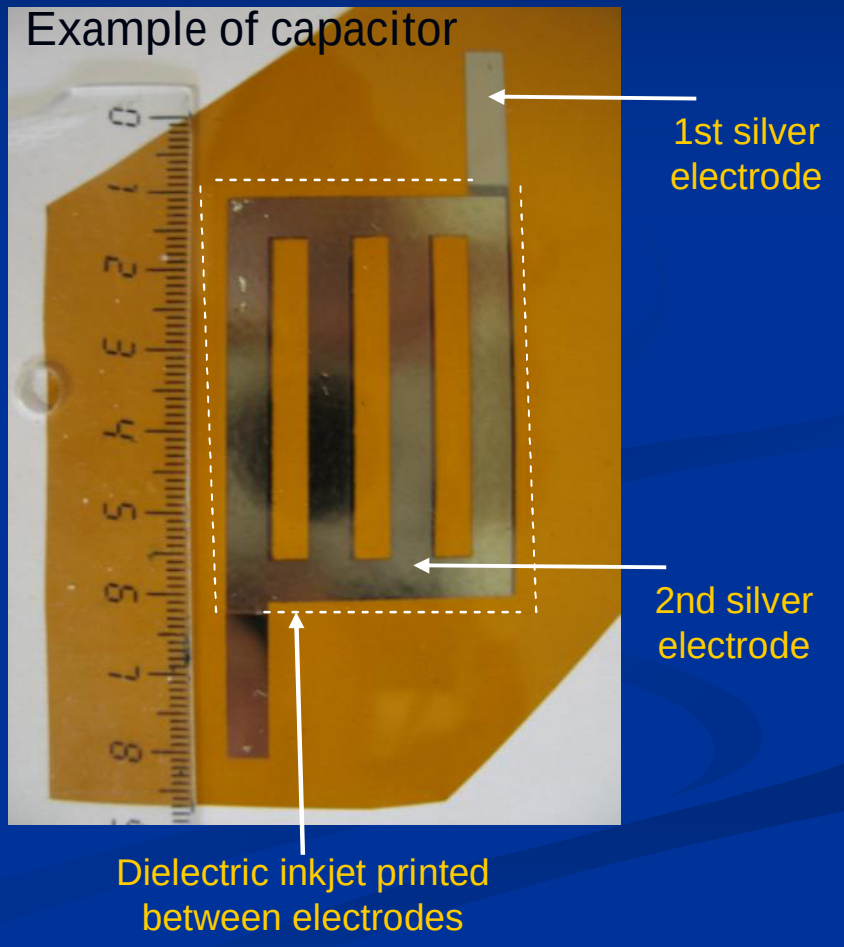
Inkjet printing multi-layer electronics

- Transistors, displays, passive components
- Multi-colour printing
  - at least one printhead for each ink
  - color registration
- Interactions between different materials
  - printing on substrate vs. printing on ink layer
  - colour bleed
- Ink availability



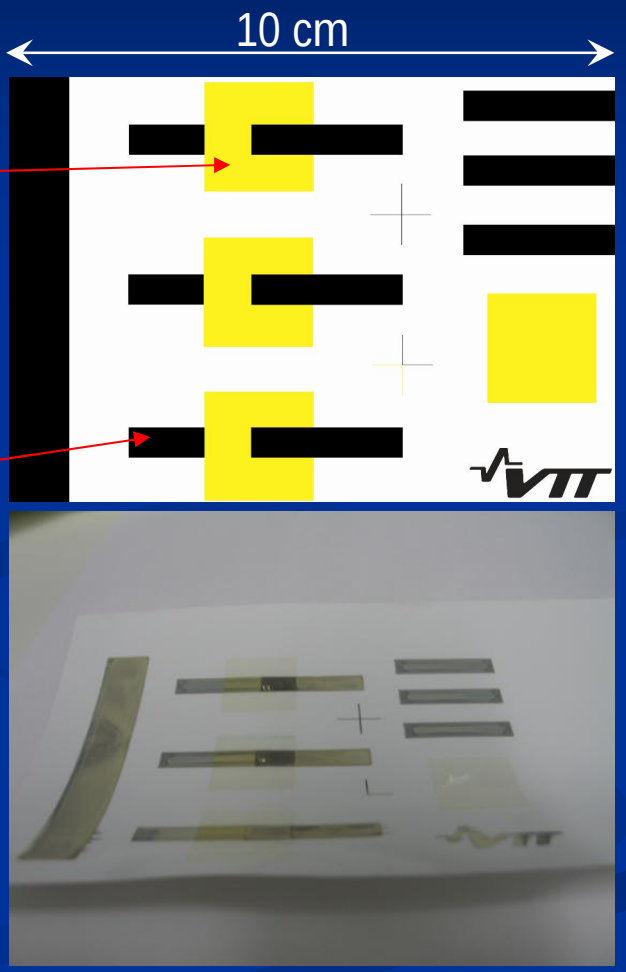
UV-curable dielectric ink for inkjet printing

