Drag Reduction Characteristics of Micro-Fibrillated Cellulose

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Lean and Green

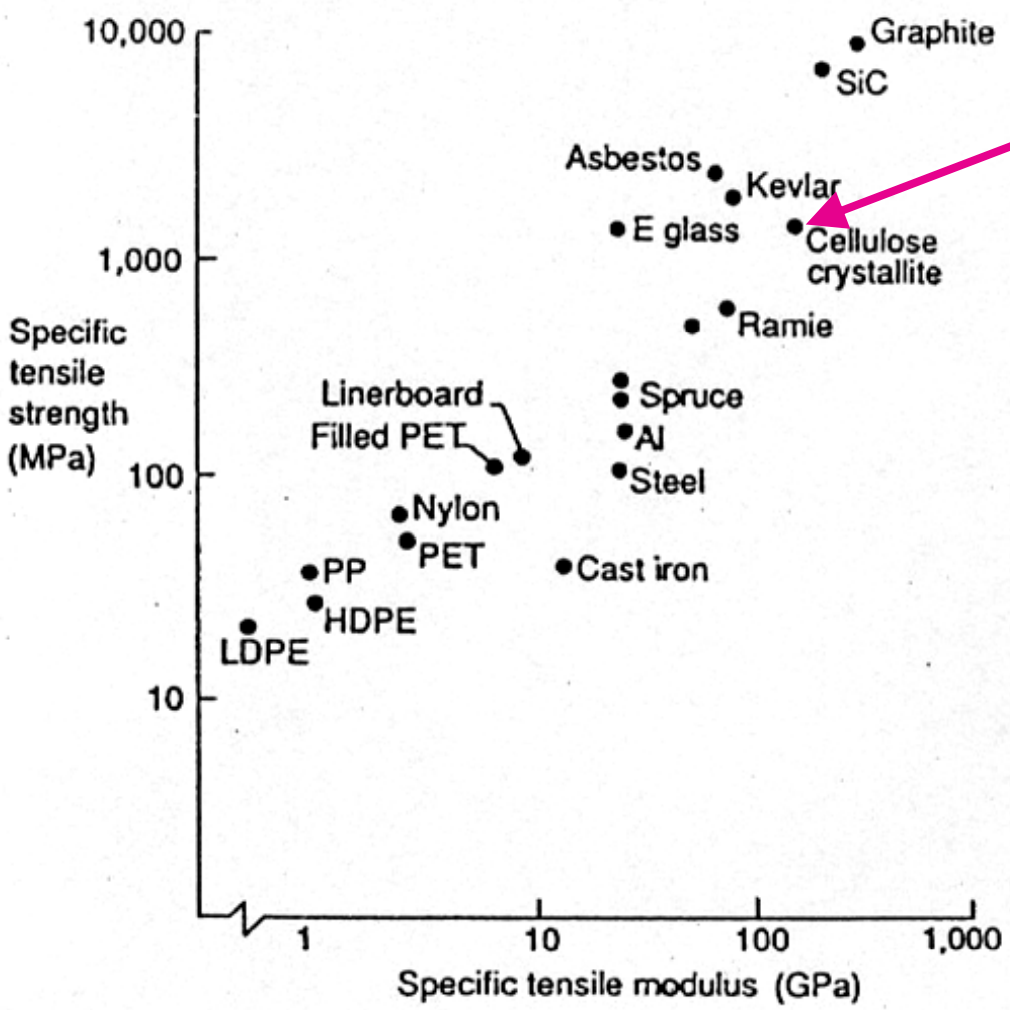
Summary

- Drag reduction characteristics of micro-fibrillated cellulose (MFC) are evaluated in a fully developed turbulent pipe flow.
- The effect of MFC concentration on percent drag reduction is evaluated in two different pipes with inside diameters 45mm and 57mm.
- A maximum drag reduction of 9% was observed at a concentration of 0.15% in both pipes.
- Drag reduction was found to generally be greater in the 45mm pipe.

Nanocellulose gel

Elementary fibril aggregates in wood-fibres

Why is it interesting?

