Building Leadership Excellence

Quantification of the penetration of coating pigments into the base paper determined by automated serial sectioning

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RETHINK PAPER:
Lean and Green

Coating Penetration and Coating Holdout

- **Coating Holdout:**
  → Fraction of coating penetrated into the base paper

- **Relevance:**
  Pigments in the base paper do not contribute to:
  → the coverage of the base paper and
  → the depending surface properties.

- **Parameters:**
  → Pigment size and distribution, aspect ratio
  → Base sheet structure

Content

- **Methods & Measurement**
  - → Related work
  - → Automated serial sectioning
  - → Quantification of coating penetration
- **Results**
  - → Experiment: influence of base paper porosity
  - → Obtained results
- **Conclusions & Outlook**

Methods & Measurement
Techniques Used to Analyze Coating Penetration

- **CLSM** (Confocal Laser Scanning Microscopy)
  → Staining of fibers and binders with different fluorescent dyes
  → Looking for intermixed regions

- **Exposing the coating backside** for further analysis
  → Dissolving fibers in a solution with CED (cupri-ethylendiamin)
  → Low temperature ashing techniques

- **Cross section images**
  → e.g. SEM or automated serial sectioning…

Methods & Measurement
Analysis Based on Cross Section Images

- **Lloyd et al.** (1)

  Coating extracted from a cross section can be divided into:

  → Surface coating (coating only at the paper surface)

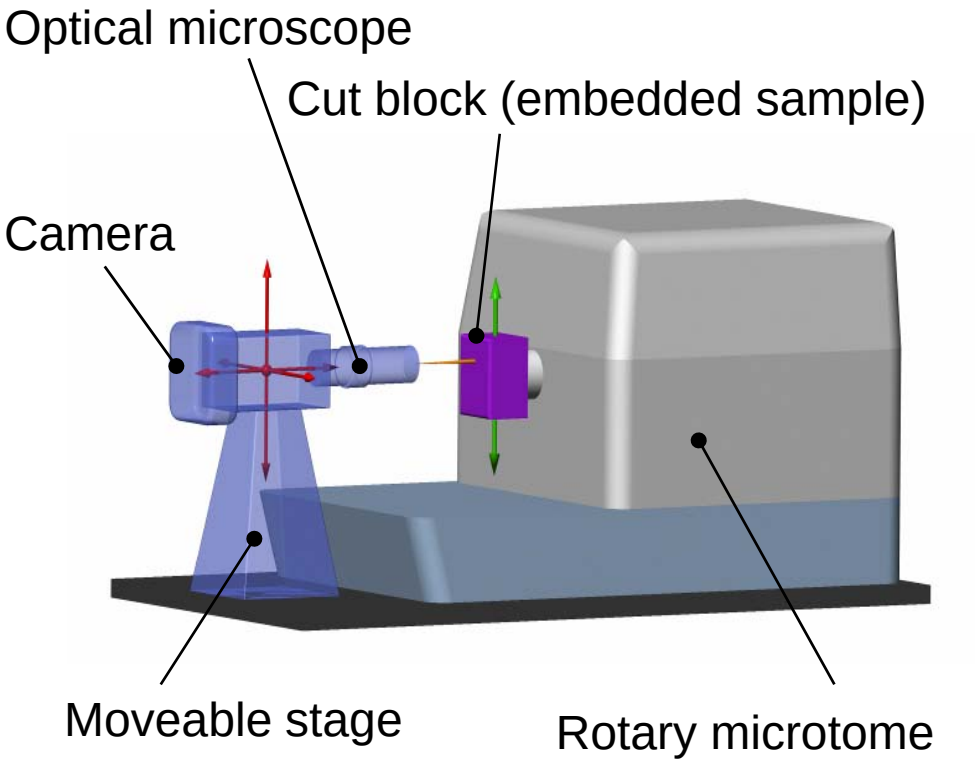
  → Hidden coating (connected to the paper surface)