- Printing in elevated printhead temperature
- Drying with absorption and UV light
- Good wear resistance
- High gloss
- Smooth ink layer without pin holes

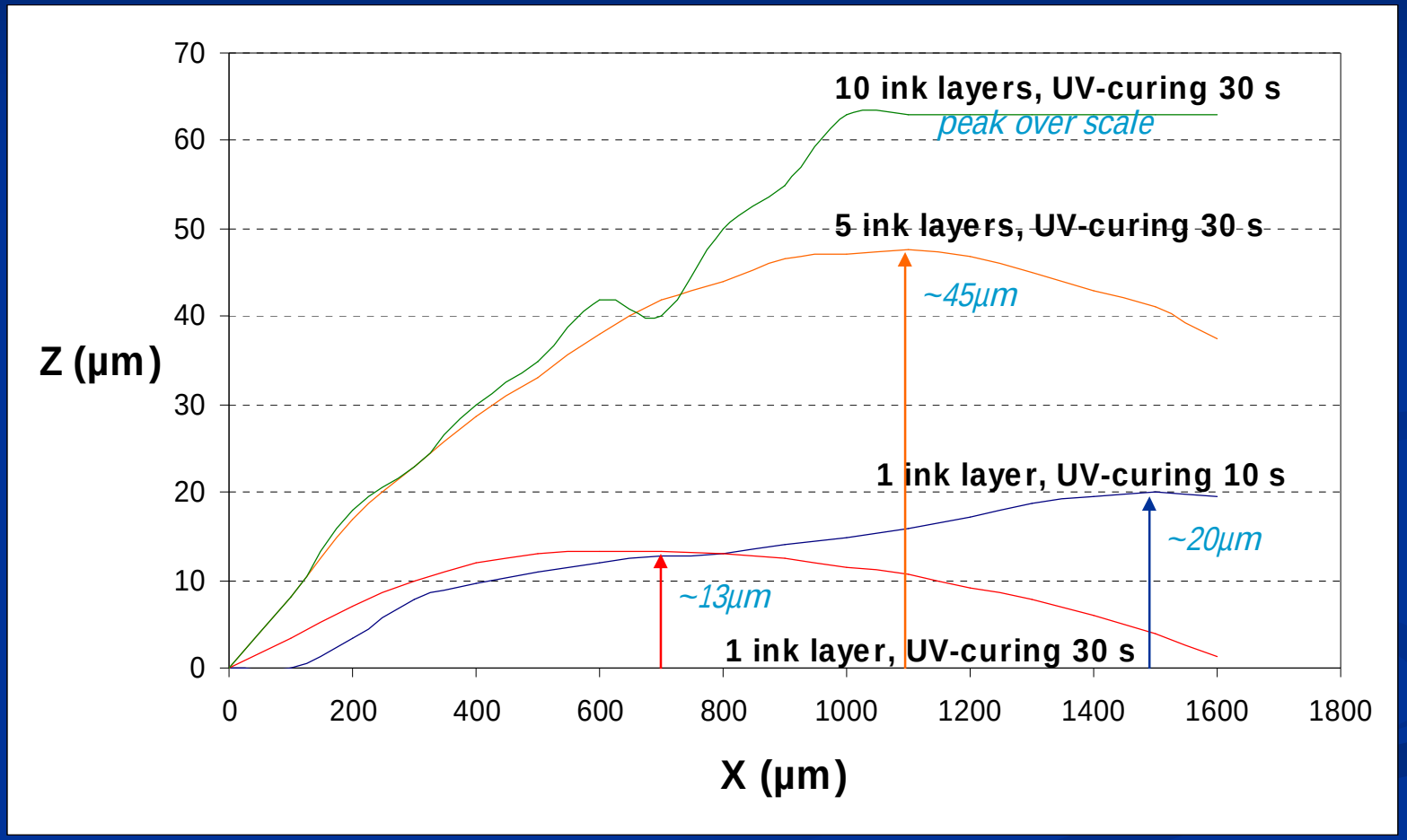


Experimental

- UV-curable polymer based dielectric ink (yellow)
  - Curing with 120 W/cm H bulb UV light source for 20 seconds
  - 1 or 2 ink layers
- Silver nano-particle ink (black)
  - Curing in 120 °C for 15-30 minutes
  - 1 or 2 ink layers
- Paper and plastic substrate
- Piezo-electric inkjet, 80 pl drop size, 630 dpi resolution