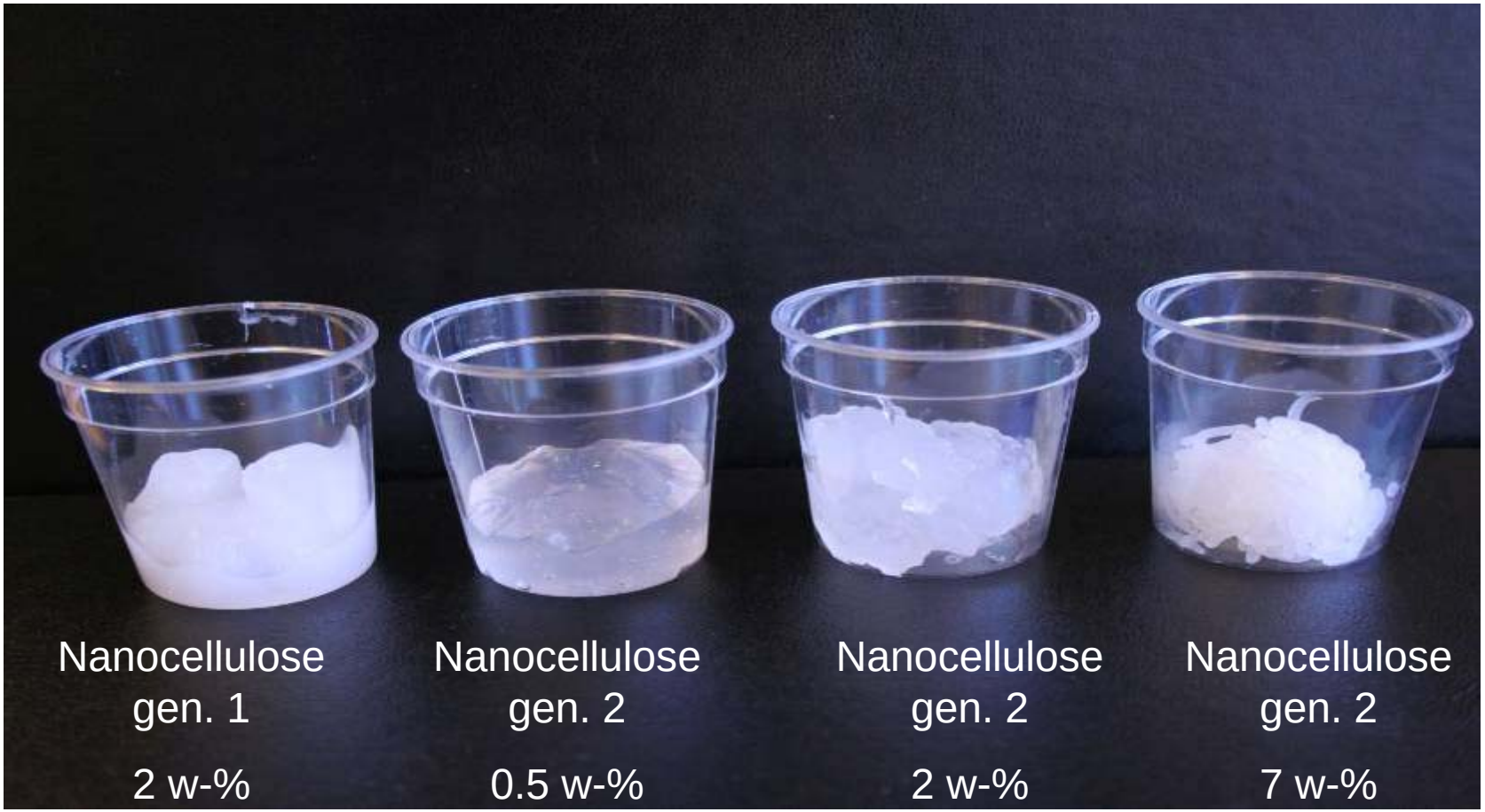


Cellulose crystallite

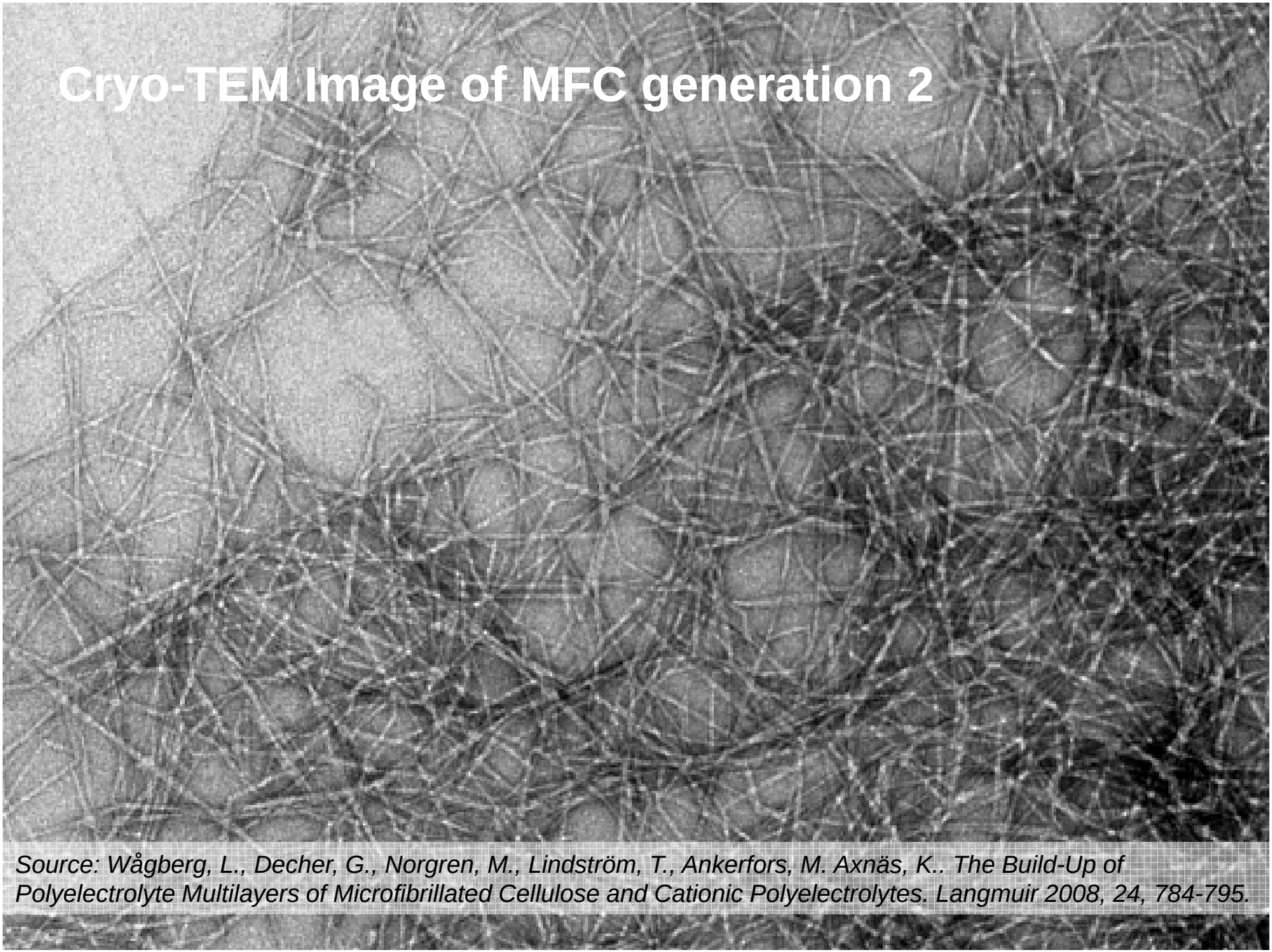
E≈140 GPa

Source: Hongu, T and Phillips, G.O. (1997). New Fibres, Woodhead publishing

Different types of nanocellulose



Cryo-TEM Image of MFC generation 2



Source: Wågberg, L., Decher, G., Norgren, M., Lindström, T., Ankerfors, M. Axnäs, K.. The Build-Up of Polyelectrolyte Multilayers of Microfibrillated Cellulose and Cationic Polyelectrolytes. Langmuir 2008, 24, 784-795.

Nanocellulose applications

Paper and board

- Dry strength agent for paper and board
- Surface strength agent to prevent linting
- Coating formulations
- Nanobarriers

