Berner Fachhochschule
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Yellowing of Thick-Film Coatings Printed with UV-Curable Inkjet Varnishes

▸ Institute for Print Technology

Authors

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Overview

- In context with the production of a Braille book
- Use of Industrial inkjet technology to print layers of 250-500 µm needed for Braille letters and tactile elements
- Investigation of safe UV inkjet varnishes
- Study the yellowing of UV cured clear varnish

Introduction and background

- UV curing chemistry and ink-jetting is now an established printing technique
- Clear UV curable inkjet varnish is becoming important in “up-value” production steps
- For tactile impressions UV curable inkjet varnish can also be used
  - For distinct haptic effects layer thickness of 20 to 200 µm is needed
  - Braille letters, raised imaging for illustrations in Braille books, museum and gallery signage and descriptive labels

Introduction and background

- Tactile adaption of Paintings
- *“Portrait of Empress Elisabeth of Habsburg”*
- Roland UV LEC-330 inkjet printer to reproduce the haptic effect in a multi-step, layered printing process (Krivec et al., 2014)

Introduction and background

- Manufacturers, such as Roland, Mimaki and Scodix, have integrated the capability to process such raised textures into their industrial inkjet printers and Raster Image Processors.

Lec-330 LED-UV Inkjet
(Roland, 2014)

Mimaki UJF-3042 UV LED
(Mimaki, 2014)

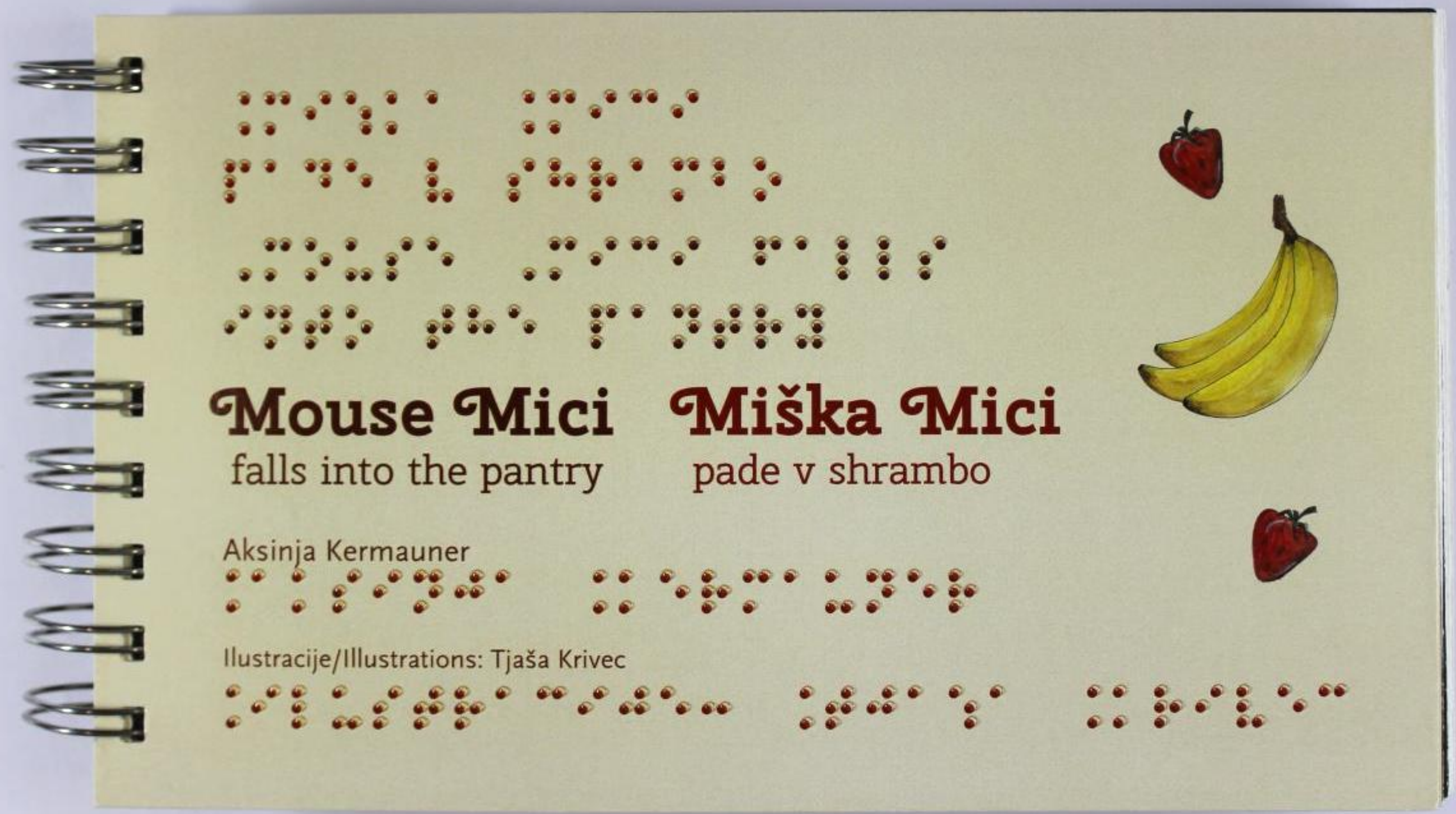
Scodix SENSE Digital Press
(SCODIX, 2014)

Research goals

- Small series publication for blind children using typical industrial printing equipment
- Textual and graphical elements in the book were produced using digital printing equipment

