REFINED AND HOMOGENIZED NANOCELLULOSE:

FIBER QUALITY, ENERGY AND STRENGTH

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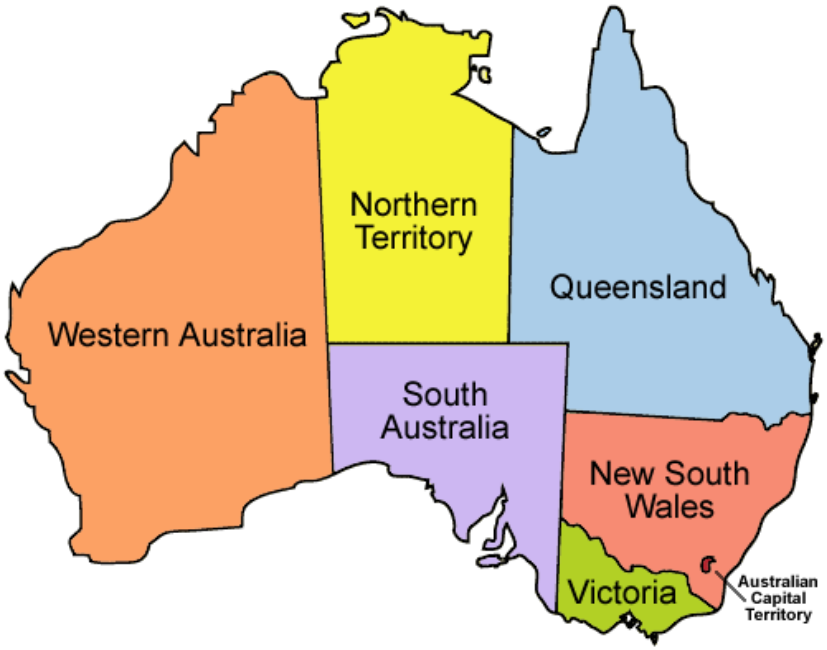
Victoria in Australia



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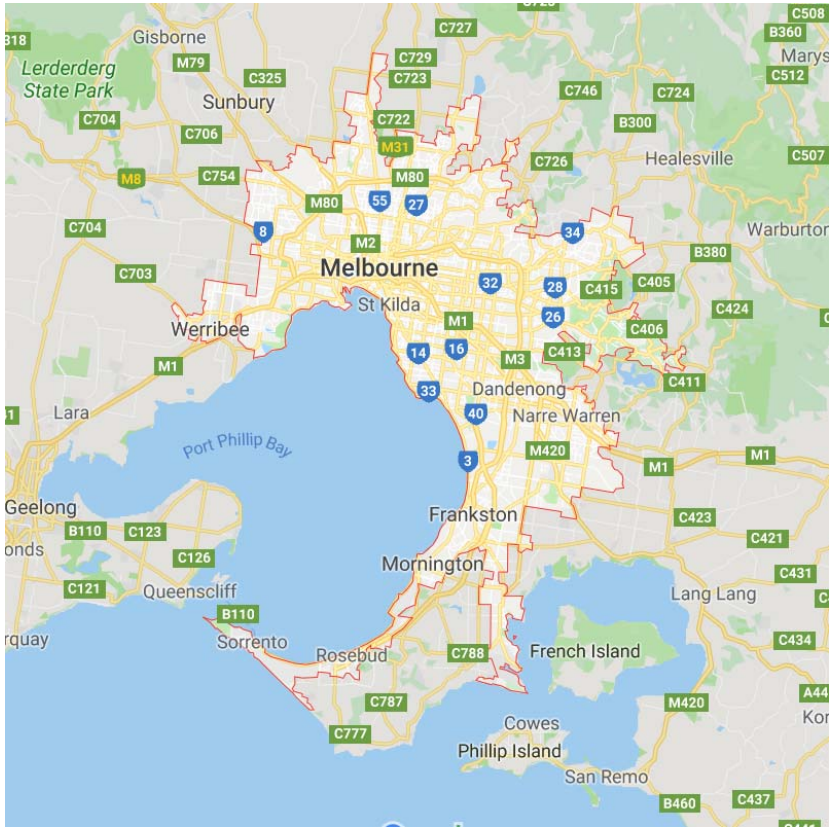
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Rosebud
Dandenong
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FIBER QUALITY, ENERGY AND STRENGTH

Ang, S., Haritos, V. and Batchelor, W., 2019.
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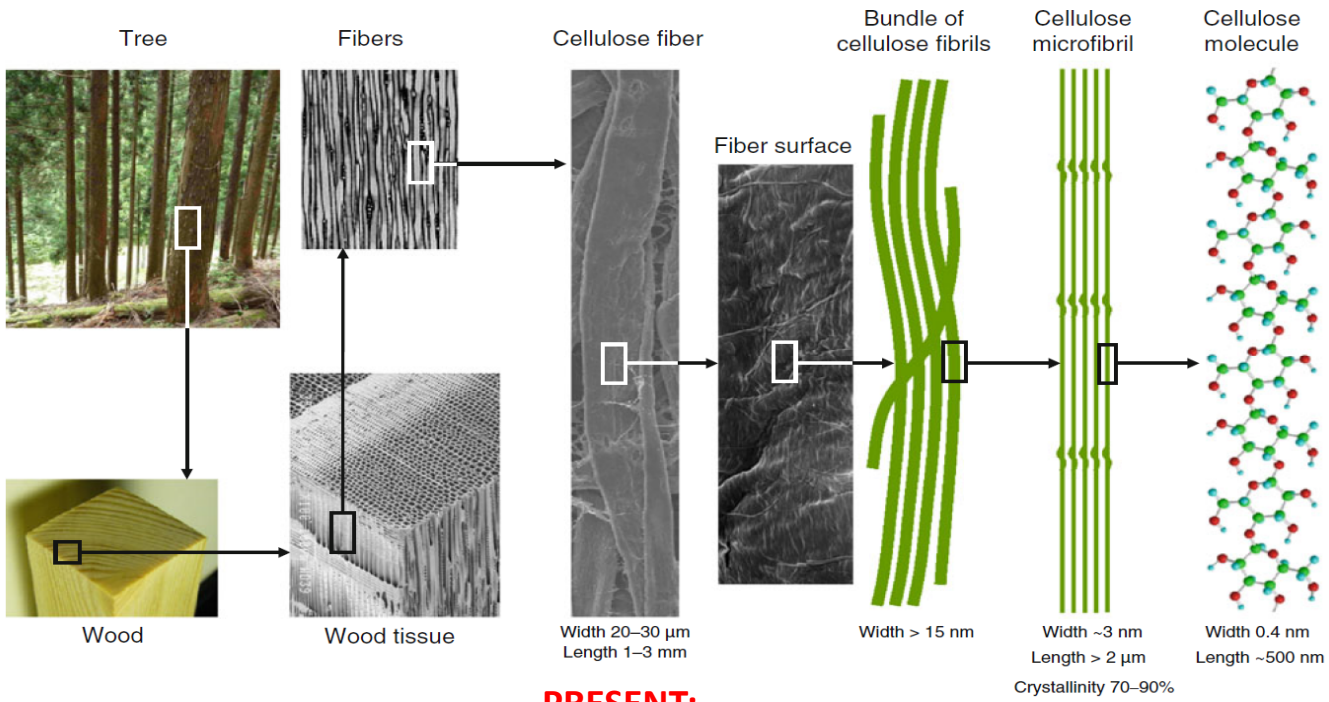
https://doi.org/10.1007/s10570-019-02400-5

