Fluid dynamic challenges of future Nano Cellulose Fiber processes

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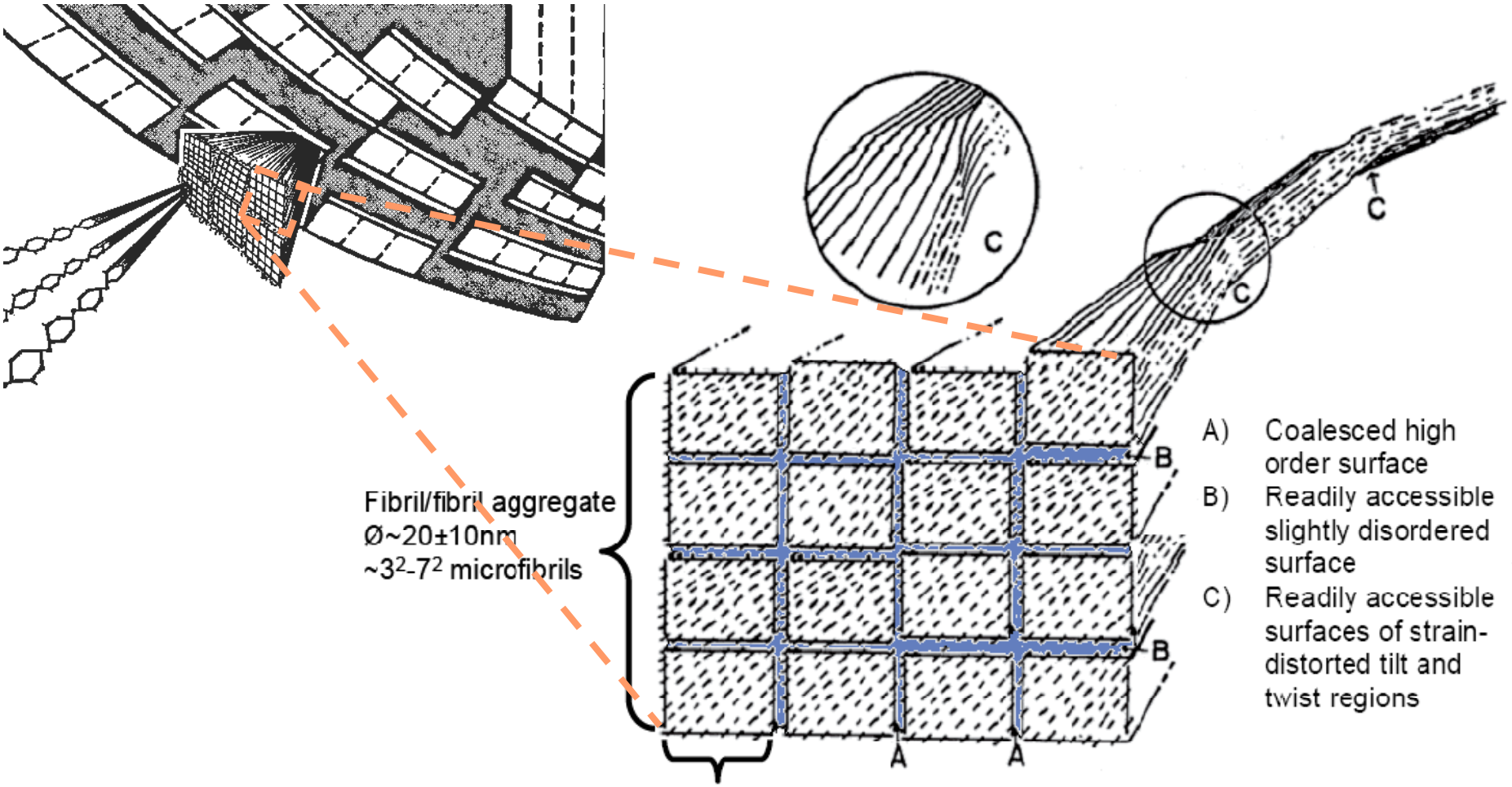
RETHINK PAPER:
Lean and Green

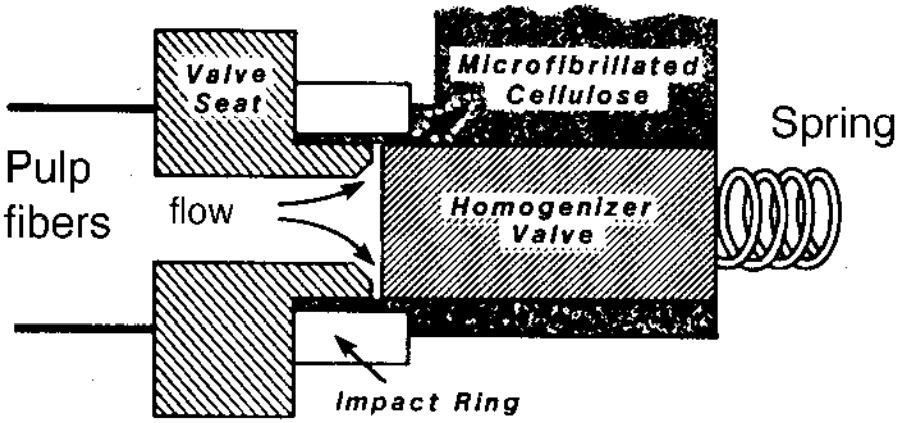
Organisation of Cellulose in Fibres

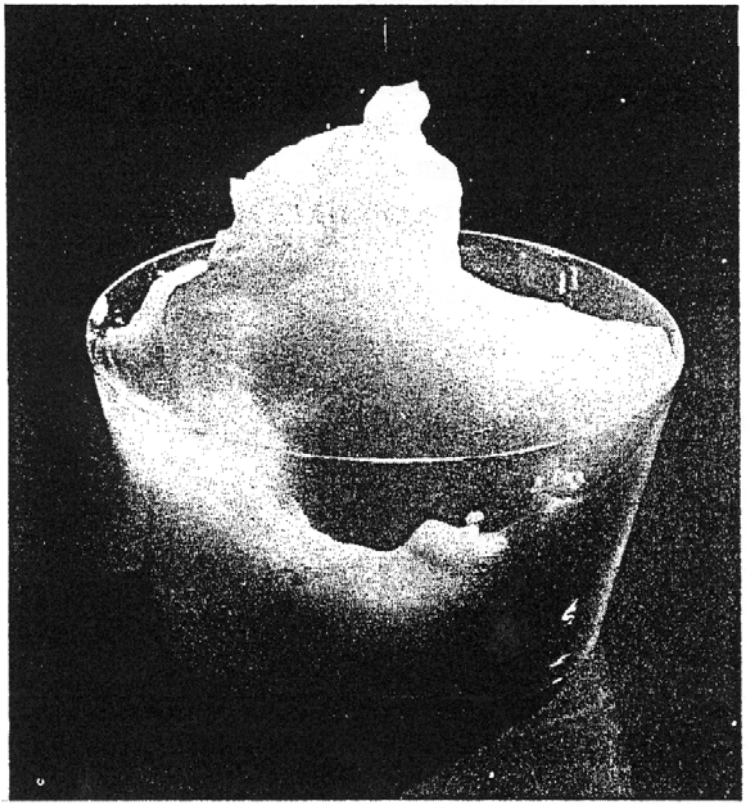


Adapted from:
Rowland and Roberts (1972)

