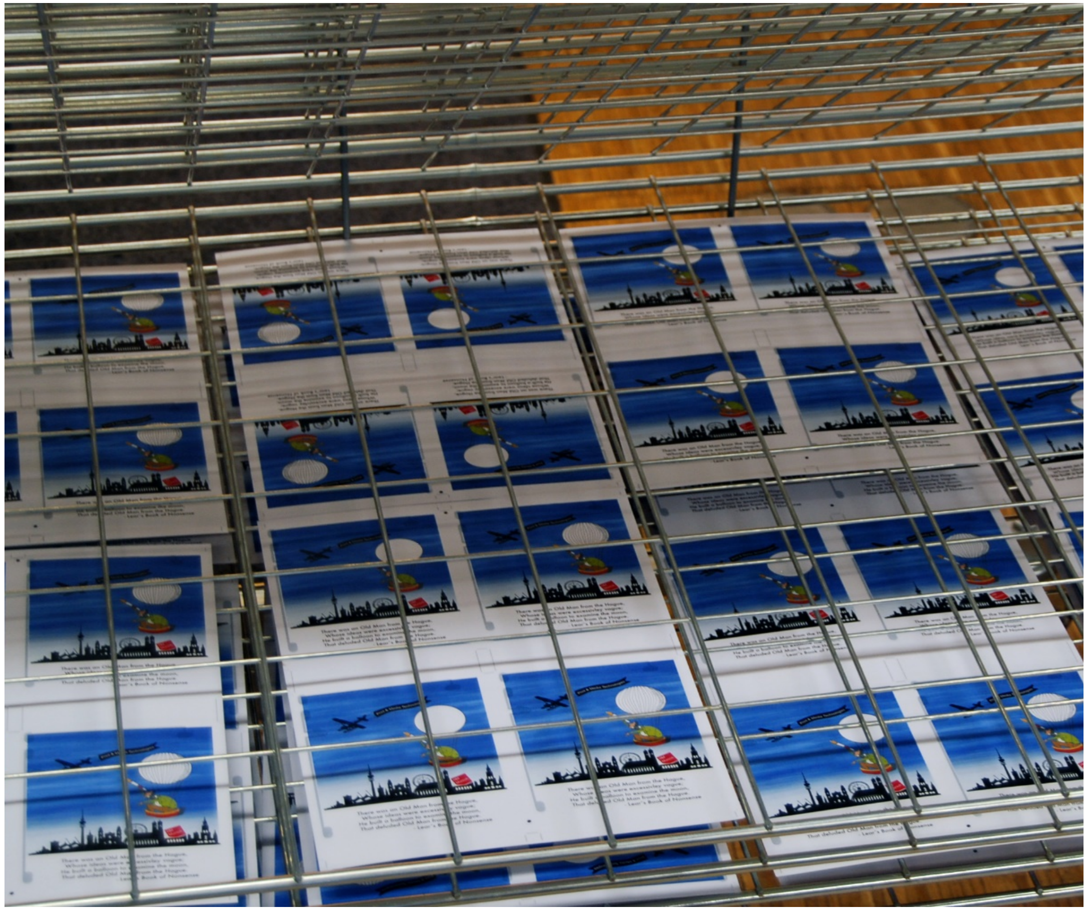

Analysis of the Process to Develop and Produce a Two-Part Printed Electronics Demonstrator

– The Hague Project

Moosheimer, U.; Jakob, C.; Maske, S.
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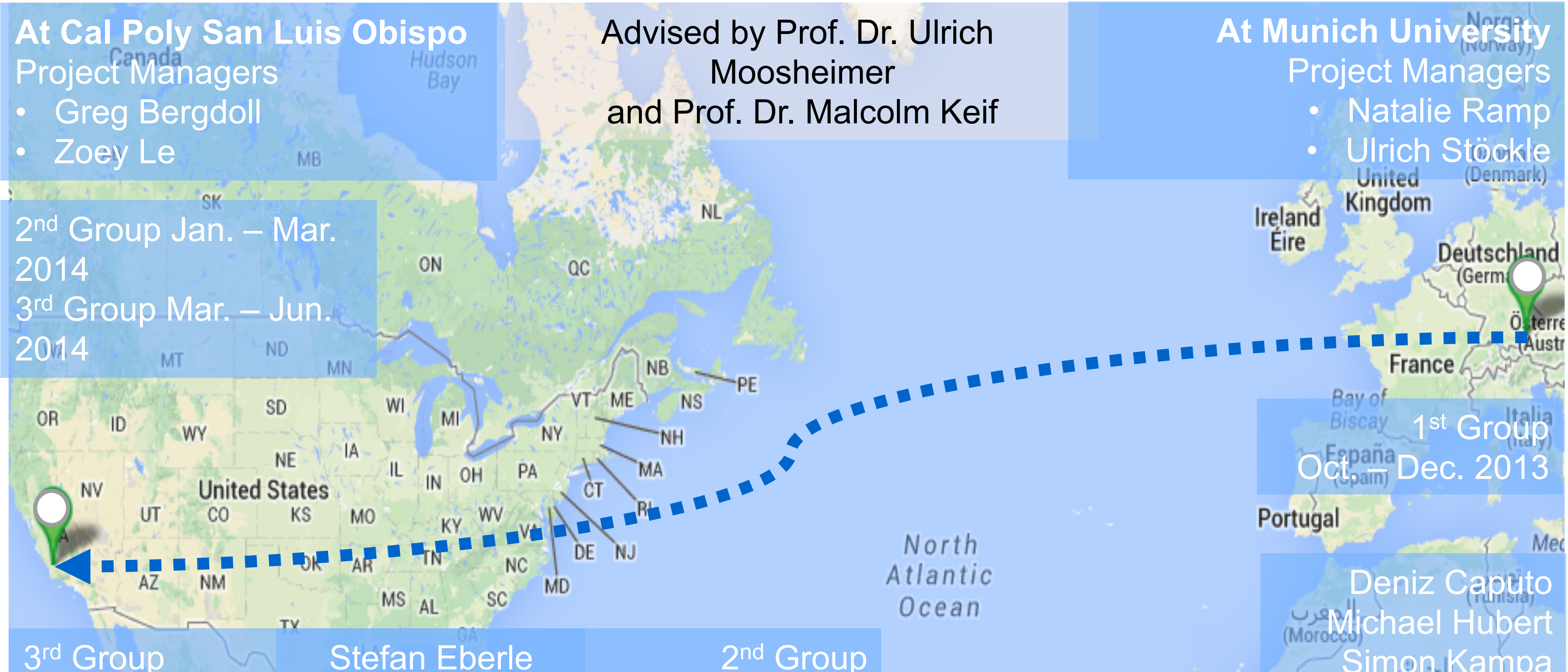
UNIVERSITY OF APPLIED SCIENCES MUNICH

Transatlantic Printed Electronics Project



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- Zoey Le

Advised by Prof. Dr. Ulrich Moosheimer
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At Munich University
Project Managers
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3rd Group Mar. – Jun. 2014

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Introduction - FluxTime

Transatlantic Printed Electronic Group (TAPE)

- California Polytechnic State University
- Munich University of Applied Science

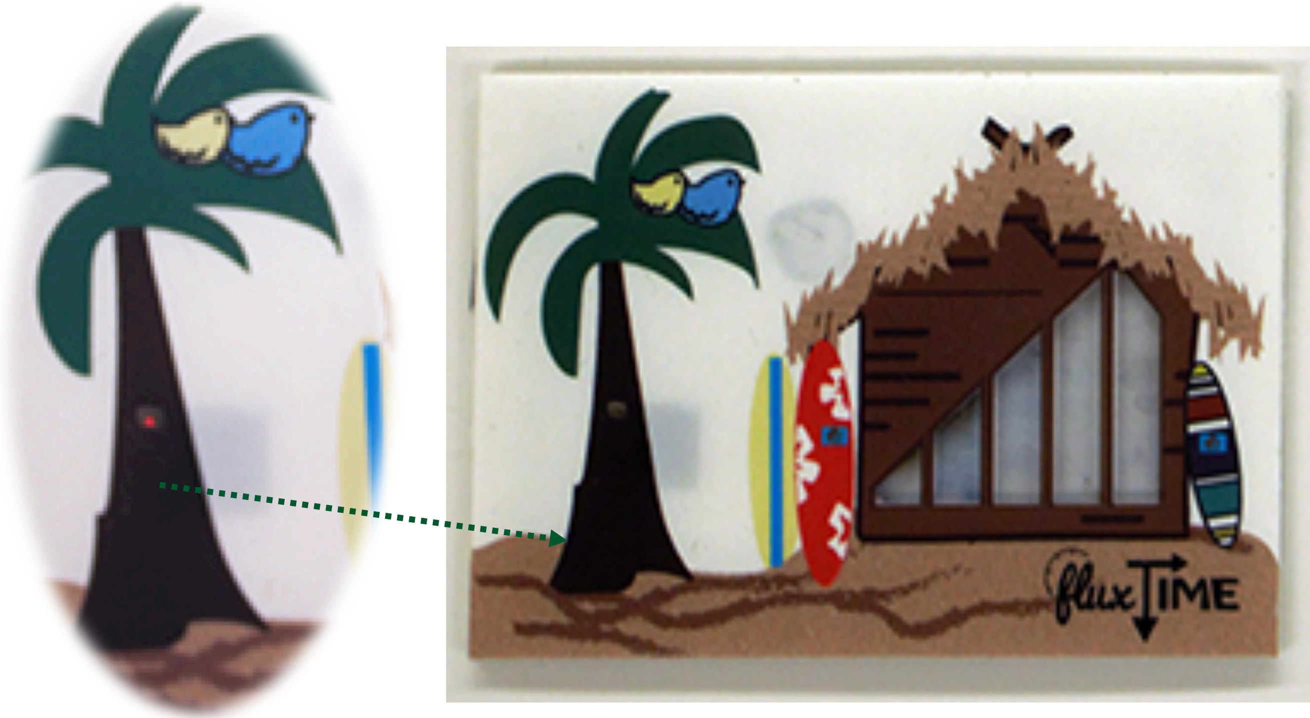
TransAtlantic
Printed Electronics Group

Product FluxTime

- Timer for rough environmental conditions
- RFID - charging
- RFID - trigger

Components

- RFID Antenna
- Accumulator
- Microcontroller
- Silver lines
- PeDot
- Isolation layers
- Electrochromic ink



→ OE-A Competition 2015: Best Freestyle Demonstrator

Introduction

Development of a New Printed Electronic Demonstrator

Requirements

- General
  - Printed electronics as key feature
  - Disposable in domestic waste

- Layout
  - Stand-alone demonstrator of each university
  - Additional feature by combining the demonstrator of both universities
  - Attractive design

- Production
  - Easy to produce on standard printing machines of both universities
  - Low material costs
  - High reliability
  - Easy to handle