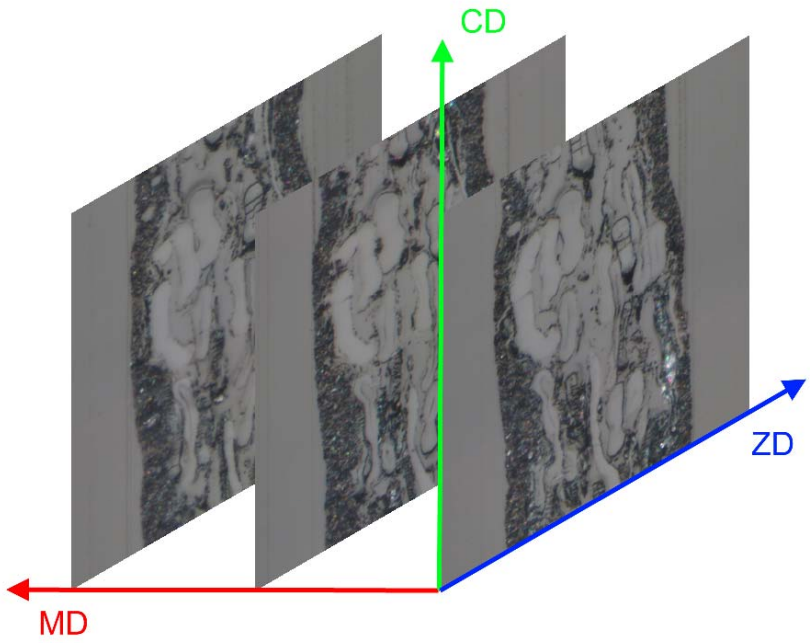
  → Trapped coating (not visibly connected to paper surface)

- **Relationships** between these different types are determined

(1) M. Lloyd, S.-A. Stuart, G. Bristow and M. Reich. Characterization of coated paper structure. Appita Journal, 56(6):421-425, 2003

Methods & Measurement
Automated Serial Sectioning



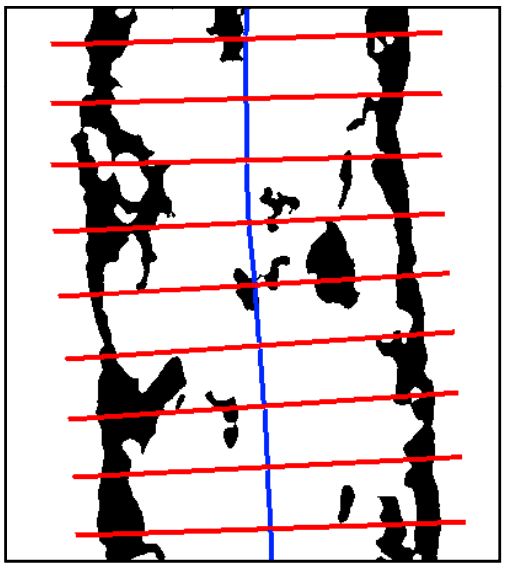


Methods & Measurement
Coating Layer Analysis

Image analysis:

Cross section image

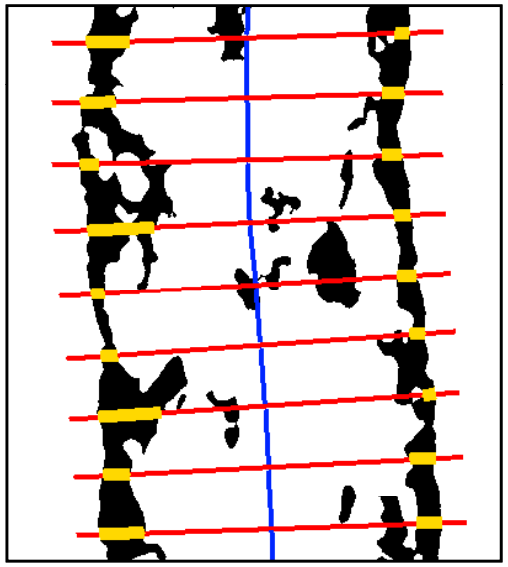
Coating segmentation



Measuring lines to extract coating thicknesses

Methods & Measurement
Evaluation of Coating Penetration

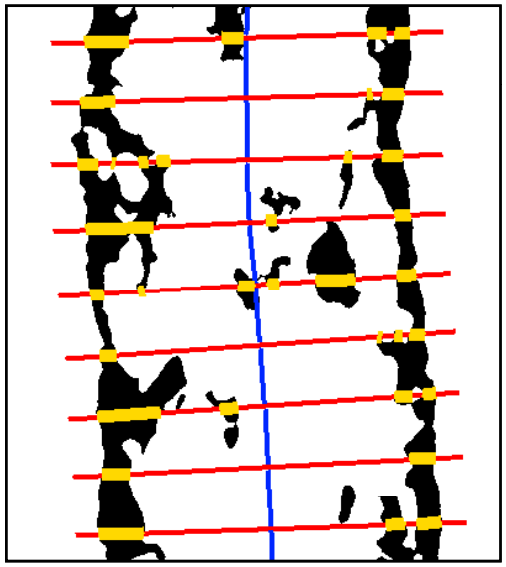
Surface coating thickness – C1:



- Coating only on the paper surface
- Counting pixel from the outermost coating pixel toward the paper center line until the first interruption appears
- “Standard” coating thickness

Methods & Measurement
Evaluation of Coating Penetration

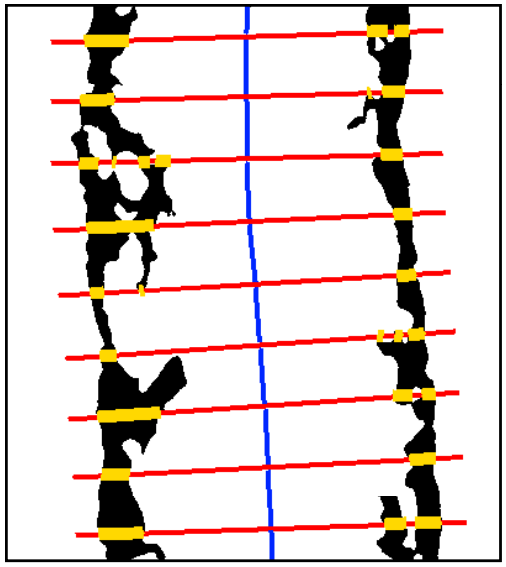
All regions detected as coating – C2:



- All inorganic regions detected are considered
- Also includes filler agglomerates
- Surface coating + hidden coating + trapped coating

Methods & Measurement
Evaluation of Coating Penetration

All regions connected to paper surface – C3:



- Trapped coating removed by additional image analysis step
- Surface coating and hidden coating are considered

Methods & Measurement
Measures to Quantify Coating Penetration

- First approaches:

  → **Calculating relations by considering only mean values (C1, C2, C3)**

- Upper level of penetrated coating:

$$Upper\ Limit = \frac{C2 - C1}{C2}$$

- Lower level of penetrated coating:

$$Lower\ Limit = \frac{C3 - C1}{C3}$$

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Results
Experiment: Influence of base paper porosity

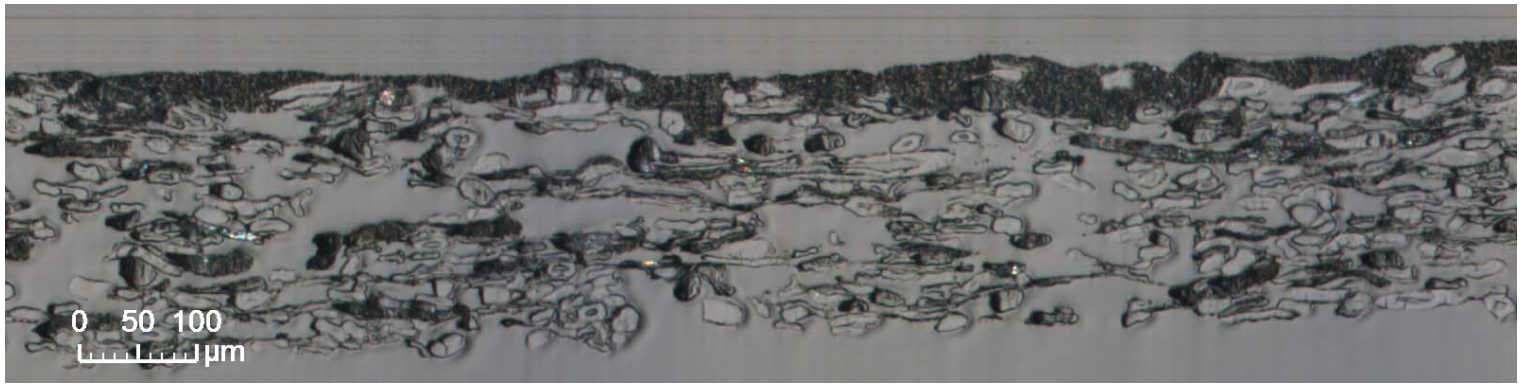
- 100% eucalypt pulp unfilled base paper
  (pilot paper machine, varying base sheet porosity)