Microfibrillar Cellulose (MFC)
Turbak and co-workers at ITT in the beginning of the 80´s

Disintegration (homogenization)





Microfibrillated Cellulose MFC
Turbak, A.F., Snyder, F.W. and Sandberg, K.R.
J. Appl. Polym. Science. Applied Pol. Symp. 37
(1983)

NanoCellulose Gel (Innventia)

Nomenclature

- Microfibrillated cellulose (MFC)
  - Original name
- Nanocellulose
  - Collective name for all types of nanocellulose. Used for this material the last 10 years.
  - Other nanocelluloses are NanoCrystalline Cellulose (NCC) and Bacterial NanoCellulose (BNC)
- Nanofibrillated cellulose (NFC) = new name started to be used 2 years ago

NFC particle size

NFC width/diameter

- TEM-imaging: 5-30 nm
- AFM-imaging: 5-30 nm
- Solid state NMR: 17 nm
- Light scattering: 20 nm

NFC length

- Indicative length = 100 nm to > 1 μm

NFC aspect ratio l/d

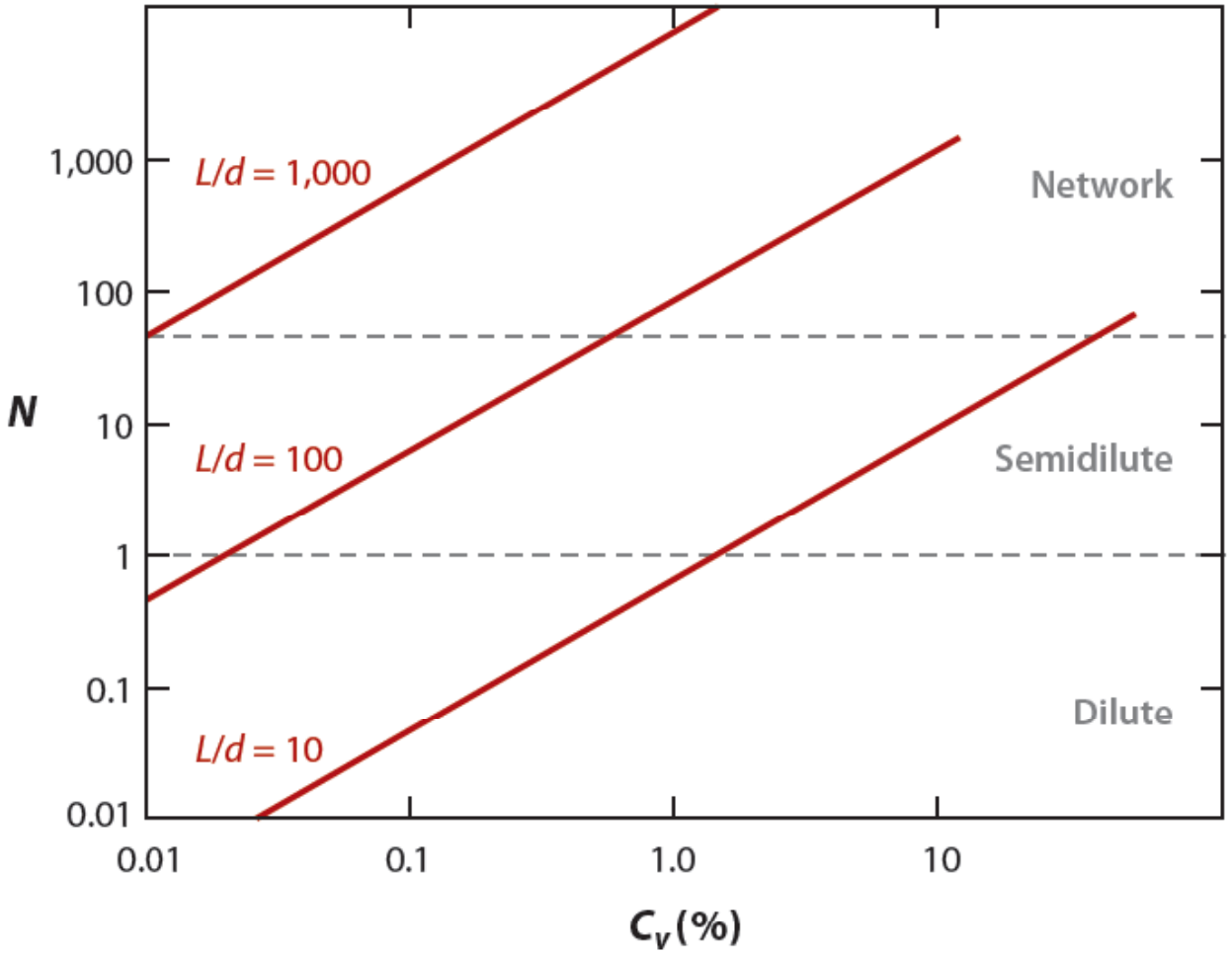
- Given the above data $5 < l/d < 200$

Flocculation state characterization
(Kerekes 1992)