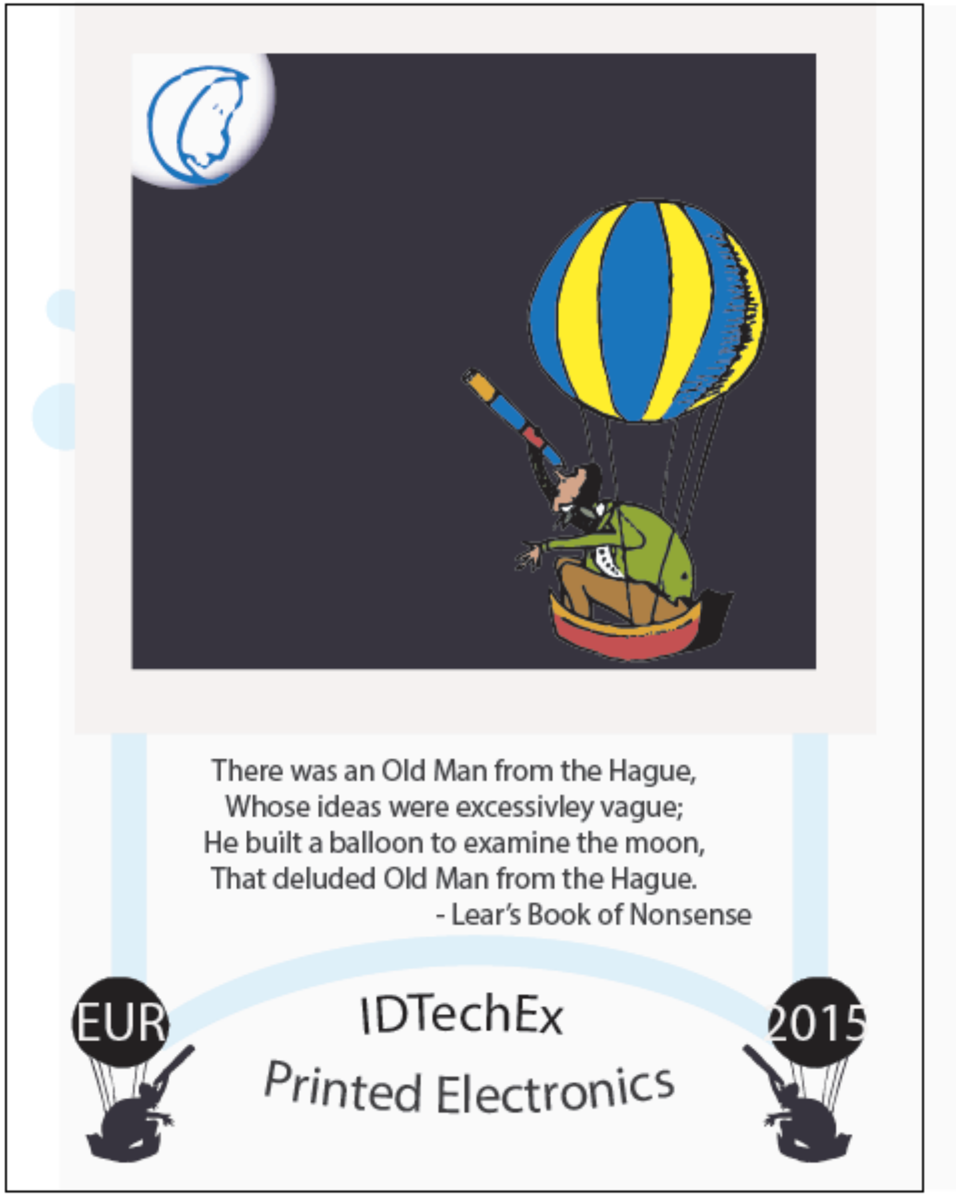
The Hague Project

Connecting an USB micro plug to the transparent front page

- Electrochromic displays change color
  - the balloon
  - the telescope

Placing the Cal Poly card into the Munich Brochure,

- Themochromic display shows stars
- Electrochromic display shows the moon.



HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN MÜNCHEN

The Hague Display Layers

Foil: Substrate

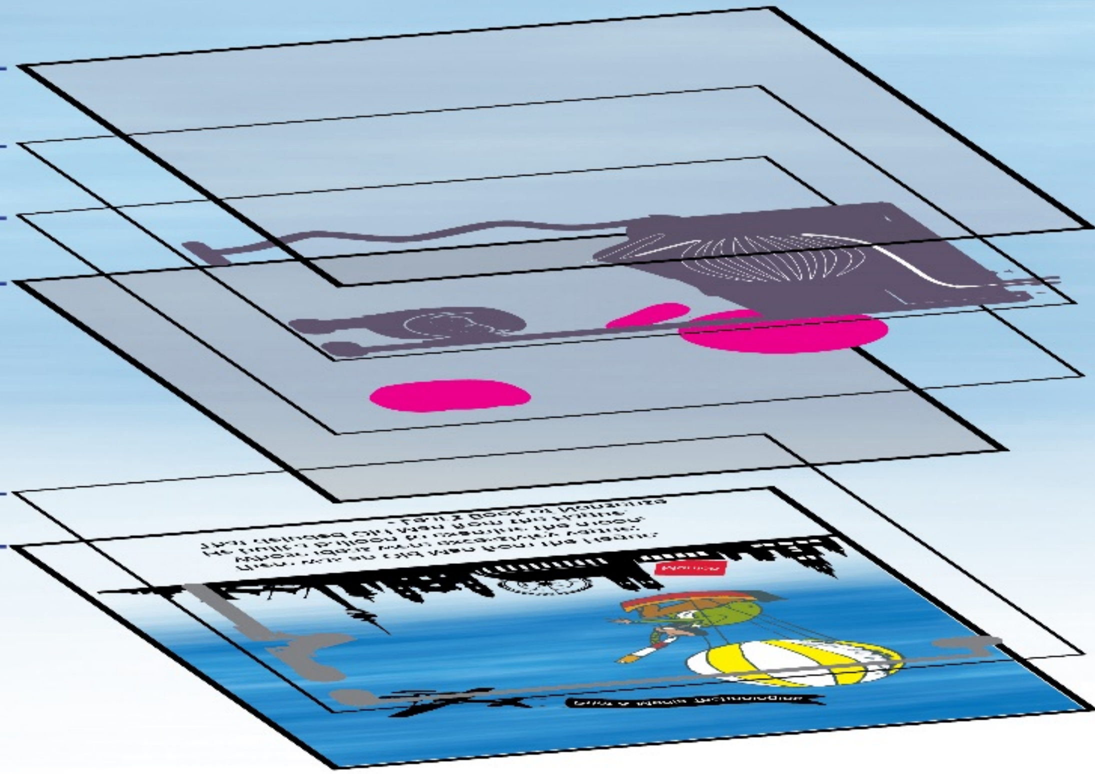
PeDot: Screen Printing

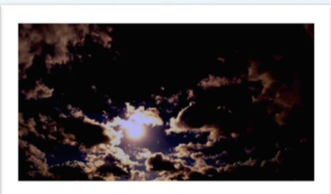
Lithium: Screen Printing

Plastic Film: Laminating

Silver: Screen Printing

Paper: Laser-Printing





Project Plan

Project group I	14 WS – Development of demonstrator – First steps to develop the production process
Bachelor thesis	January 2015 – May 2015 – Presentation at IDTechEx
Project group II	March 2015 – April 2015 – Development of production process – Production of 2.000 demonstrators – Documentation at homepage

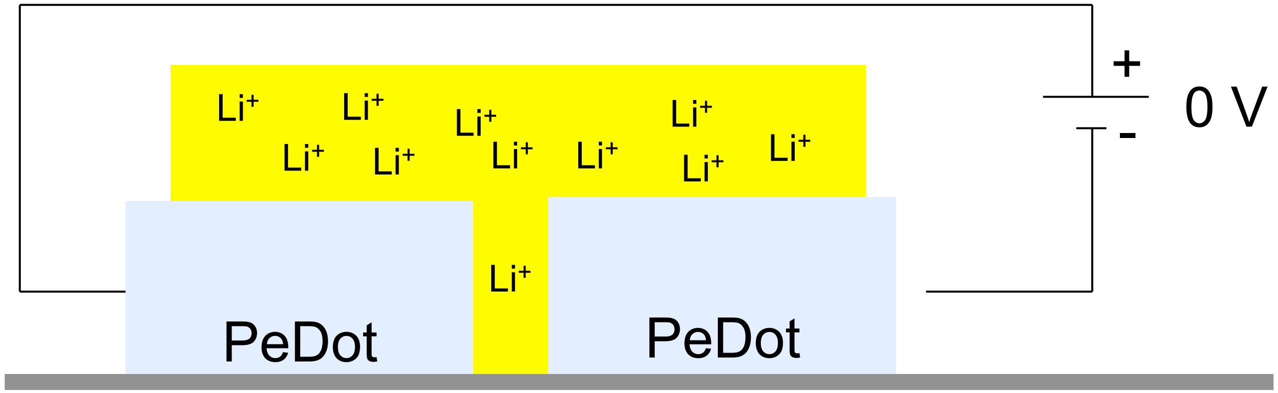
Electrochromic Display

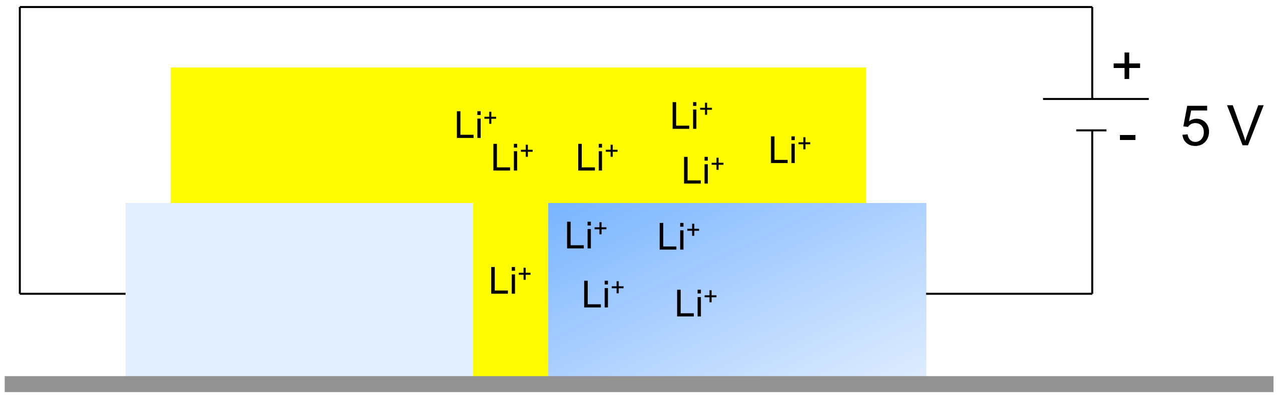
Features

- General
  - Disposable in domestic waste
- Production
  - Screen printing
    - PeDot
    - Electrolyte (Li^+)
  - Low material costs
    - External power source
  - High reliability
  - Easy to handle
- Risk
  - No printable electrolyte available