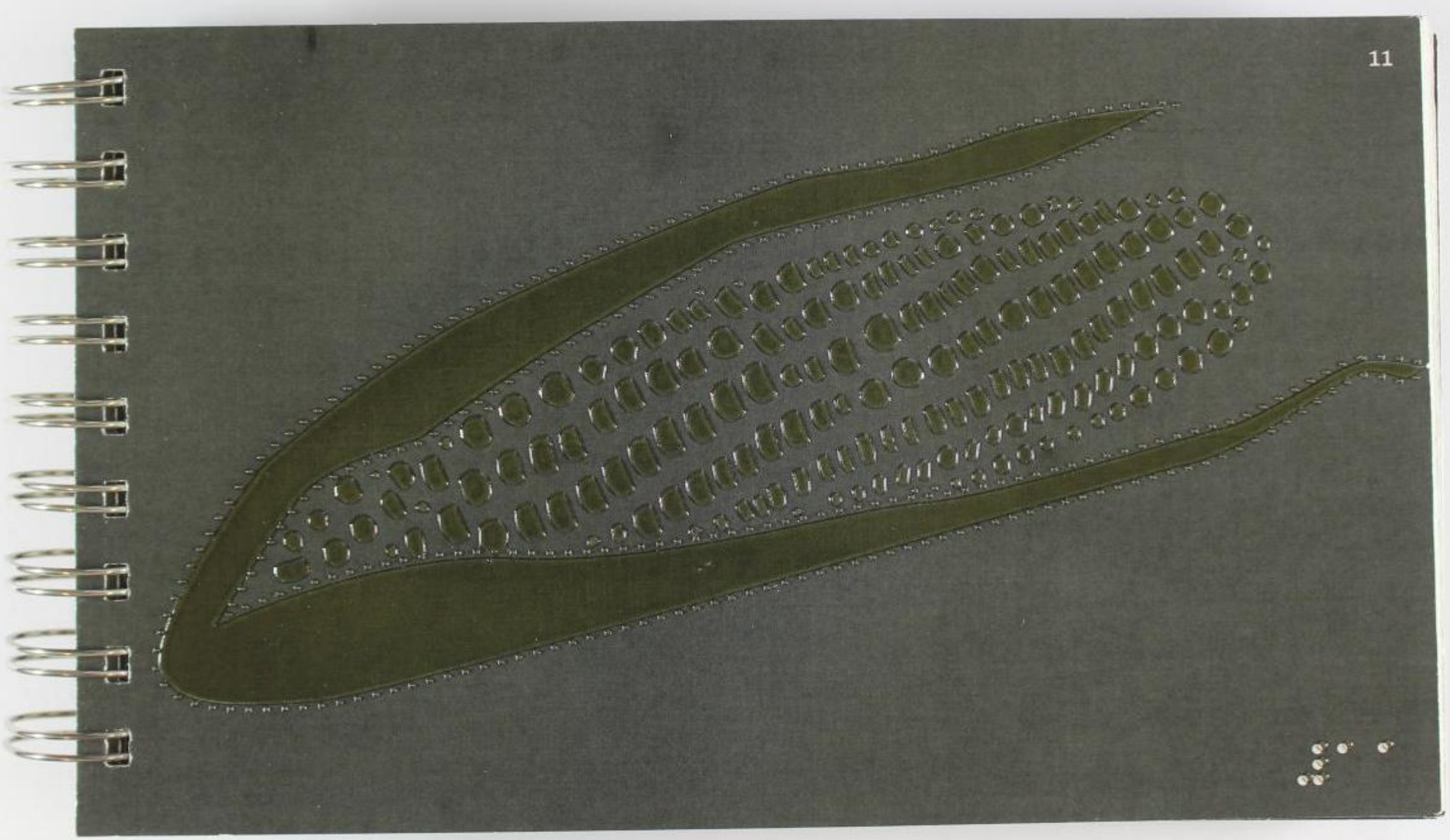
Research goals

- Tactile and Braille elements were printed using ink jet technology
- Yellowing or color shifting could not be tolerated
- No health risks caused by inks used for the tactile elements



Research goals

- Study the yellowing of several UV curable inkjet inks caused by UV-curing and artificial aging
- Detailed study of the yellowing of one ink



Materials and Methods

- Health safety of UV curing varnishes
- UV curable inkjet varnishes
- Paperboards
- Experimental setup
    - Printing of the samples
    - Accelerated aging process
    - Measuring and evaluation of the color change

Safety issues of UV curing inks

- UV cured ink can be hazardous to human health
- Special attention was paid to the ink’s suitability for use in tactile images, since the printed product will be handled by children
- European Union directives and safety measures for toys were applied

EU Directives and standards for toy safety

Standard	Description
Directive 2009/48/EC	Toys are defined as “products designed or intended, whether or not exclusively, for use in play by children under 14 years of age.”
EN 71---2: 2011 Safety of toys Part 2: Flammability	Spread of flame and flame speed on paperboard
EN 71---9, 10 and 11: Organic Chemical Compounds	With varnish layers higher than 500 µm tests, as described in this standard, should be made.
The Chemicals in Toys; A General Methodology for assessment of chemical safety toys with focus elements report 320003001/2008	Special considerations for products which are in close dermal contact.

Components of UV curable inkjet varnishes

SCODIX varnish		ROLAND varnish		TEST varnish		FLINT varnish
Scodix PolySense 100		Roland EUV-GL		Overprint Varnish		Flint Overprint Varnish
Ink composition	% by weight	Ink composition	% by weight	Ink composition	% by weight	Ink composition
Acrylic ester	30-40	Acrylated amine synergist	10-20	Dipropylenglycol diacrylate	25-50	No information retrievable
Trimethyl benzoyl diphenyl phosphine oxide	1-2	hexamethylene diacrylate hexane-1,6-diol diacrylate	30-40	2,2-bis(acryloyl oxymethyl)butyl acrylate	10-2,5	
Acrylic acid ester	10-20	Acrylic esters	30-40			
1,6-Hexanediol diacrylate	1-2	Other photo sensitive monomers	10-20			
		Phosphine oxide derivative	5-15			
		Others	0-1			

Paperboards

Properties	Iggesund Invercote Creato	Storaenso Ensocoat	Standards
Weight (g/m2)	260	250	ISO 536
Thickness (µm)	290	300	ISO 534
Color L*	96.5	97.7	ISO 5631-2
a*	2.3	2.5	ISO 5631-2
b*	-7.8	-7.1	ISO 5631-2
Whiteness (%)	127	125	ISO 11475
ISO brightness (%)	94	95	ISO 2470
Customization	none	one color offset printing (black) on printing side	

Experimental setup

- Step 1: Screening of the four varnishes regarding yellowing
- Step 2: Evaluate and choose one varnish
- Step 3: Study the yellowing of the this varnish in more detail

Printing of the coatings

Coating

- Profiled rods
- For screening four rods
  24, 80, 140, 220 µm
- For detailed study nine rods
  4, 6, 12, 22, 40, 80, 140, 220, 400 µm

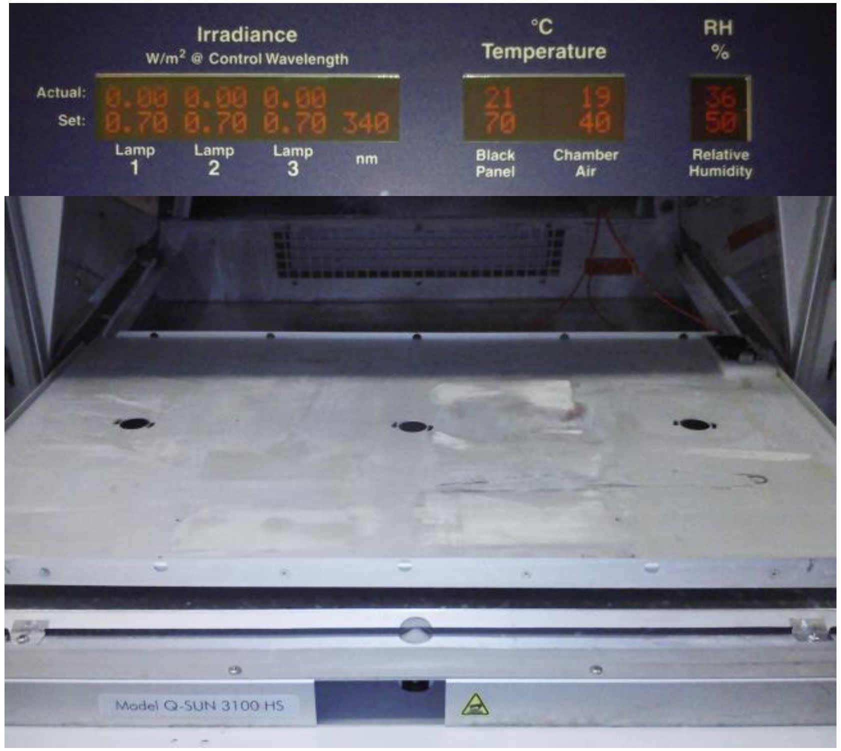
UV curing

- Hönle UVAPRINT
- 6.0 kW Fe doped Hg-lamp
- 100 % UV power
- belt speed 15 m/min

Xenon test chambers for artificial aging

Screening process (4 varnishes)
Q-SUN 3100 HS

Detailed study (1 varnish)
Q-SUN Xe-1



Set points for the aging process

Screening process (4 varnishes)
Q-SUN 3100 HS

- Set points for aging process:
- Irradiance 0.70 W/m2 @ 340 nm
- Black panel temperature 70 ° C
- Chamber air temperature 40 ° C
- Relative Humidity 50%