Crowding Factor N:

$$N = \frac{2}{3} c_v \left(\frac{L}{d} \right)^2$$

Crowding factor and concentration as a function of aspect ratio

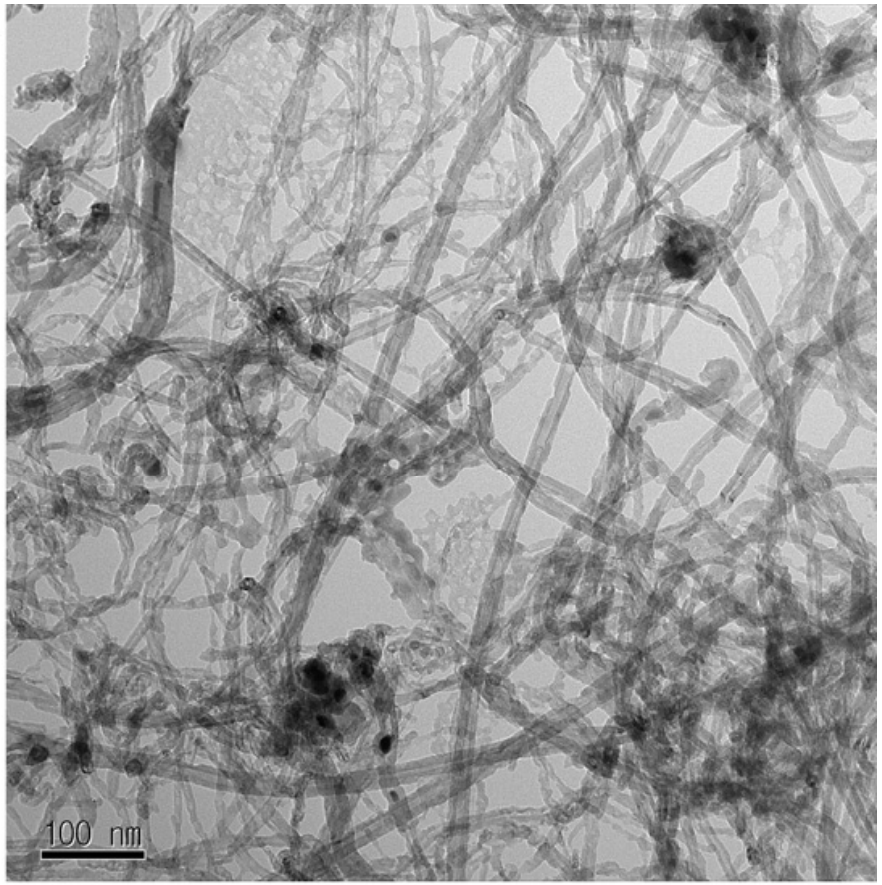


Lundell, Söderberg and Alfredsson (2011), Annu. Rev. Fluid Mech, 43

WHAT DO WE NOW FROM OTHER AREAS?

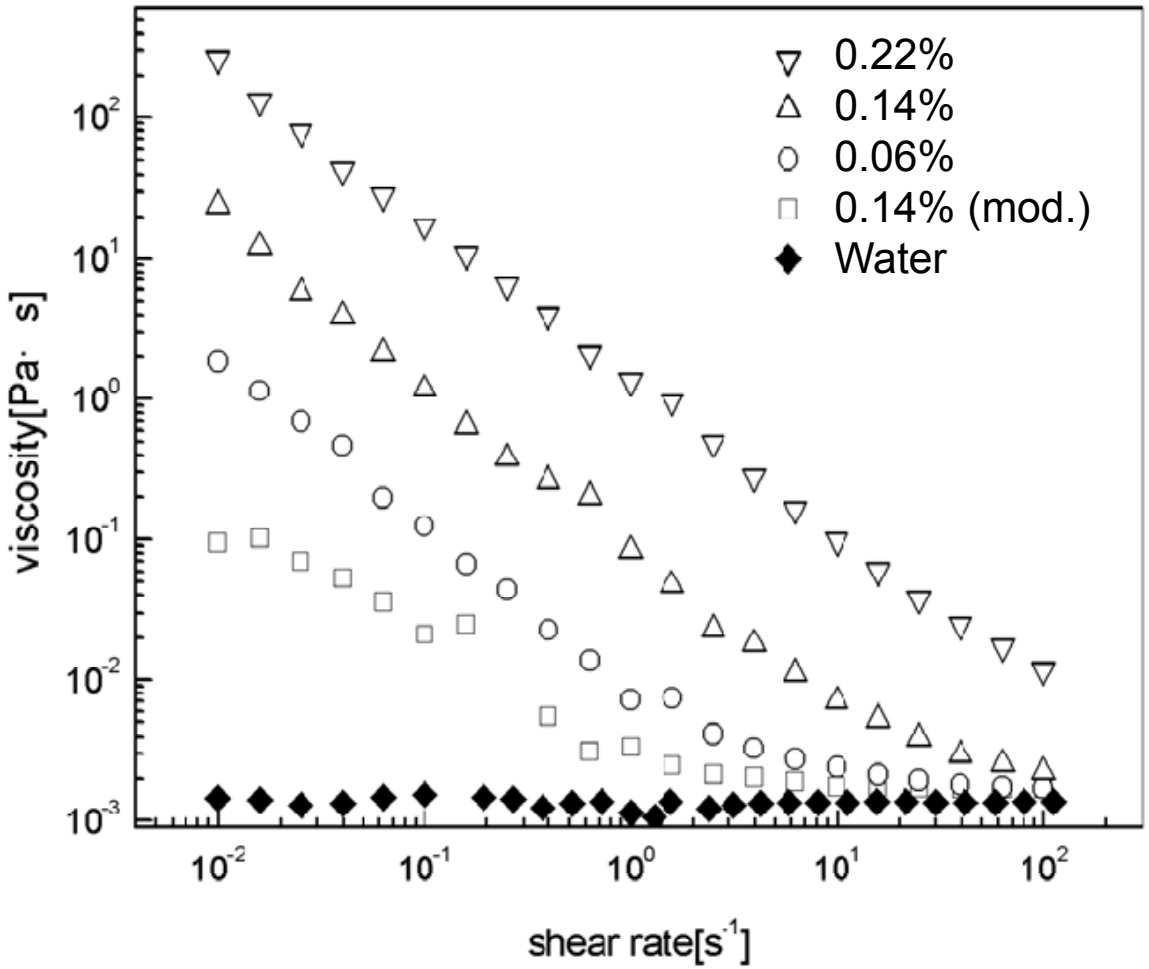
What do we know from other areas?
Carbon nano-tubes

