Top layer coatability on barrier coatings

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FUNMAT FUNCTIONAL MATERIALS

TAMPERE UNIVERSITY OF TECHNOLOGY

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RETHINK PAPER:
Lean and Green

Electronics on paper

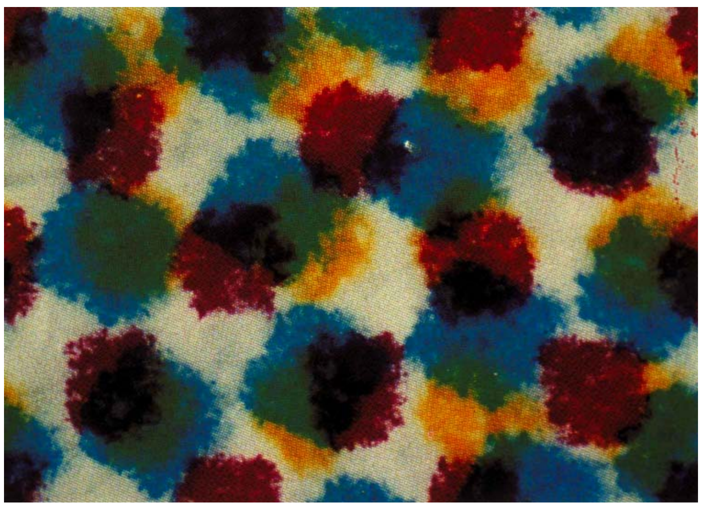
- Inexpensive
- Recyclable
- Easily upscalable to mass production
- Existing product base
  - Communication papers
  - Packaging
  - Technical papers

- Potential for numerous value-added product concepts
  - Disposable electronics
  - Smart packaging
  - Home diagnostics
  - Simple displays
  - Sensor applications

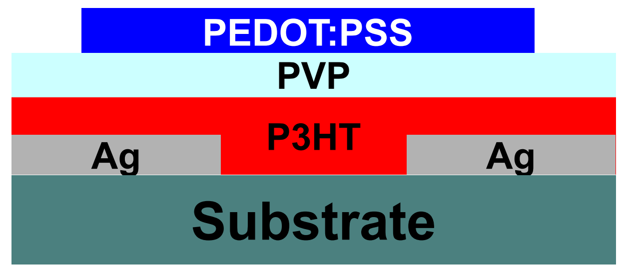
Printing electronics

- **Fast process for transferring of material (ink) to substrate**
- **Developed for graphical printing with visual properties in focus**

Graphical printing

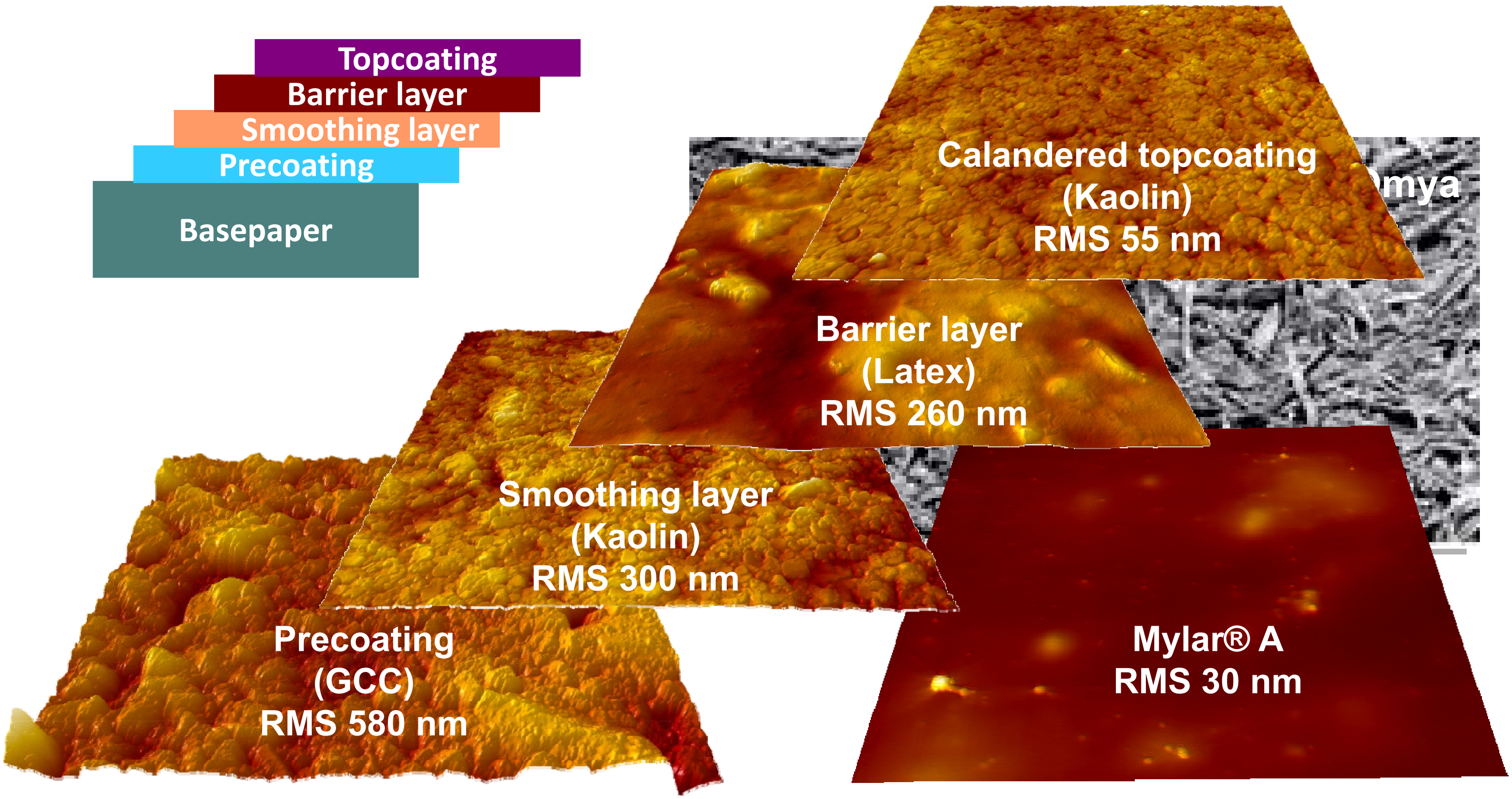


Printed device



"You can cheat the human eye but not the conductivity"