New materials

- Nanofilms
- Nanocomposites
- Nanostructured foams for packaging

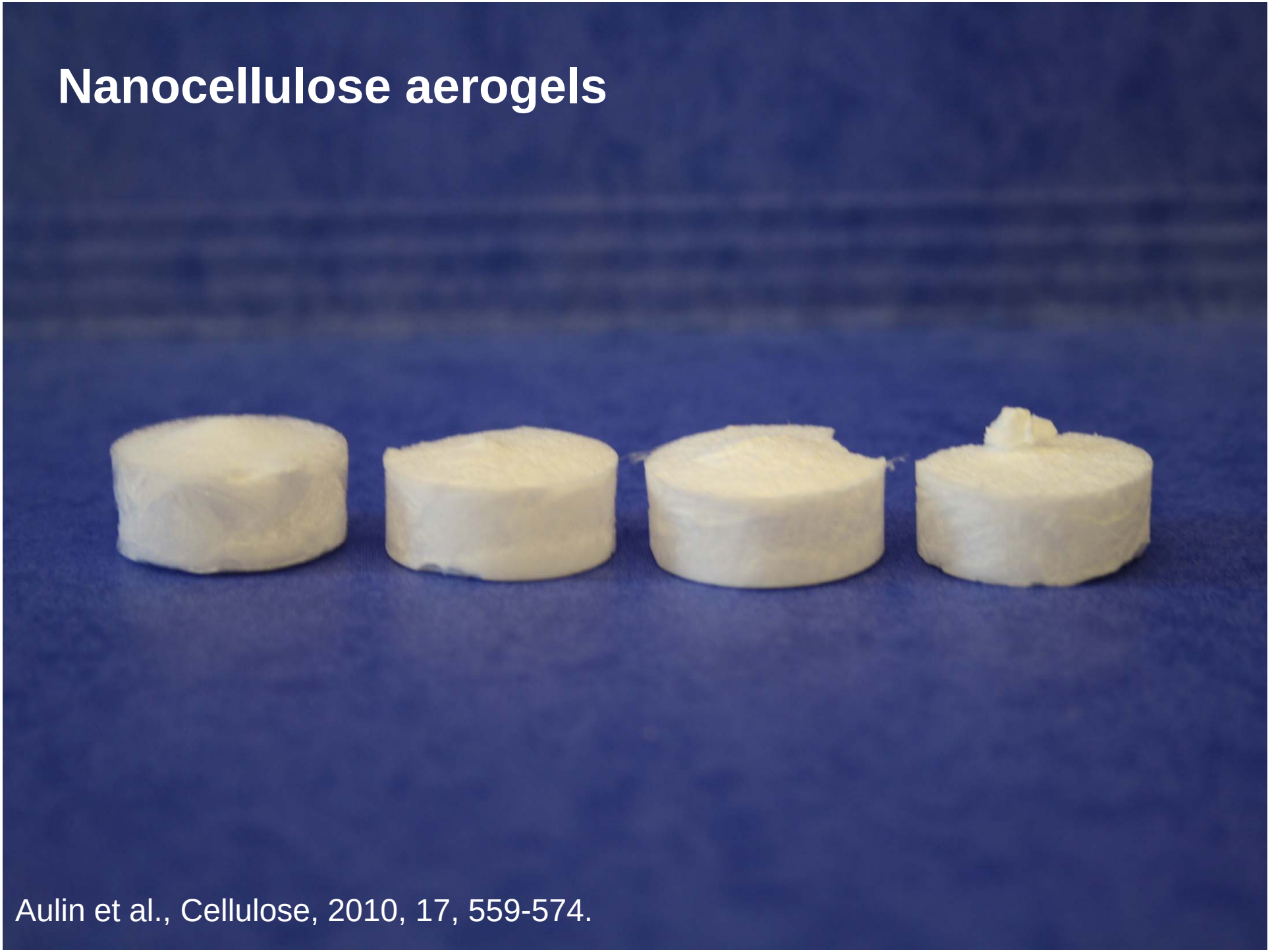
Other applications

- Food applications
- Cosmetics
- Medical/pharmaceutical applications
- Hygiene/absorbent products
- Emulsion/dispersion applications

Transparent film of nanocellulose

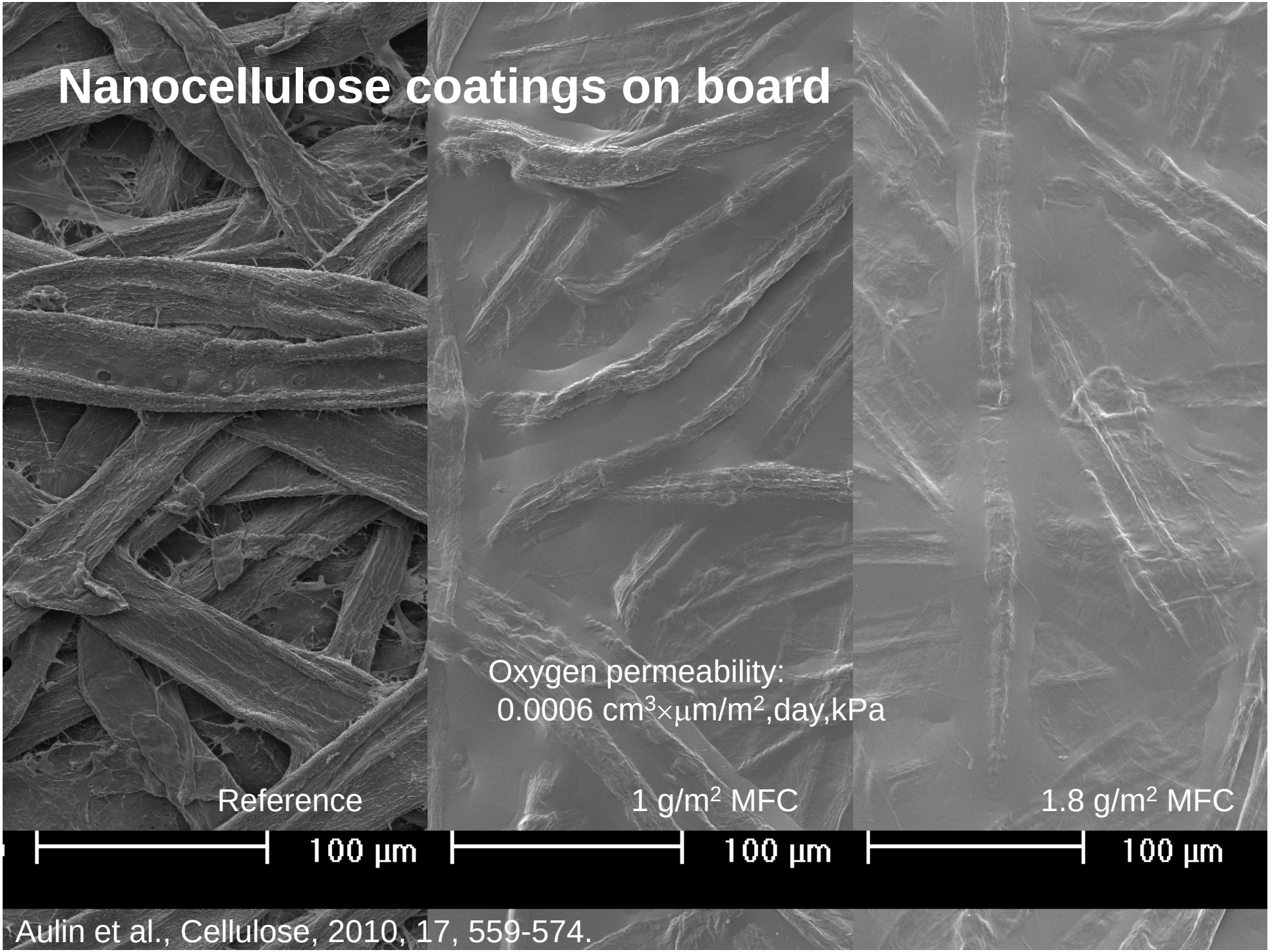
Aulin et al., *Cellulose*, **2010**, 17, 559-574. Fukuzumi et al., *Biomacromolecules*, **2009**, 10, 162–165. Syverud et al., *Cellulose*, **2010** 16, 75-78.

Nanocellulose aerogels



Aulin et al., Cellulose, 2010, 17, 559-574.