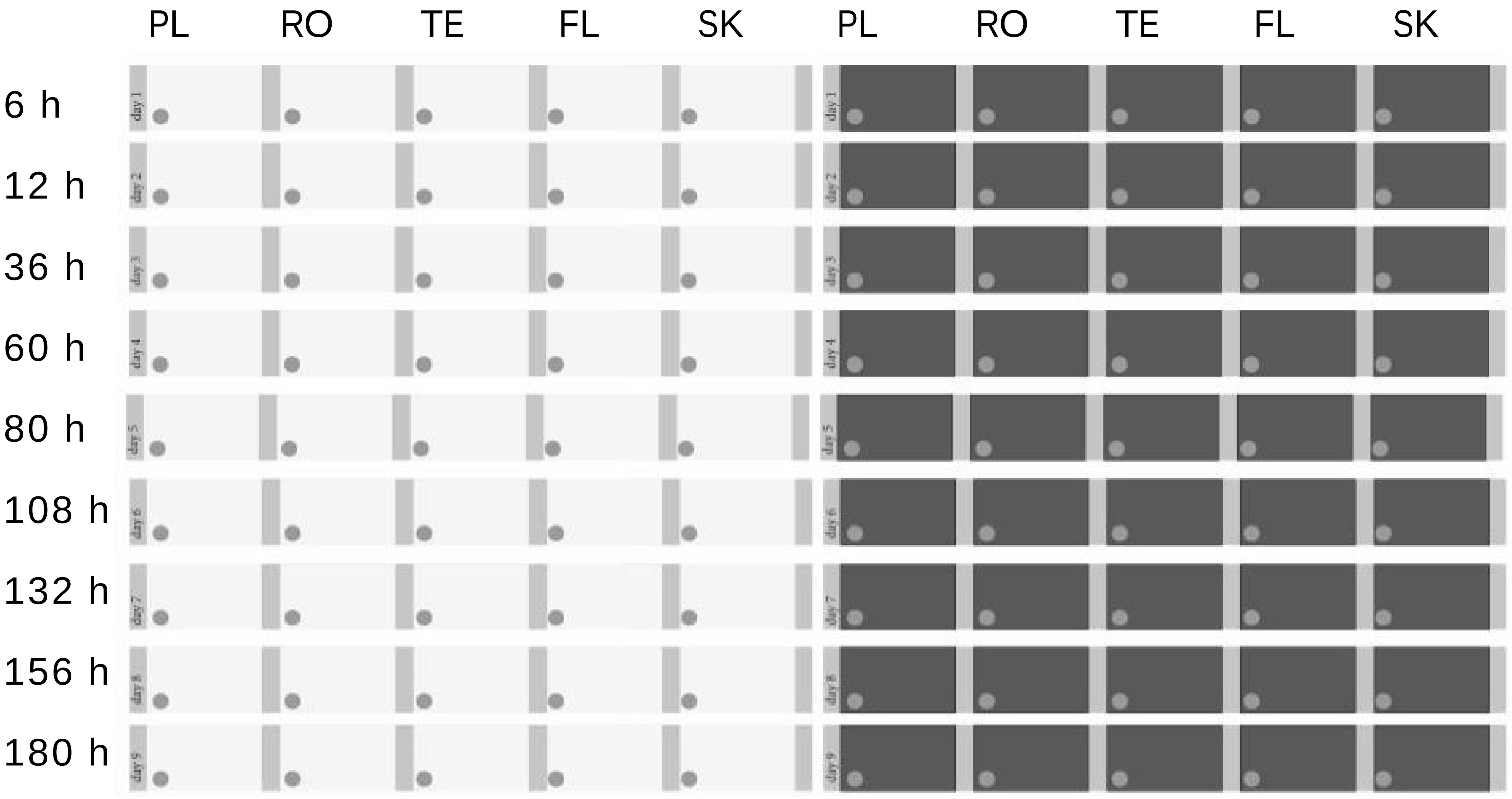
- 9 exposure intervals starting from 6 h up to 180 h

Detailed study (1 varnish)
Q-SUN Xe-1

- Set points for aging process:
- Irradiance 50 W/m2 @ TUV
- Black panel temperature 60 ° C
- Relative Humidity 50%

- 30 testing intervals starting from 0.5 h up to 48 h

Layout for the screening of the four varnishes



Layout for the detailed study of one varnish

Calculation of the color change

- Color is measured in CIE L*a*b* values
- L* = lightness
- a* = red / green color component
- b* = yellow / blue color component

- Color difference is calculated according to:

$$\Delta E^*_{ab} = \sqrt{\left(L^*_b - L^*_a\right)^2 + \left(a^*_b - a^*_a\right)^2 + \left(b^*_b - b^*_a\right)^2}$$

- Where $\left(L^*_b - L^*_a\right)$ $\left(a^*_b - a^*_a\right)$ $\left(b^*_b - b^*_a\right)$

  are differences of measured CIE L*a*b* values of aged coating b and original coating a

Evaluation of the color change

ΔE^*	Perception of the color difference
0.0 … 0.5	Almost no difference
0.5 … 1.0	Small difference noticeable to the trained eye
1.0 … 2.0	Just noticeable difference
2.0 … 4.0	Noticeable difference
4.0 … 5.0	Significant difference which could not be tolerated
> 5.0	Perceived as other color

Rough estimation to give an idea what the numbers ΔE mean

Measuring of the color and the coating thickness

x-rite SpectroEye spectrophotometer

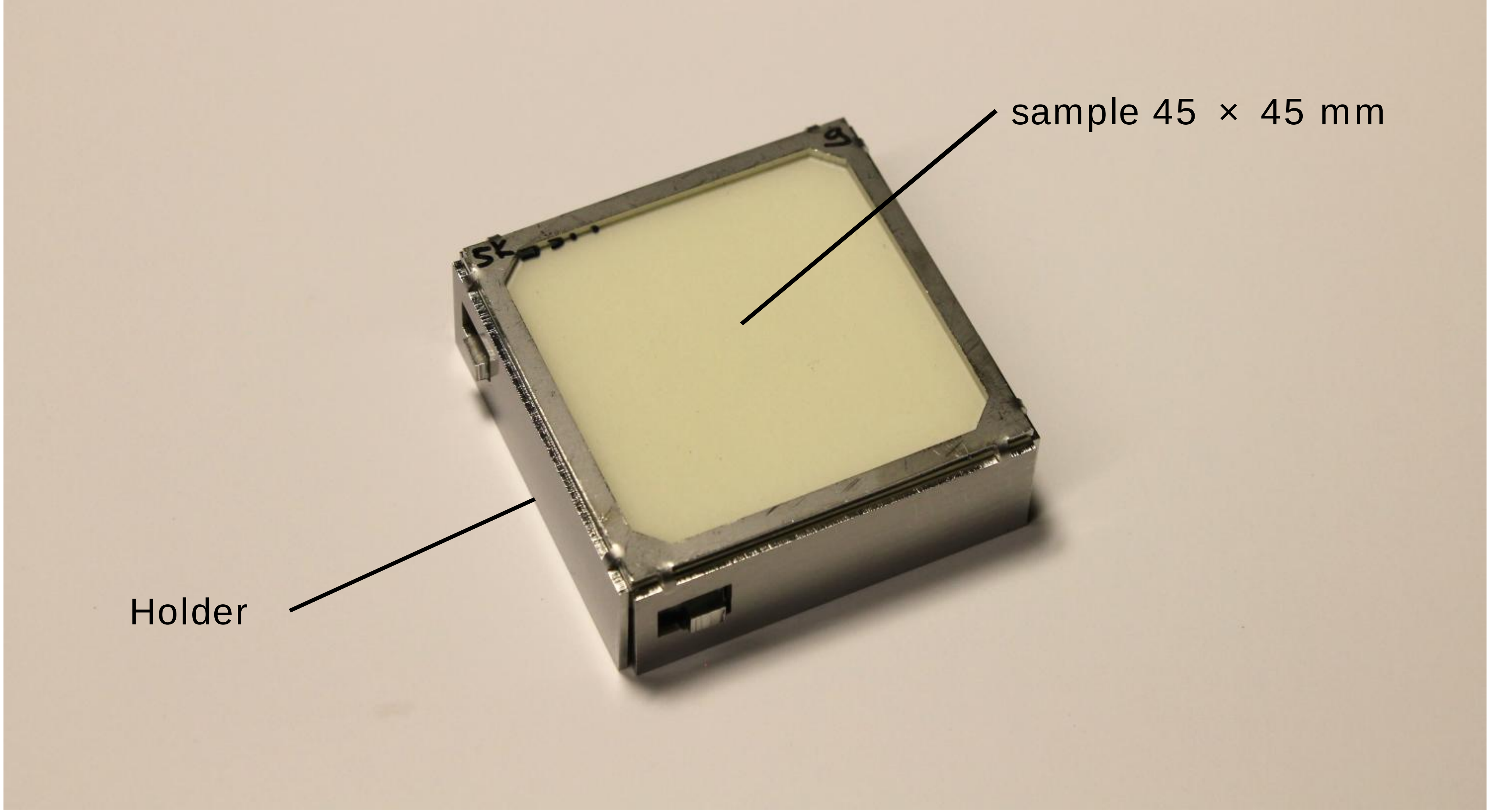
- Measuring conditions
  White base: ABS
  Normalised illuminat: D65
  Standard observer: 2 °
- Short term repeatability: 0.02 ΔE*CIElab (D50, 2)