Multilayer coating structure



R. Bollstrom et al. *A multilayer coated fiber-based substrate suitable for printed functionality*, **Org. Electronics, 10, 1020 (2009)**
WO 2010/086511, PCT/FI2010/050056, *Method for creating a substrate for printed functionality, substrate, and printed functional device*
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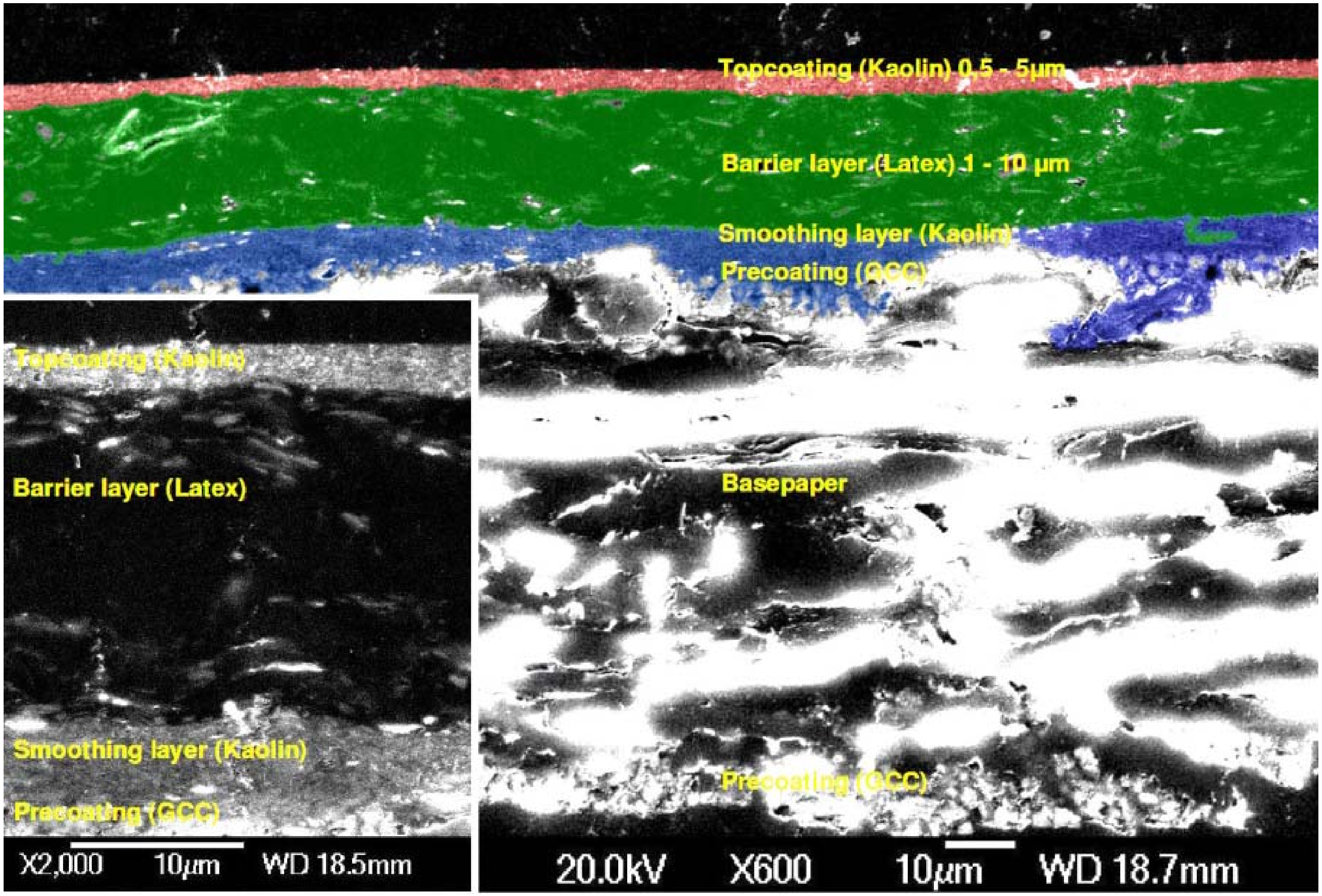

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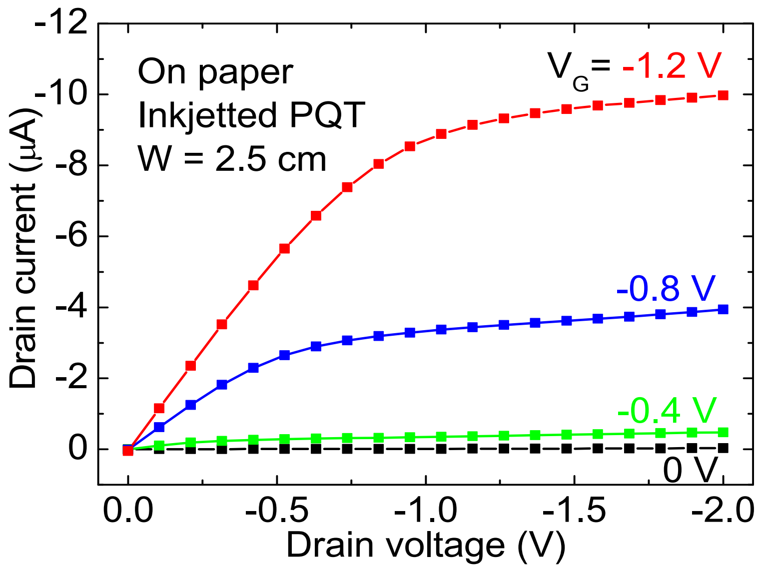
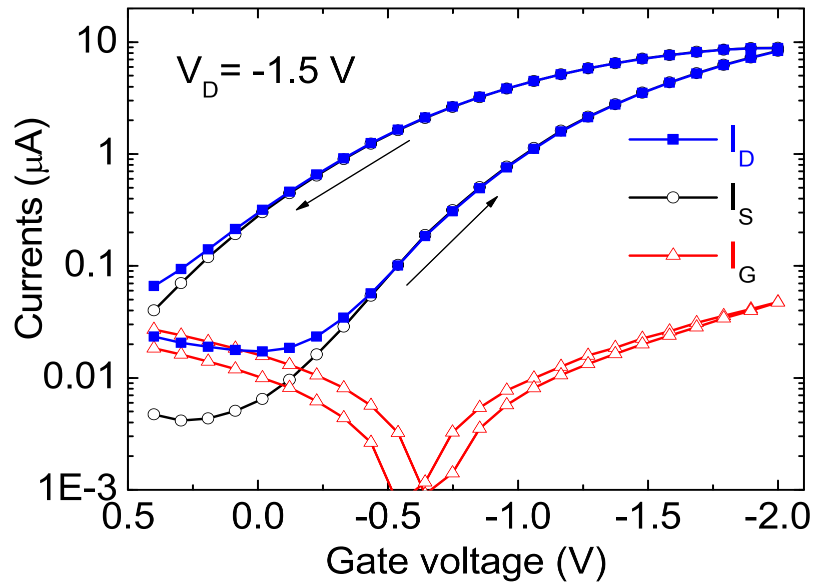
Proof of concept -Printed transistors on paper

