Production of Translucent Films from Cellulose Filaments for Packaging Applications

Part 1: Development of Properties

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FPInnovations

TAPPI NANO DIVISION

Outline

- Background & Objective
- Introduction to Cellulose Filaments
- Properties of CF handsheets
  - Mechanical
  - Optical
  - Barrier
- Summary

Background & Objective

- Plastic pollution is expected to reach 80 Mt/y by 2040 without concerted action to address the problem[1]
- Consumers & brand owners are looking for alternative packaging materials that are environmentally responsible and perform similarly to plastics
- <u>Objective:</u> Use Cellulose Filaments (CF) papermaking technology to manufacture translucent packaging products that are repulpable, recyclable and compostable

Recycling rates

Paper/board: **70%**

Corrugated board: **85%**

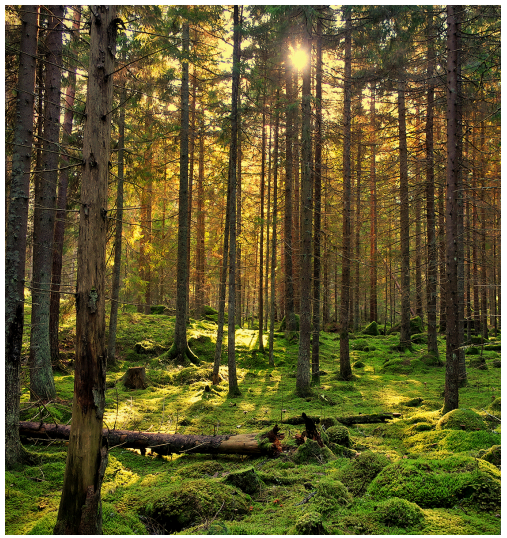
Plastics: **14-18%**

[1] W. Y. Lau et al., *Science* **369**, 1455 (2020)

Introduction of Cellulose Filaments

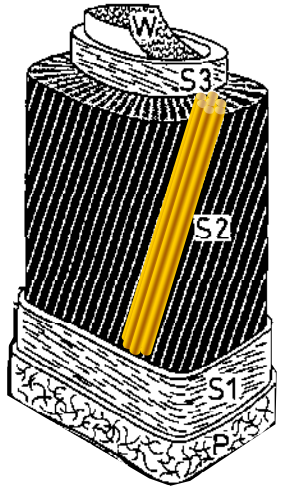
From Wood Fibres to Cellulose Filaments

Wood

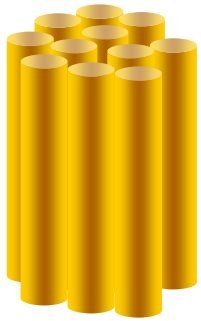


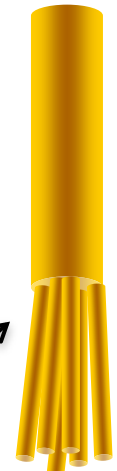
Kraft pulp

Single fibre

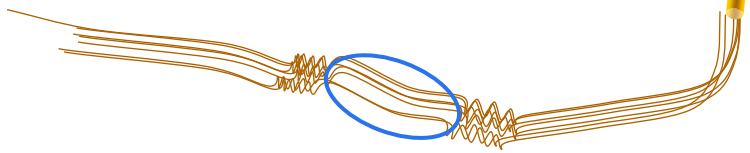


Fibrils

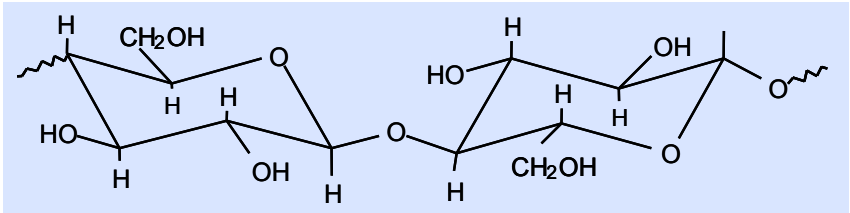




Cellulose Filaments (CF)



Nanocrystals (CNC)



Cellulose

CF Properties in a Nutshell

- CF is produced by multi-pass, high consistency refining of wood fibres

- CF dimensions: length: 100-2,000 µm; width: 30-500 nm; aspect ratio: 100-1000
  - Average dimensions and size distribution depend on source material and process parameters
- CF is a remarkable strengthening agent for paper
  - Demonstrated in numerous laboratory, pilot and mill trials

"Cellulose Filaments: Discovery by FPInnovations of a Novel Strengthening Agent". X. Hua, M. Laleg, and T. Owston, 2016 Int. Conf. on Nanotechnology for Renewable Materials

CF Product Forms

- Never-dried CF is produced at ~30% consistency
- CF is currently being produced in two plants both located in Québec, Canada. One is operated by Kruger Biomaterials, the other by Resolute Forest Products
- CF film can also be produced in rolls on a paper machine
  - Grammage: 15-40 g/m^2
  - Fully repulpable
  - **Translucent**