Mitutoyo Digital indicator

- Accuracy ±0.001 mm
- Calibrated with a 1 mm gauge block
- Coating thickness is the difference of the coated to the uncoated paperboard
- The probe head is flat to prevent it punching into the paperboard

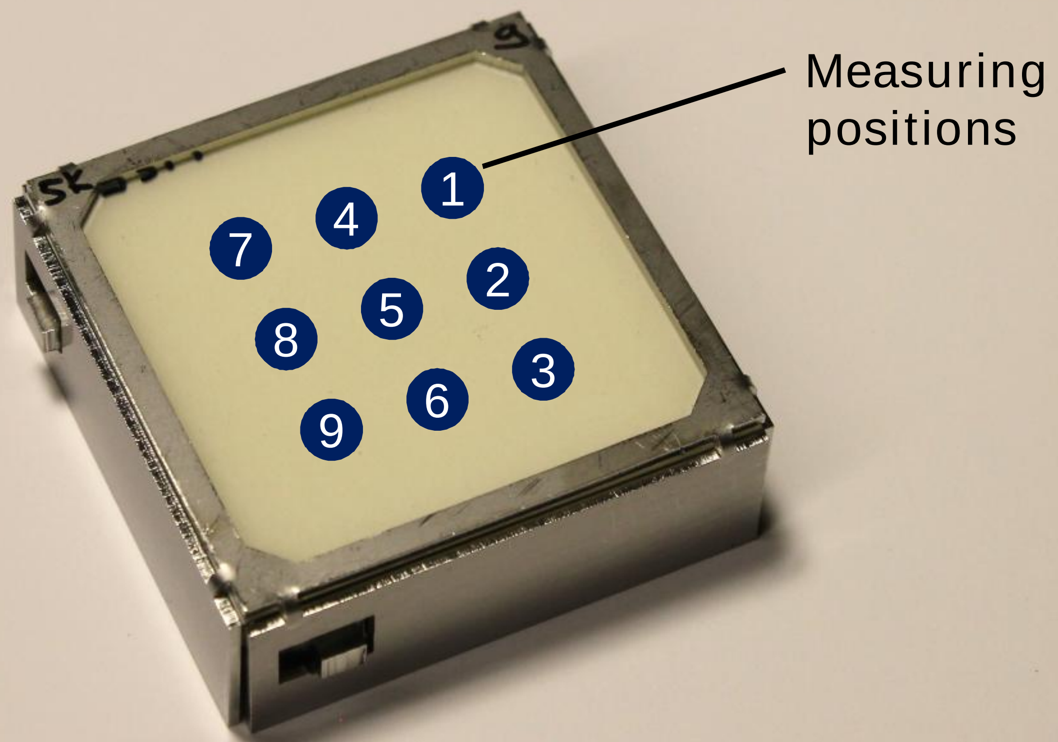
Sample holder for the detailed study

- Holder keeps sample in flat position



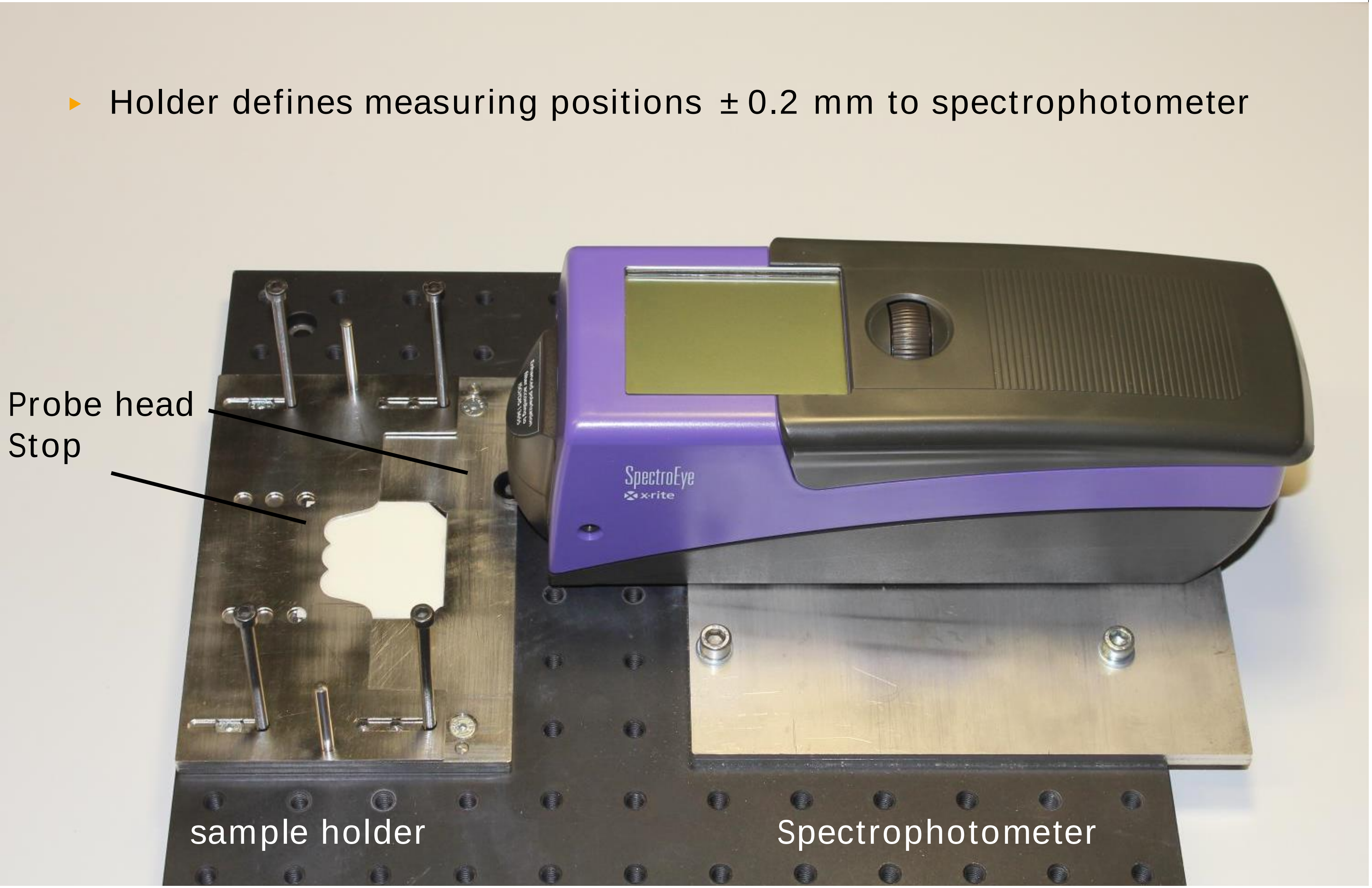
Color reading positions on the sample

- 9 measuring positions on sample for color
- Each position has 6 color readings
- 54 color measurements per sample



Device for color measurements

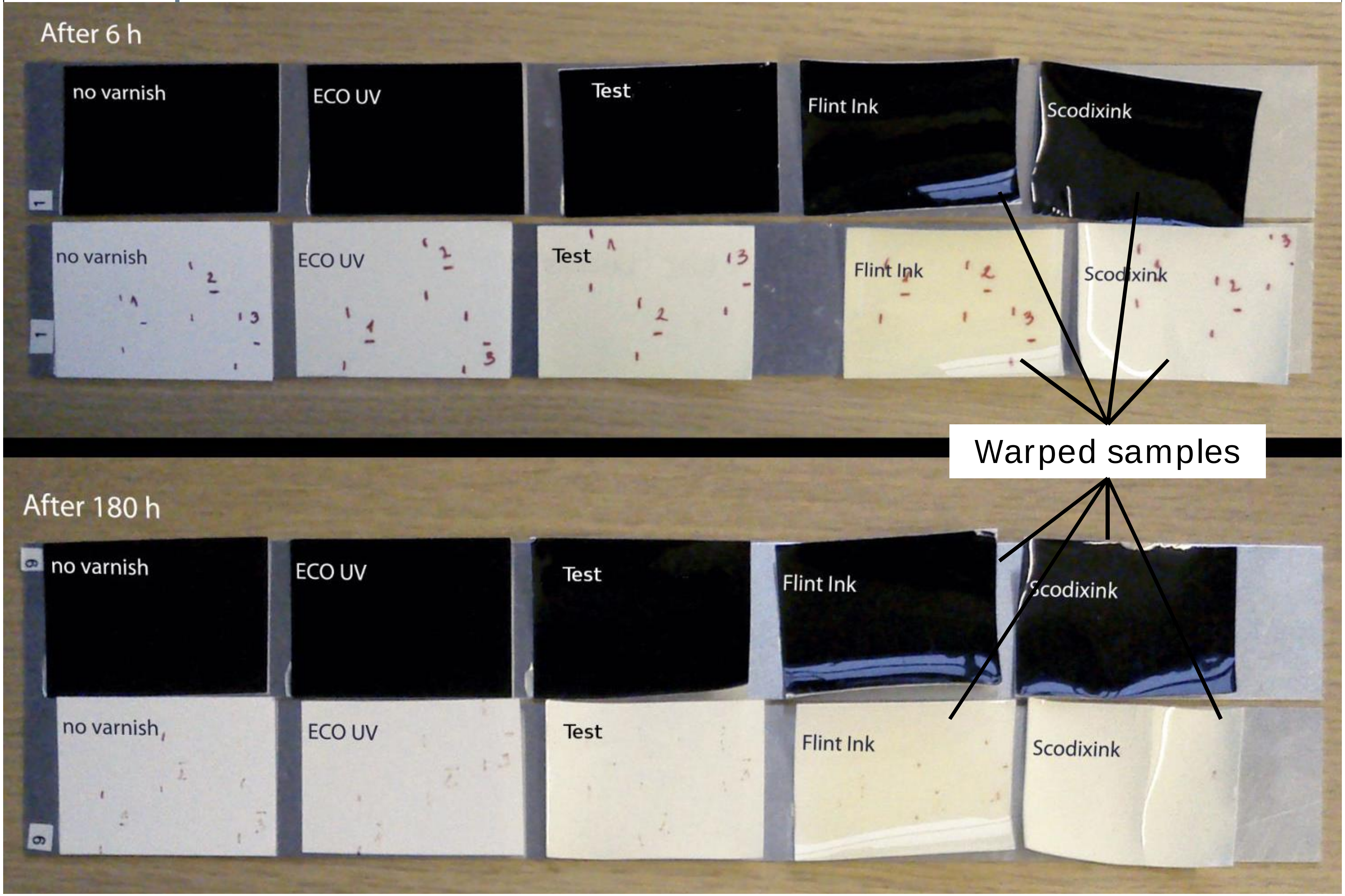
- Holder defines measuring positions ± 0.2 mm to spectrophotometer



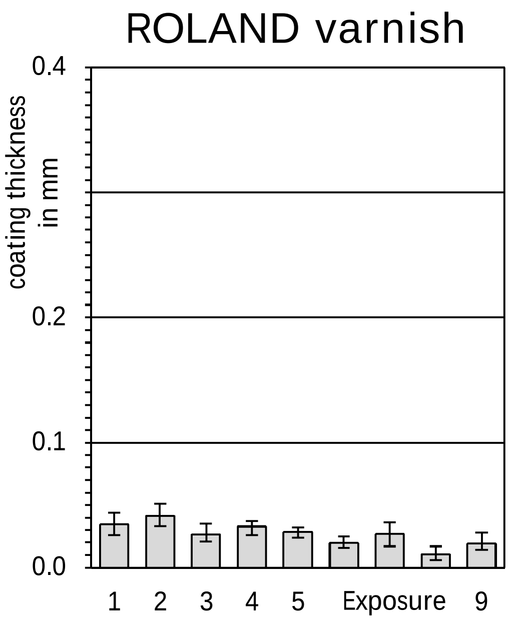
Results and Discussion

- Sample appearance
- Coating thickness
- Color changes (Delta E)