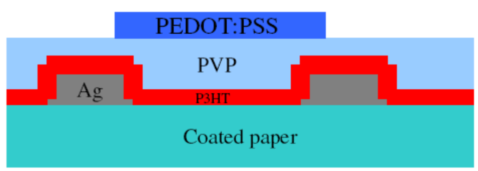
- Output and transfer characteristics

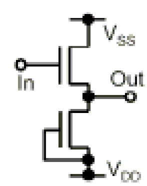


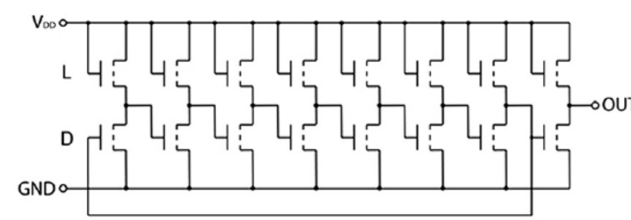


Logic circuits

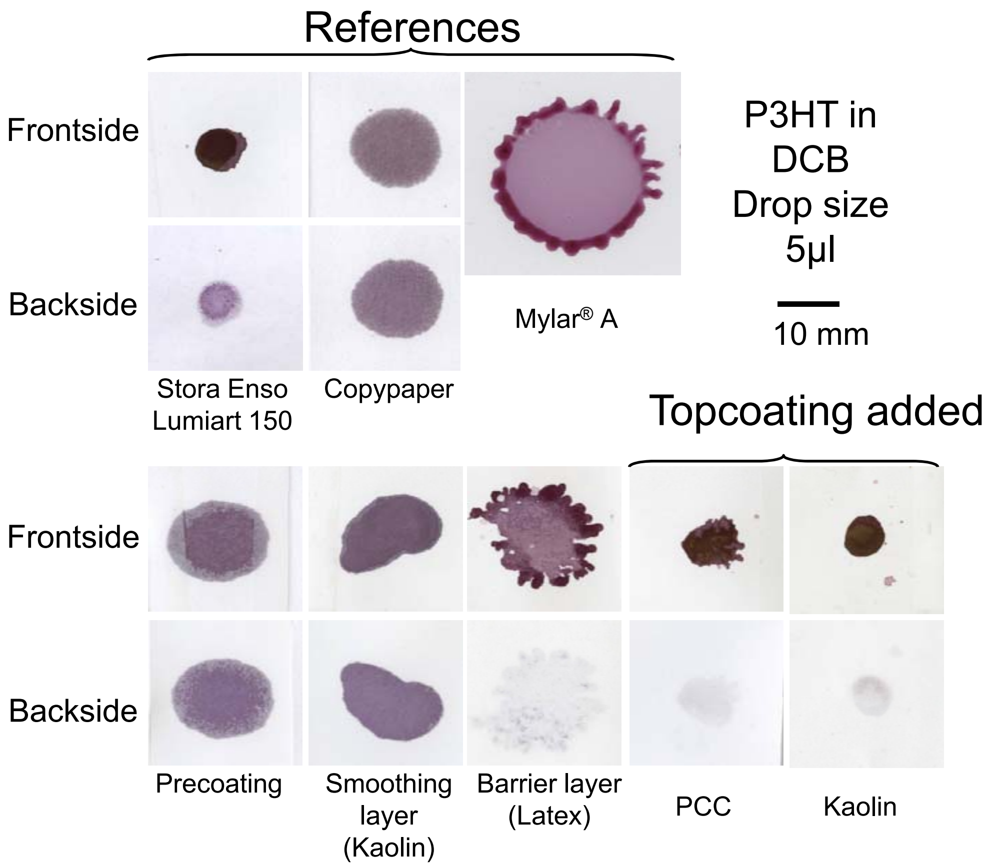
- Inverter
- Ring oscillator:
  Odd number of inverters in parallel