C_V=0.05%

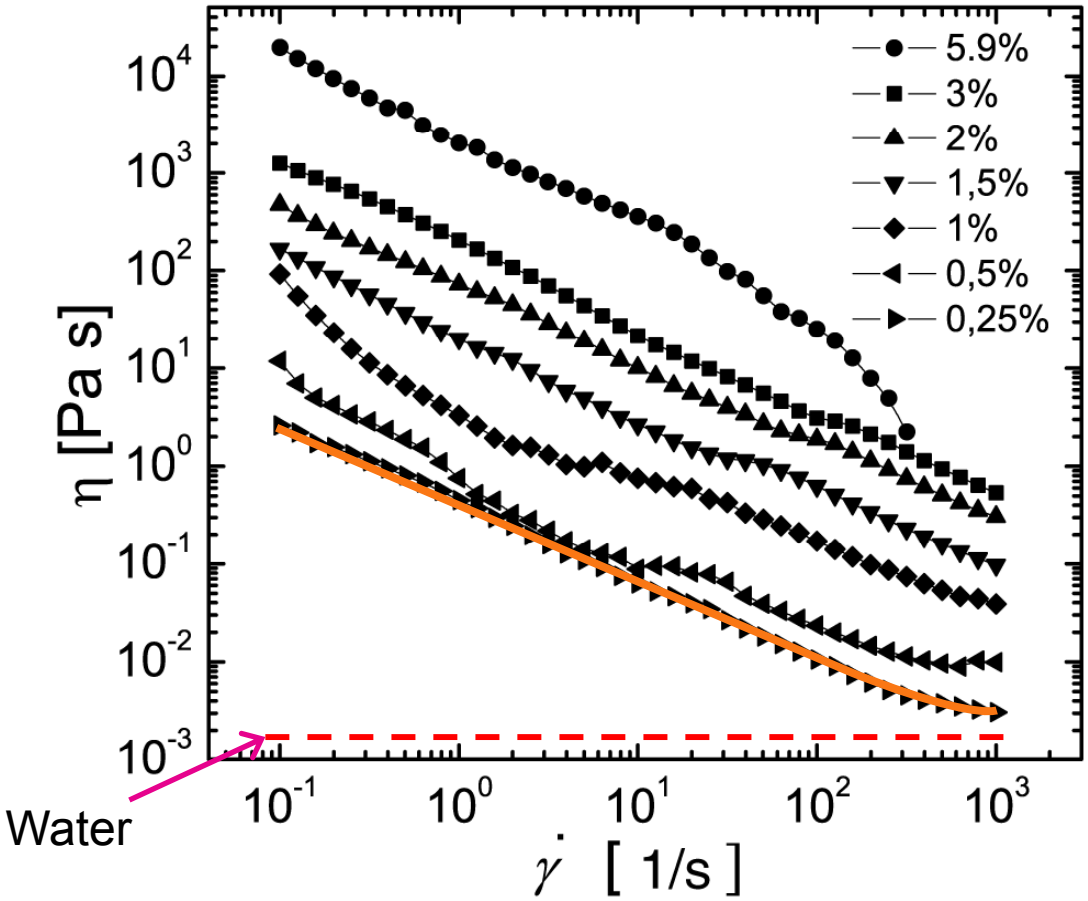


Hyun Koa, Heo, Lee, Kim, Kim, Sohn, Choi (2007), Int. J. of Heat and Mass Trans., 50

Shear thinning comparison
Carbon nano-tubes

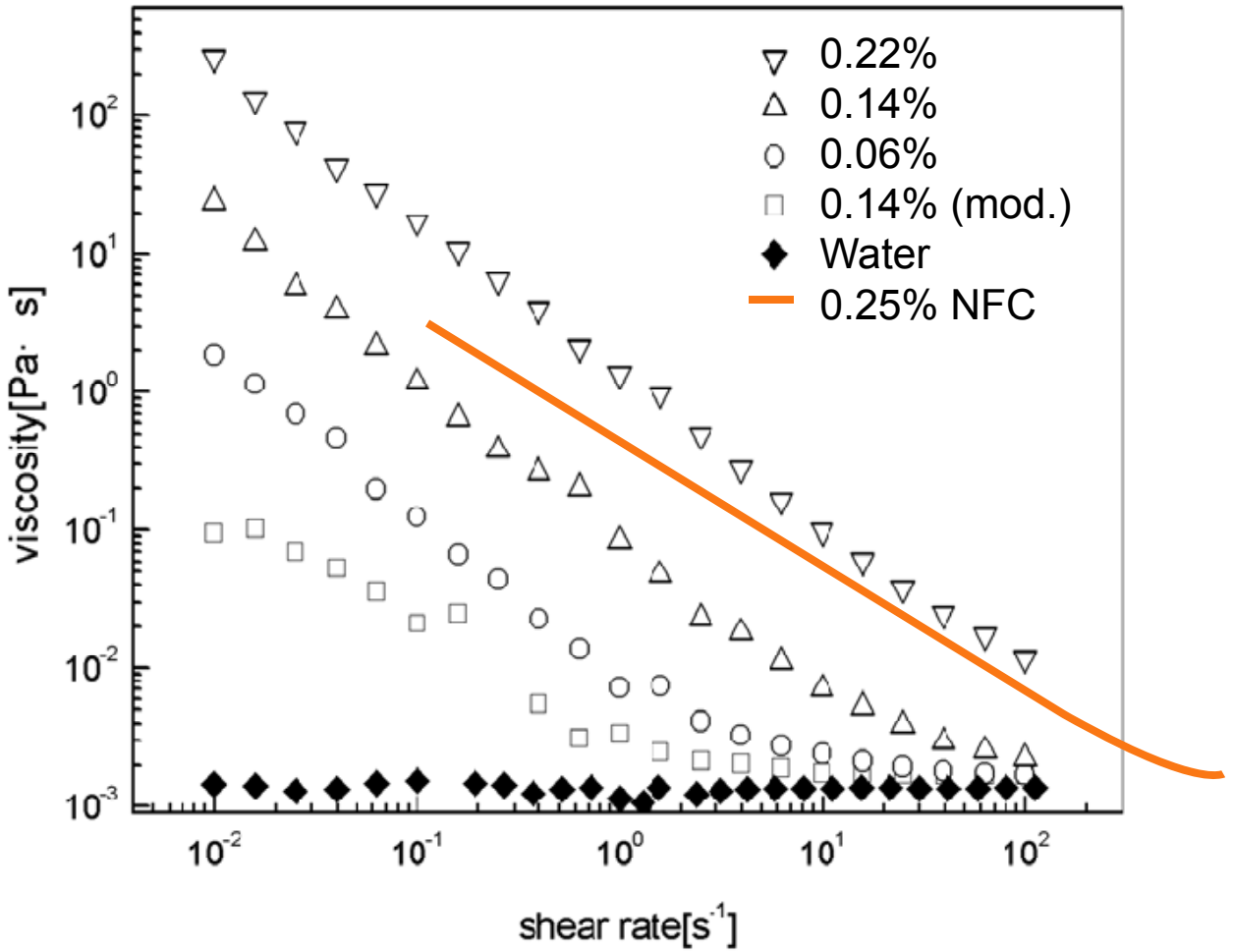


Shear thinning
Nanocellulose



Source: Pääkkö, Ankerfors, Kosonen, Nykanen, Ahola, Österberg, Ruokolainen, Laine, Larsson, Ikkala and Lindström (2007): Biomacromolecules 8(6)