PALS

MONASH University

Cellulose and Nanocellulose [1]



PRESENT:

Pulp and Paper Industry **Nanocellulose**

[1] Isogai, *Journal of Wood Science,* 59 (6) 449-459, 2013

Nanocellulose

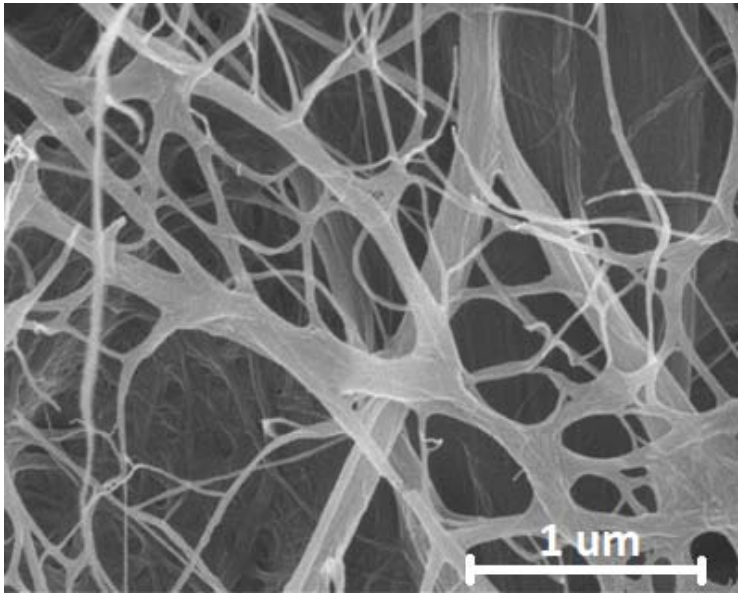
- **3 Orders of Magnitude Smaller Dimensions and Pore Sizes**

  (Diameter: µm to nm)

- **Large Surface Areas**

  (Compared to Wood fibers)

- **Form Dense Films**



Nanocellulose Production

- **Mechanical Treatment**

  Homogenizer, Microfluidizer, Grinding [2]

- **High Energy Expenditure**

  30,000 – 70,000 kWh/t
  (nanocellulose) [3]

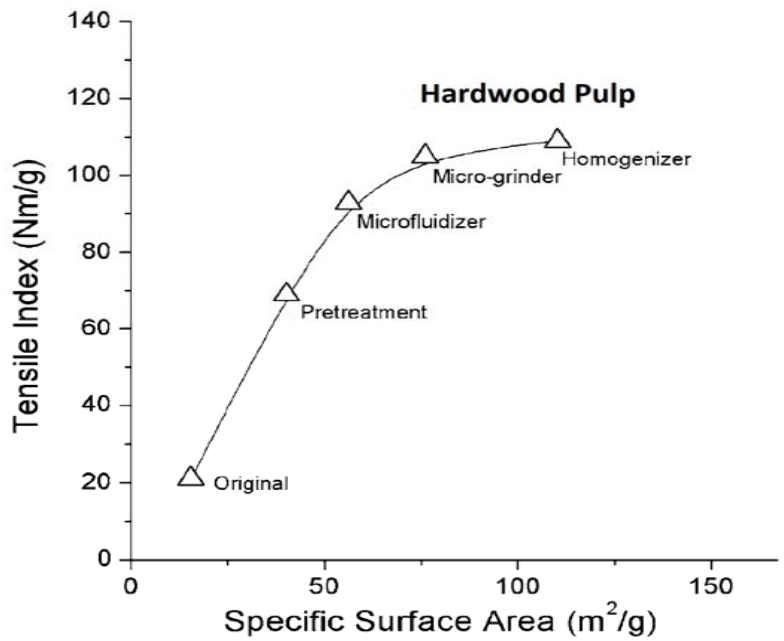
  2,000 – 3,000 kWh/t
  (industry: thermomechanical pulp)
  250 kWh/t
  (industry: Kraft pulp refining)

Homogenizer

Microfluidizer

[2] Lavoine et al, *Carbohydrate Polymers,* 90 (2) 735-764, 2012
[3] Eriksen et al, *Nordic Pulp and Paper Research Journal,* 23, (3), 299-304, 2008

Strength Properties [4]



Heavy Mechanical Treatment results in Improved Strength

[4] Spence et al, *Cellulose*, 18 (1) 1097-1111, 2011

Research Question

HIGHER Mechanical Energy Consumption = SMALLER Fiber Dimensions = HIGHER Strength Performance ?

Mechanical Treatment

Bleached Eucalyptus Kraft Pulp (BEK)

Refining

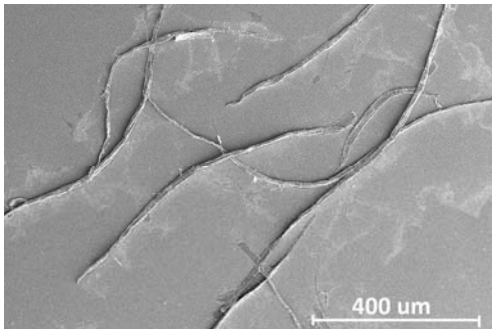
10K 30K 50K

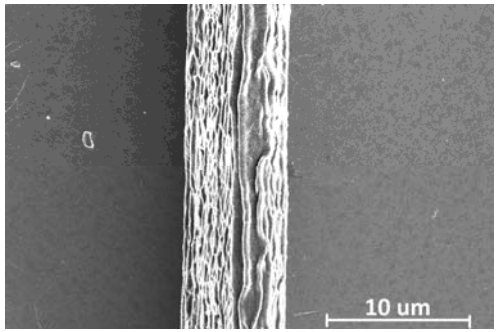
Refining and Homogenizing

10K1P 30K1P 50K3P

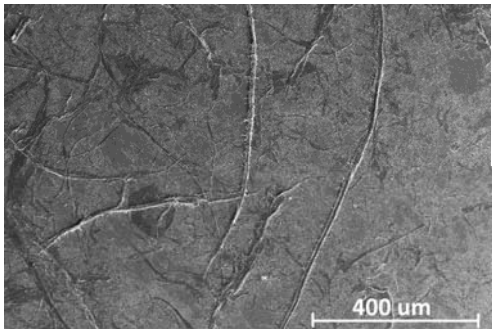
Energy Consumption Measurement

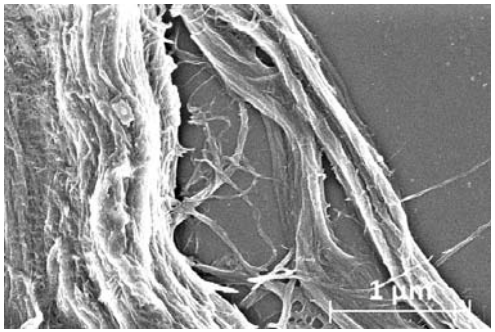
Fiber Sample	Specific Energy Consumption (kWh/oven-dry tonne fiber)
BEK 0K	0
BEK 10K	3,542
BEK 30K	10,625
BEK 50K	17,709
BEK 10K1P	10,742
BEK 30K1P	17,825
BEK 50K3P	39,309