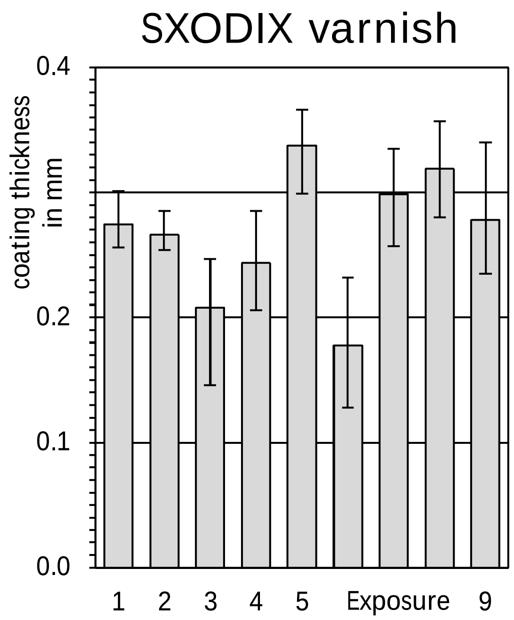
Samples of the four varnishes



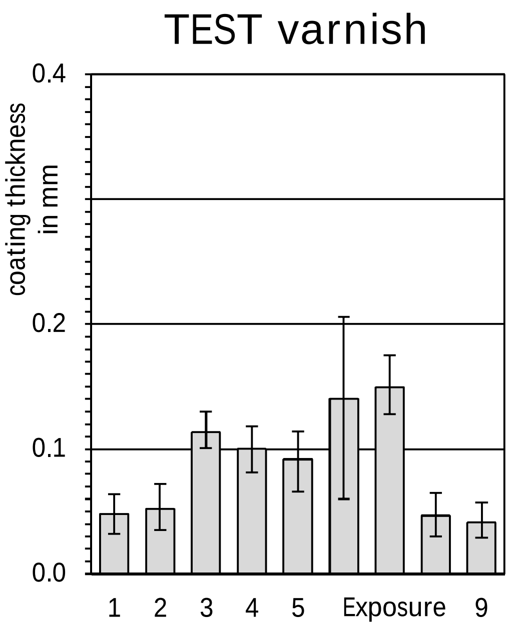
Coating thickness of the screening of 4 varnishes