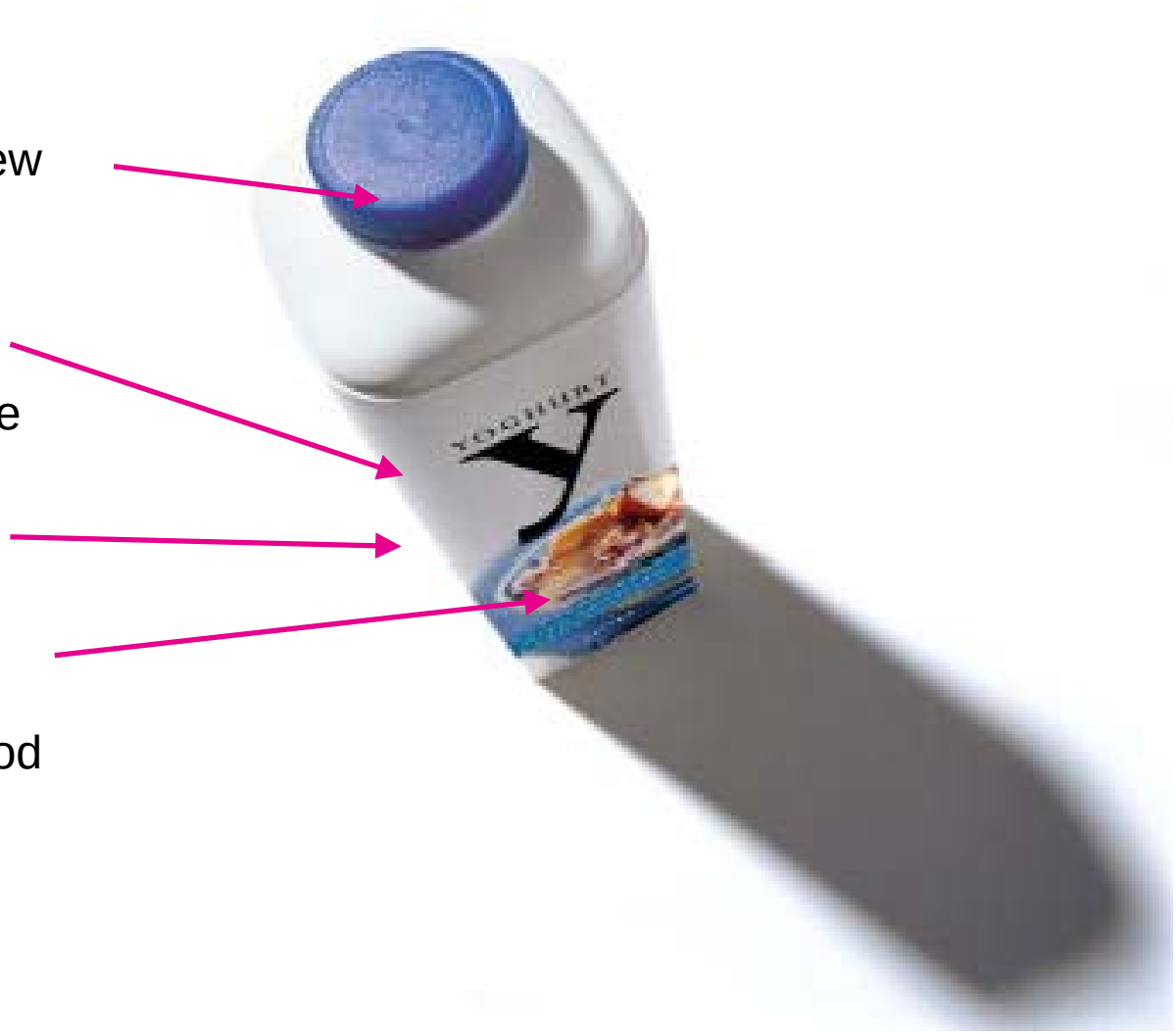
Nanocellulose coatings on board



Aulin et al., Cellulose, 2010, 17, 559-574.

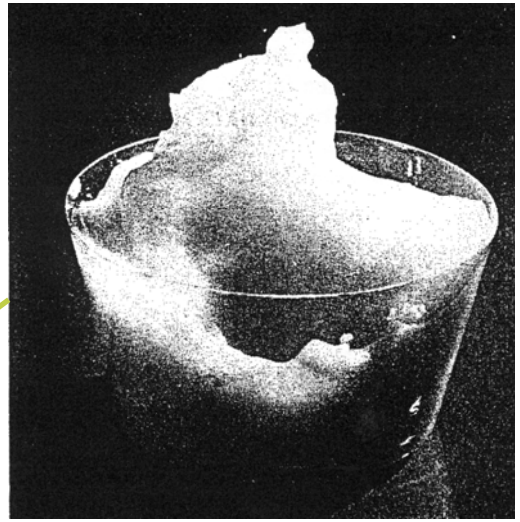
Potential uses in packaging

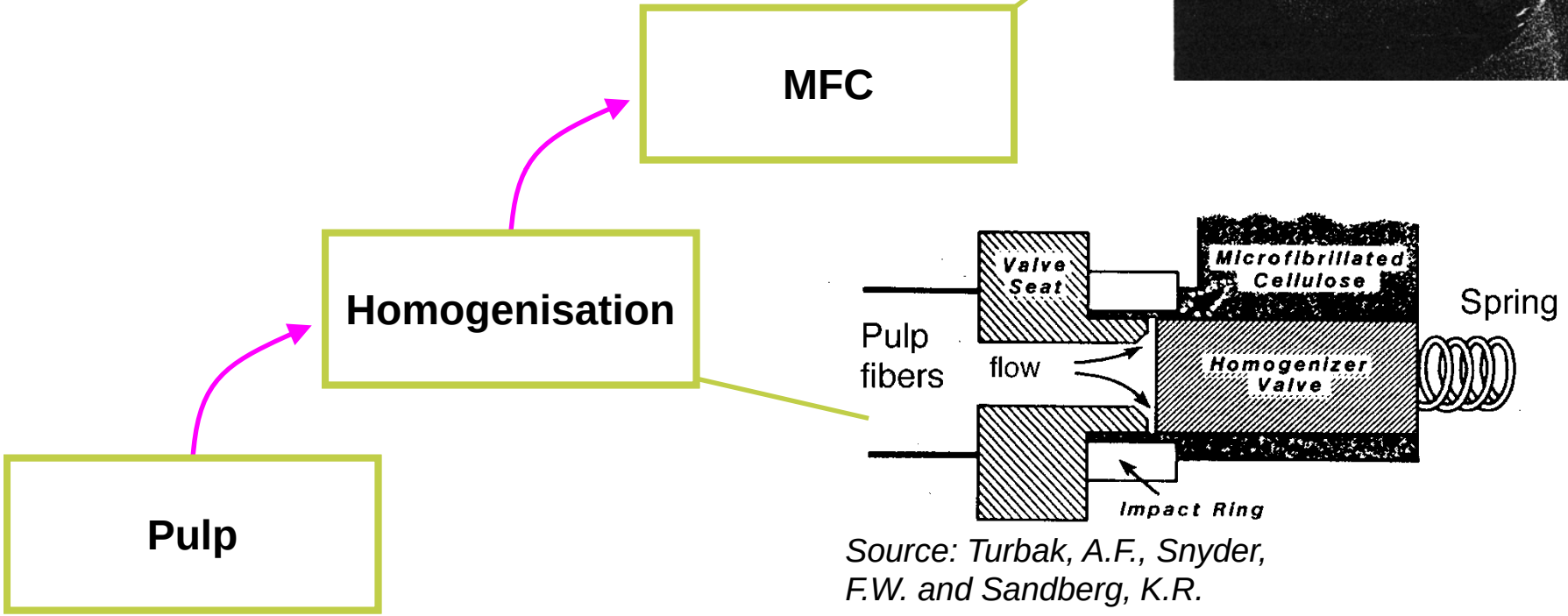
- Bio-nanocomposites in screw cap
- Nanobarrier inside the bottle
- Dry strength agent in board
- Rheology modifier in the food product