Applying a voltage colors PeDot blue

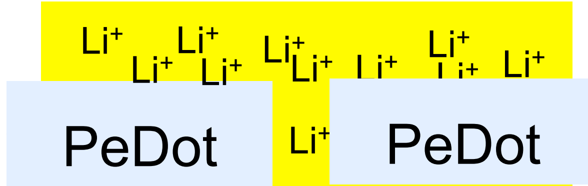
- Mobility of Li^+ mandatory





Printing of an Electrochromic Display – PeDot

Printing of two PeDot areas separated by a gap
(Commercial available PeDot from Heraeus)



Requirements for a fast color changing transparent display

- Transparency
  - → Thin layer of bluish PeDot
- High switching speed
  - → Low resistance of PeDot layer
    - → Thick PeDot layer
  - → Small gap between PeDot areas
    - → Risk of electrical shortcuts
- No visible PeDot structure
  - → Thin layer of bluish PeDot
  - → Small gap between PeDot areas
    - → Risk of electrical shortcuts

1st optimization problem:
Thickness of PeDot layer

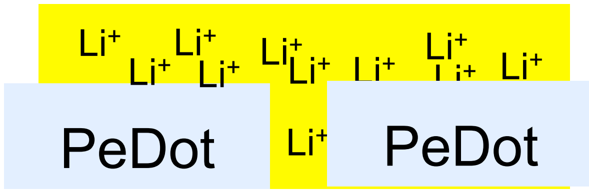
2nd optimization problem:
Gap between PeDot areas

Printing of an Electrochromic Display – PeDot

1st optimization problem: Thickness of PeDot layer

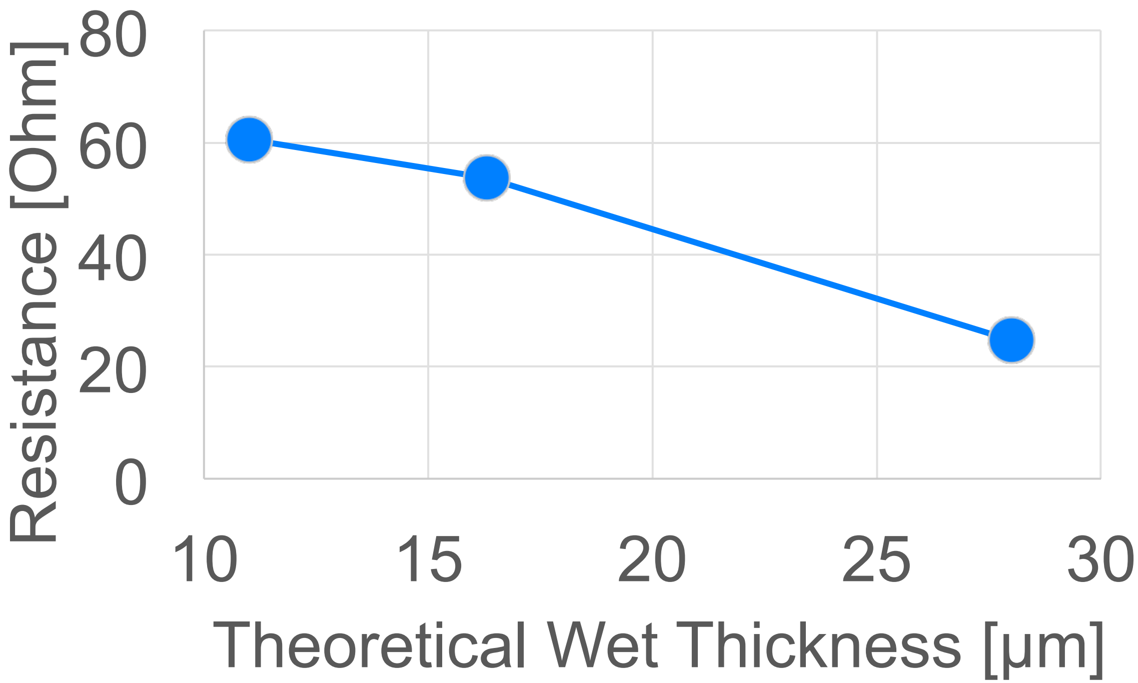
Setup

- Printing of 100 mm x 1 mm lines
- Variation from 195 to 380 mesh



Result

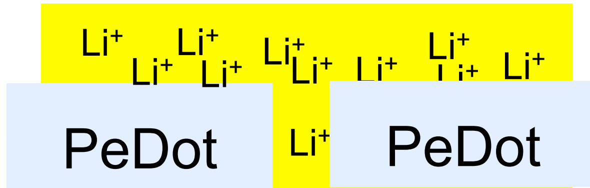
- Resistance decreases with mesh
- Sufficient reaction time of thinnest PeDot layer
  - → Maximum transparency
  - → Minimum visible PeDot structure