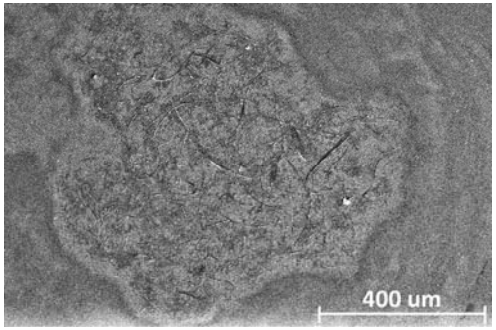


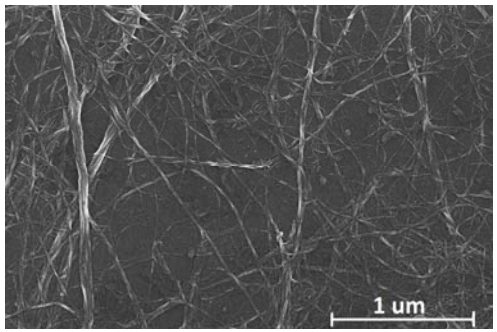
0K (Unrefined)





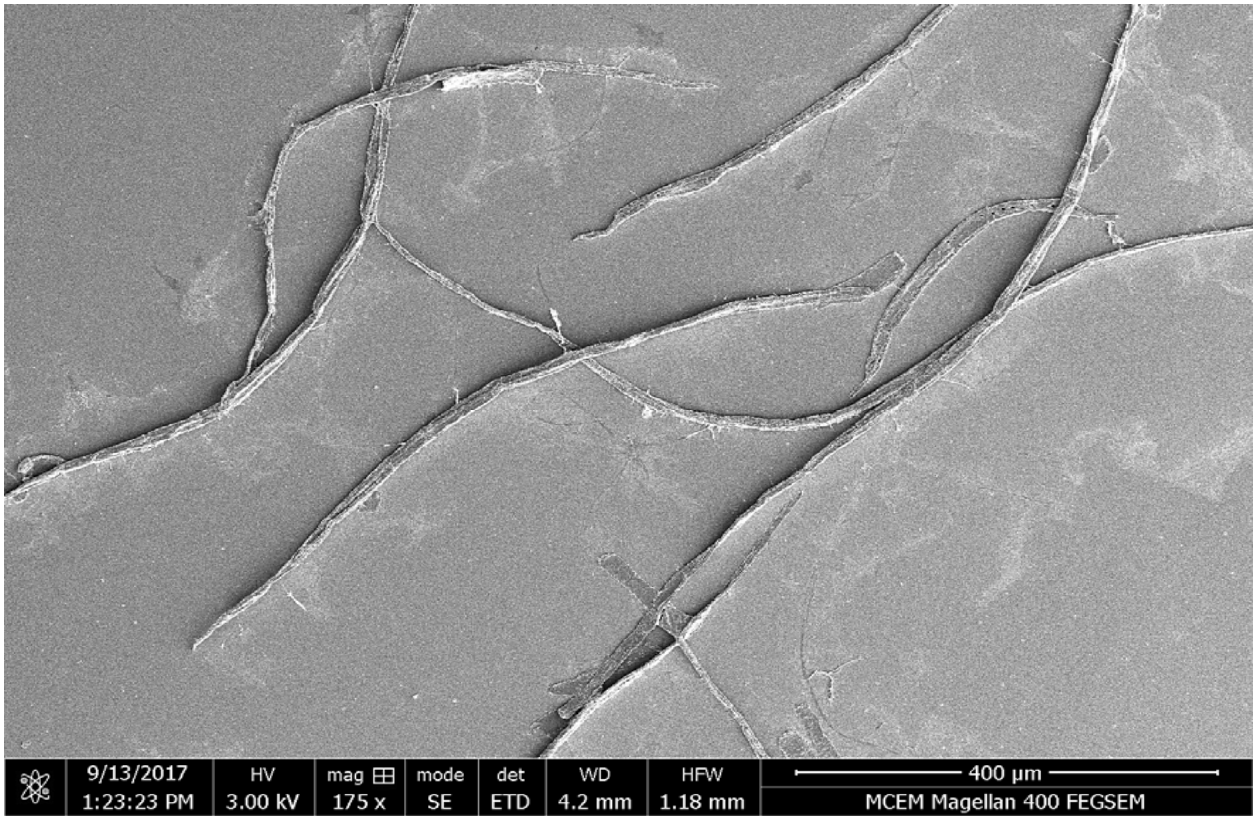
10K (Refined)