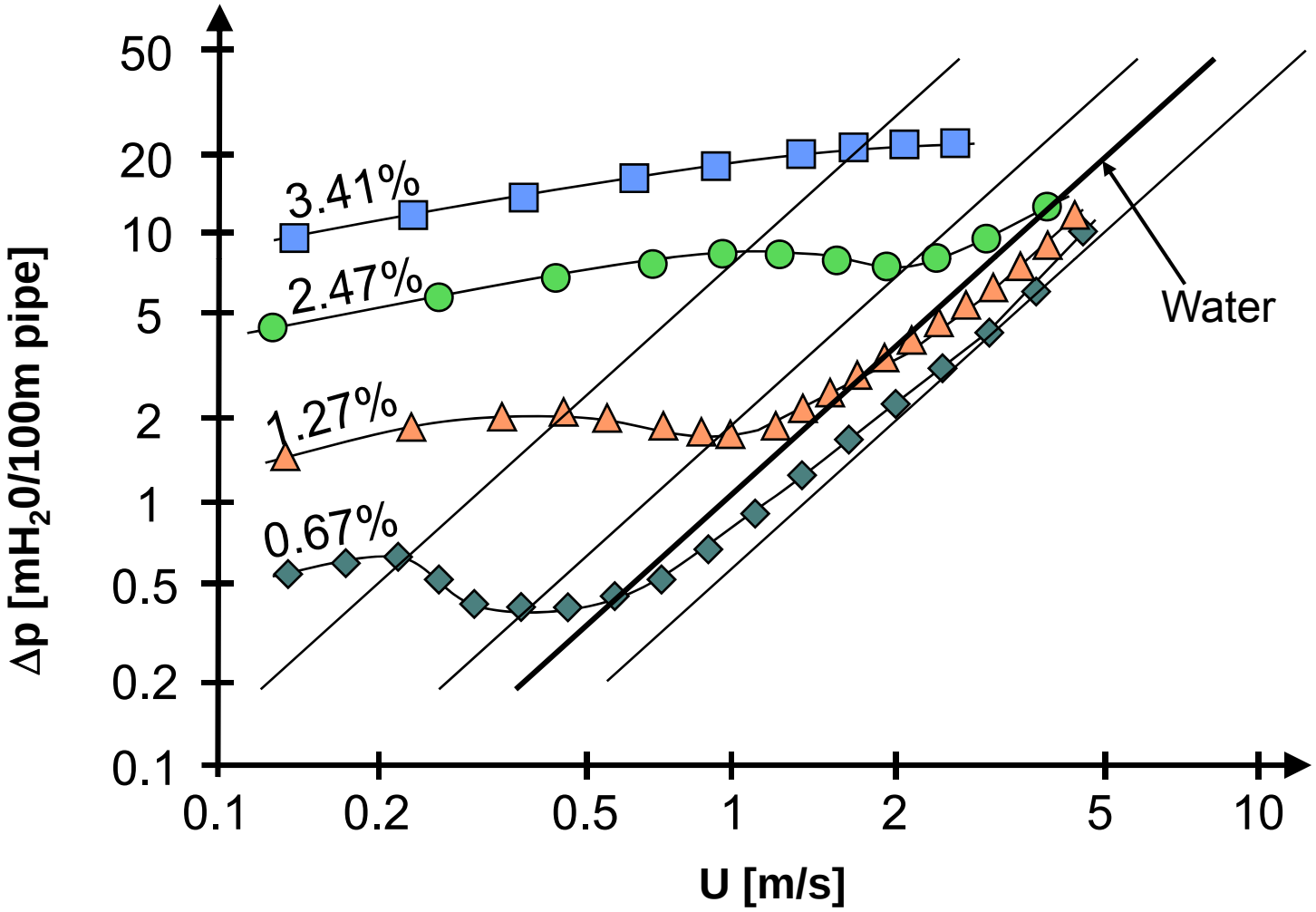
Shear thinning comparison
Carbon nano-tubes



WHAT ABOUT HIGHER FLOW-RATES?