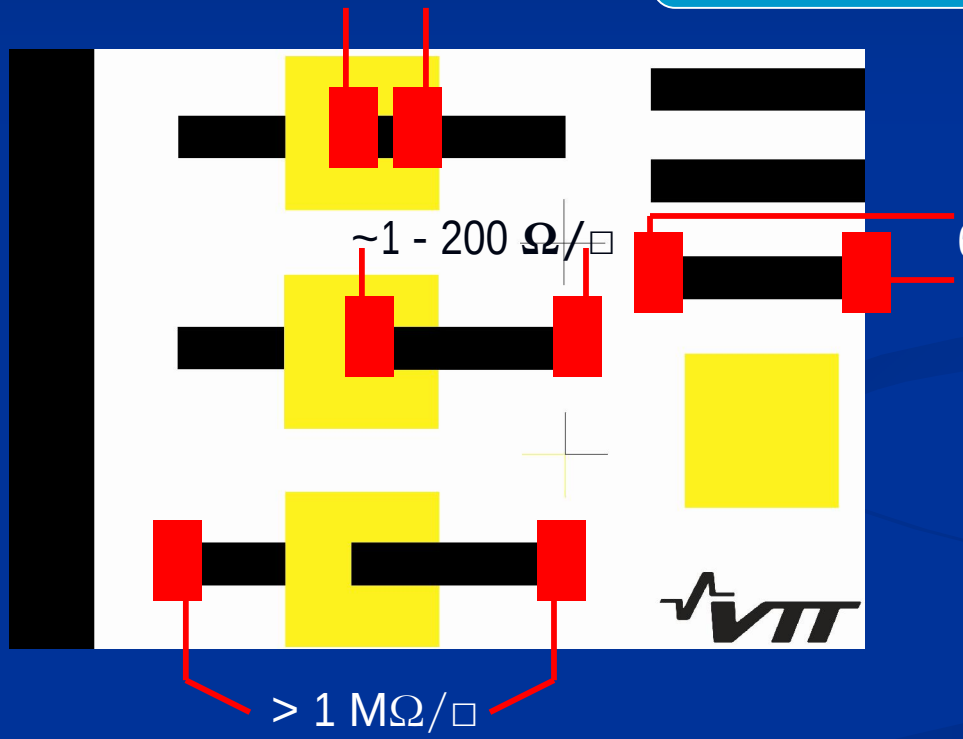


Height profile of UV-cured dielectric ink layers on plastic substrate



Performance of multi-layer electronics

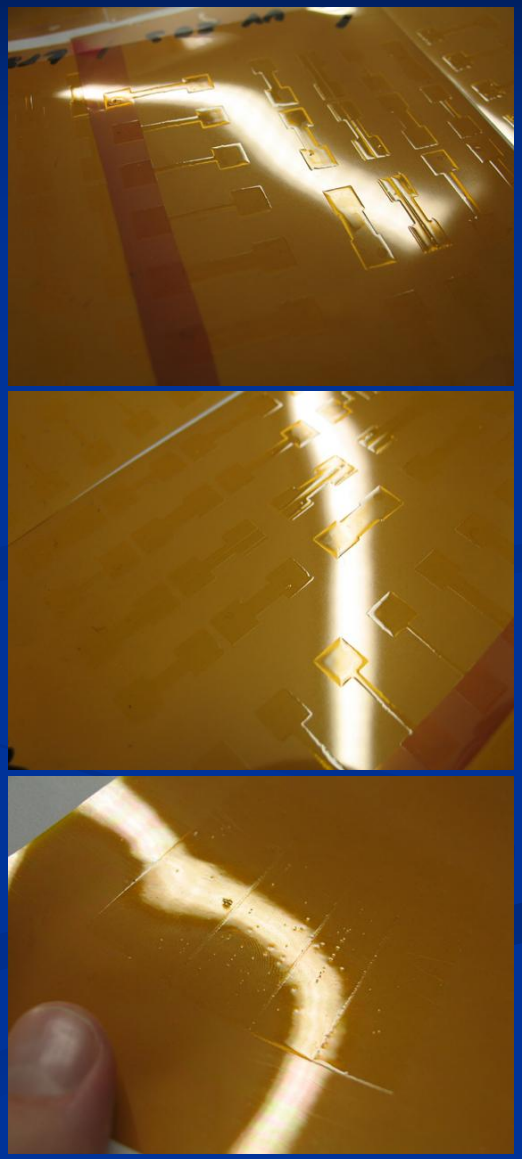
- on paper increase in amount of dielectric layers increases resistance on top of it



1 layer dielectic and 1 layer silver on paper 190 mΩ/□
→ pin holes?

Summary

- Inkjet printing suitable method for manufacturing electronics
- Fine inkjet printed conductors possible even without substrate pre-treatment
- Metal nano-particle inks produce conductive structures with low resistance
- Inkjet printing suitable method for making multi-layer structures
- UV-curable dielectric ink produces smooth and thick ink layers



Thank you for your attention!

Liisa Hakola, Research Scientist

VTT – Technical Research Centre of Finland
Functional Printing

P.O.Box 1000, FI-02044 VTT, Finland

phone: +358 20 722 7206

fax: +358 20 722 7052

e-mail: liisa.hakola@vtt.fi