Printing of an Electrochromic Display – PeDot

2nd optimization problem: Gap between PeDot areas

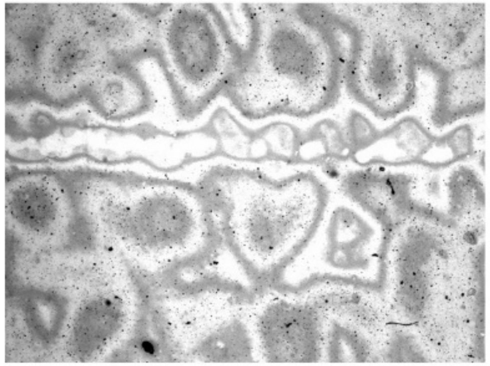
– Optimization of printing parameters

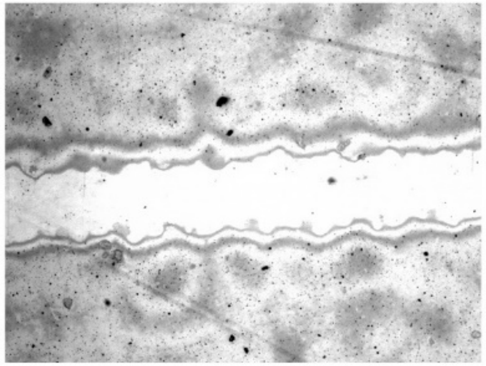


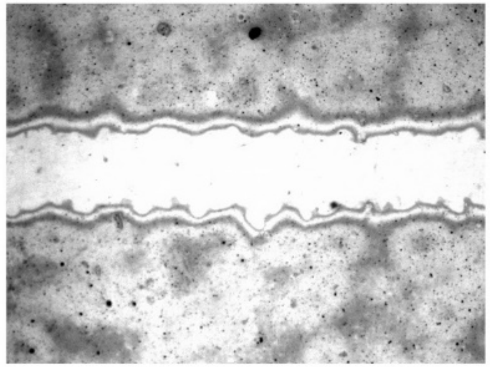
Setup

– Printing of 1 mm thick negative lines

Lines parallel to squeeze direction

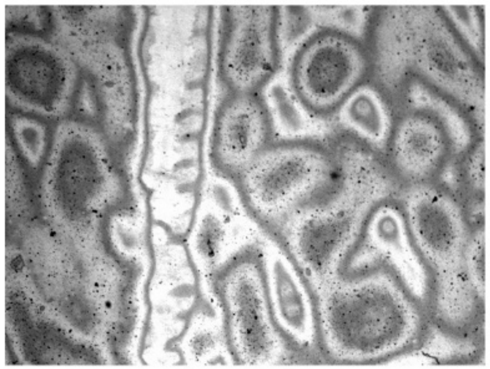


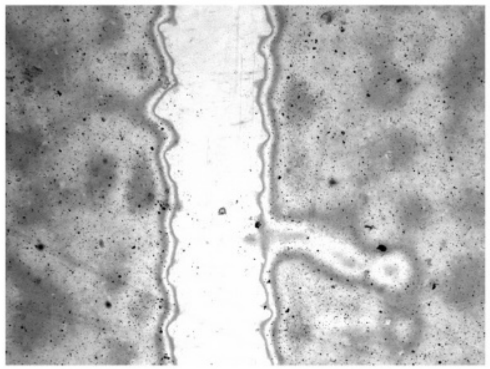


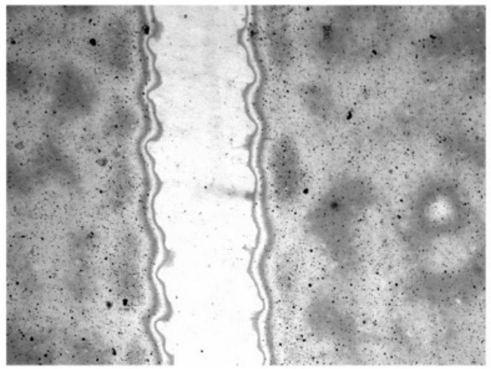


Short cut | Starting printing conditions | Optimized Conditions

Lines vertical to squeeze direction



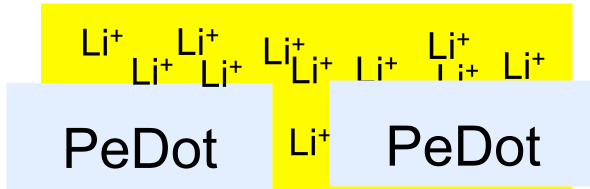




Printing of an Electrochromic Display – PeDot

2nd optimization problem: Gap between PeDot areas

– Optimization of printing parameters

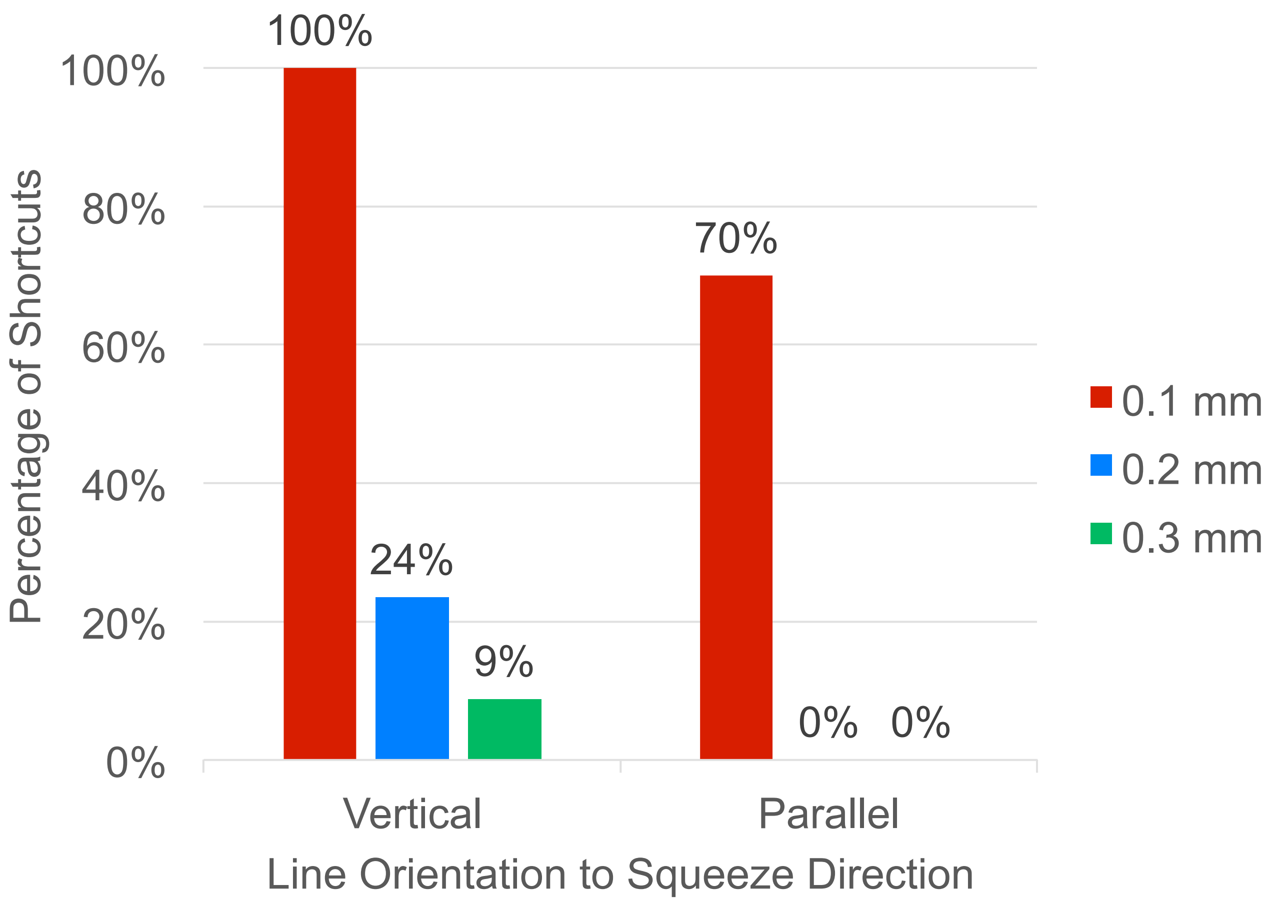


Setup

– Printing of different thick negative lines

Result

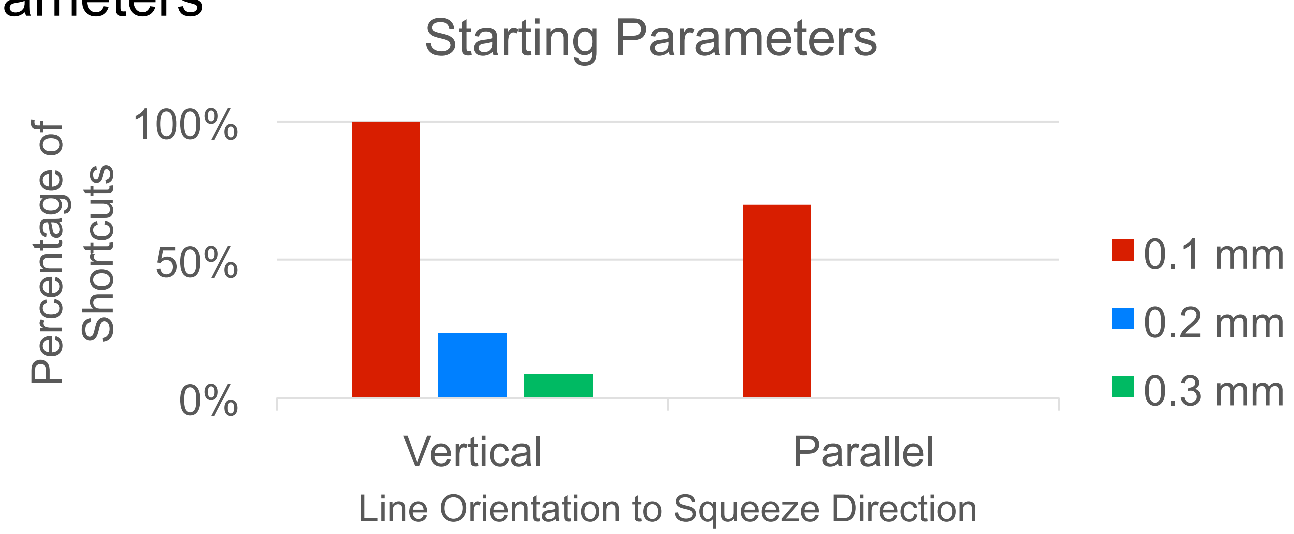
– Higher process stability by
  – Thicker lines
  – Parallel lines



Printing of an Electrochromic Display – PeDot

2nd optimization problem: Gap between PeDot areas

– Optimization of printing parameters

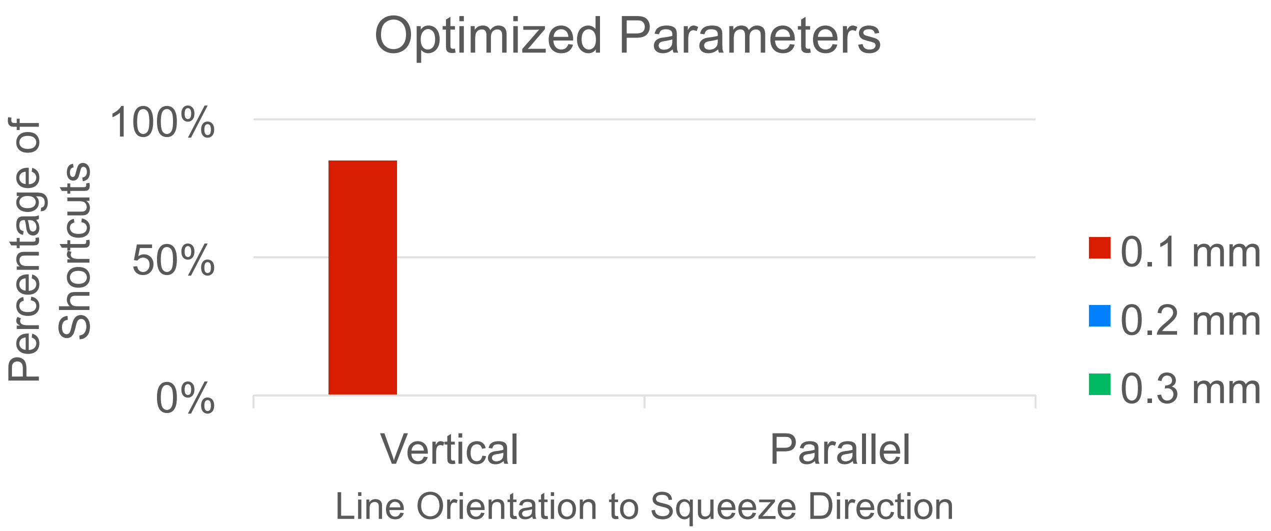


Setup

– Printing of with different machine settings

Result

– Optimized Parameters
→ 0.2 mm lines

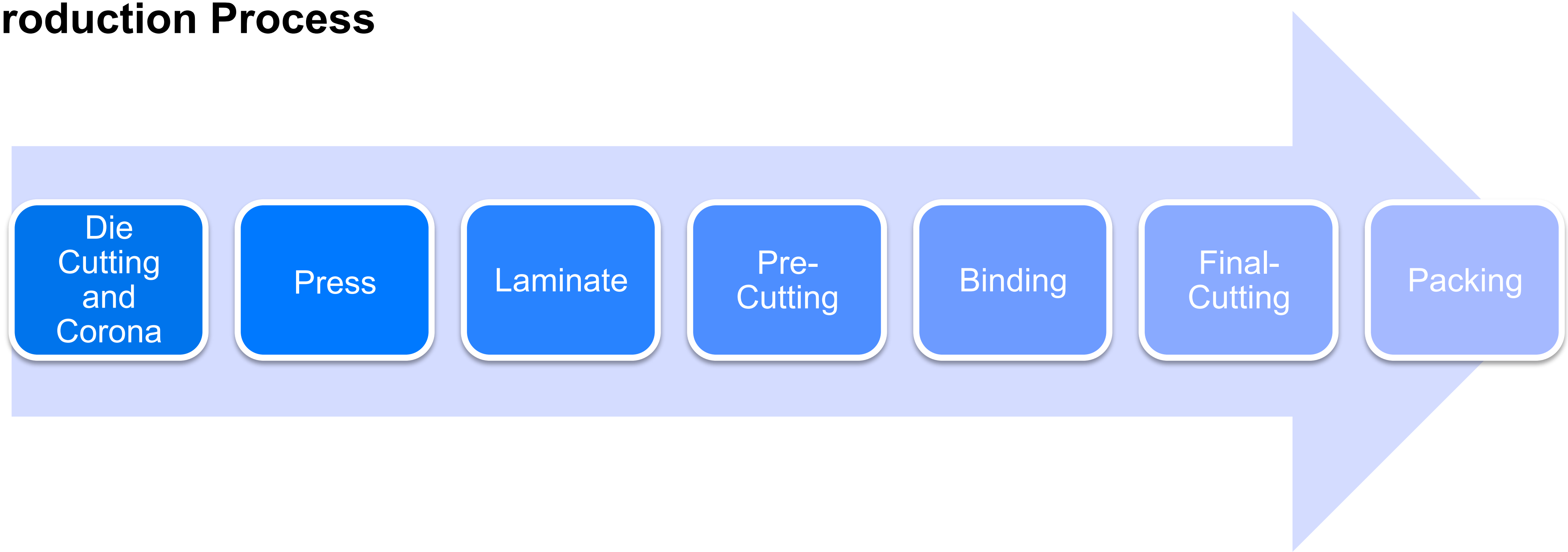


Electrochromic Display – Electrolyte

Development of electrolyte

- Requirements
  - Electrochromic reaction
    - Powered by 5 V USB
    - High mobility of Li^+ ions → fast reaction time
    - Reversible
    - Long life time
  - Application
    - Screen printable
    - Electrochromic layer can be
      - dried
      - semi-dried and laminate
    - Easy to handle (no health risks)
- Starting point
  - 15 wt% of polymethyl methacrylate (PMMA) and 84.5 wt% of propylene carbonate are mixed with 0.5 wt% of $LiClO_4$