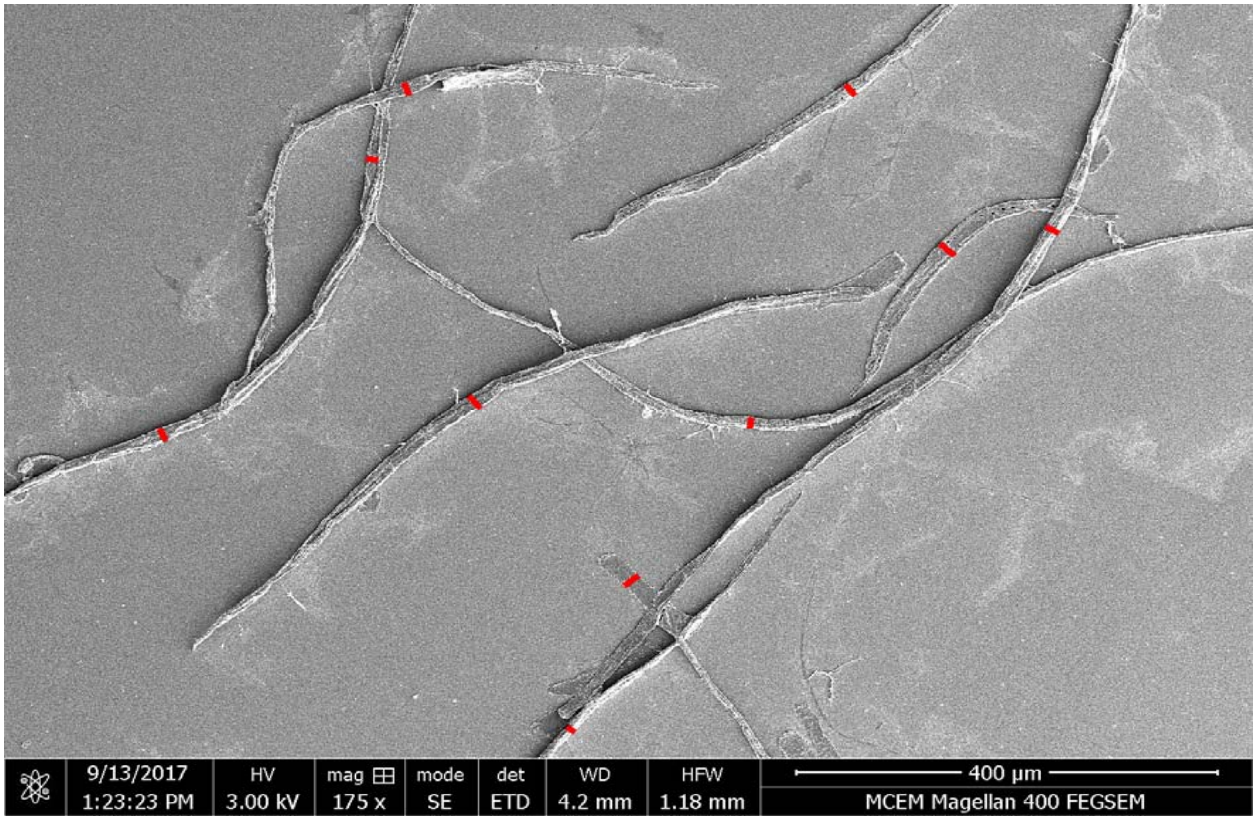


10K1P (Refined and Homogenized)