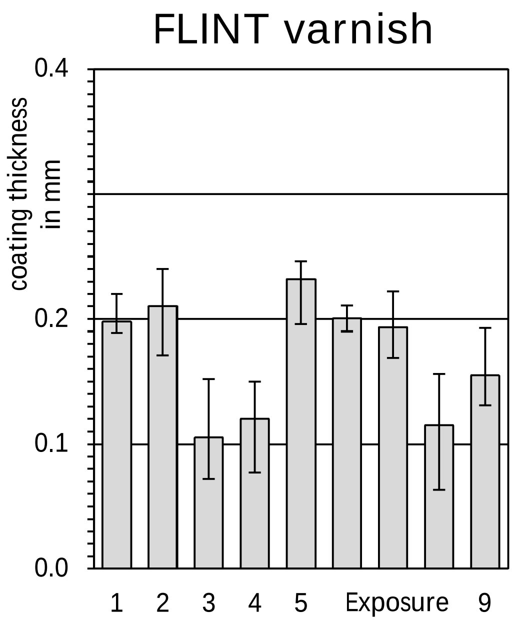
0.027 mm



0.267 mm

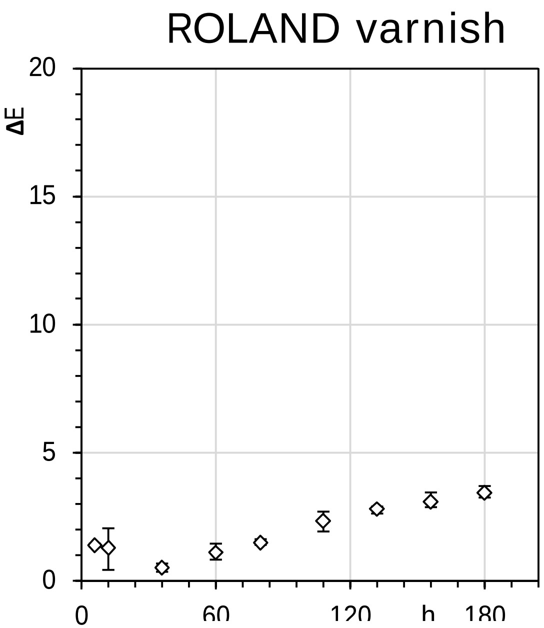


0.087 mm

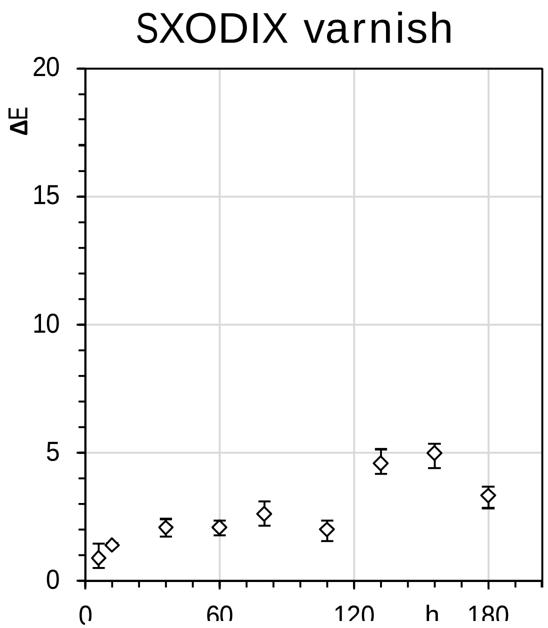


0.170 mm

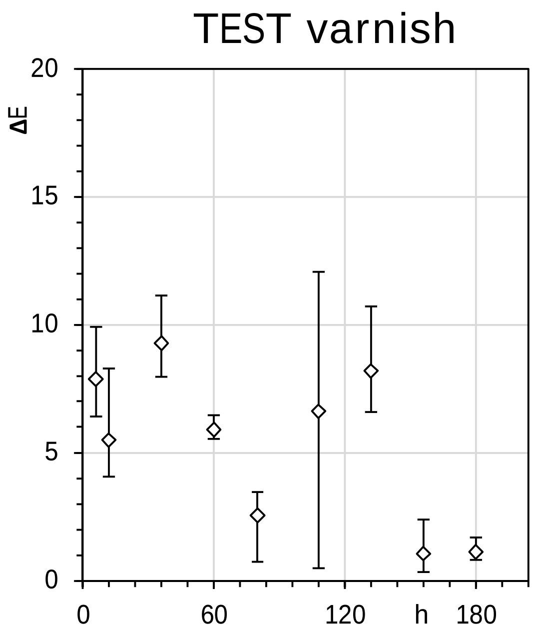
Color change ΔE of four varnishes



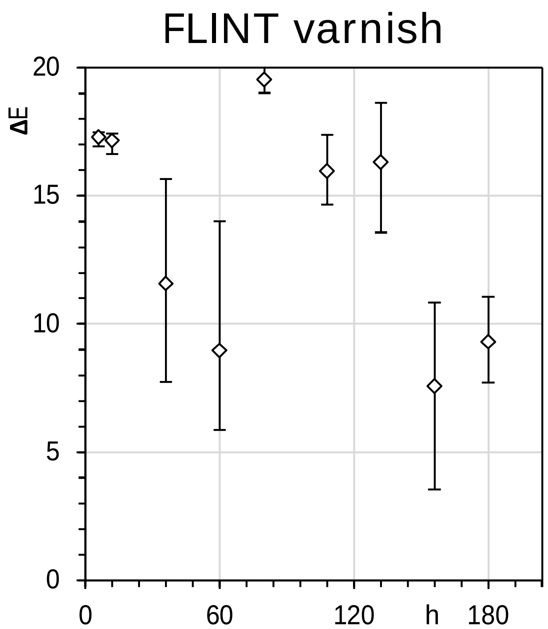
0.027 mm



0.267 mm



0.087 mm