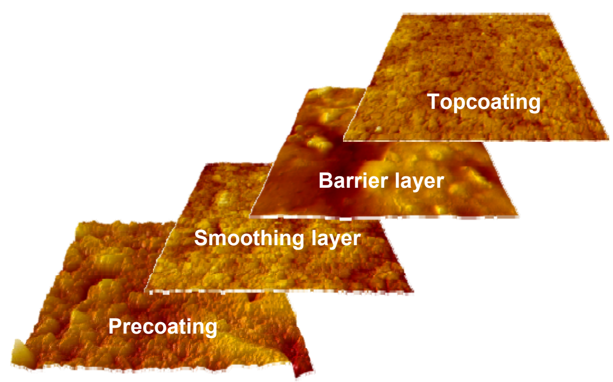






Multilayer structure
-Combined printability and barrier properties





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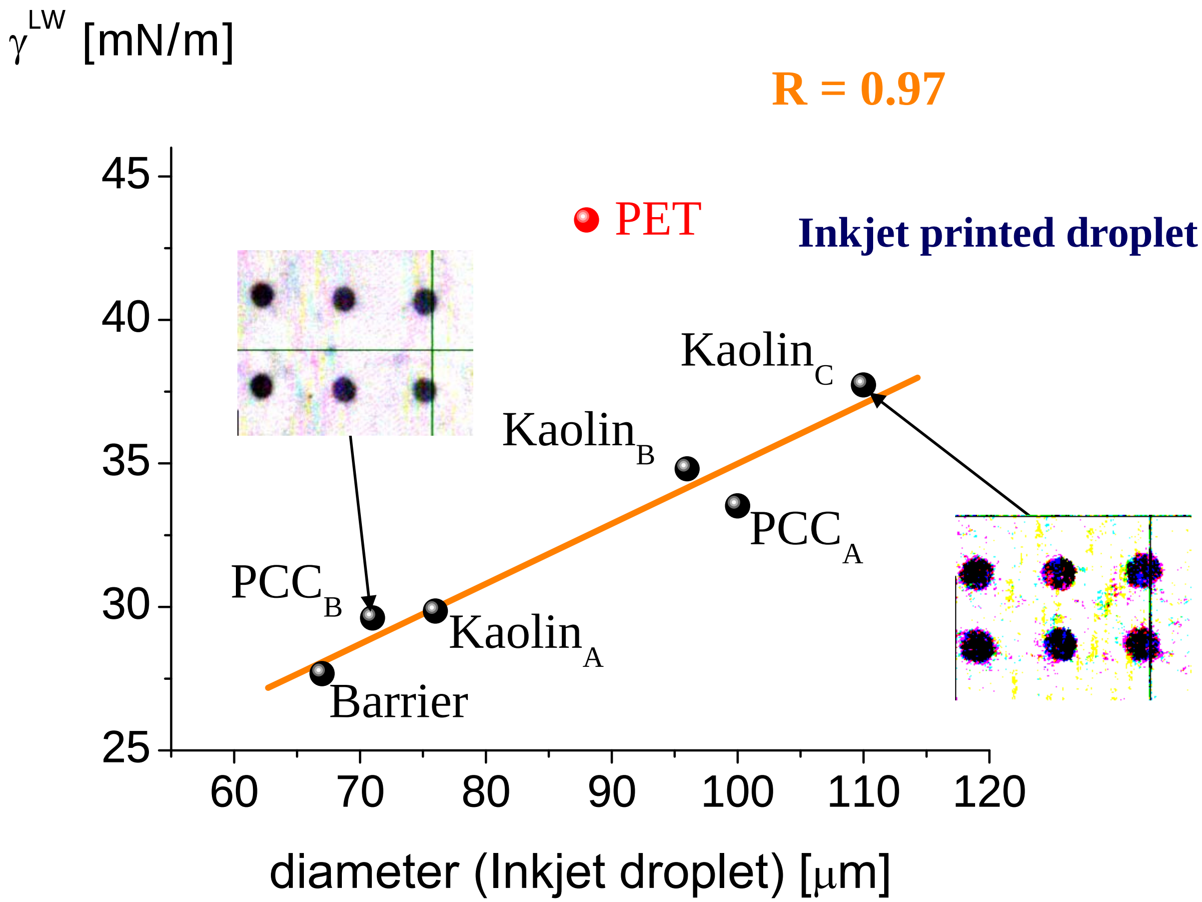
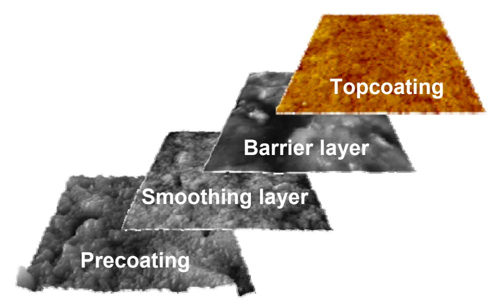
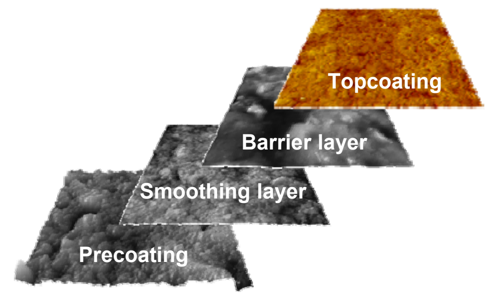