Microfibrillated cellulose (MFC) generation 0

Energy consumption = 30000 kWh/tonne



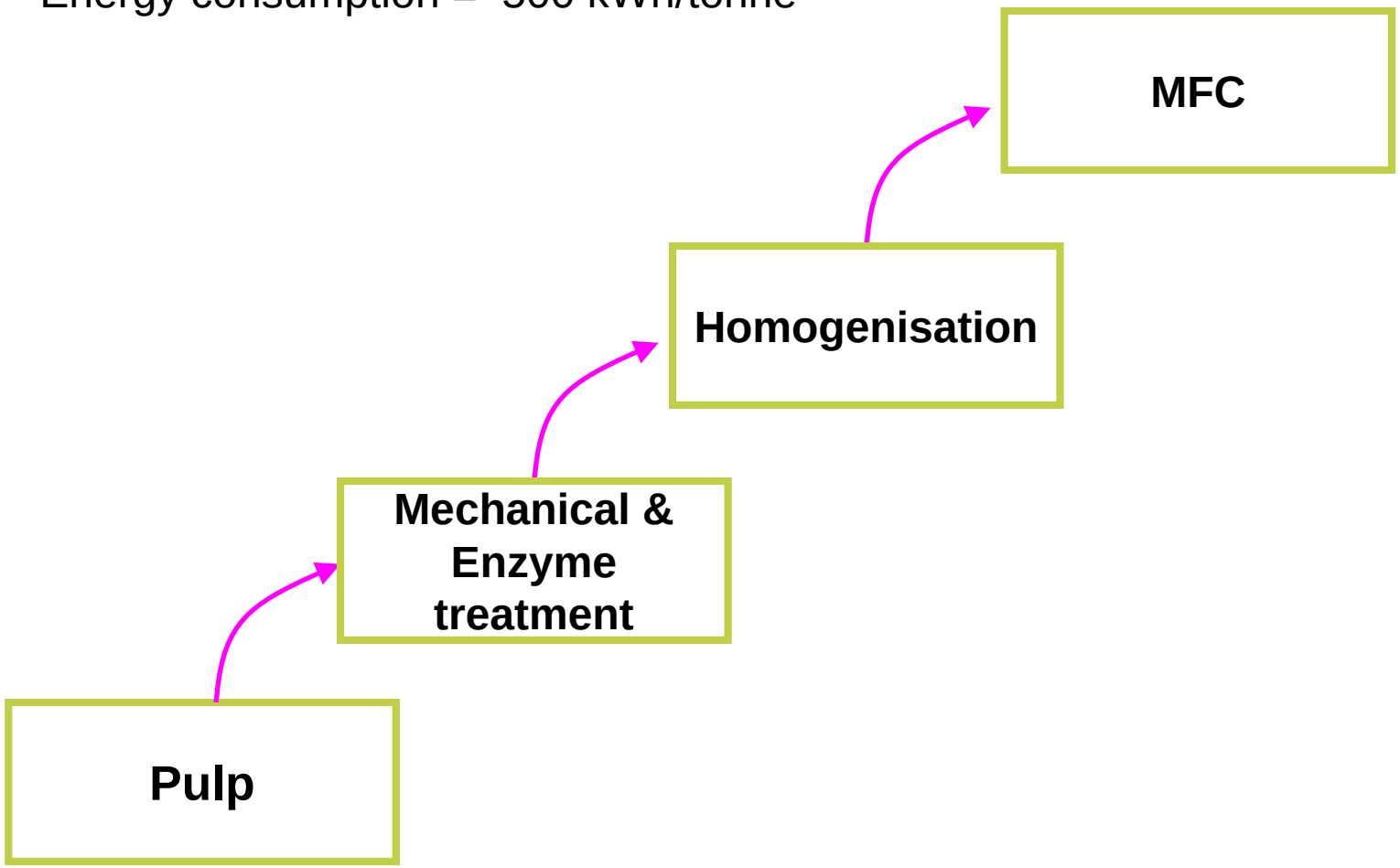


Source: Turbak, A.F., Snyder, F.W. and Sandberg, K.R. (1983). J. Appl. Pol. Sci.: Appl. Pol. Symp. 37: 815-827.

Source: Lindström, T. and Winter, L. (1988). Mikrofibrillär cellulosa som komponent vid papperstillverkning. STFI-meddelande C159 (internal STFI-report)