Never-dried CF

Kruger Biomatériaux Biomaterials

resolute Forest Products

PERFORMANCE BioFilaments


Roll of CF Film

Properties of CF Handsheets

Properties of Laboratory-Made CF Films

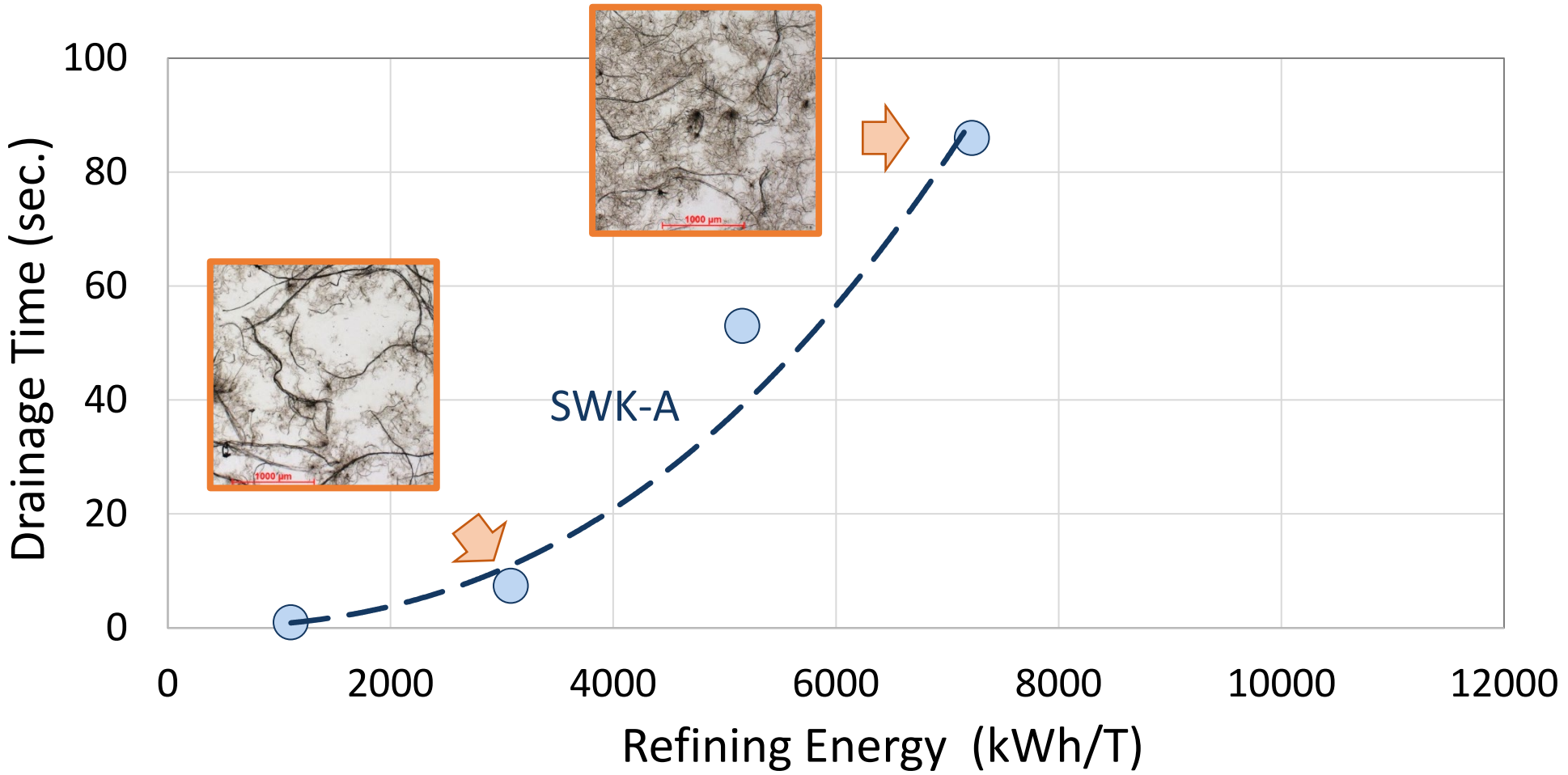
- Procedure to make CF films:
  - Dispersion in a British disintegrator for 15 min.; Consistency: 1.2%; Temperature: 80°C
  - Formation: in a handsheet machine fitted with a 400 mesh screen
  - Drainage time is measured during handsheet formation
  - Drying: in rings at 23°C and 50% RH

- Basic physical properties of handsheets:

CF handsheet properties	
Grammage	20 to 30 g/m^2
Tensile Index	> 90 N·m/g
Elongation at Break	> 4%
Tear Index	3-6 mN·m^2/g
Gurley air resistance (sec)	> 1,800
Opacity* (%)	< 25
Transmittance (%)	> 75
Haze (%)	> 80