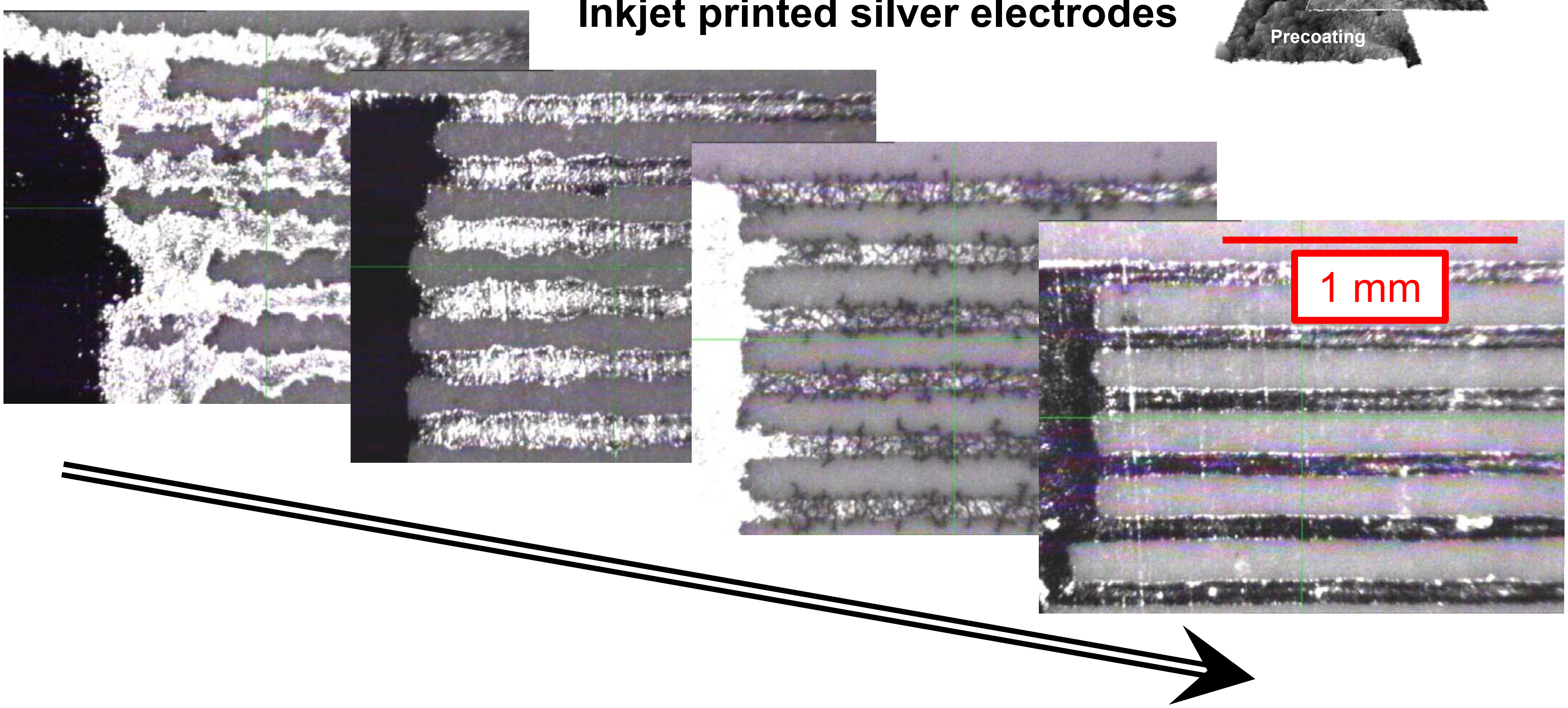


A. **Määttänen et al.** Wetting and print quality study of an inkjet-printed poly(3-hexylthiophene) on pigment coated papers, **Colloids and Surfaces A: Physicochem. Eng. Aspects 367 (2010)**

Printability – functional inks



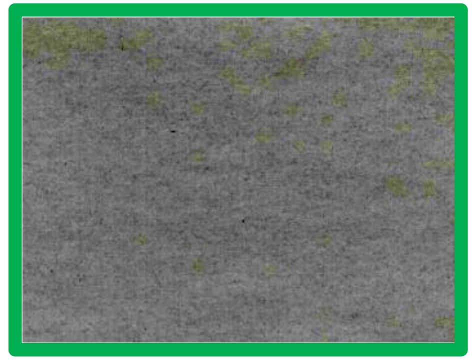
Inkjet printed silver electrodes



Printability by controlled properties in topcoating

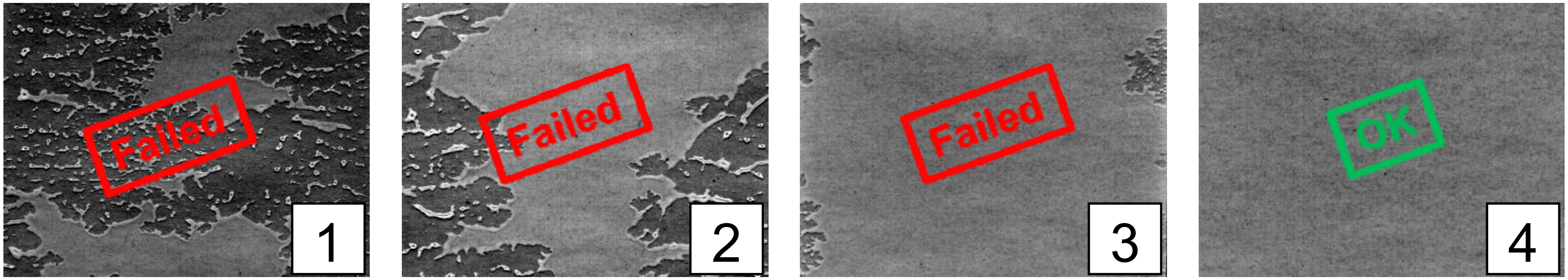
Objectives

- Create barrier properties by dispersion coating
- Understand factors impacting top layer coatability



  - Surface properties of barrier layer
    - Wettability
    - Surface energy
    - Surface roughness
  - Properties of top coat dispersion
    - Surface tension

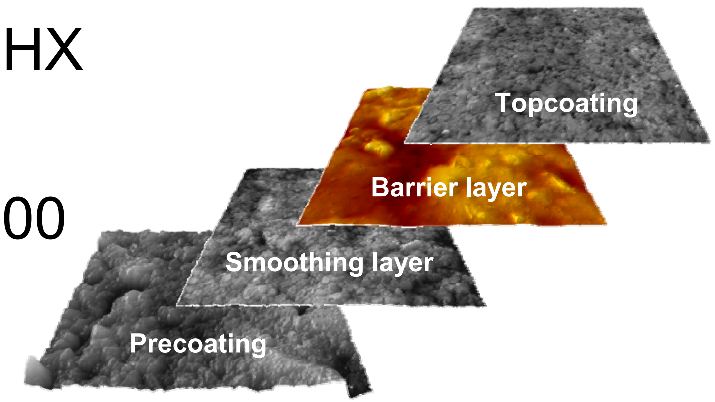
Evaluation of coatability



- Visually evaluated
  - 1: No wetting
  - 2: Inadequate wetting, large areas still uncoated
  - 3: Small defects, on the limit to required wetting
  - **4: Proper wetting, adequate coatability**

Materials – dispersion coated barrier layer

- **Pigments**
  - **Talc** (barrier layer)
    - Mondo Minerals B.V., C10B
  - **Kaolin** (barrier layer)
    - Imerys Minerals Ltd., Barrisurf HX
  - **PCC** (topcoating)
    - Specialty Minerals Opacarb 3000



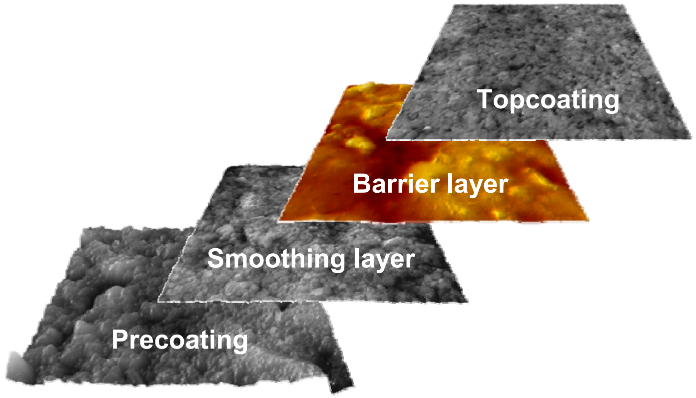
- **Latexes**
  - Styrene acrylate
  - SA1: Ciba Finland Oy, (Particle size: 130 nm, Tg 7,5°C)
  - SA2: Styron Europe GmbH., (Particle size: 110 nm, Tg 0°C)
  - Two experimental latexes, Exp1 and Exp2 (Styron Europe GmbH.)