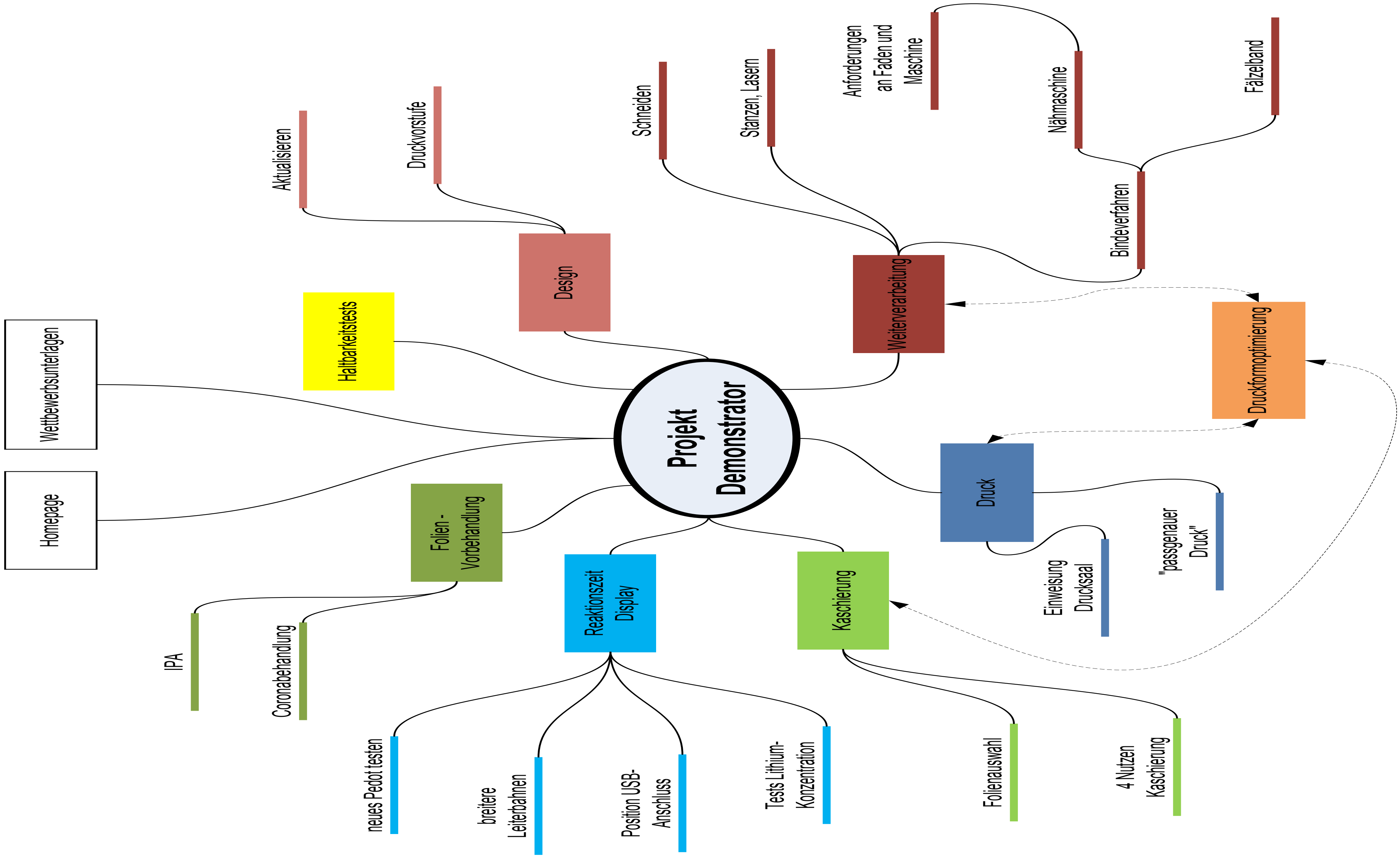
Production Process



Challenges

- Stable “mass” production of about 1500 demonstrators within 7 days
- Almost no experience in printing the newly developed electrolyte
- High registration of dye cutting to PeDot less than 0.1 mm
- No short cuts in PeDot
- …
- Some others

Production of The Hague – Process Analysis



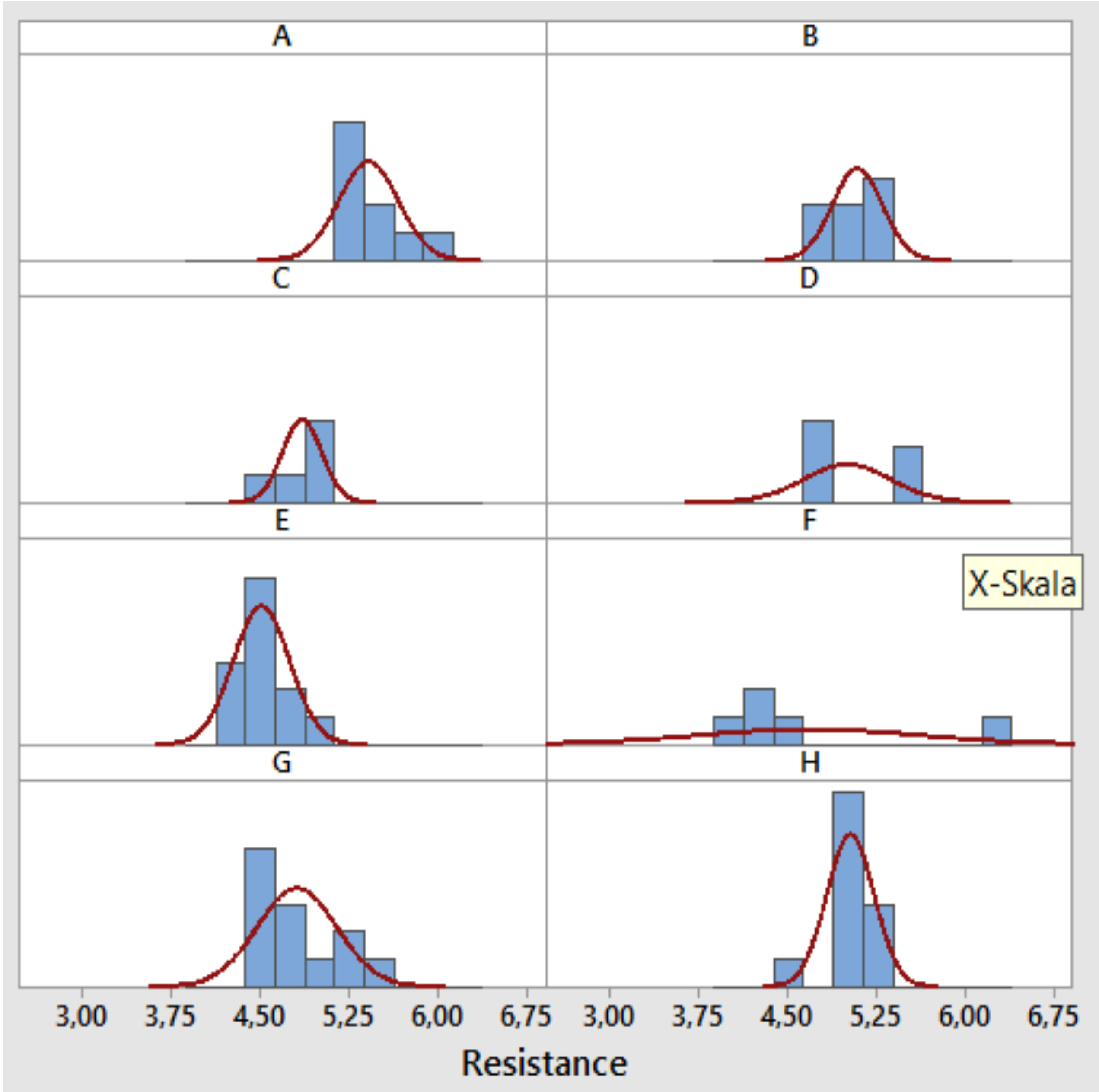
Statistical Process Analysis

Begin of production

Test of normally distributed data ($p > 0.05$)

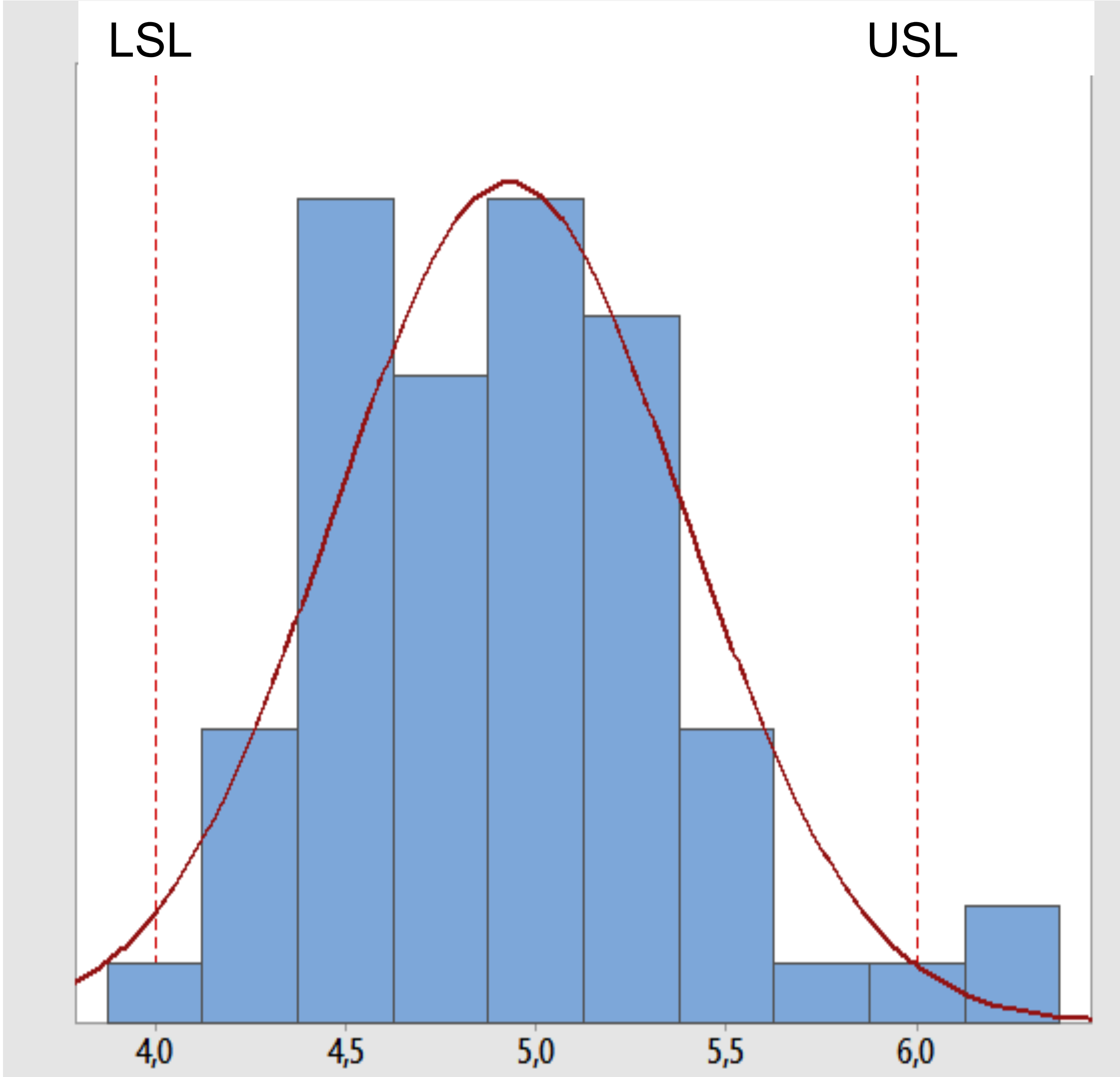
→ Basis for statistic process analysis

→ A, B, C, G and H are normally distributed



Statistical Process Analysis

Begin of production



Process capability study

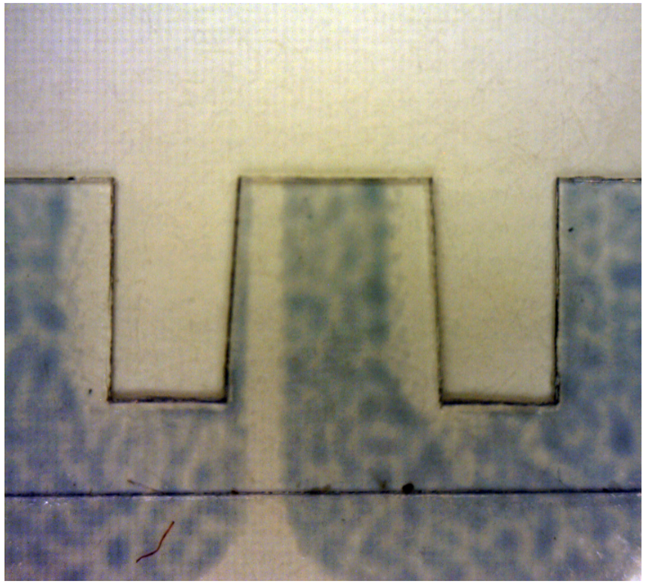
– Mean value	4.93
– Standard derivation	0.46
– Process potential	0.72
– Process capability	0.67
– Error probability	3.22%