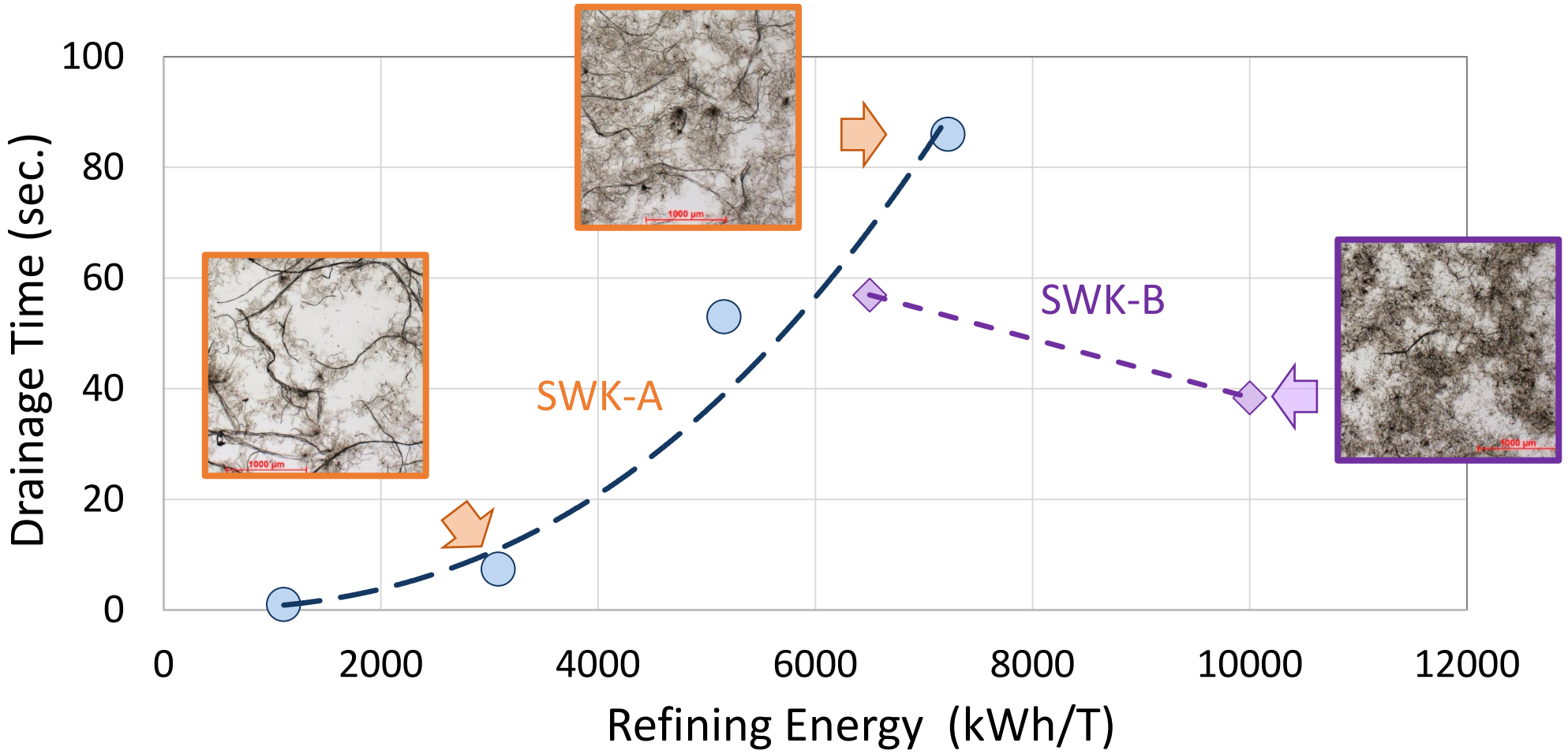
* R_∞ is measured by placing the film over a white backing

Impact of Refining Energy on CF Morphology & Drainage



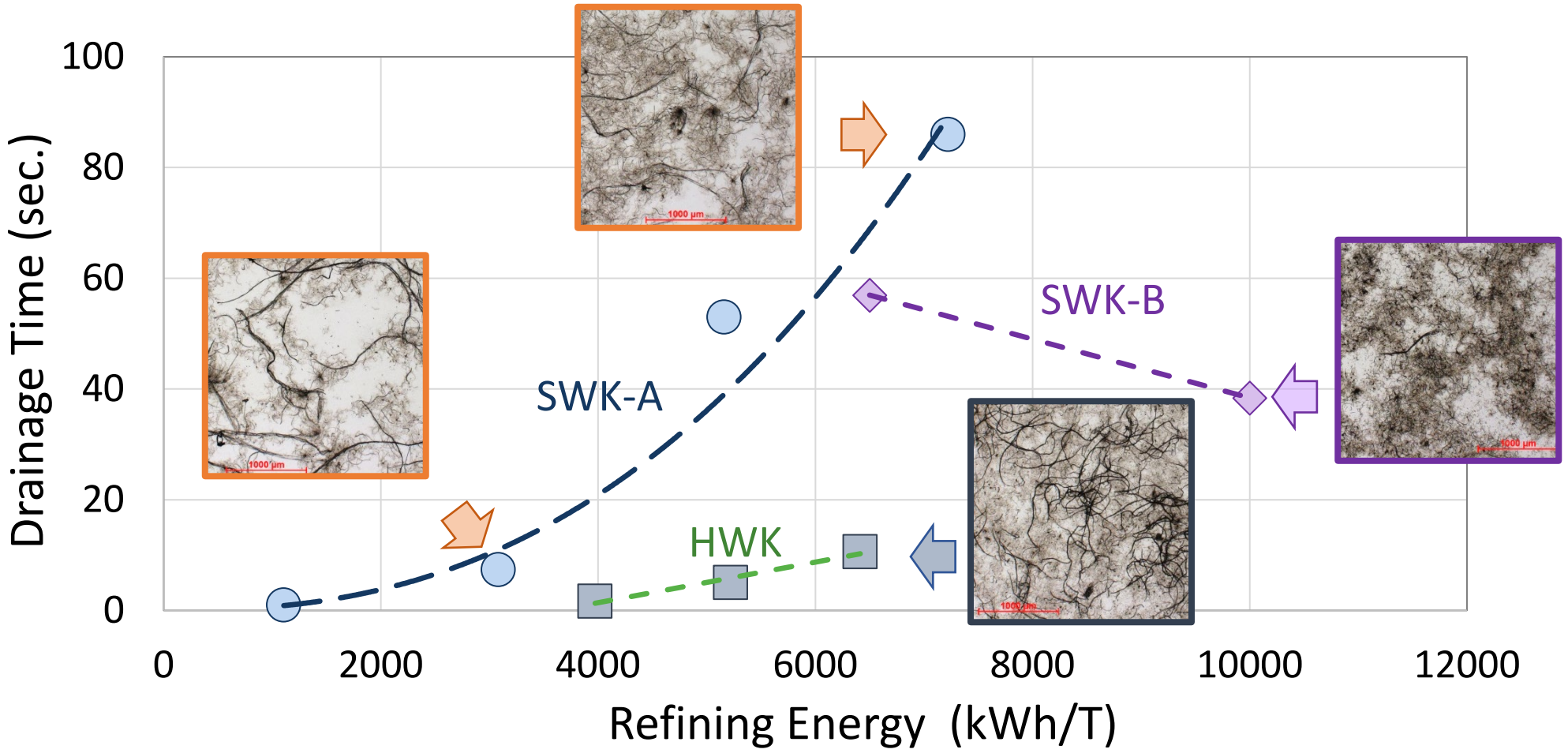
- Fraction of fine material and drainage time both increase with refining energy