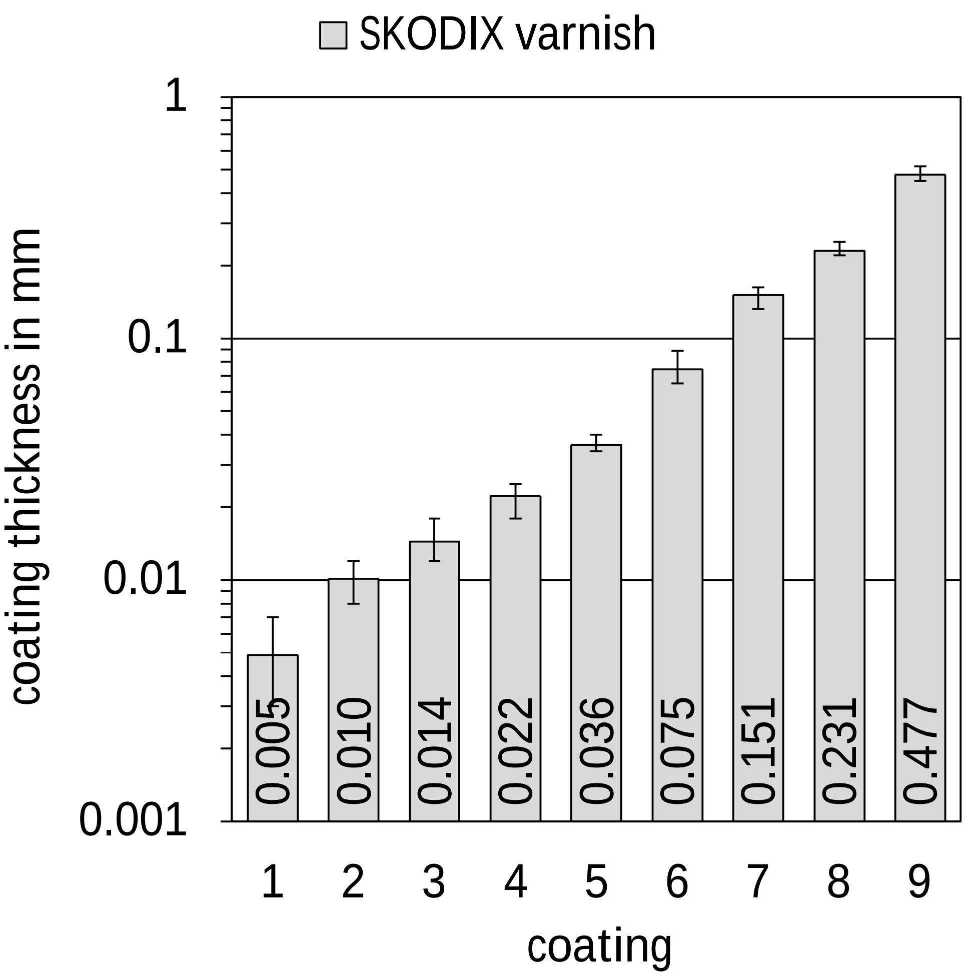


0.170 mm

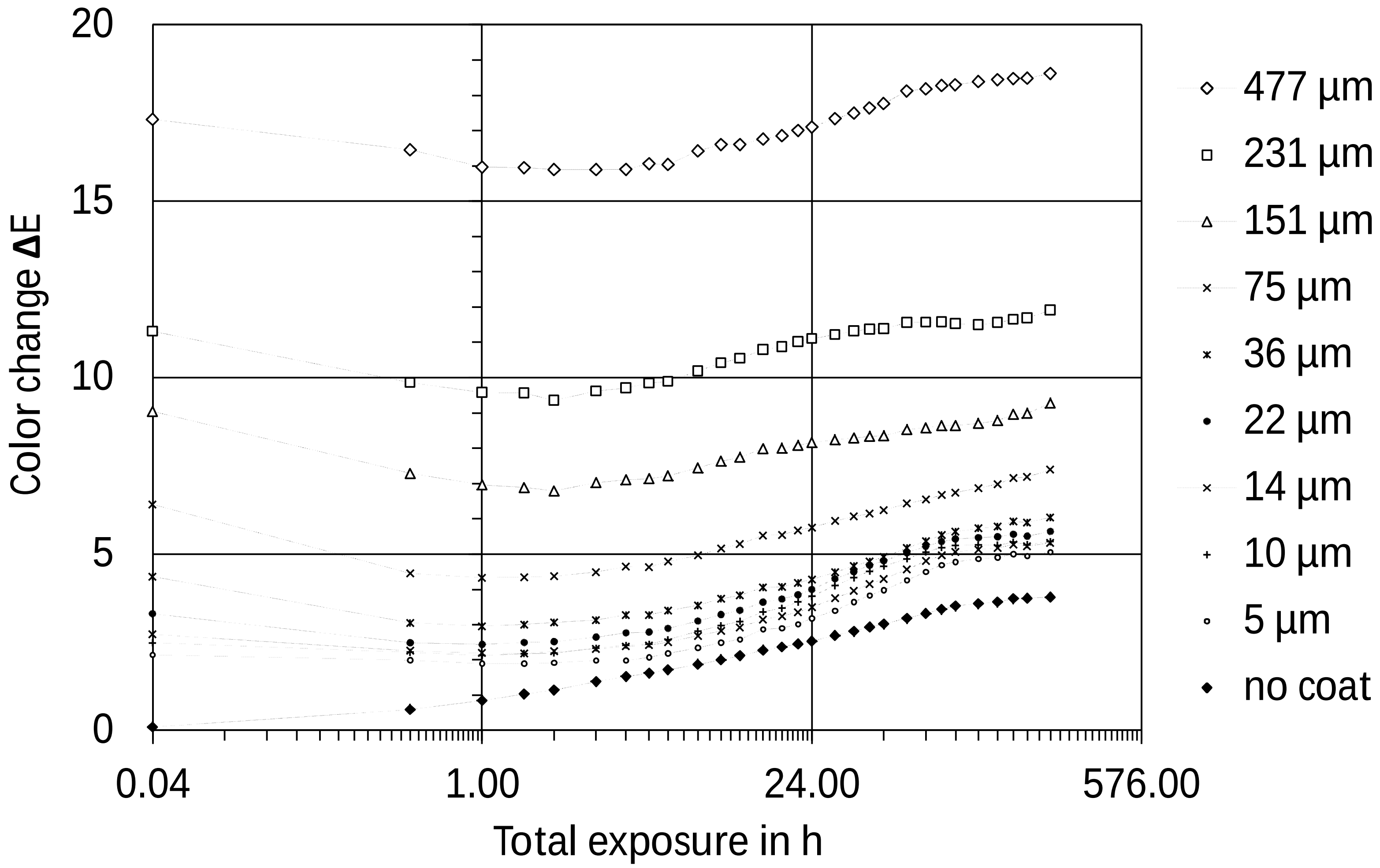
Conclusion from the screening of four varnishes

- Thick clear coatings undergo a significant yellowing
- While the yellowing is clearly visible on white paperboard, it is not noticeable on black paperboard
- The SKODIX varnish should be studied in more detail