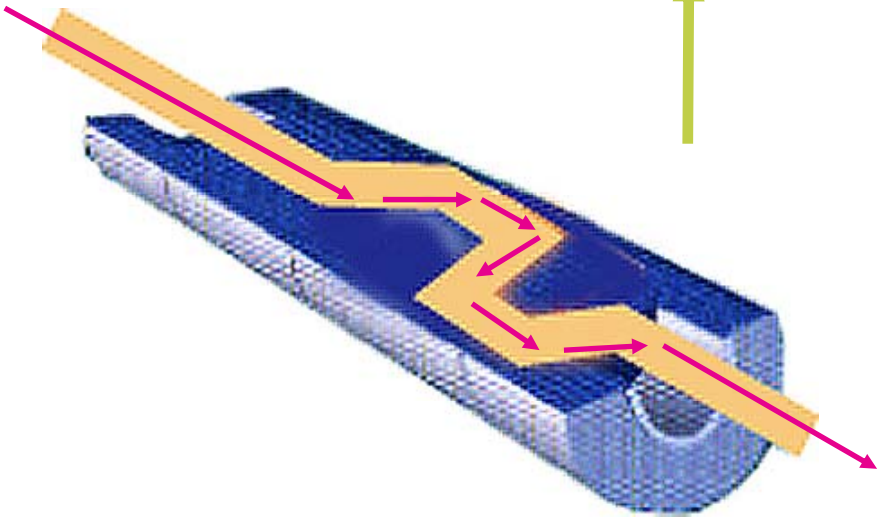
Solution – Pre-treatments

Energy consumption = 500 kWh/tonne



Laboratory nanofacility

Homogenisation in
Z-shaped chamber




Nanocellulose pilot plant
Capacity=100 kg/day

Need

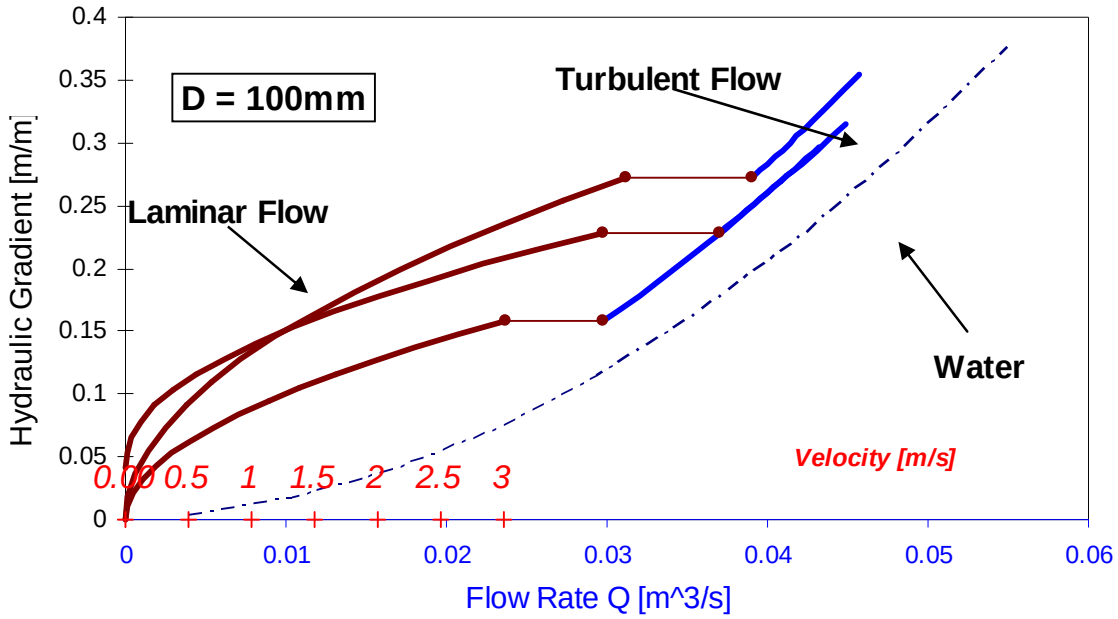
- In light of these developments with MFC is available, there is a strong interest in characterization:
  - Rheological
  - Large scale flow characteristics (at lower concentrations)
  - Drag reduction potential.
  - Morphological

- A lack of knowledge regarding the optimal design of processing systems.

- Interactions with other solids phases, e.g. papermaking materials such as fibres, retention aids, filler.

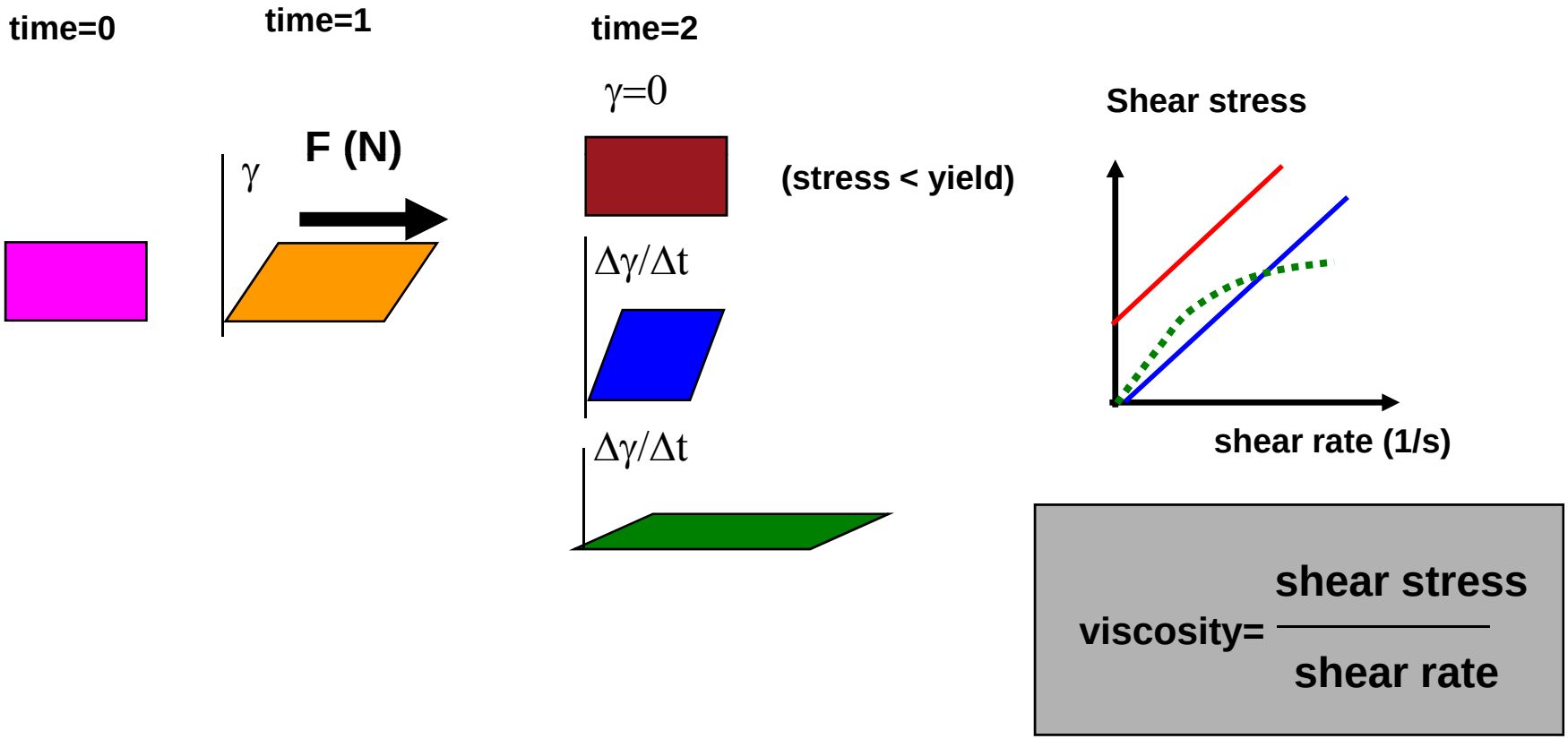
Discussion of rheology for suspensions

- Use information about MFC in the laminar region gives estimation for transition behaviour to turbulent flow region
- Reference to water gives the form of drag reduction
- *Of greatest interest*: a positive drag reduction, observed in fiber flows