Measured pressure loss

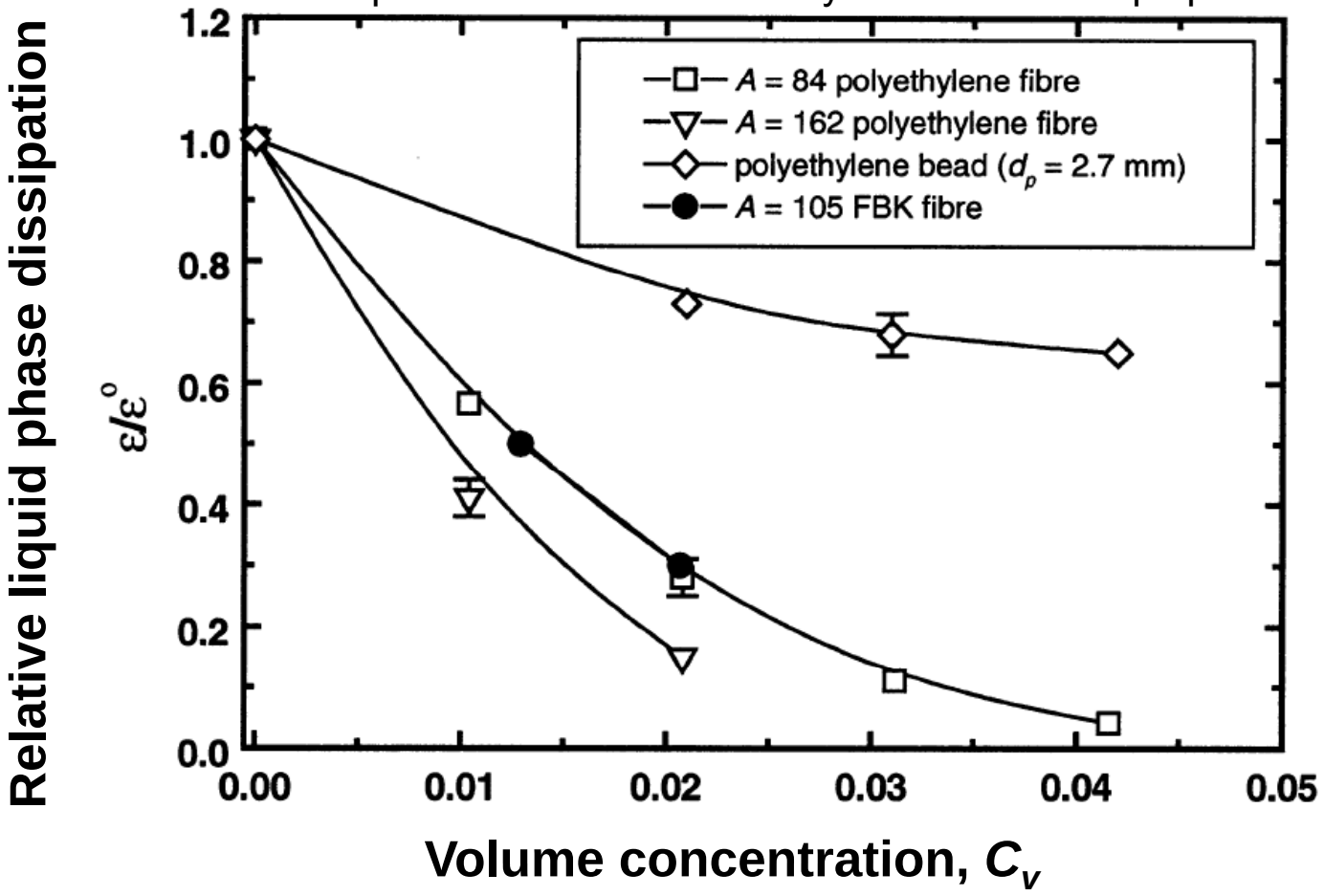
Long-fibre chemical pulp



Effect of fibres

On relative liquid-phase dissipation

A = aspect ratio and FBK = Fully Bleached Kraft pulp

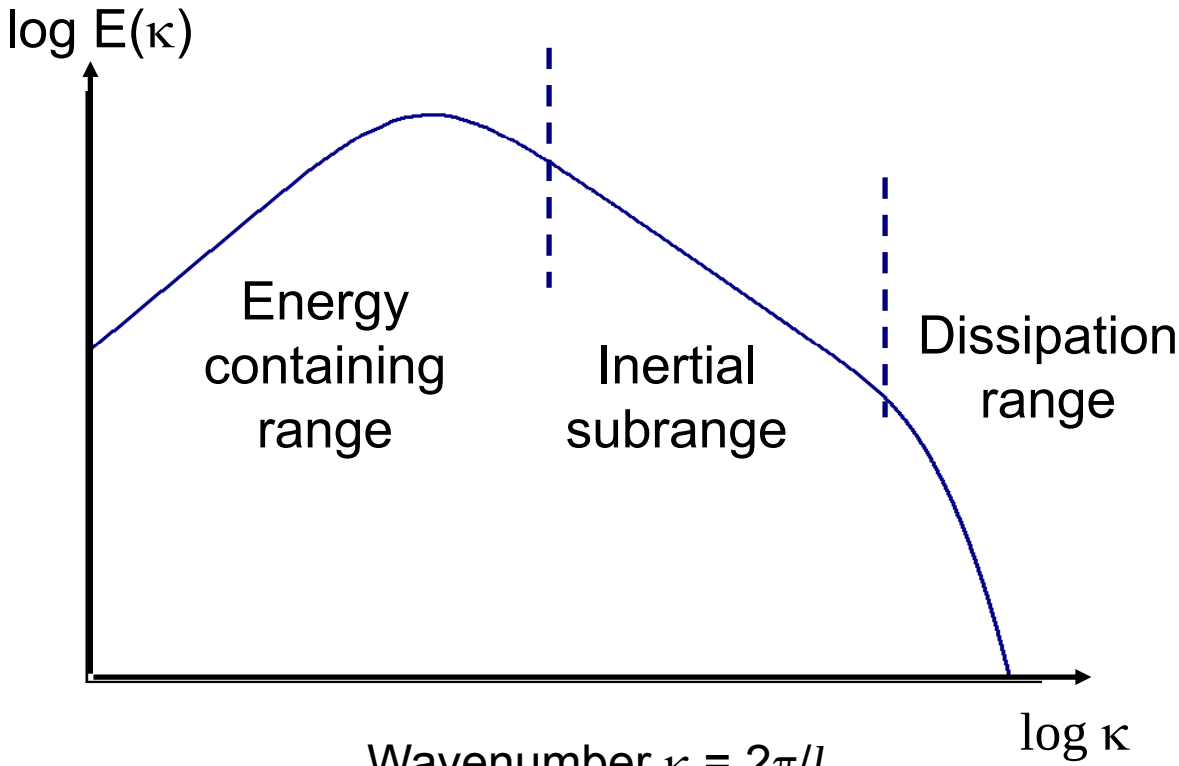


Bennington & Mmbaga, *12th Fundamental Research Symp. 2001*

Turbulent spectrum

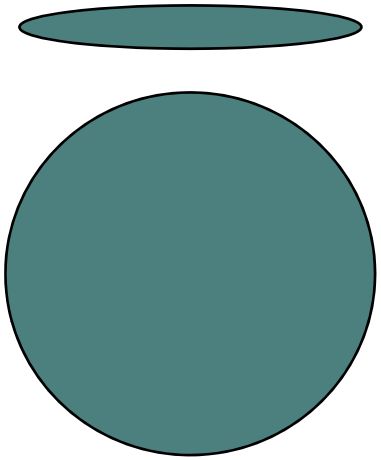
By definition the turbulent kinetic energy k is the integral of $E(\kappa)$ over all wavenumbers