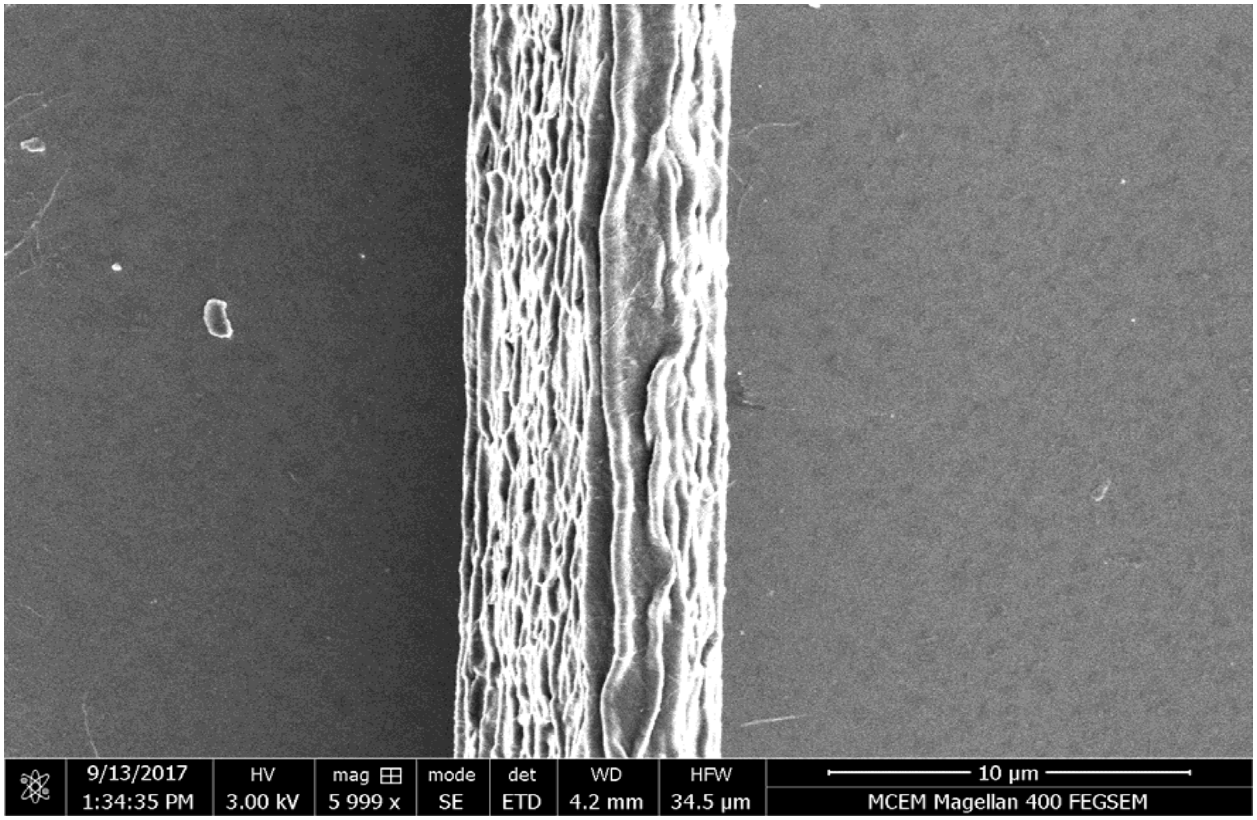
BEK 0K – Low Magnification



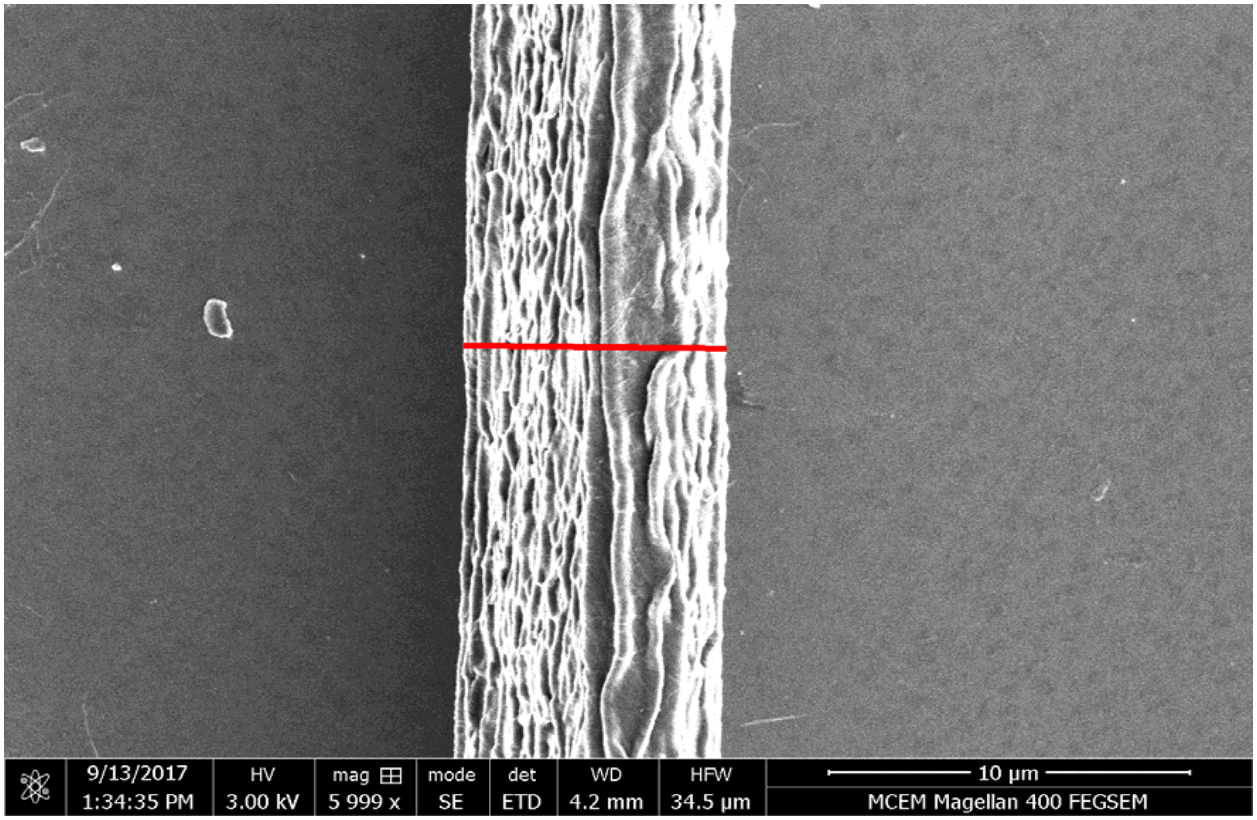
BEK 0K – Low Magnification



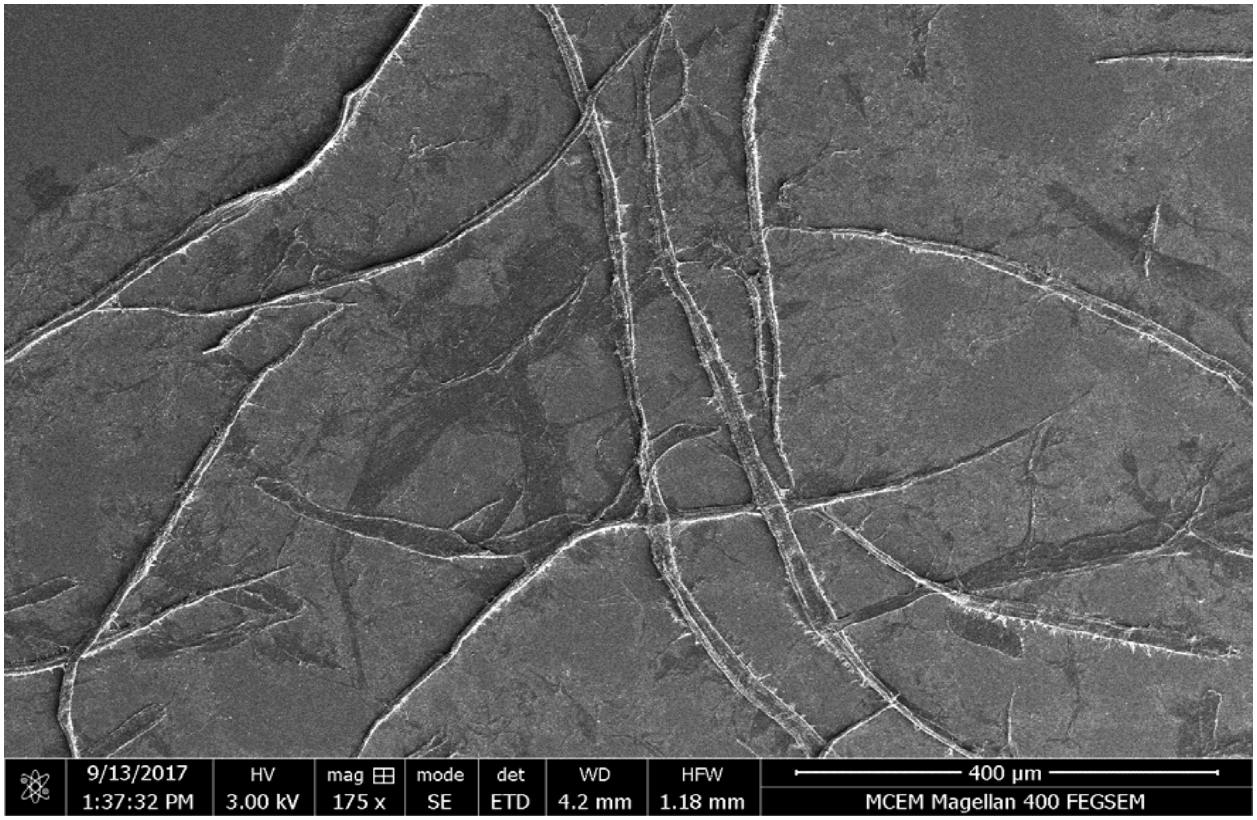
BEK 0K – High Magnification



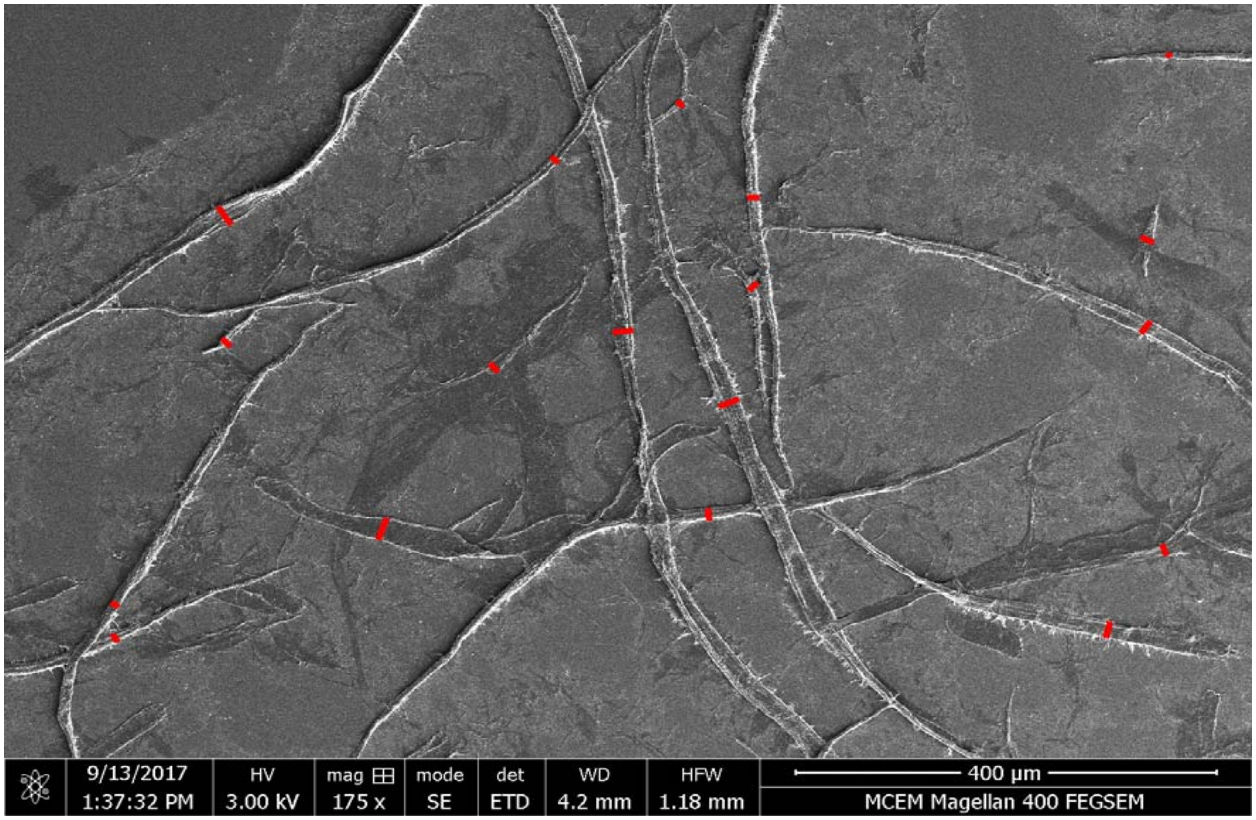