- Coating formulation:

	Coating I	Coating II
Hydrocarb 90 – ME (78%)	100	60
Hydragloss 90 – EM (73%)		40
PVA (BF-05, 6-98)	0.4	
CMC (Finnfix 10)	0.5	
Latex (Styronal D 628)	11.0	
OBA (Leucophor VM fl)	0.5	
Solids content	71.4%	68.7%
Coat weight	14.2 g/m²	14.3 g/m²

Results
Cross section images: Coating I

Influence of base paper porosity:

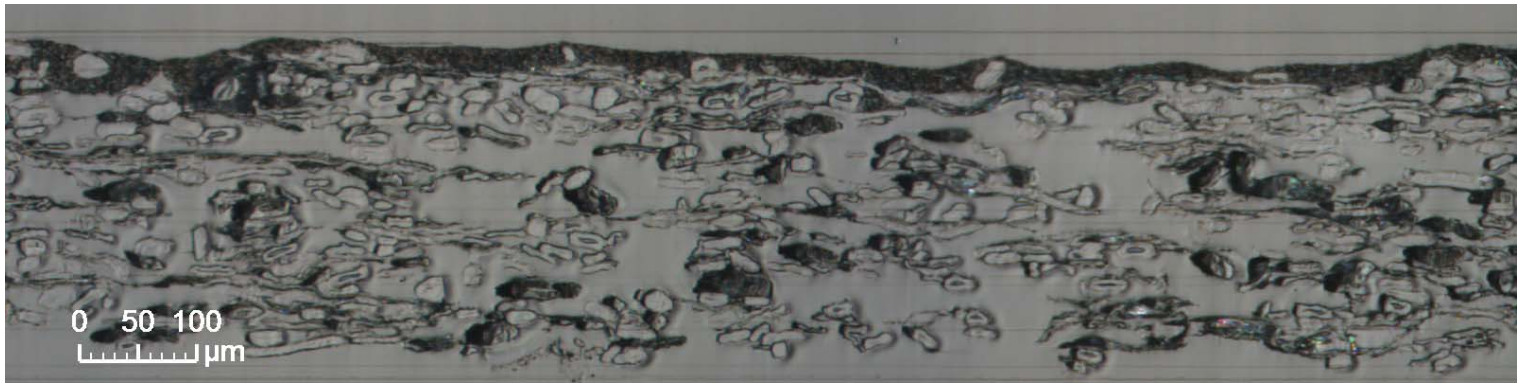


Open sheet structure (Coating I, carbonate only)