Impact of Refining Energy on CF Morphology & Drainage



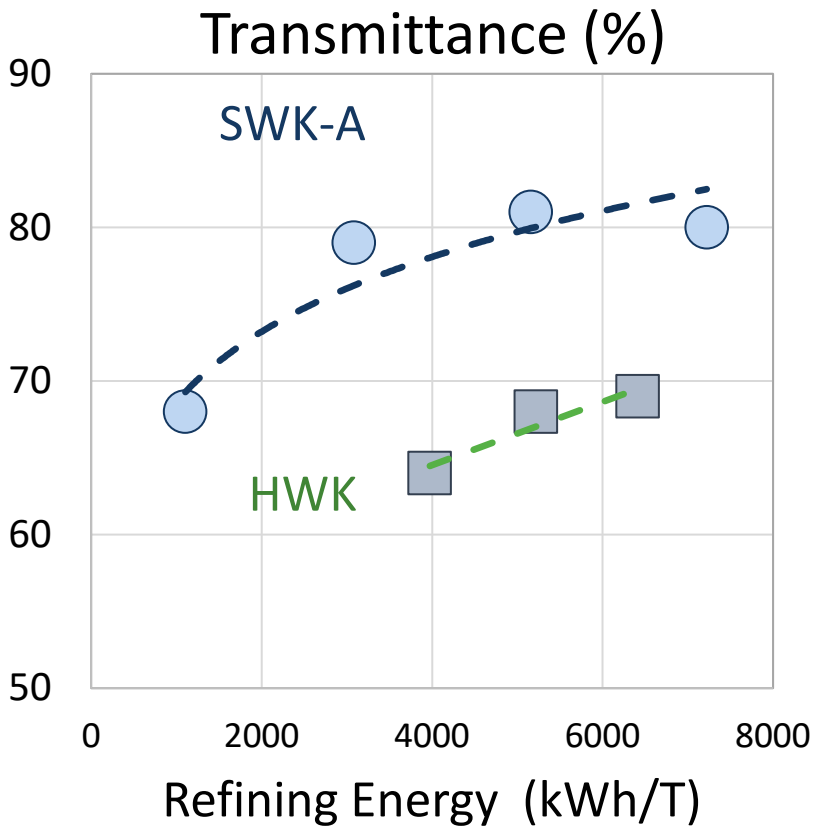
- Fraction of fine material and drainage time both increase with refining energy
  - At very high energy, drainage time starts decreasing again due to lower retention of fines

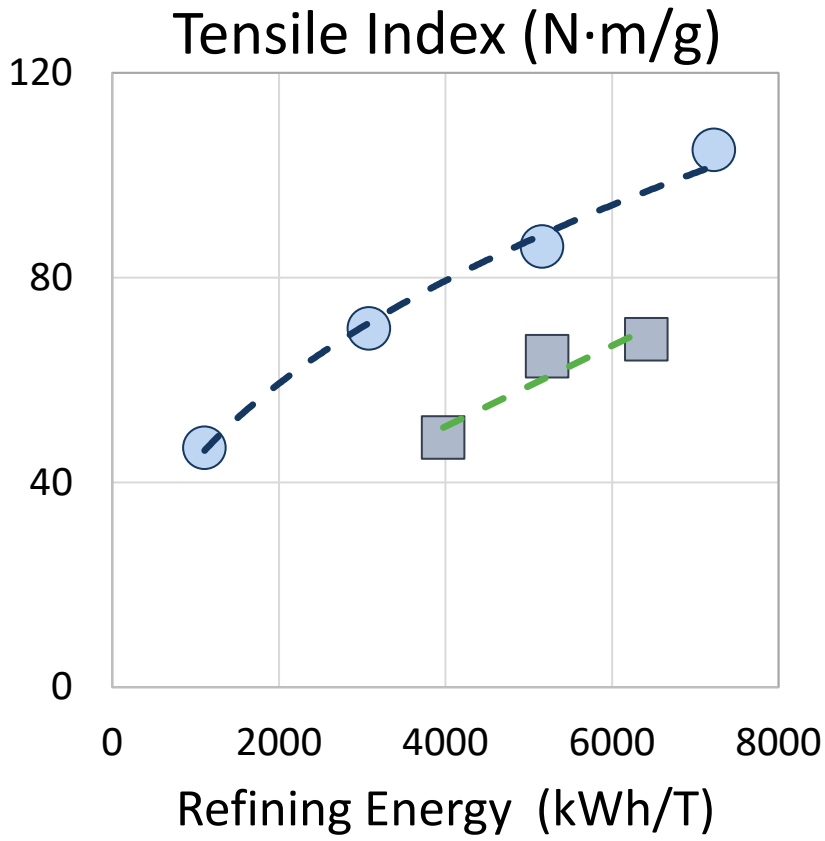
Impact of Refining Energy on CF Morphology & Drainage