BEK 0K – High Magnification



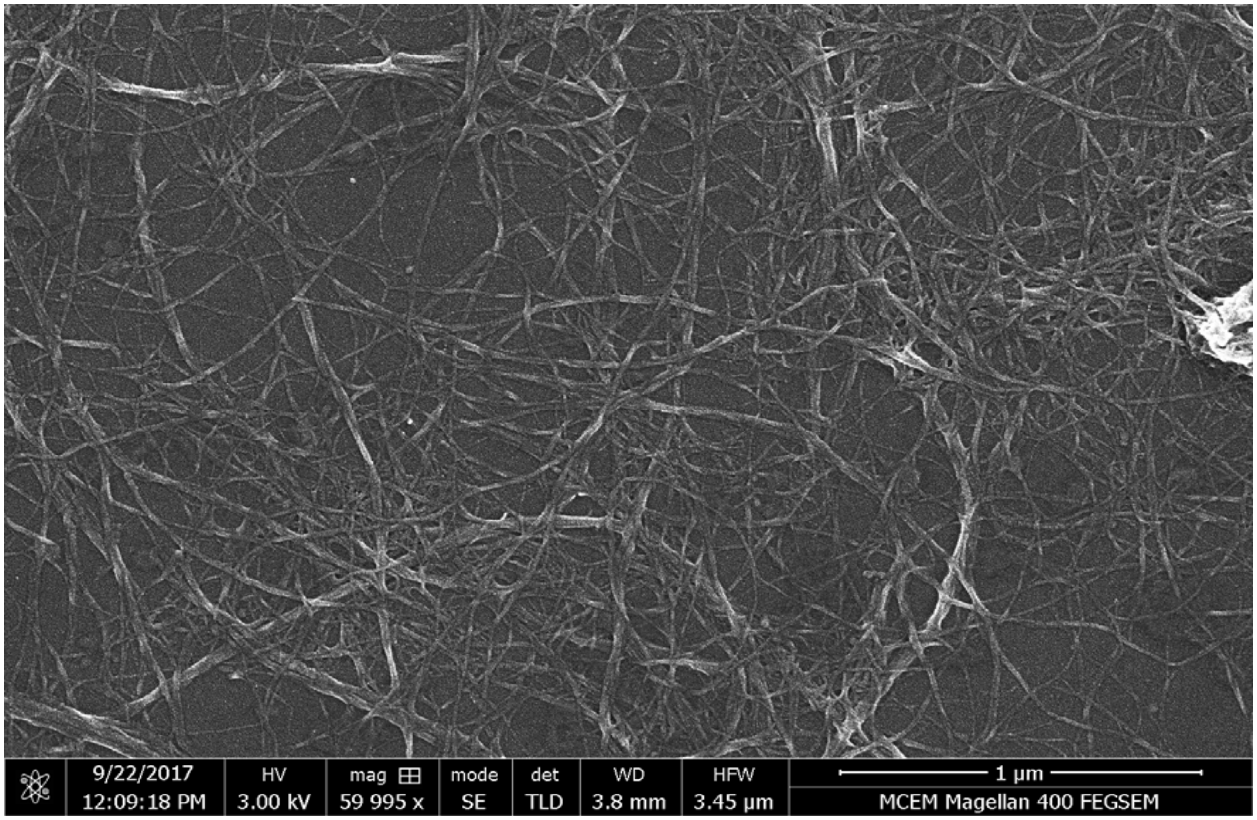
Refined BEK 10K – Low Magnification



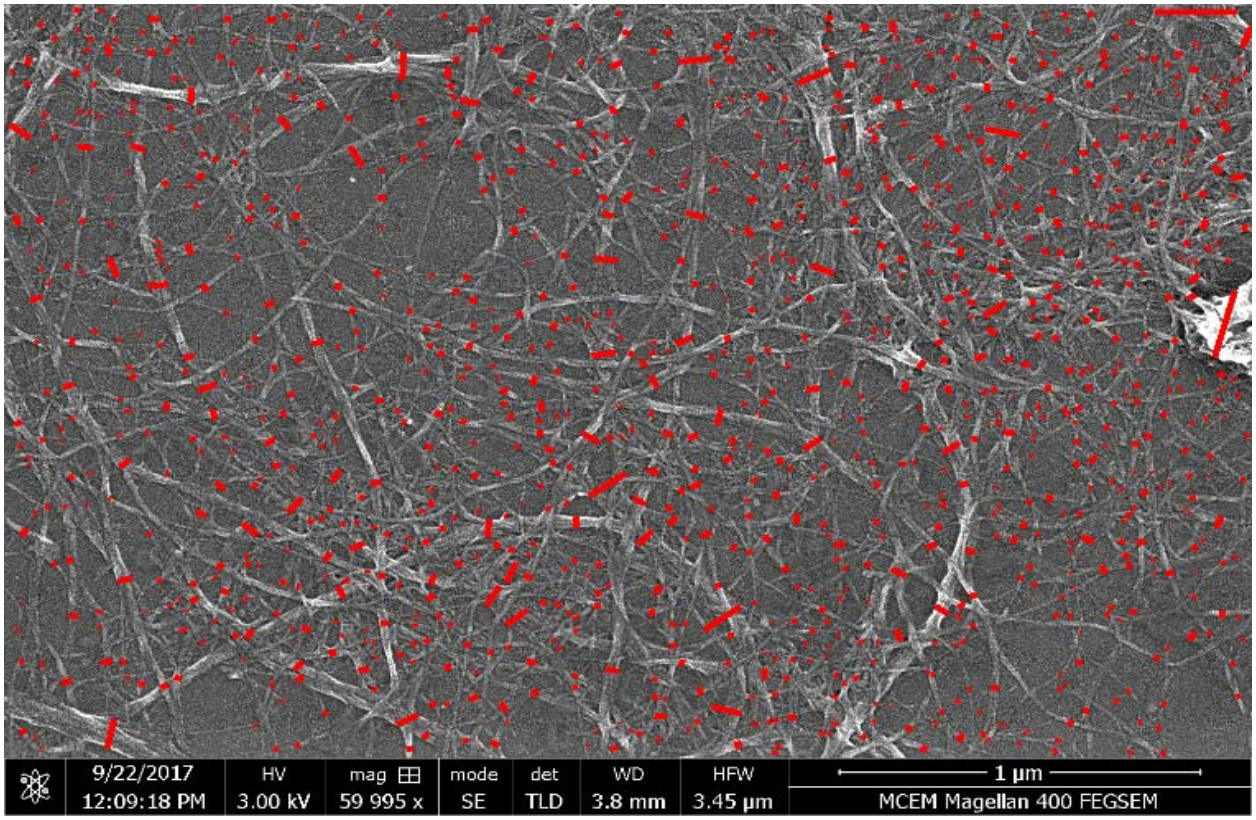
Refined BEK 10K – Low Magnification



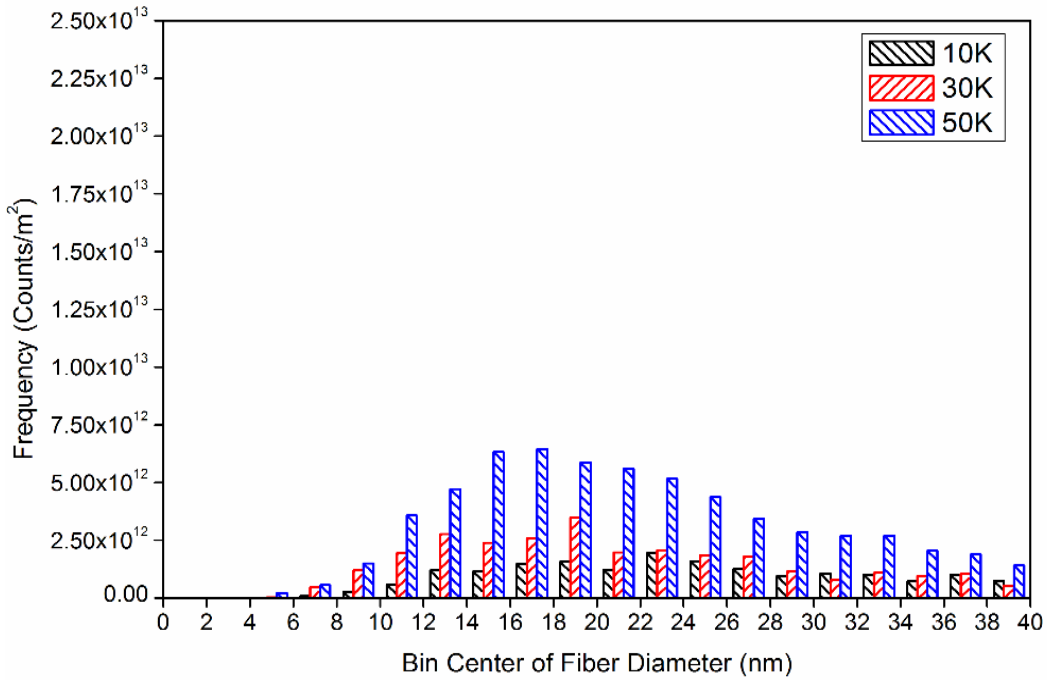
Homogenized BEK 50K3P – High Magnification