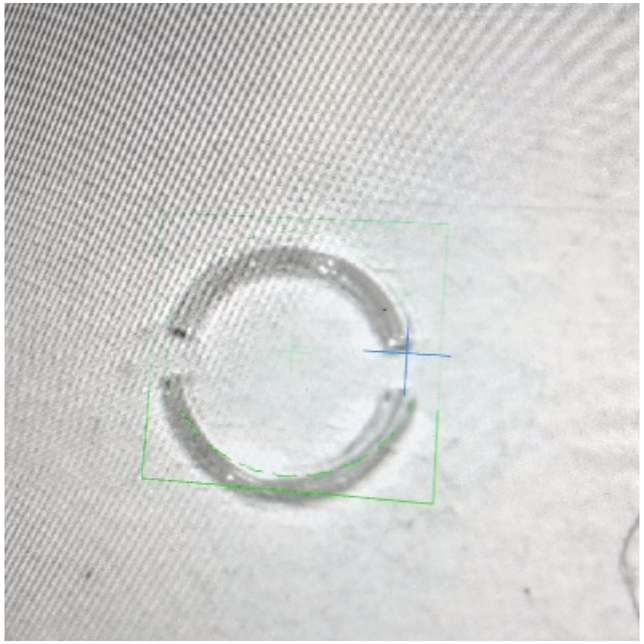
Production Challenges
USB – Plug

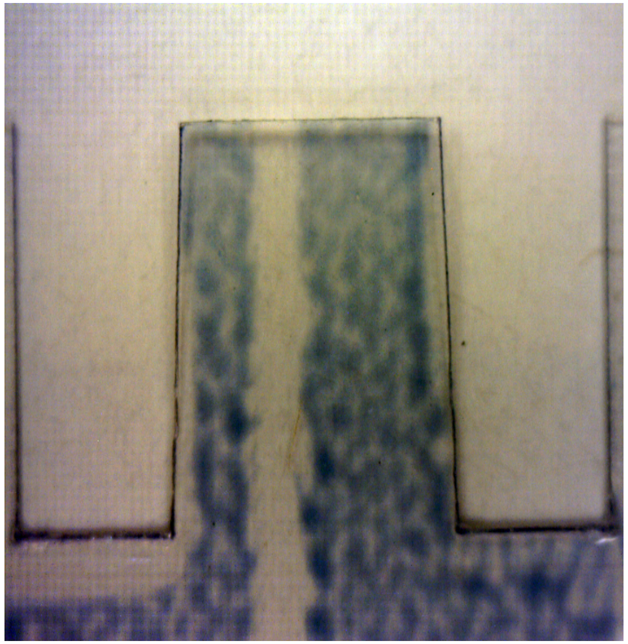
Plan
- Laser cutting

Problem
- Too low registration between printed PeDot and dye cutting line
- Long production time

Solution
- Roll-to-roll flexographic label printer with dye cutting unit
- Registration by cameras of screen printer







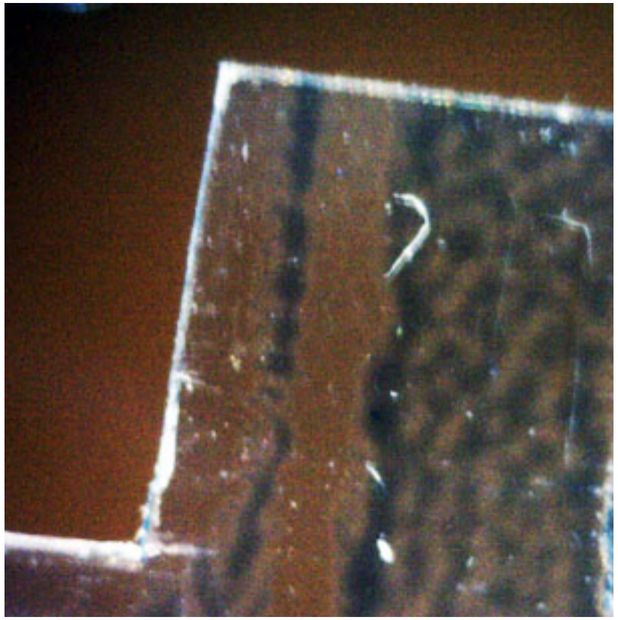
Production Challenges

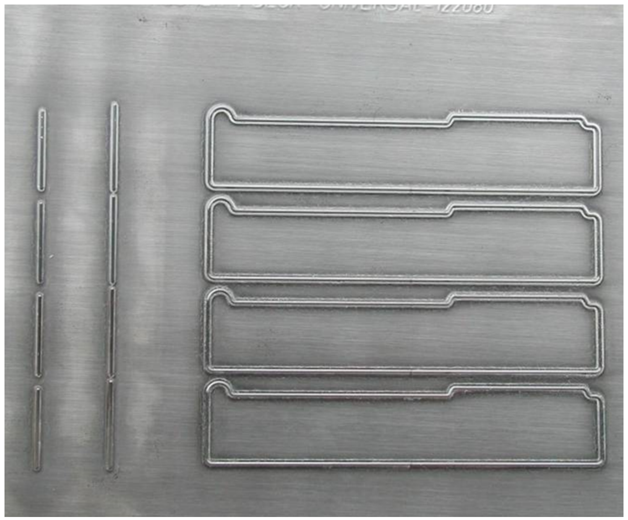
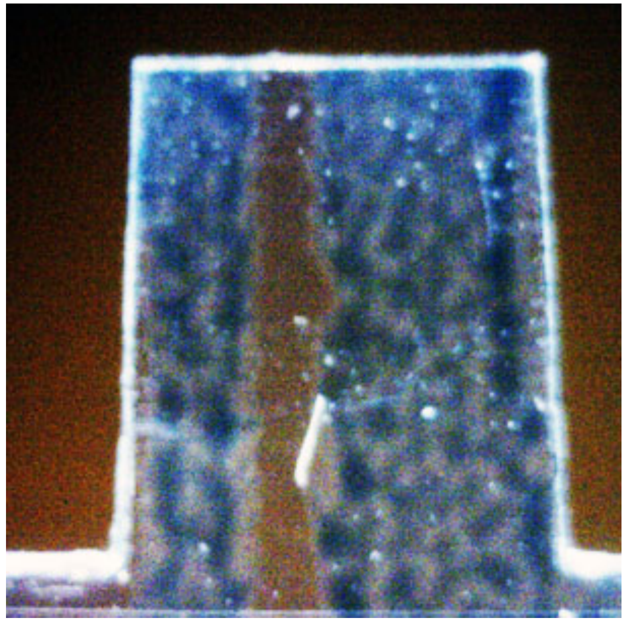
USB – Plug

Plan
– Rotative Corona pretreatment and dye cutting

Problem
– Wettability problems at dye cutting line

Solution
– Optimization of screen printing settings
– Cleaning of PET with isopropyl alcohol
– Removing of oil or silicone protection of dye



Production Challenges

Lamination of impurities

Plan

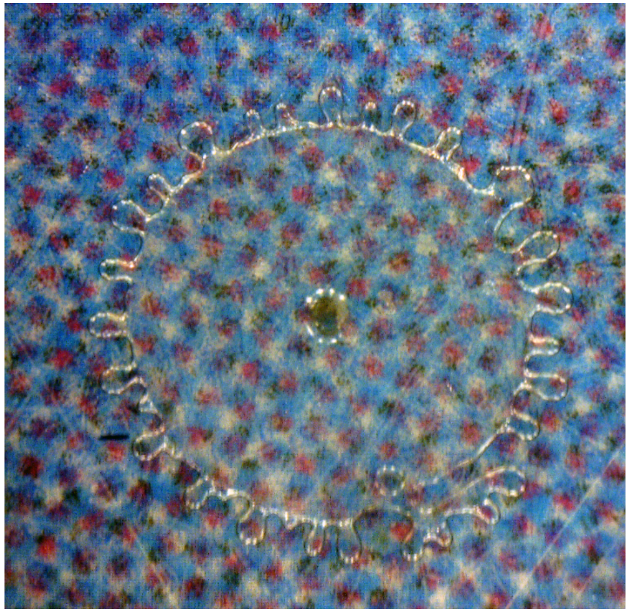
– Crystal clear display

Problem

– Impurities
  – Dust
  – Hairs
  – Finger prints
  – Fly
– Compression of display

Solution

  – Gloves
  – Ionized cleaning before lamination
  – Protective layer in cutting unit