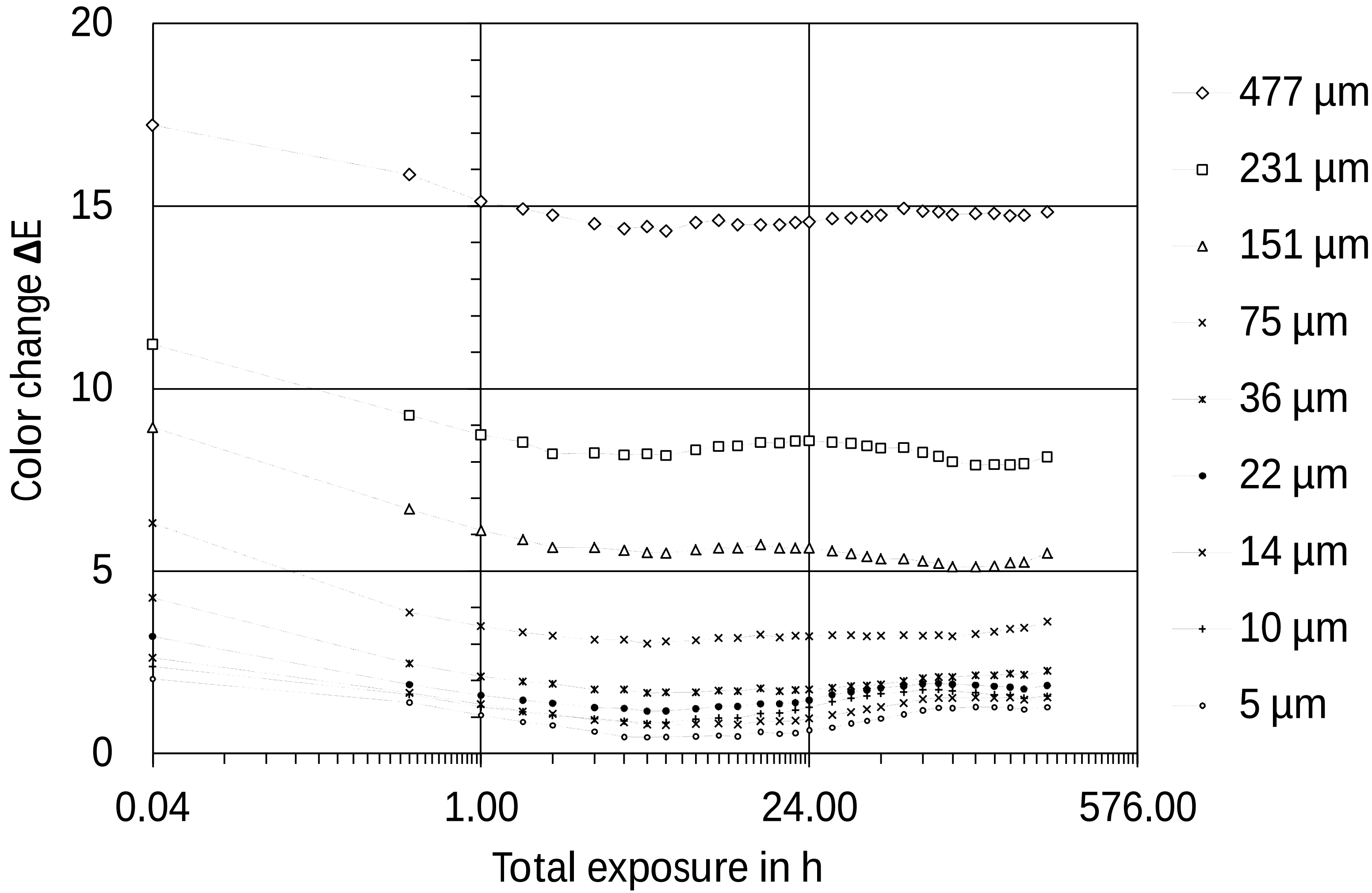
Coating thicknesses of the SKODIX varnish



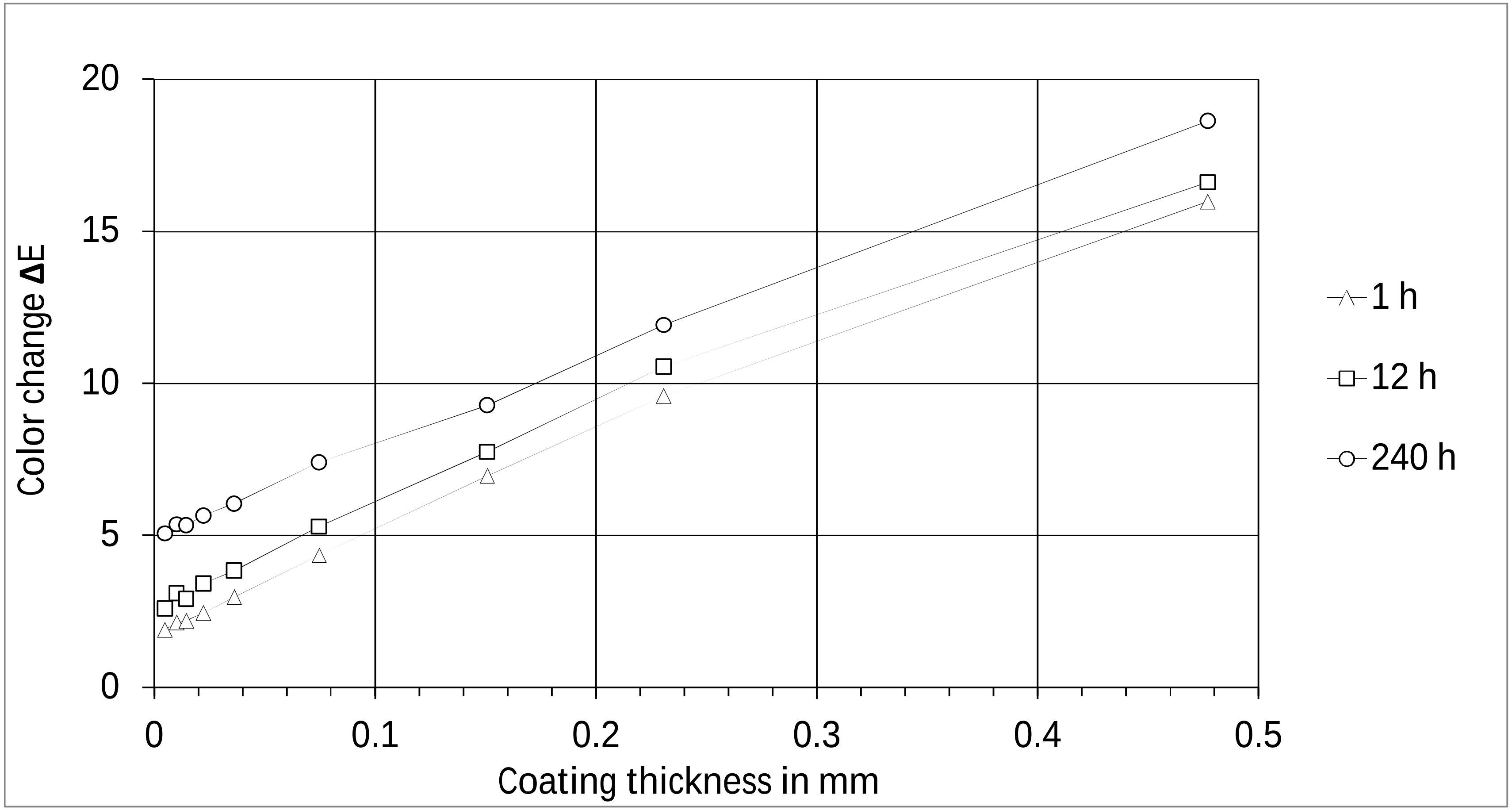
Color change ΔE of the Skodix varnish



Color change ΔE of the Skodix varnish



Color change ΔE vs thickness of Skodix varnish



Conclusion

- The yellowing respectively the color change ΔE of SCODIX varnish due to UV curing and artificial aging was measured for nine different coating thicknesses.
- In the end, the choice of SKODIX varnish for the book for blind children was confirmed . Although the tactile elements produce a yellowing dependent from the coating thickness, the yellowing is now predictable due to the measurements of ΔE against the coating thickness.
- For the Braille book a dark gray background was chosen for the tactile elements. This ensured that the yellowing would be less noticeable without giving the book an overly dark appearance to sighted readers.

Thank you