Towards Paper Electronics

- A multilayer coated fiber-based substrate suitable for printed functionality

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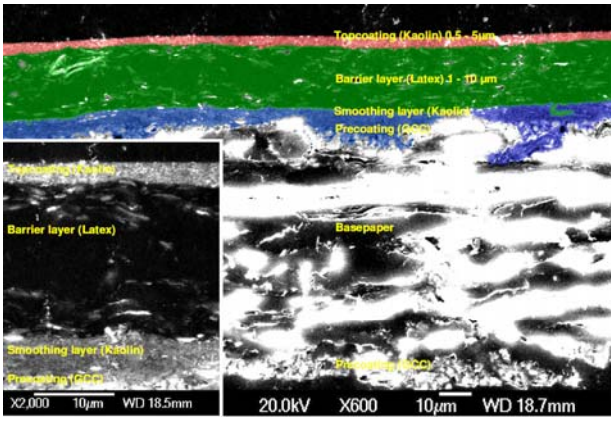
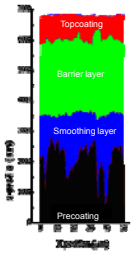
The profitability of the global forest industry has been dismal in recent years, due to increases in raw material and energy costs, competition from electronic media and overcapacity in production of traditional paper grades. New value-added products or existing products with novel functionality could be a way to improve the situation. The added value could be in form of e.g., sensors, displays or radio-frequency identification (RFID) tags, which analyze product quality, show transport conditions or streamline logistics. In this area one of the trends is to develop low-cost disposable electronics. For these to become reality, devices with reasonable electrical performance and practically negligible production cost are required. One way to reduce the manufacturing cost is to fabricate the electronics on inexpensive paper substrates by using roll-to-roll techniques ("Paper Electronics"), as an alternative to conventional electronics manufactured with batch processes on glass or polymer film substrates.

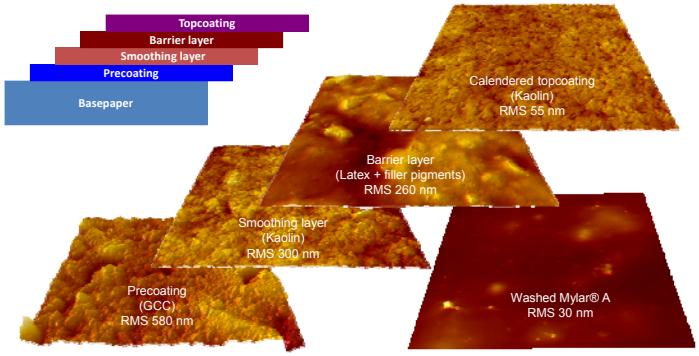
Structure of the substrate



SEM cross-section images showing the structure of the multilayer coated substrate

PCT/FI2010/050056, WO 2010/086511, Bollström Roger, Määttänen Anni, Ihalainen Petri, Toivakka Martti, Peltonen Jouko





AFM topography images (20 x 20 µm²) of the different substrate layers and Mylar® A plastic film
RMS roughness (100 x 100 µm²)

Mineral pigments

-Kaolin, PCC, GCC, Talc, Silica

Binders and barriers

-Styrene-n-butyl-acrylate (SA)
-Styrene-Butadiene (SB)

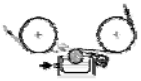
Manufacturing methods

Blade coating

- Precoating
- Smoothing layer
- Barrier layer

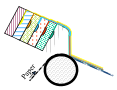
Reverse gravure coating

- Barrier layer
- Topcoating



Curtain coating

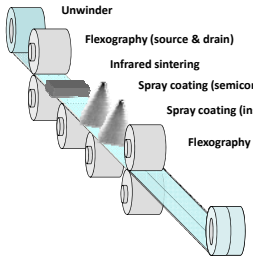
- Precoating
- Smoothing layer
- Barrier layer
- Topcoating



Functional printing

Roll to roll hybrid printing of functional materials

Setup for printing transistors reel-to-reel

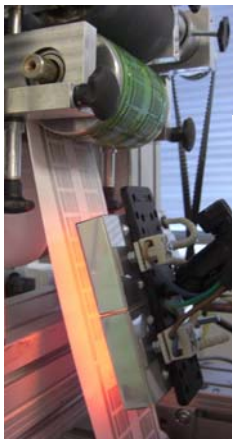


The surface properties of the topcoating layer can be tuned to meet the demands set by ink and printing method

Low surface energy
Low absorption

High surface energy
Low absorption

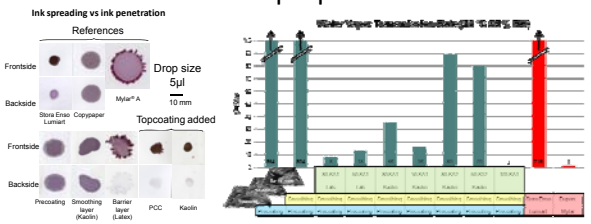
High surface energy
High absorption



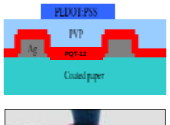
Source and drain printed with flexography.
The silver ink is sintered online using IR radiation

Proof of concept

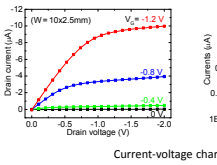
Barrier properties



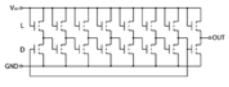
Hygroscopic Insulator Field Effect Transistor



Digital camera picture of all-inkjetted transistor



Current-voltage characteristics



Ring-oscillator (Schematic setup)

Conclusions

- It is possible to create a paper-based substrate suitable for printed functionality by utilizing recyclable, commercially available raw materials in a multilayer structure
- The substrate can be tailored for each device by modifying surface energy, surface roughness and surface porosity through choice of raw materials and surface treatment methods
- Adequate barrier properties and sufficient printability can be combined
- For large scale manufacturing curtain coating can be used