Materials -coating recipes

- Woodfree basepaper and precoating with coarse GCC (107 g/m^2)
- Smoothing layer consisting of kaolin + 5 pph SB latex (10 g/m^2)
- Barrier layer
  - Thickness ~ 20µm
  - Grammage 23 – 40 g/m^2
- Barrier layer formulation
  - Talc or kaolin as pigments
  - Latexes (SA1 and SA2) in 10 – 20 – 30 – 50 – 70 pph
- Topcoating
  - PCC + 10 pph SB latex

Surface treatment -barrier layer

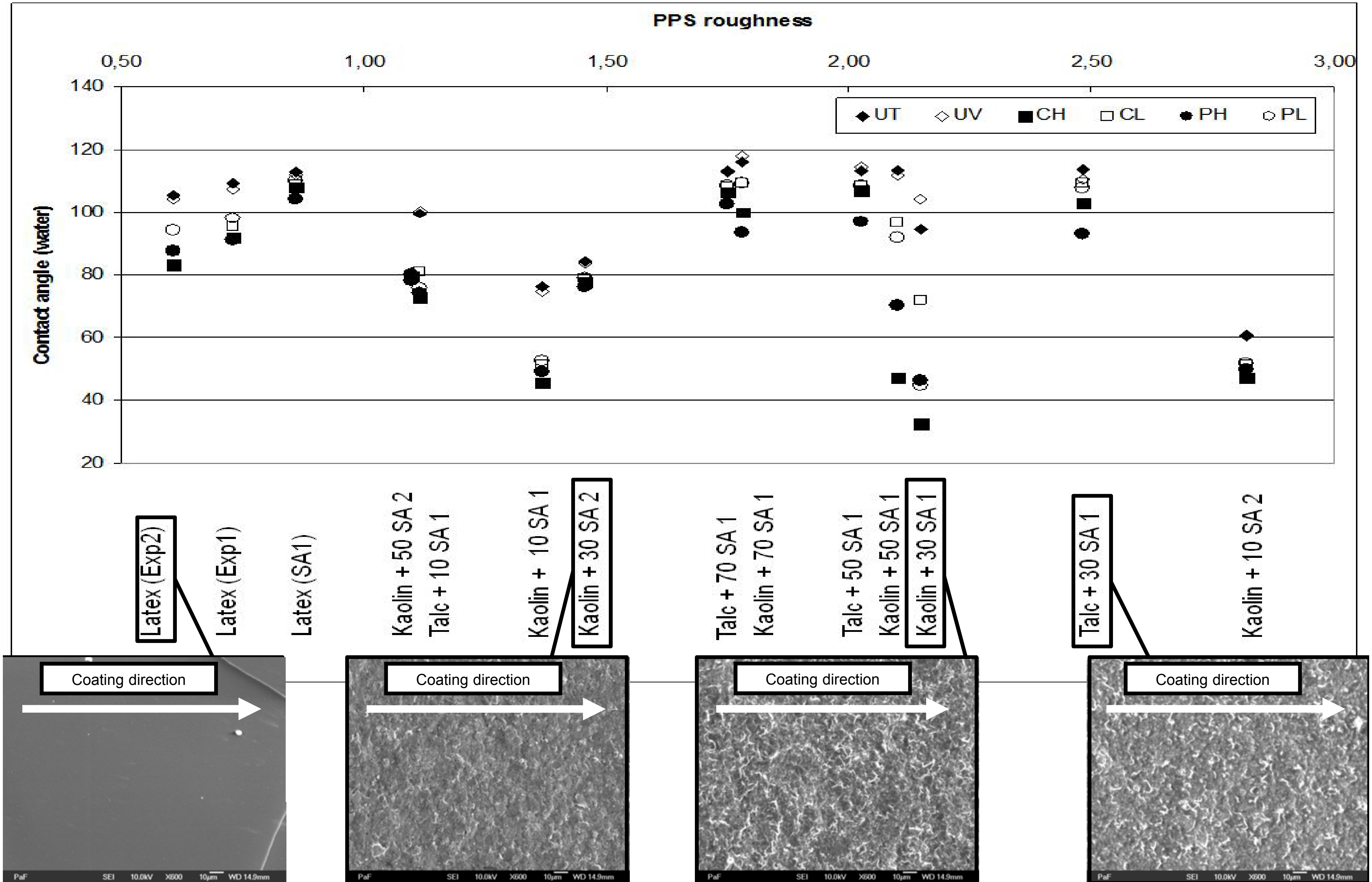
- **Plasma**
  - Argon
- **Corona**



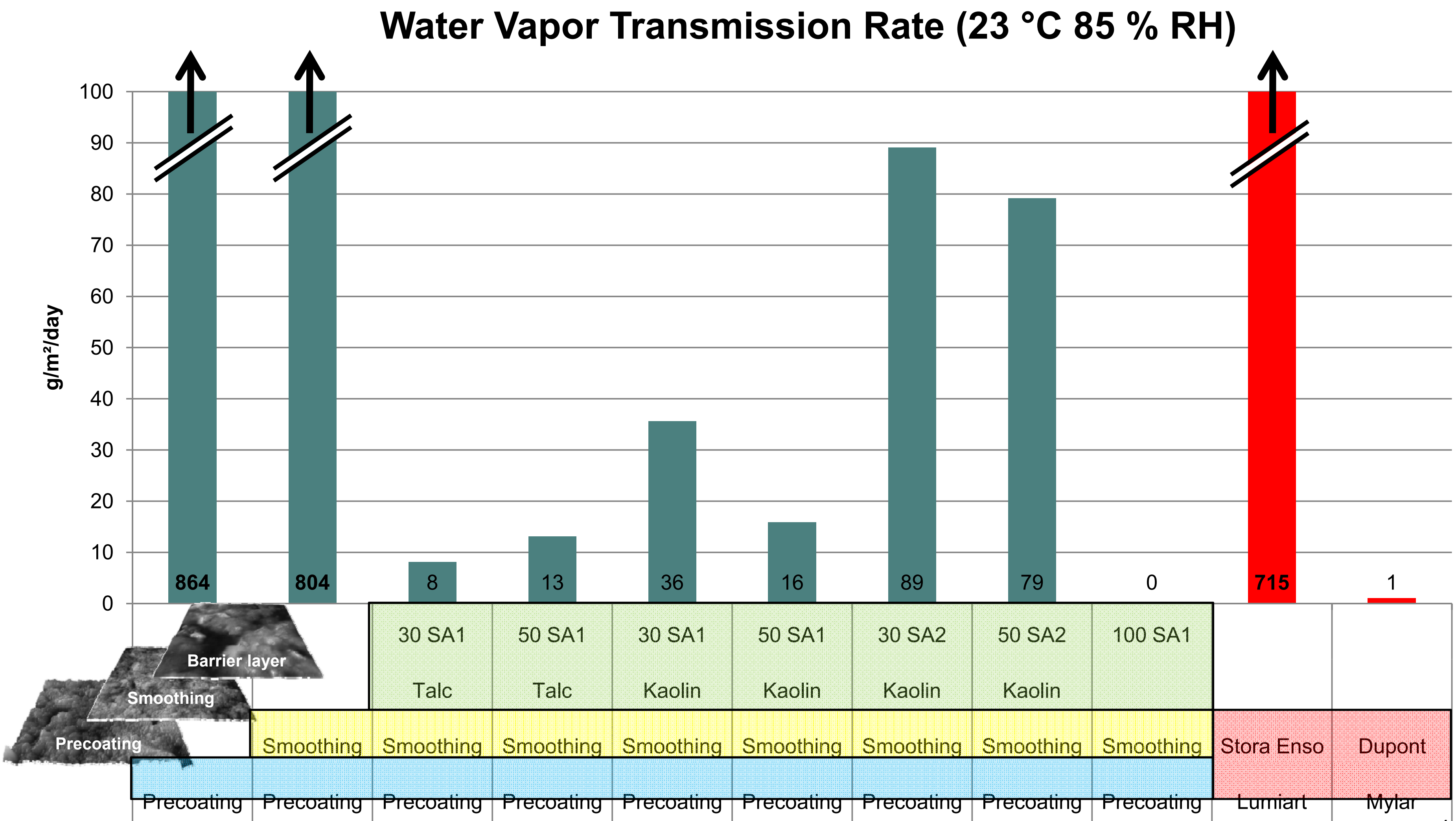
Treatment	Power	Speed	Width	Efficiency value	Gas feed	Frequency
Corona low (CL)	1300 W	50 m/min	500 mm	52 Wmin/m²	-	24,8 kHz
Corona high (CH)	1300 W	20 m/min	500 mm	130 Wmin/m²	-	24,8 kHz
Plasma low (PL)	780 W	50 m/min	380 mm	41 Wmin/m²	30 l/min	28,3 kHz
Plasma high (PH)	780 W	20 m/min	380 mm	103 Wmin/m²	30 l/min	28,3 kHz