$$k = \int_0^\infty E(\kappa) d\kappa$$



Wavenumber $\kappa = 2\pi/l$
where l is the eddy size

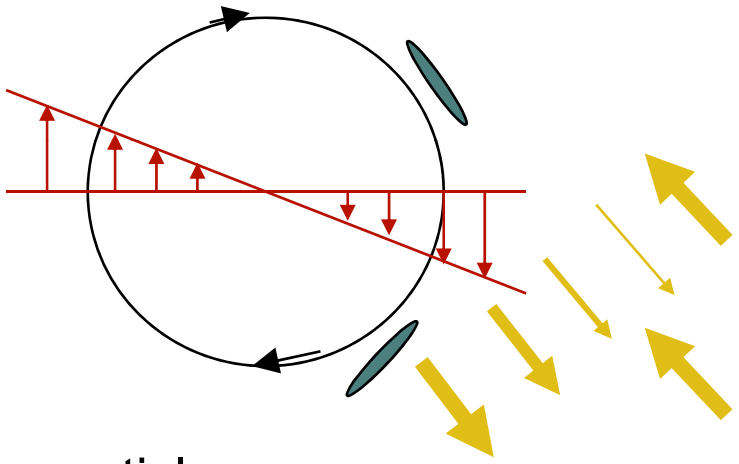
Visualization technique

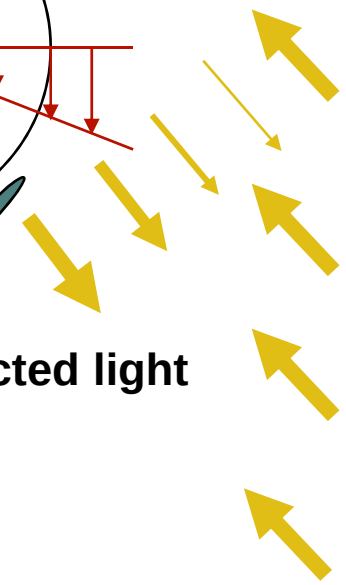


Platelets

$D \approx 5\mu m$

Vortical structure in the flow





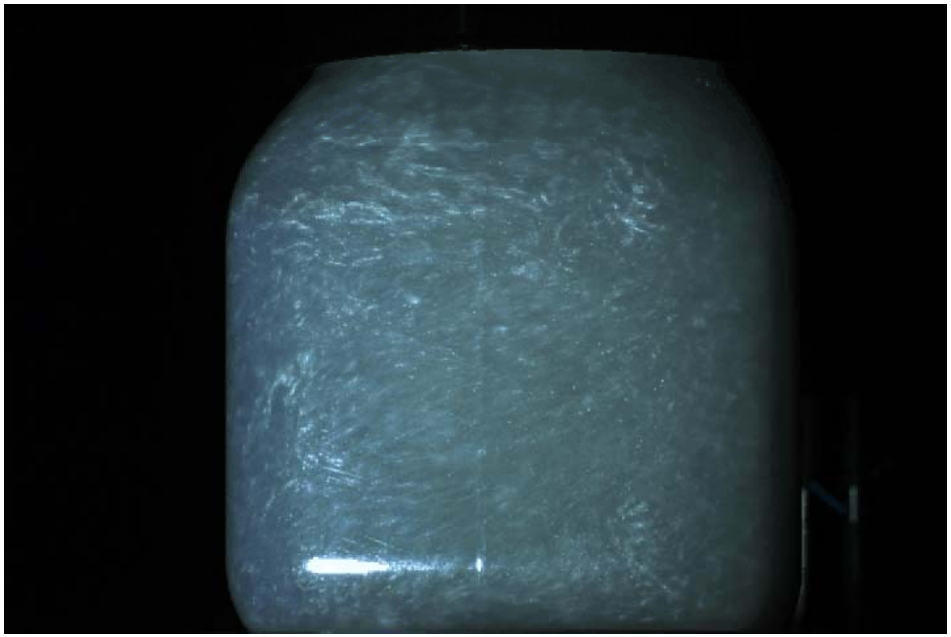
Reflected light

Incident light

- Structures in the flow are visualized by Iriodin particles
- The flow is filmed by a digital camera
- Analysis of captured images can provide data of the flow condition and structure size

Turbulent decay

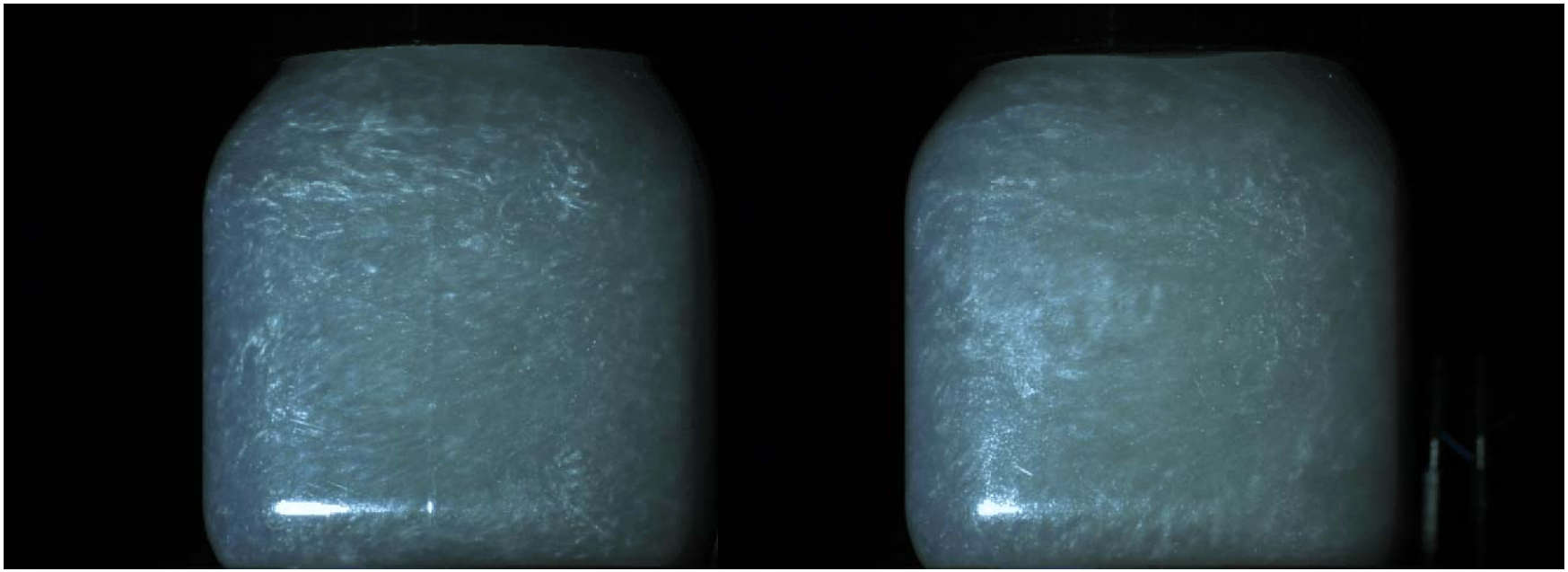
Iriodin particles are added to visualize flow structures