Homogenized BEK 50K3P – High Magnification

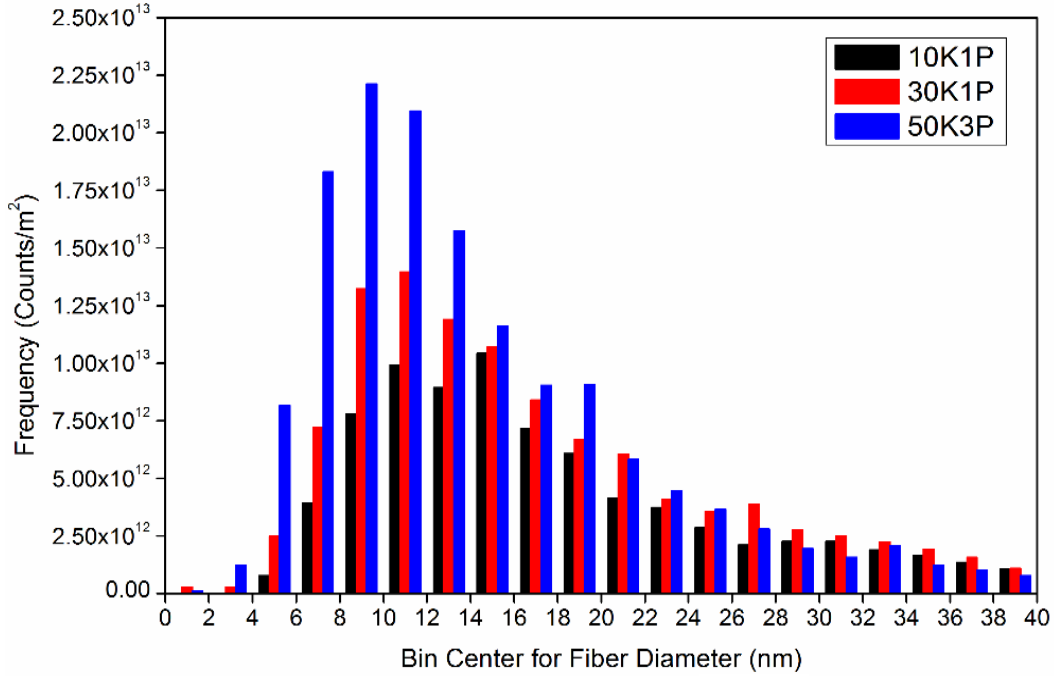


Fiber Diameter Distribution - Refined



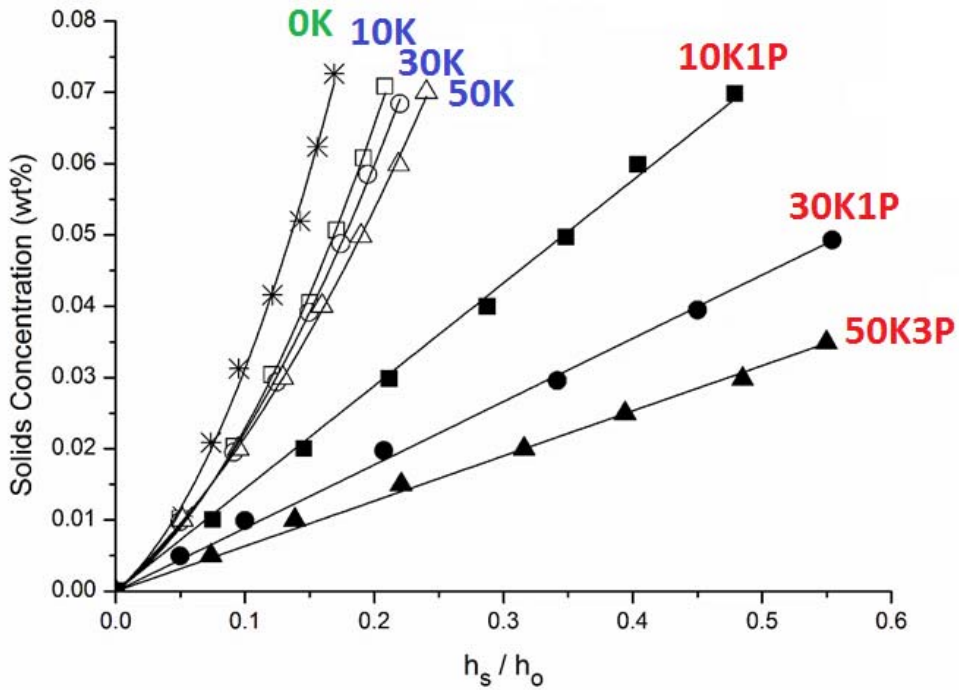
Higher Energy Consumption from Refining, Smaller Fiber Diameter