- **UVC**
  - Laboratory scale
  - 50 mW/cm² at λ_{max} 254 nm for one minute

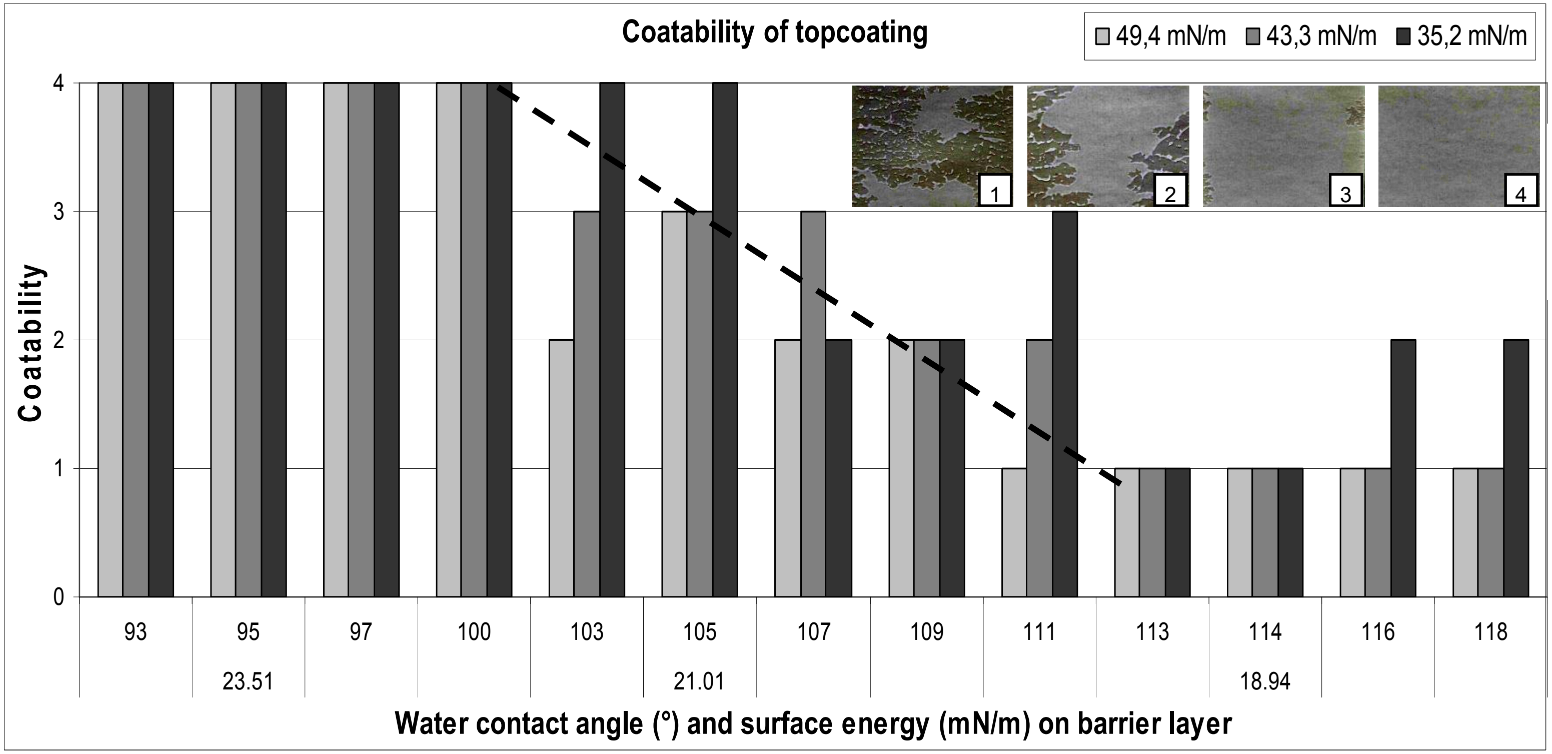
Contact angle and PPS roughness



Barrier properties -water and vapor

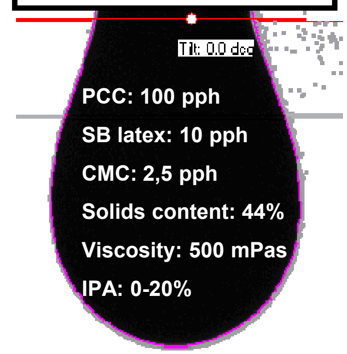


Coatability -as function of wettability



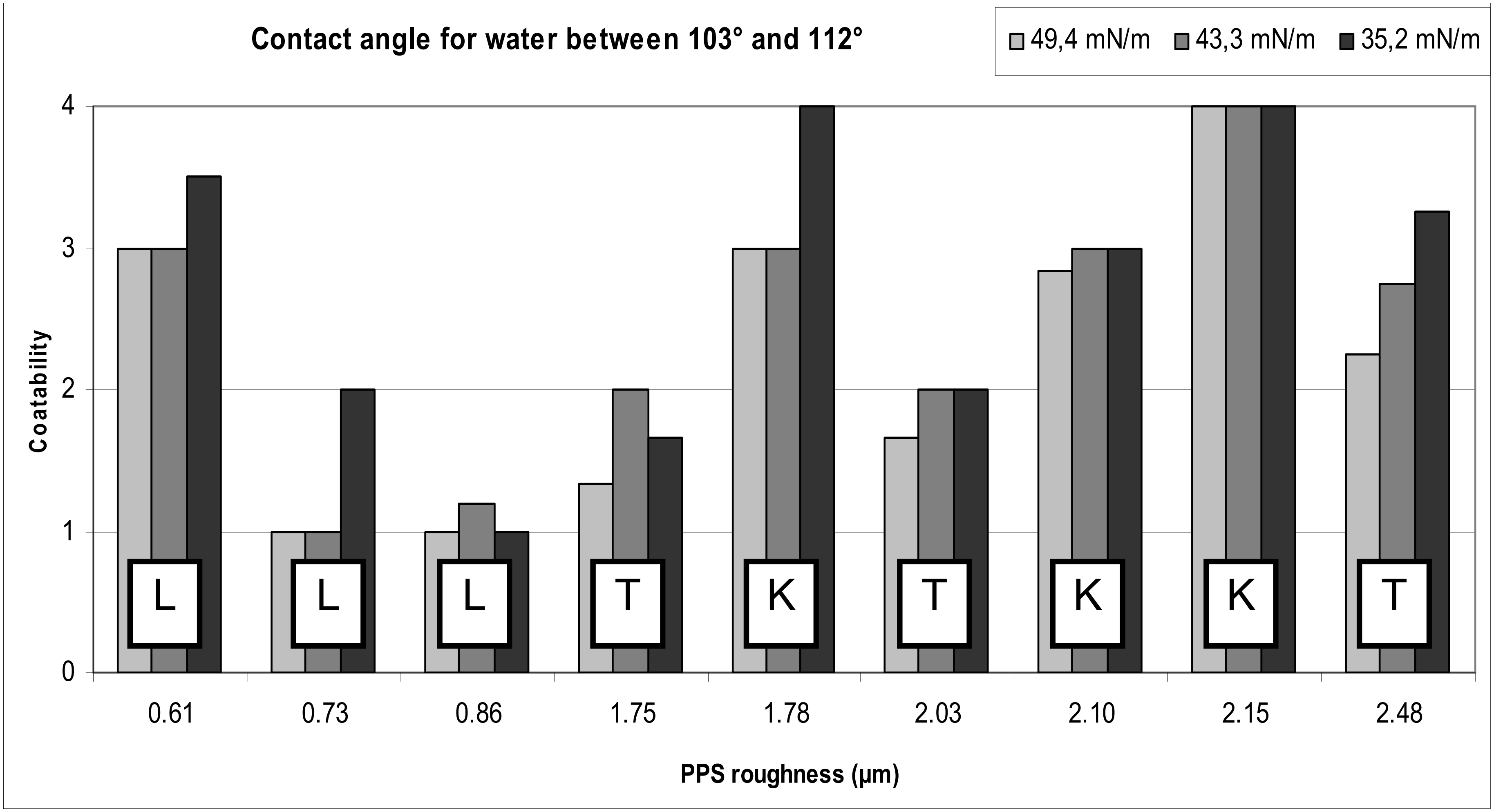
Surface tension of topcoat

35,2 – 49,4 mN/m



- Surface tension in topcoat dispersion adjusted
  - Replacing water with isopropanol
  - Solids content and viscosity constant

Influence of roughness



L = 100 pph latex T = Talc + 30 to 50 pph latex K = Kaolin + 30 to 50 pph latex.

Conclusions

- Water contact angle most important factor
  - Preferably below 100°
- A lower surface tension in top coat dispersion improves coatability
  - In the water contact angle range 100 - 110°
- No significant effect by roughness
  - Could only be studied on water contact angles higher than 100°
- Particles sticking out from the surface might pin the coating color
- Thin topcoatings not possible to coat using blade technique
- Curtain coating alternative method for industrial scale production

Products of tomorrow?

YLE TV 1 Prisma Studio

Acknowledgements

- **Industrial partners**
  - Imerys Minerals Ltd.
  - Styron Europe GmbH
  - Mondo Minerals B.V.
  - Specialty Minerals Nordic Oy
  - Ciba Finland Oy (BASF)
- **B.Sc. Thesis worker**
  - Vesa Tertsunen
- **Adjunct professors**
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