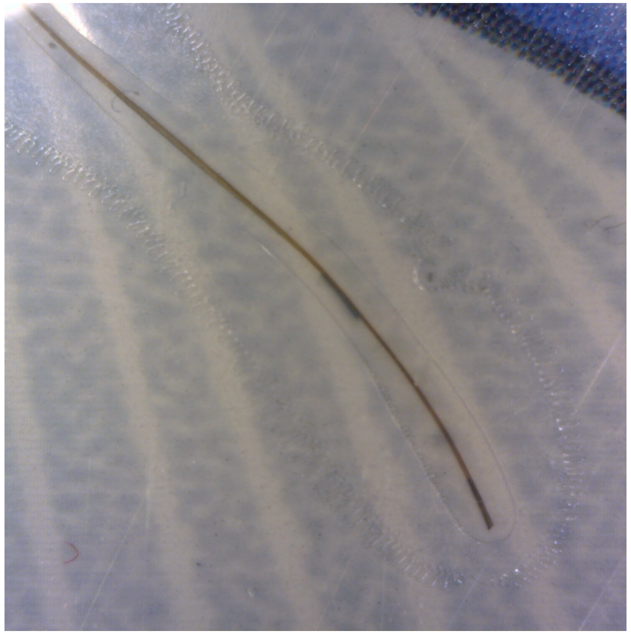


Production Challenges
Lamination of impurities

Plan
- Crystal clear display

Problem
- Impurities
  - Hairs
- Compression of display

No solution
  - Hairnets
  - Lab coats



Production Challenges

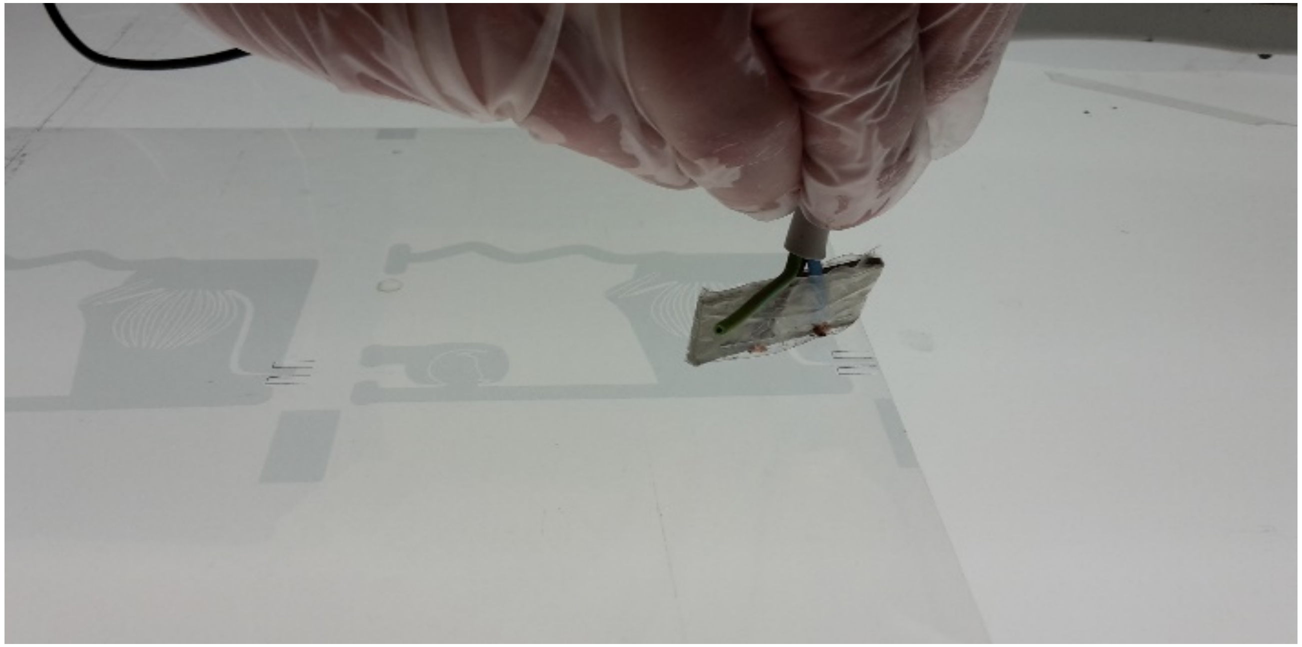
Electrical shortcuts in PeDot

0 Ohm → ∞ Ohm

Plan
– Electrical isolated PeDot layers

Problem
– Shortcuts mostly at balloon
– Invisible shortcuts

Solution
– 100 % process control
– Thicker spacing line between PeDot layers
– Healing of shortcuts by high voltage



Production Challenges

Non working displays

Plan

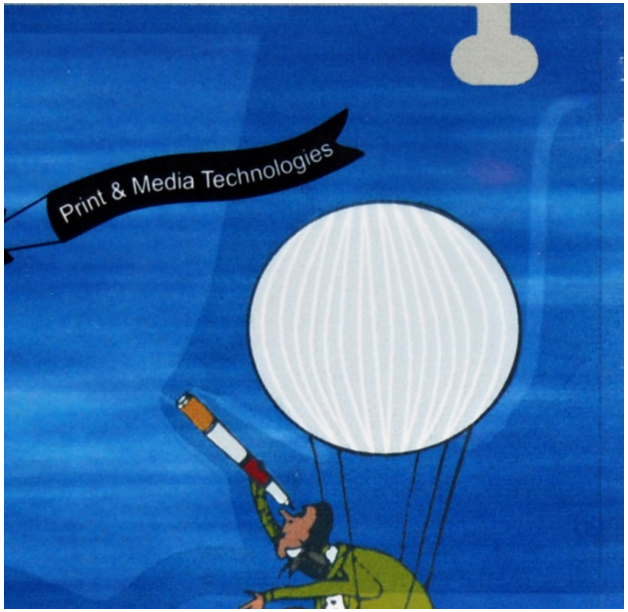
– Powering displays by USB plug

Problem

– Displays work at power supply but only at some USB plugs

Solution

– Micro short cuts consuming to much current
– Using USB plugs with high current of 2.1 A



Video

Statistical Process Analysis

End of production

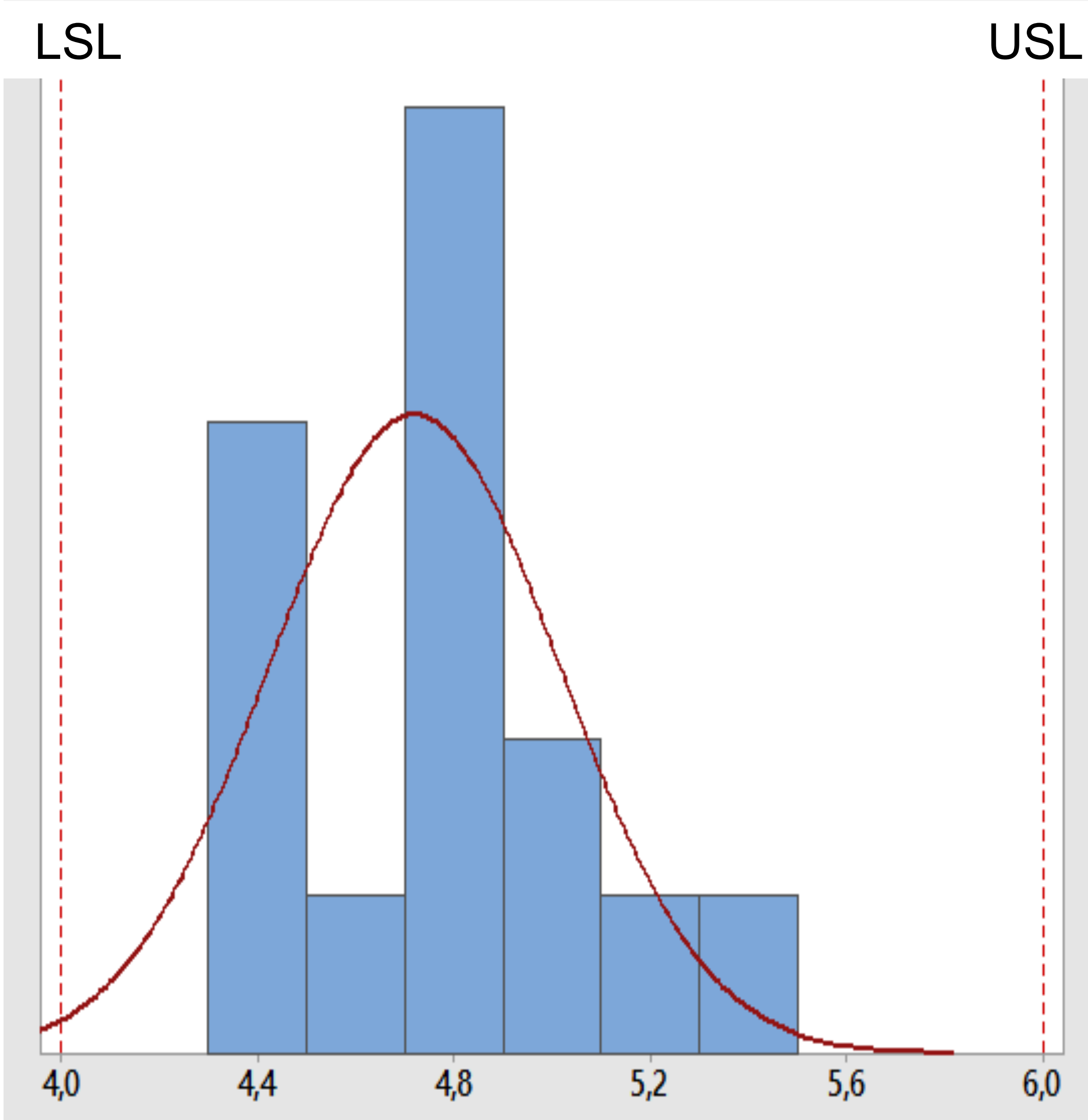
p = 0.313

Process capability study

- Mean value 4.72
- Standard derivation 0.30

- Process potential 1.13
- Process capability 0.81

- Error probability 0.8 %
- Begin of production 3.2 %



Cost Analysis of Electrochromic Front Page

Production
- Roll-to-sheet screen printing
  - Unwinding
  - PeDot printing
  - Electrolyte printing
  - Lamination
  - Dye cutting

Printing machine
- Machine cost 200 €/h
- Prints/h 2000
- # per print 2

Materials
- PET substrate 3.5 €/qm
- Lamination film 1.5 €/qm
- PeDot 500 €/kg
- Electrolyte 500 €/kg