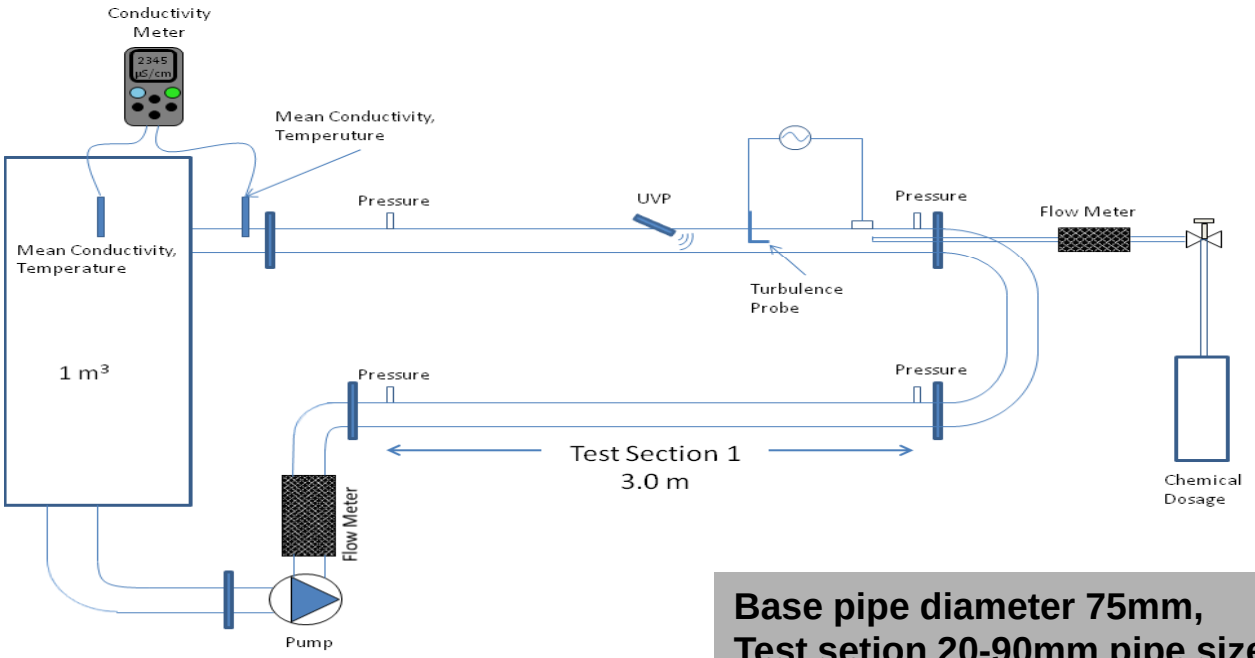


General : shear rheology

- A shear deformation and determination of the fluid respons



Approach: Experimental trials in a flow loop



Standard transducers:
pressue and flow rate

Advanced methods :
UltraSonicVelocimeter,
Conductiviety probe

Temperature control

Base pipe diameter 75mm,
Test setion 20-90mm pipe size

Tank volume 1000 liter

Centrifugal pump (4.2kW)
Variable Speed Drive

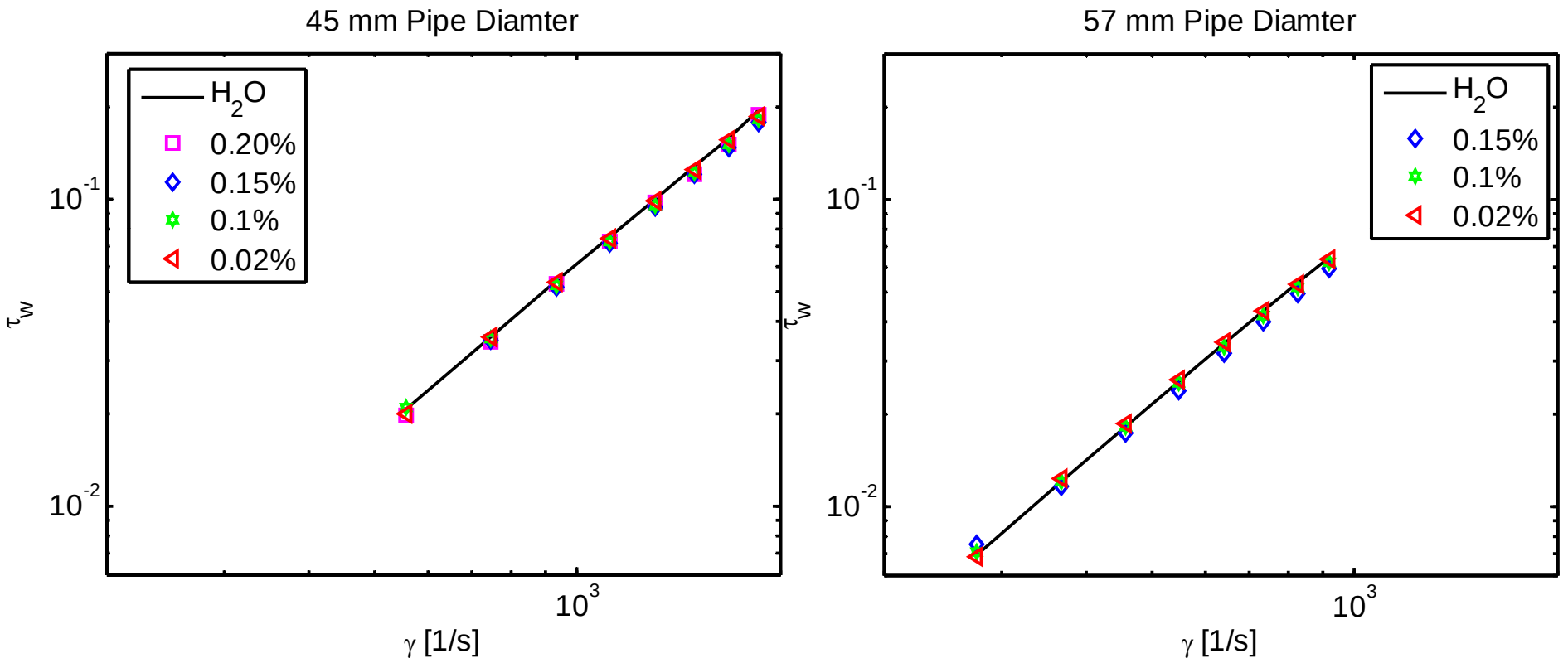
Characterization, shear flow condition

- Pressure drop, ΔP, measured across pipe length with differential pressure transducer.
- Shear Stress: $\tau_w = \frac{d\Delta P}{4L_p}$
- Strain rate: $\dot{\gamma} = \frac{8V}{d}$
- Fanning friction factor: $f = \frac{\tau_W}{\frac{1}{2}\rho V^2}$
- Drag Reduction: $\%DR = \frac{\Delta P_{H_2 0} - \Delta P_{suspension}}{\Delta P_{H_2 0}} \times 100\%$