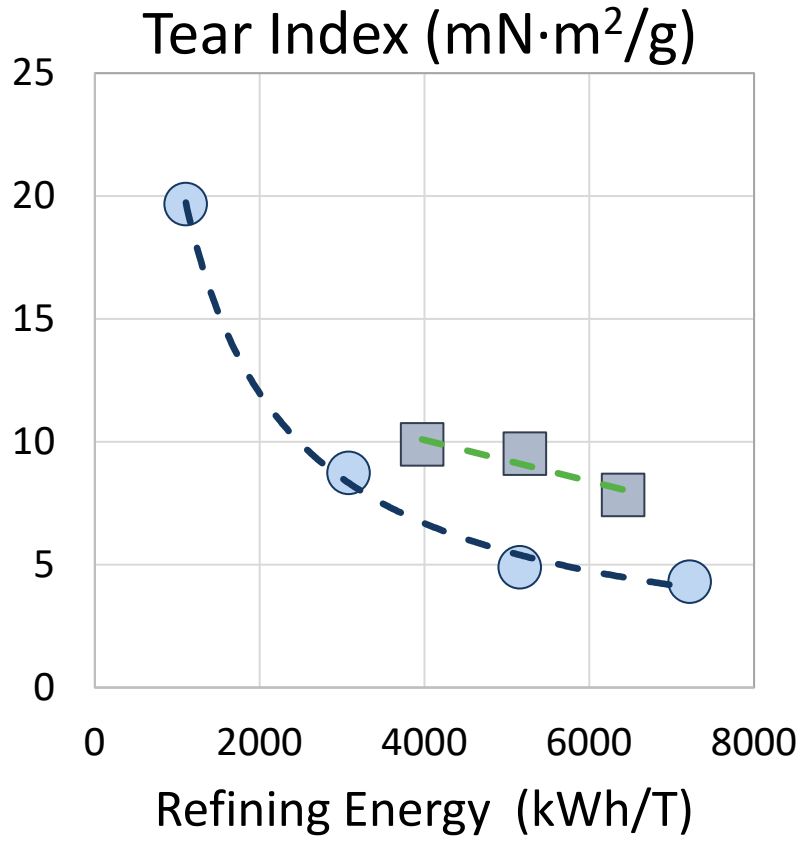


- Fraction of fine material and drainage time both increase with refining energy
  - At very high energy, drainage time starts decreasing again due to lower retention of fines
- CF produced from hardwood pulp retains a high fraction of coarse fibres