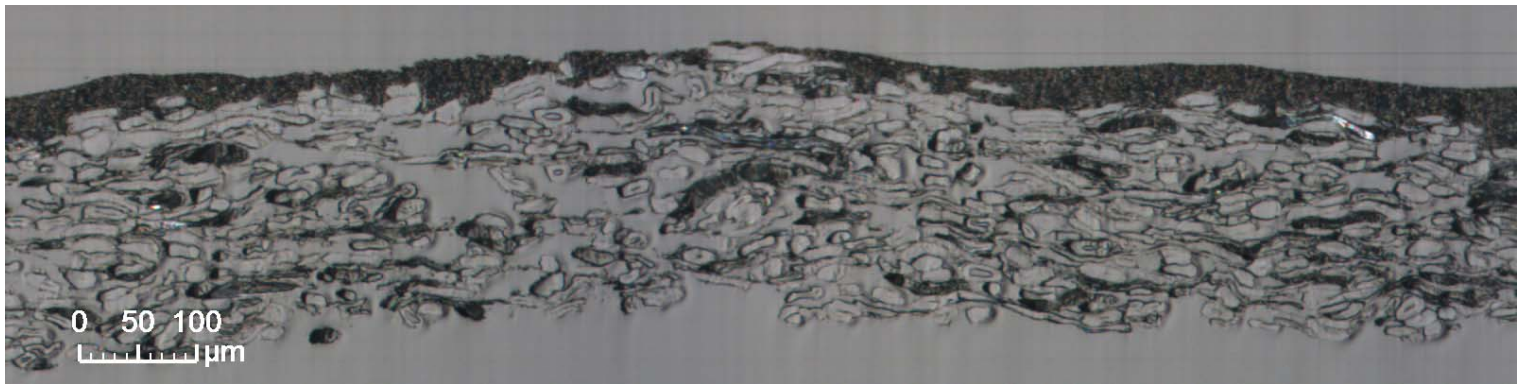
Closed sheet structure (Coating I, carbonate only)

Results
Cross section images: Coating II

Influence of base paper porosity:



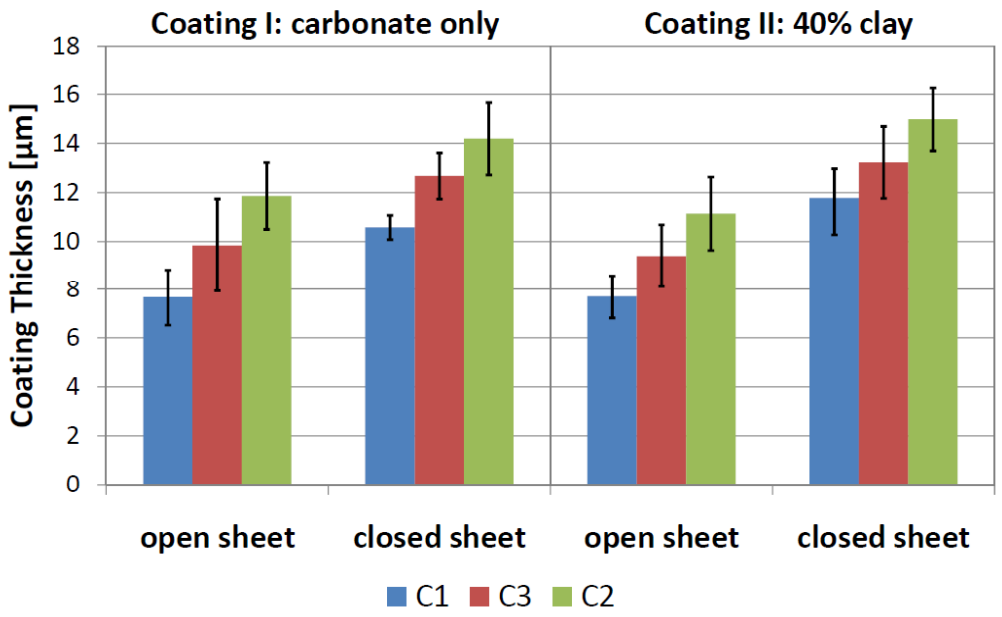
Open sheet structure (Coating II, carbonate and clay)



Closed sheet structure (Coating II, carbonate and clay)