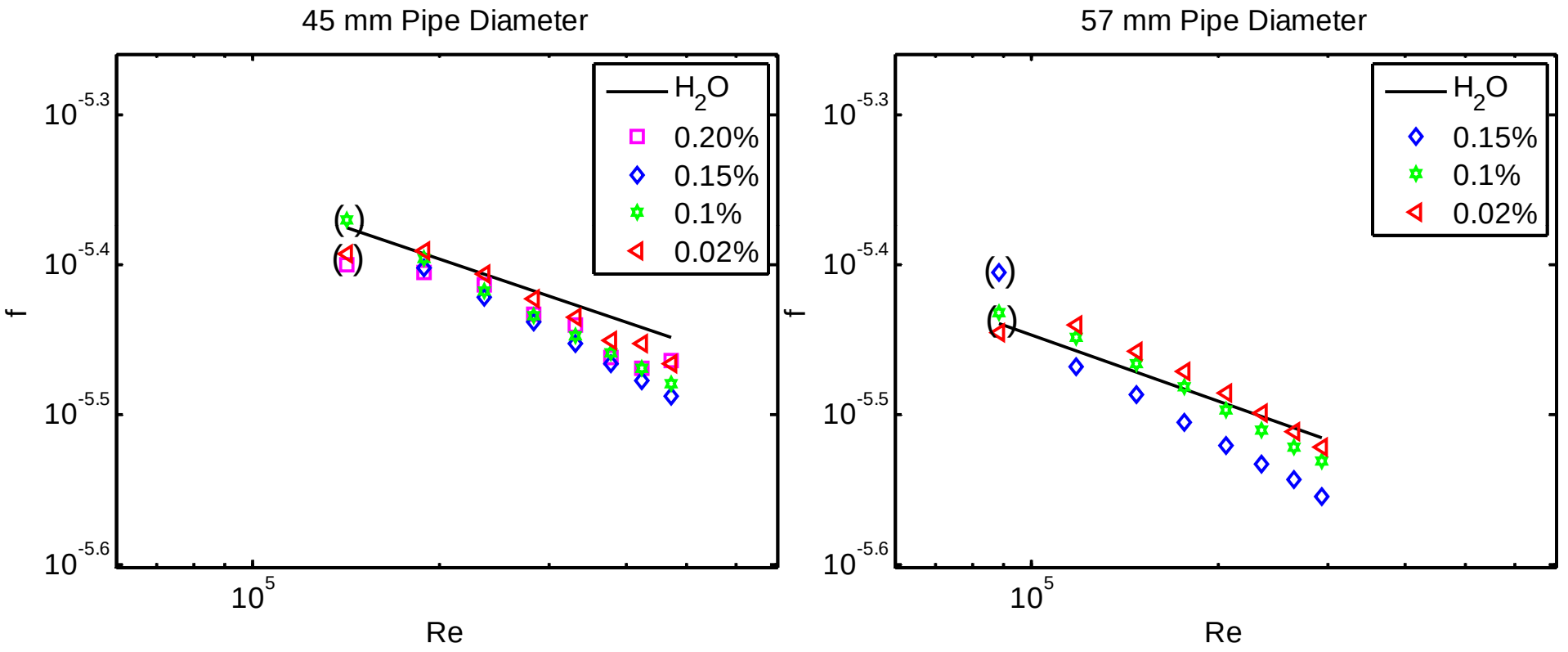
Trials Parameters

- Pipe length, L = 2.55m
- MFC, generation 1, 0.02% - 0.2% volume (and mass) fraction.
- Flow rate: 300 l/min – 1000 l/min.
- Pipe diameters: 45mm, 57mm
- Reynolds number (water based): $O(10^5)$

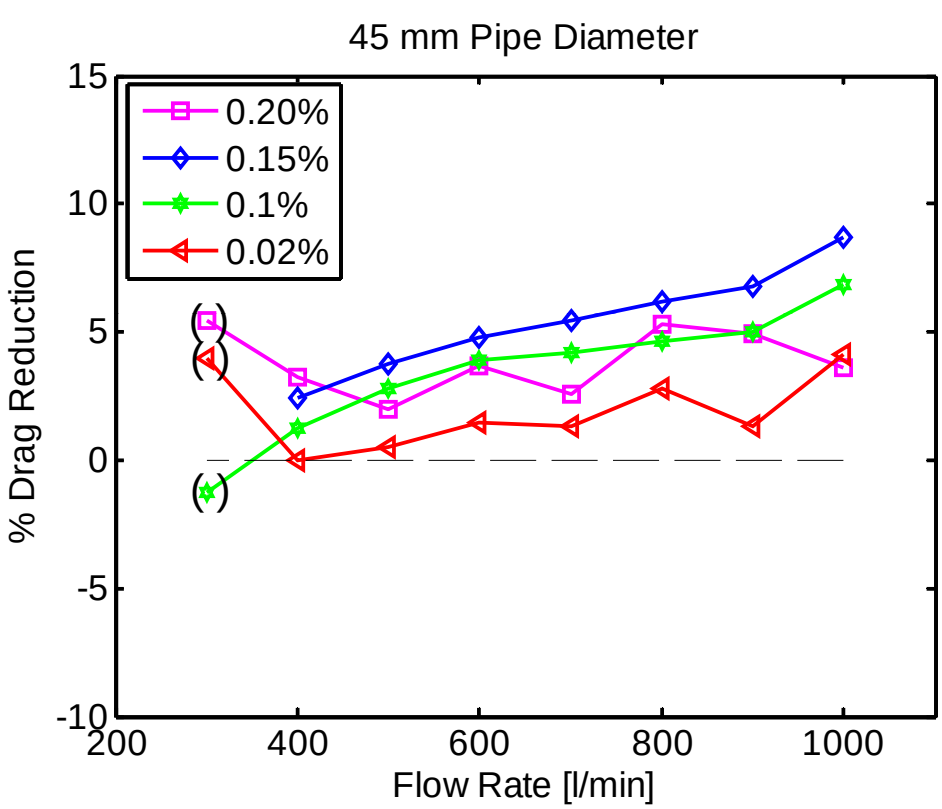
Stress-Strain – Turbulent Rheology

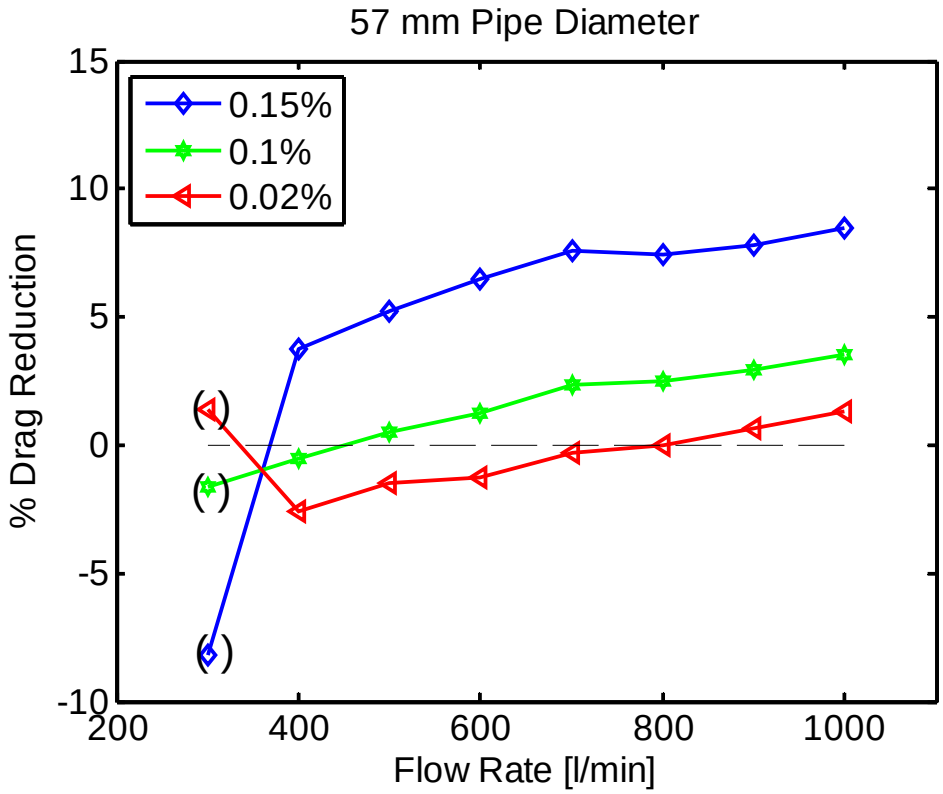


Friction factor – Reynolds number dependence



Drag Reduction





Summary

- Drag reduction characteristics of micro-fibrillated cellulose (MFC) were evaluated in a fully developed turbulent pipe flow.
- The MFC suspensions exhibit the same turbulent rheology as water.
- A maximum drag reduction of 9% was observed at a concentration of 0.15% in both pipes.
- Drag reduction is found to increase up to concentration of .15%, after which is found to decrease.
- Drag reduction was generally greater in the 45mm pipe.

Building Leadership Excellence

Thank you

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