Effect of CF Type on Optical & Mechanical Properties

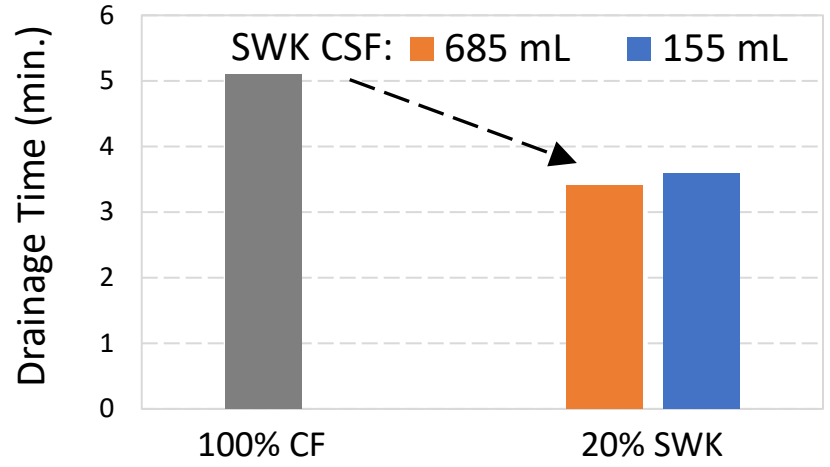


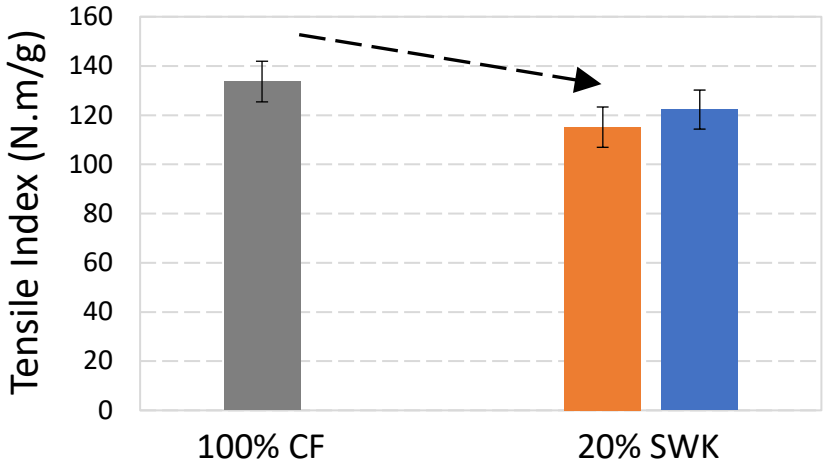


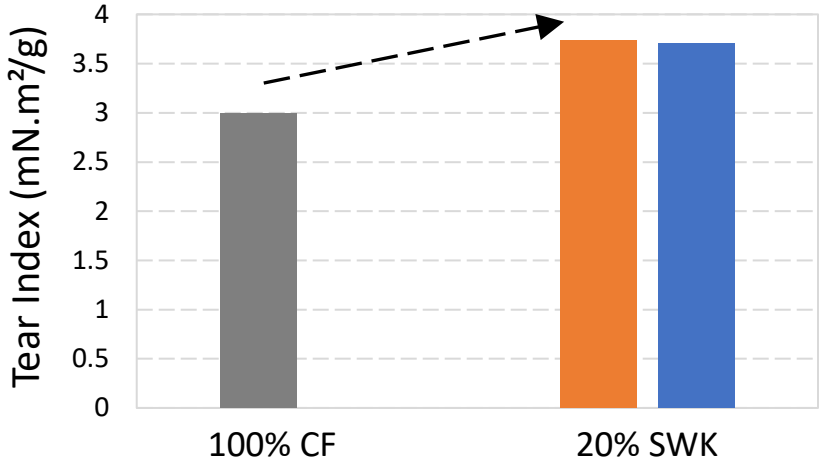


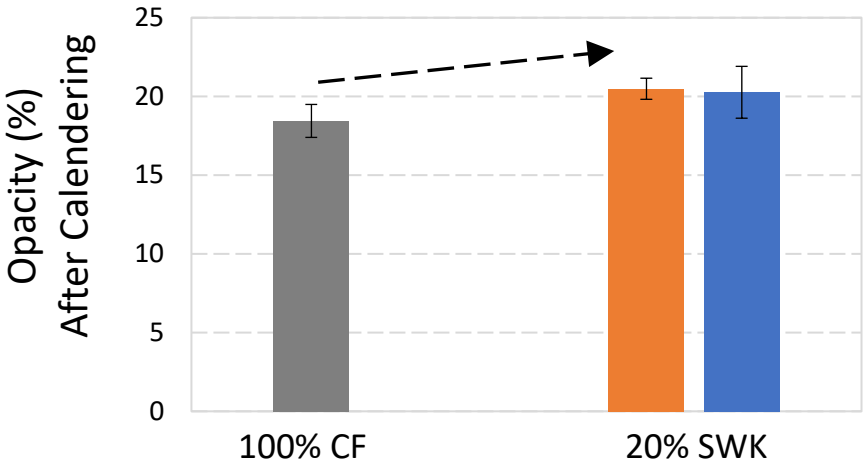
- Transmittance of CF-SWK film levels off at higher energy
- Tear & tensile strengths move in opposite directions with increasing refining energy
  - **Compromise between conflicting requirements will dictate optimal refining conditions**