Results
Coating Thicknesses

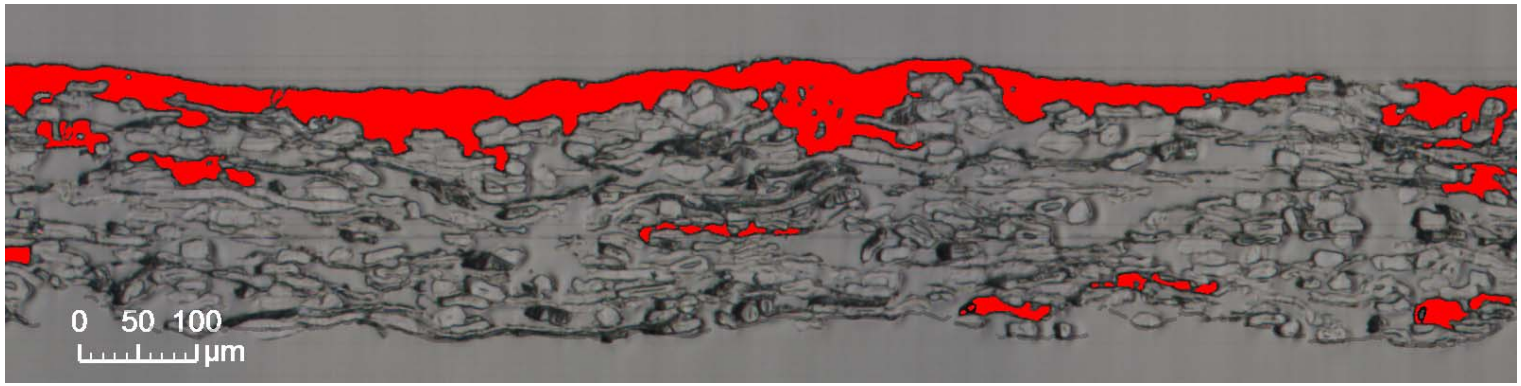
Influence of base paper porosity:



- Thinner coating layer on regions with open sheet structure
- Differences more pronounced for clay containing color
- A noticeable fraction of separated coating in the base paper!

Results
Coating Thicknesses

Depth of coating penetration:

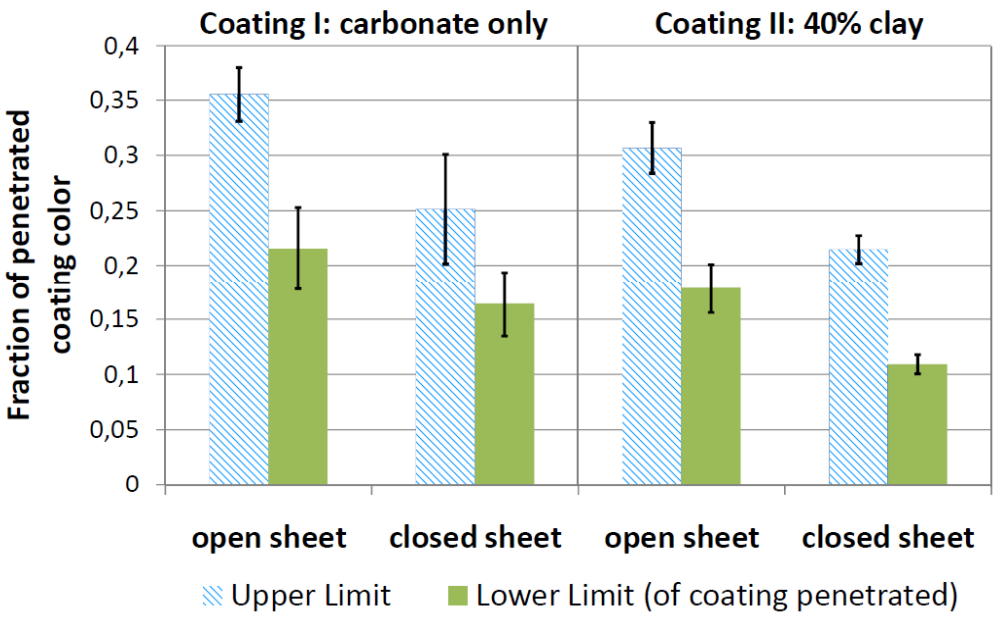


Detected coating layer highlighted

- C2: some fibers erroneously detected as coating
  → Overestimation of the fraction penetrated

Results
Fraction of coating solids entered the base sheet

Influence of base paper porosity:



- A minimum of 10-20% of detected coating located in base paper
- More penetration at open sheet structures
- Significant differences for clay containing coating
- Seemingly better holdout for clay containing color