Sizes
- Sheet 140 x 120 m
- Display 30 x 30 mm
- Conductive lines 60 x 60 mm

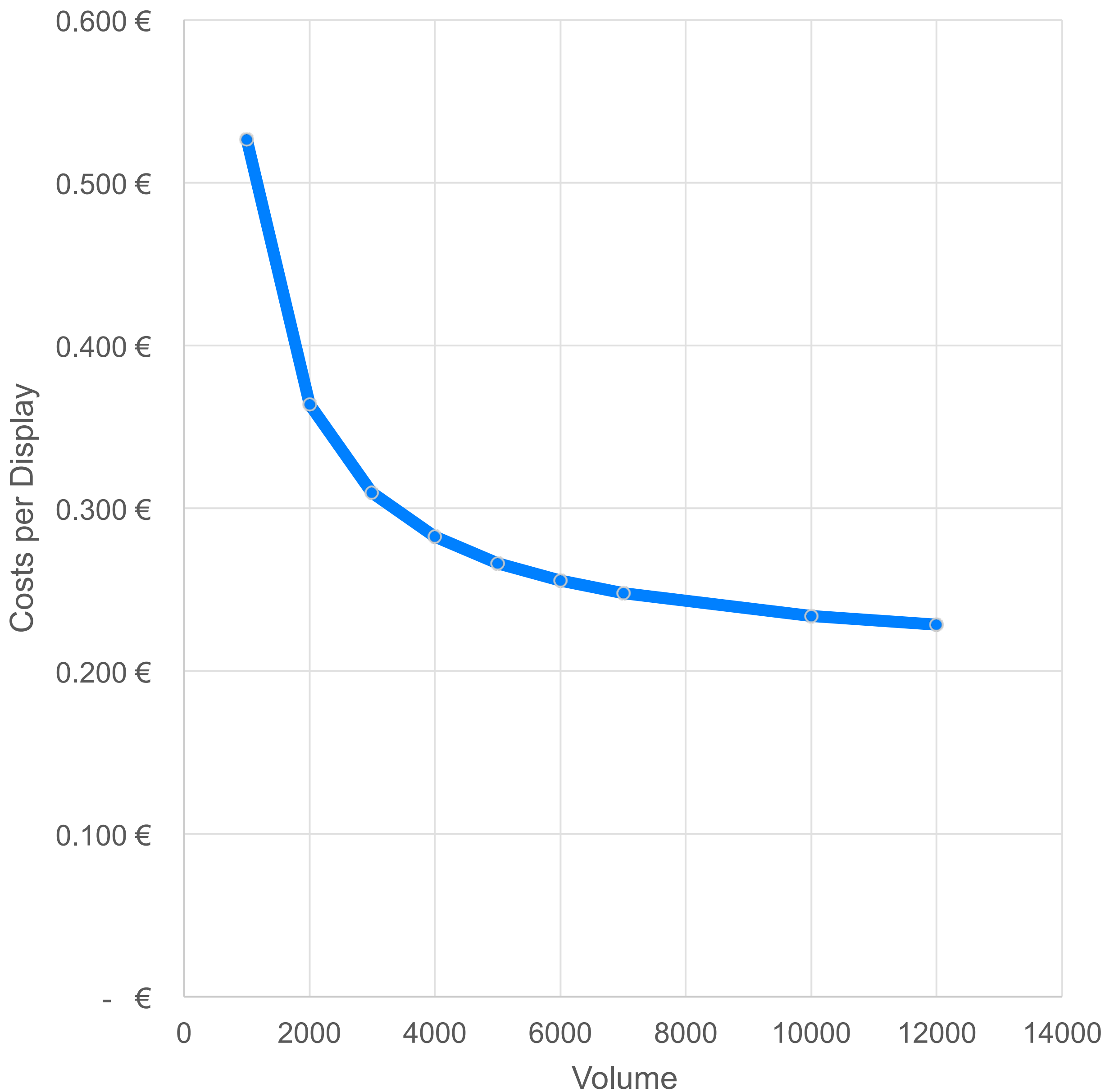
Setup
- Time 1 h
- Material 100 m
- Dye 65 €

Cost Analysis of Electrochromic Front Page

Production

- Roll-to-sheet screen printing

- Production steps
  - Unwinding
  - PeDot printing
  - Electrolyte printing
  - Lamination
  - Dye cutting

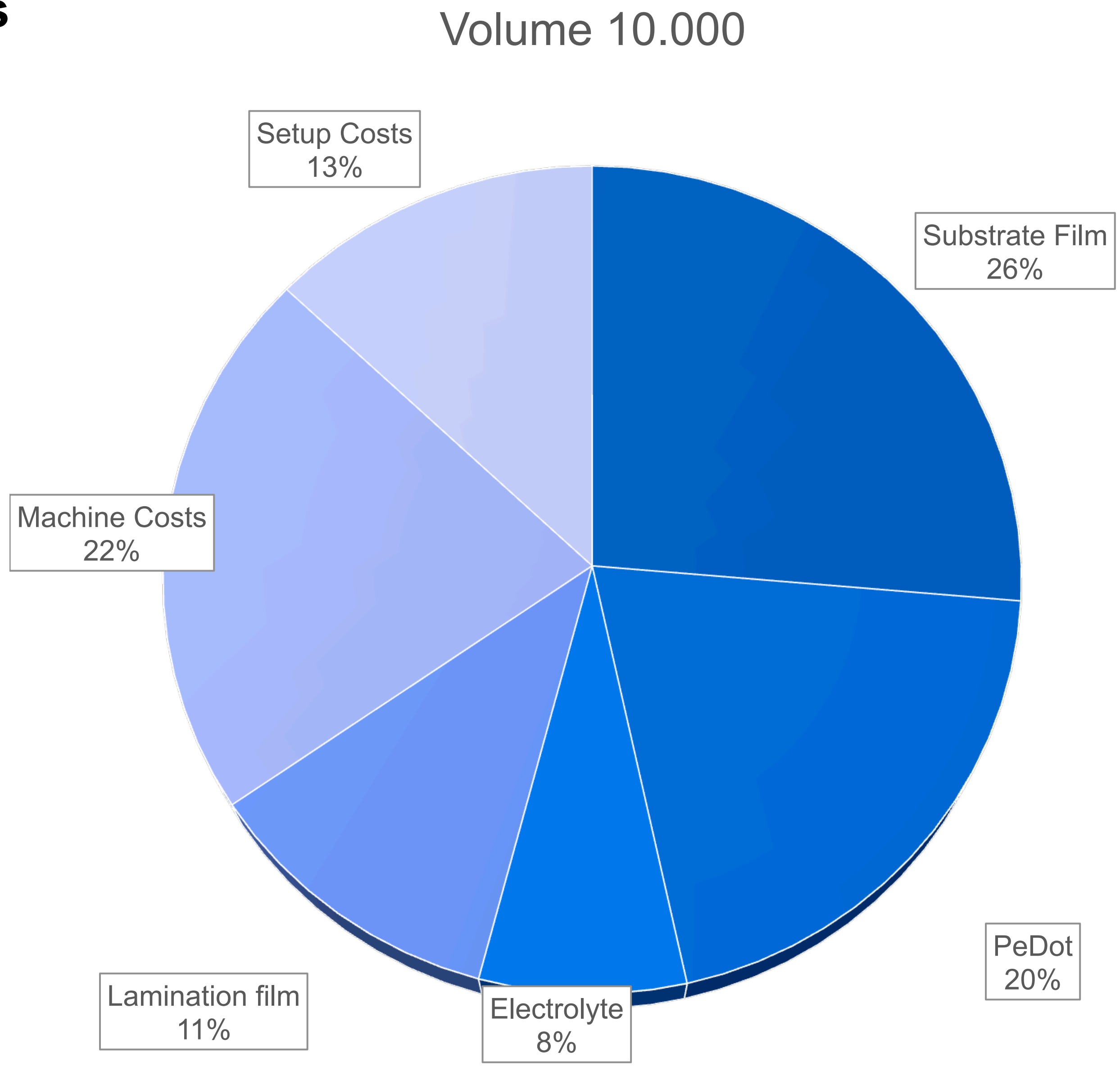


Cost Analysis of Electrochromic Front Page

Production of 10.000 displays

- Roll-to-sheet screen printing
  - Unwinding
  - PeDot printing
  - Electrolyte printing
  - Lamination
  - Dye cutting

- Cost per display 0.23 €



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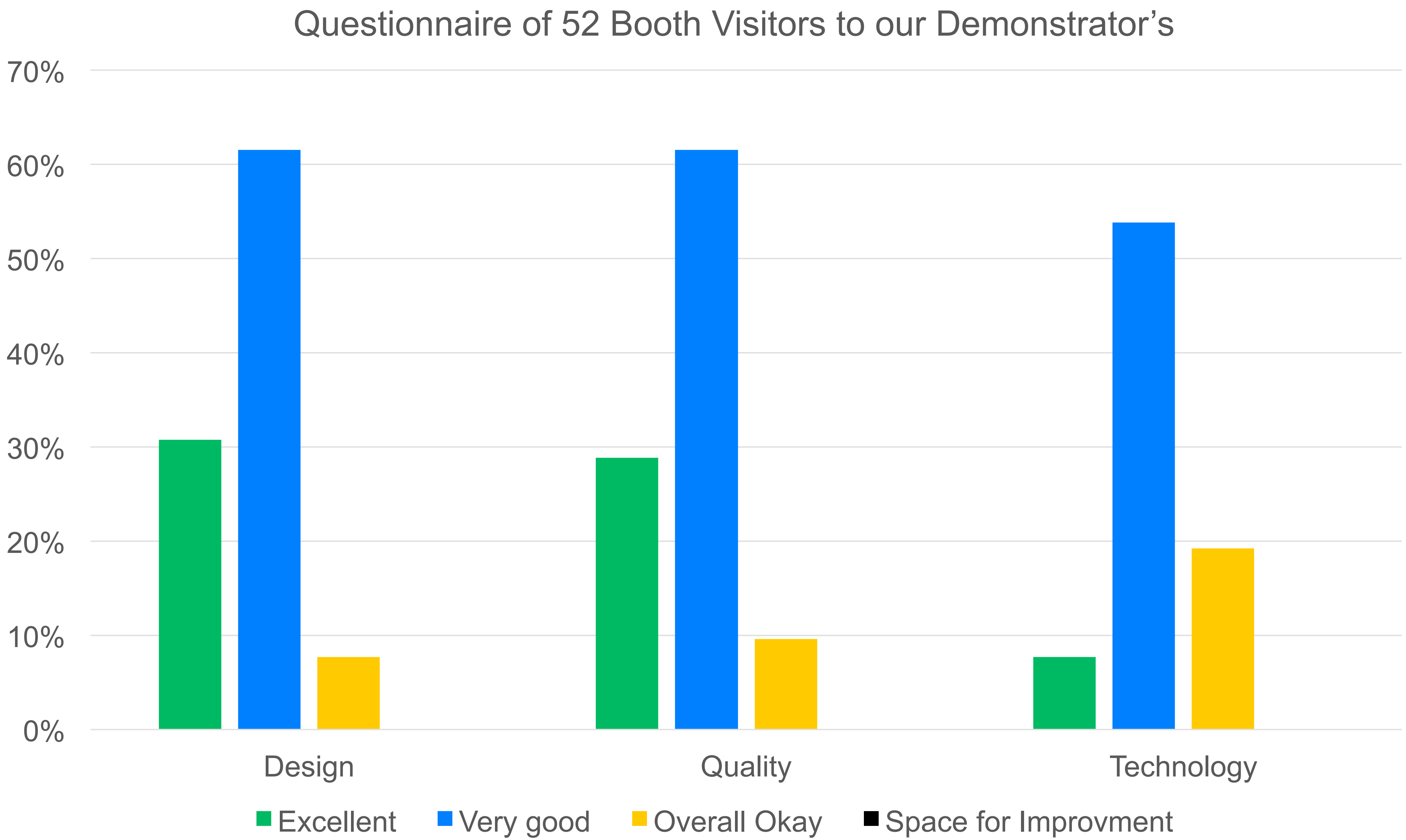
Feed-back of the IdTechEx Visitors



Project Team

Thank you very much for your great job

For details see: www.print-project.com/project/IDTechEX

Live Printing of Displays

Production of a Two-Part Printed Electronics Demonstator

Malcolm Keif,
– California Polytechnic State University, San Luis Obispo, CA, USA.

Ulrich Moosheimer,
– Munich University of Applied Sciences, Munich, Germany.

Time
– 3:05-3:55

Location
– Bldg. 26-204