Effect of Softwood Kraft Addition on CF Film Properties







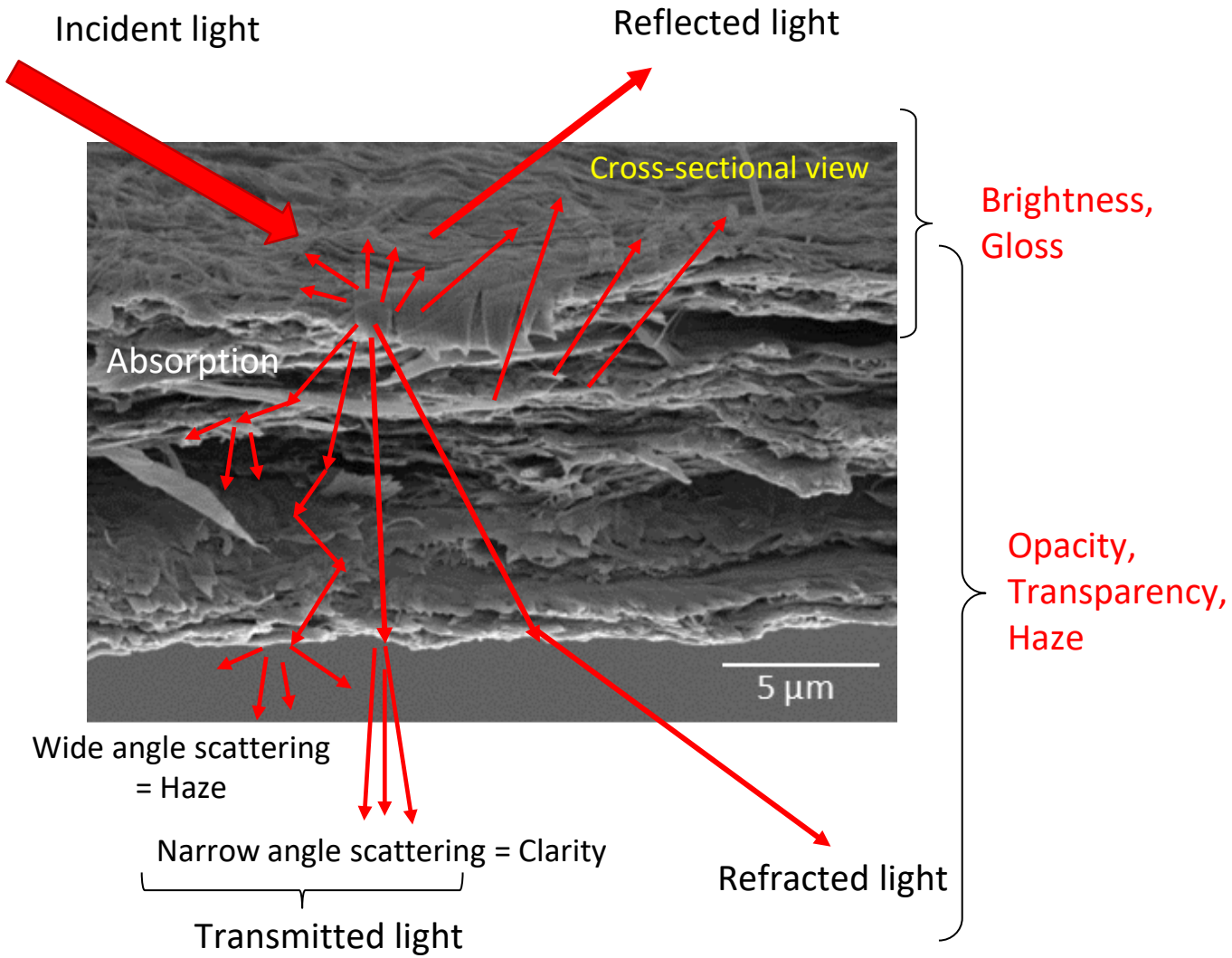


Handsheet results

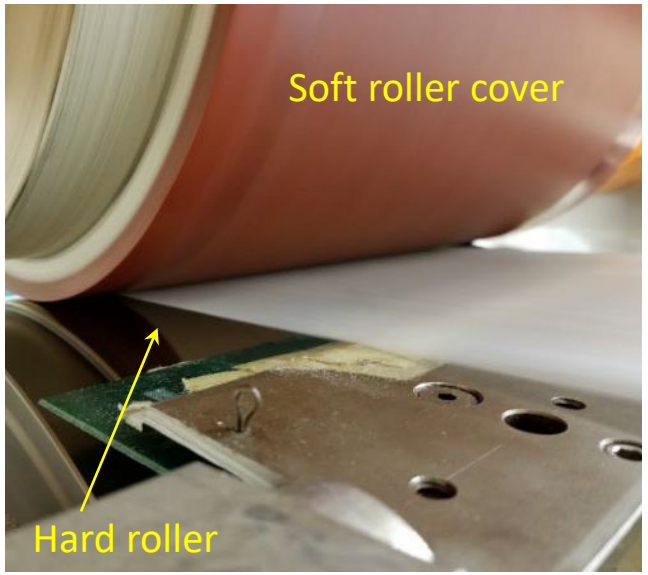
- Addition of SWK improves tear & drainage with limited impact on optical properties

Factors Controlling the Optical Properties of CF Films

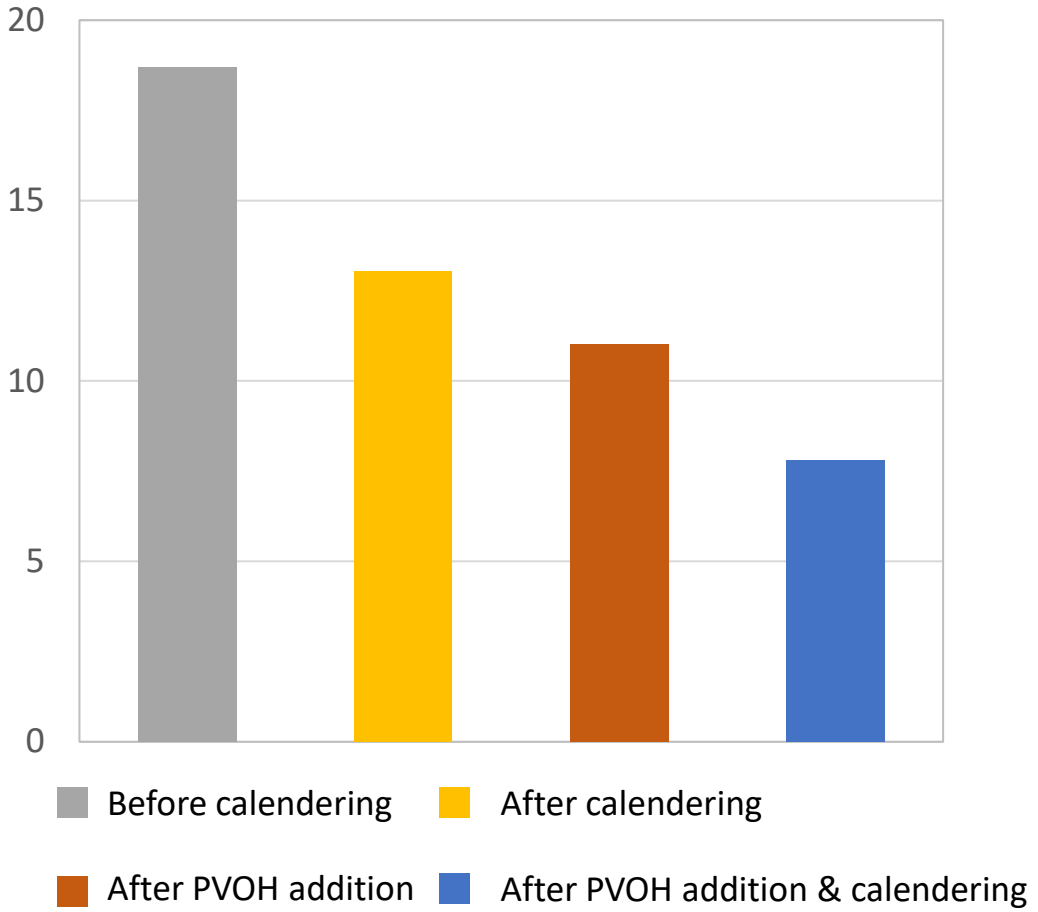
- The film's opacity and haze originate from scattering of light at air-fibre interfaces
- CF films having very low porosity, scattering of light occurs mostly at the film's surface
- Transmittance and haze can be improved by smoothening the film's surface and minimizing its refractive index



Lowering of Opacity through Calendering and Coating



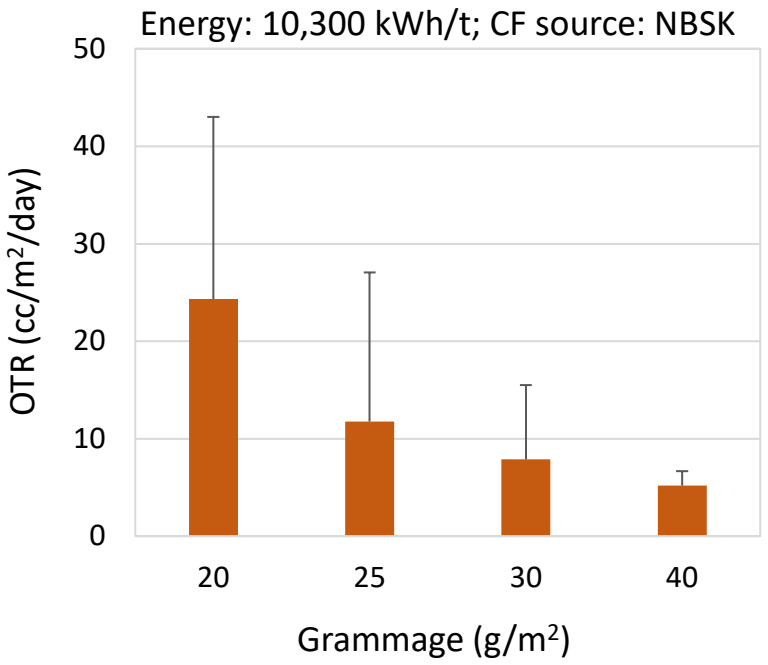
Calendering conditions:
Load: 250 kN/m, Temp.: 150°C