Fiber Diameter Distribution - Homogenized



Higher Energy Consumption from Refining and Homogenization, Smaller Fiber Diameter

Sedimentation Gel Point (Aspect Ratio)

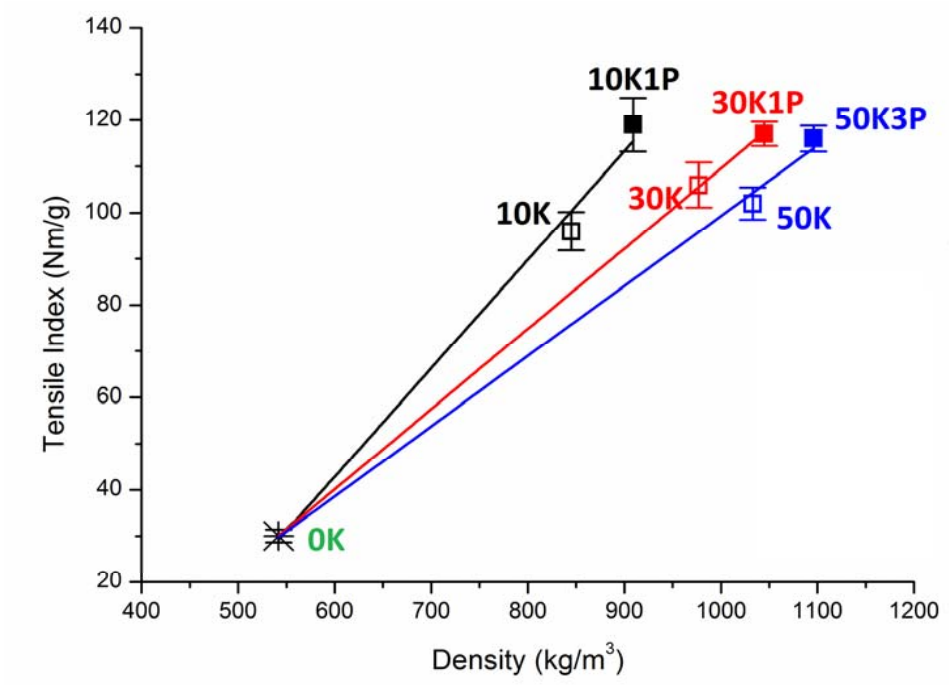


Sedimentation Gel Point (Aspect Ratio)

BEK Fiber	Gel Point (wt%)	EMT Aspect Ratio	Median Fiber Diameter (nm)	EMT Average Fiber Length (µm)
0K	0.353	**84**	13113	1101
10K	0.256	**102**	31	3.2
30K	0.243	**105**	25	2.6
50K	0.230	**108**	24	2.6
10K1P	0.144	**142**	17	2.4
30K1P	0.089	**188**	16	3.0
50K3P	0.063	**229**	12	2.7

Higher the Energy Consumption, Higher Fiber Aspect Ratio

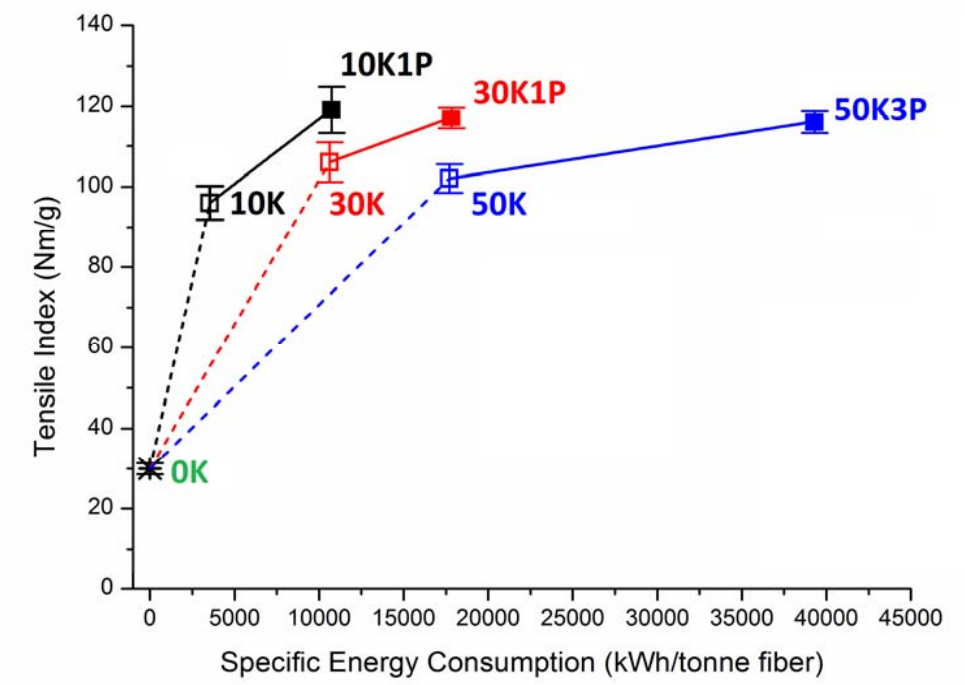
Nanocellulose Sheet Strength



- **Refined sheets:**
  3 times strength improvements
- **Refined + homogenized sheets**
  4 times strength improvements

- **All refined sheets**
  approx. same strength
- **All refined + homogenized sheets**
  approx. same strength

Nanocellulose Sheet Strength



- **Higher mechanical energy consumption produces smaller diameter fibers**
- **Smaller fibers does not equate to better sheet strength**

- **Can produce high strength nanocellulose sheets with reasonable amounts of energy**

Conclusions

- ✓ Median unrefined wood fiber **diameter decreases** from 13,000 nm to 12 nm and fiber **aspect ratio increases** from 84 to 229 with refining and homogenization
- ✓ Sheet tensile index increased by around **3-fold with refining** (100 Nm/g) and **4-fold with homogenization** (120 Nm/g) over unrefined wood fiber sheets (30 Nm/g)
- ✓ Progressive amounts of refining and homogenization passes had **little to no effect on sheet strength** despite the developments in fiber quality
- ✓ Most heavily treated fibers required a **10-fold increase** in mechanical energy to produce over the least treated refined fibers, but only had **relatively marginal strength improvements**
- ✓ **High sheet strength can be achieved without large mechanical energy consumption** for high aspect ratio and very low diameter nanocellulose fibers

Acknowledgements

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Co-funding industrial project and supplying pulp

Up Next

- Industrial refining vs lab refining
- Comparing strength and barrier performance
- Comparing energy consumption
- Trade-off between energy and product performance

Thank you

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