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Conclusions

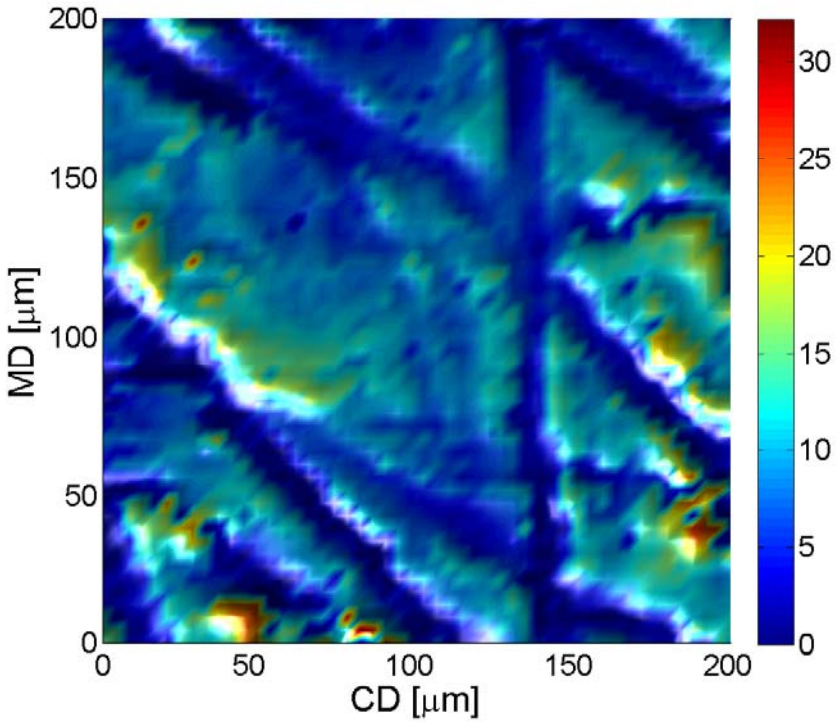
- Analysis based on automated serial sectioning is used to quantify coating penetration into the base paper.

- First experiments revealed:
  → Large fraction of coating color in the base paper
  → Paper porosity is an important parameter
  → Differences also caused by pigment system

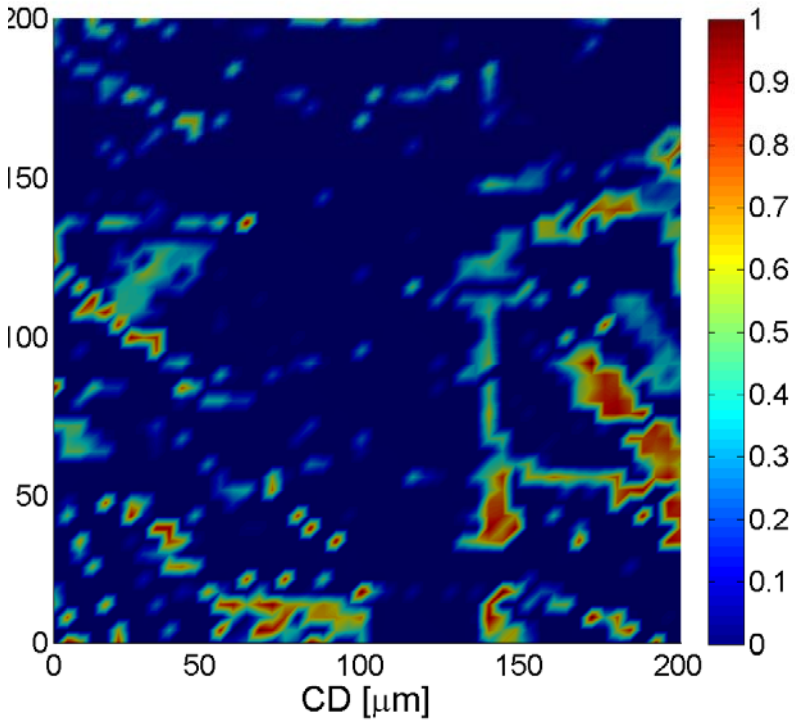
➔ **A minimum of 10% of applied coating solids does not contribute to its desired effects!**

Outlook

e.g. consideration of local coating thicknesses



Coating thickness map



Coating penetration map

Thank you for your attention.

I’d be happy to answer your questions.