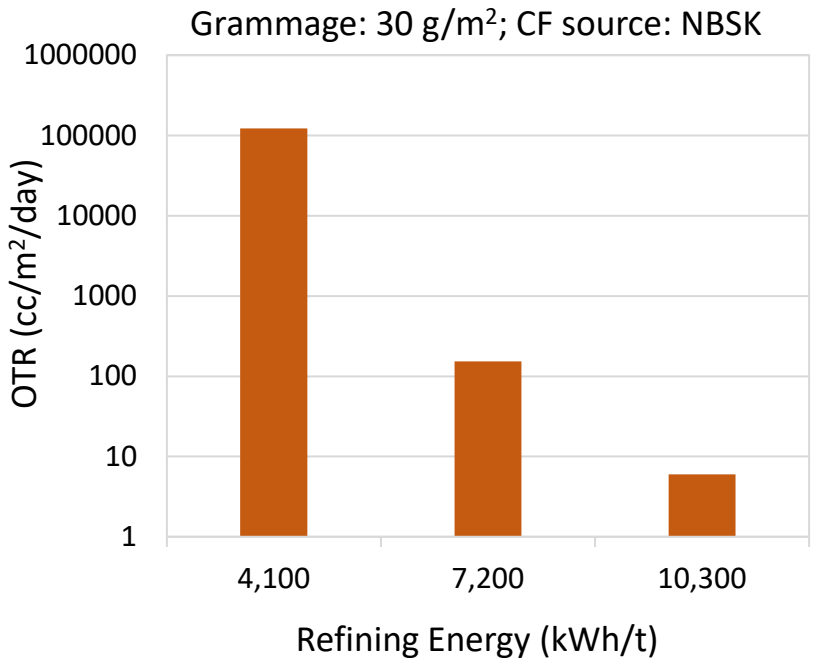


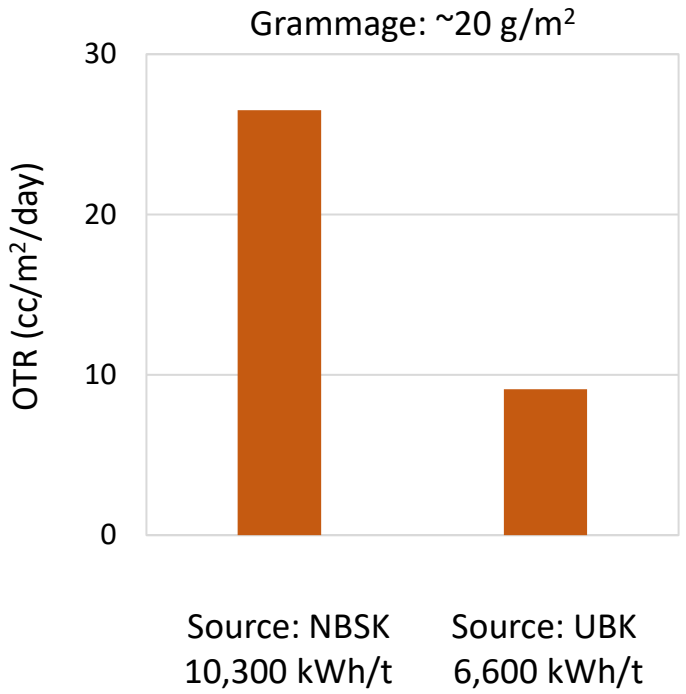
- PVOH was applied with CLC coater; target coat weight was 3 g/m^2 per side

Barrier Properties of CF Handsheets

Gurley Air Resistance	Water Vapour Transmission Rate	Oil & Grease	Oxygen Transmission Rate (23˚C, 50% R.H., 100% O_2)
> 1800 s	> 500 g/m²/day	**Kit value ~12**	**< 10 cc/m²/day**



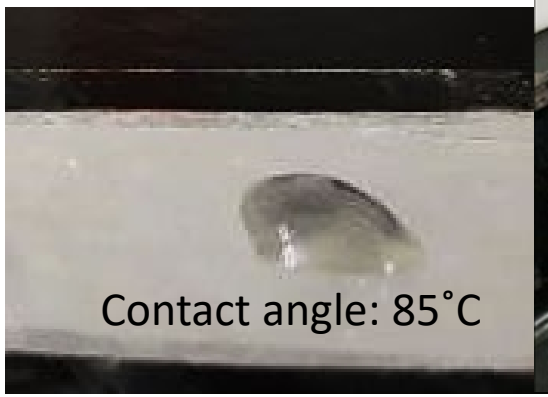




- CF film offers great resistance to oil and grease
- Refining energy has the greatest impact on oxygen barrier performance

Looking Ahead: Imparting Additional Functionalities to CF Films

- **Water resistance** through green chemistry
  - Use of cross-linker and catalyst



Heat-sealed CF film carrying a load >1.3 kg

- **Heat-sealability** and **barrier properties** through coating with water-based formulations

Summary

- Translucent, repulpable films made from cellulose filaments offer a promising alternative to plastic films for various packaging applications
- CF average dimensions and size distribution depend on the source fibre from which the filaments are made, as well as the refining conditions and total energy applied during manufacturing
- Laboratory-made CF films have excellent barrier properties against oil-and-grease and can also provide very good resistance to oxygen at sufficient grammage and CF refining energy
- Additional barrier properties and heat-sealability can be obtained by surface treating the film with water-based coating formulations
- Rolls of CF films can be produced using a conventional papermaking process

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