Water

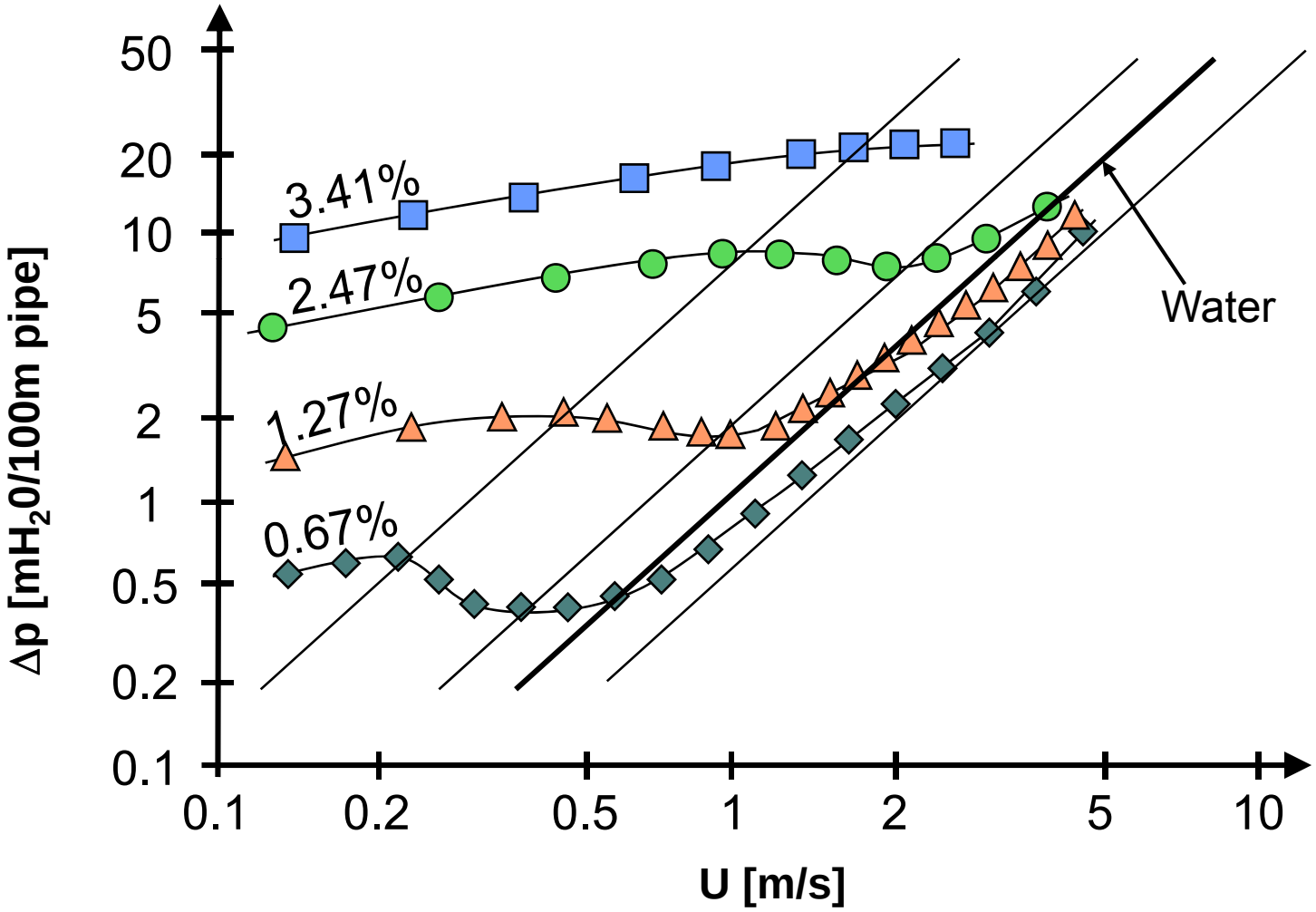
Turbulent decay
Fibres strongly modify turbulence

Iriodin particles are added to visualize flow structures



Without pulp **With 0.2% NBSK**

Measured pressure loss
Long-fibre chemical pulp



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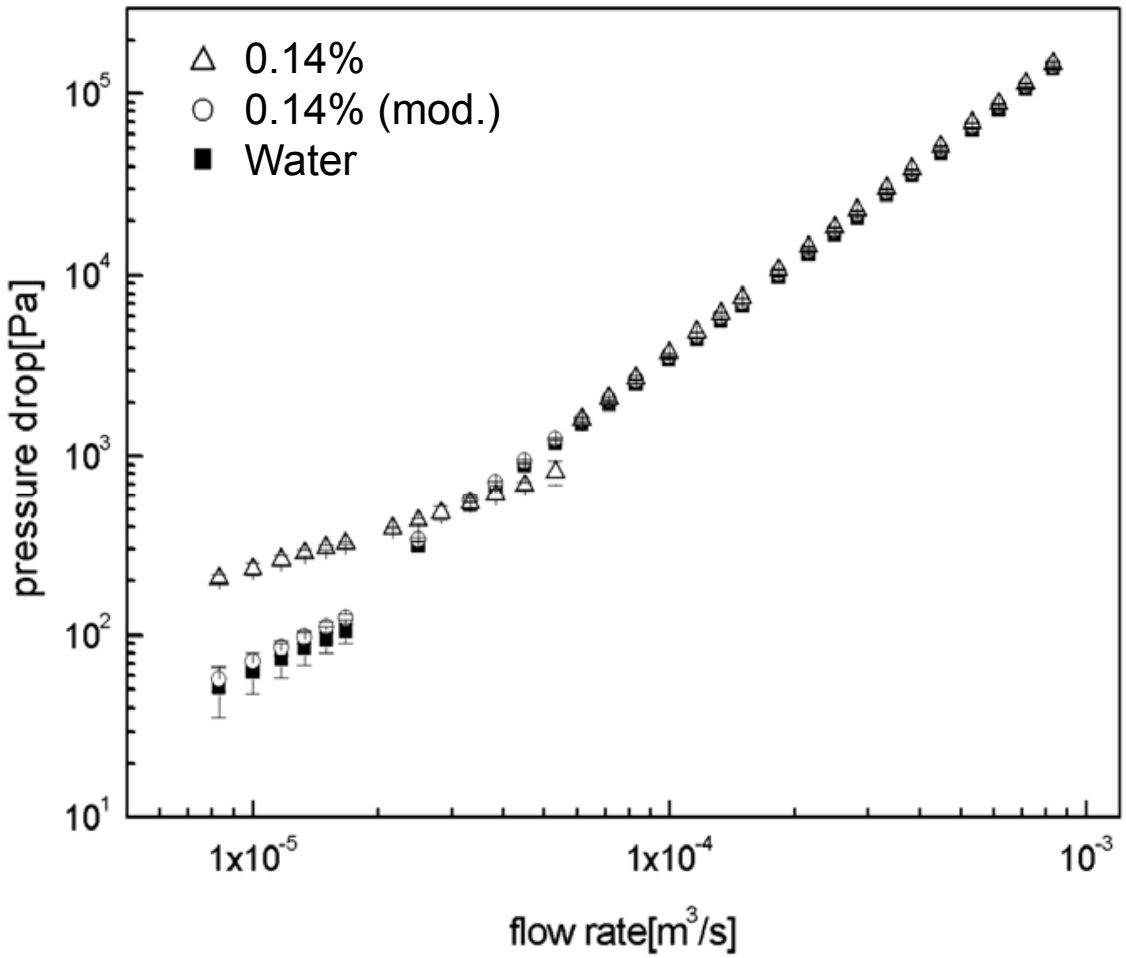
Carbon nano-tubes



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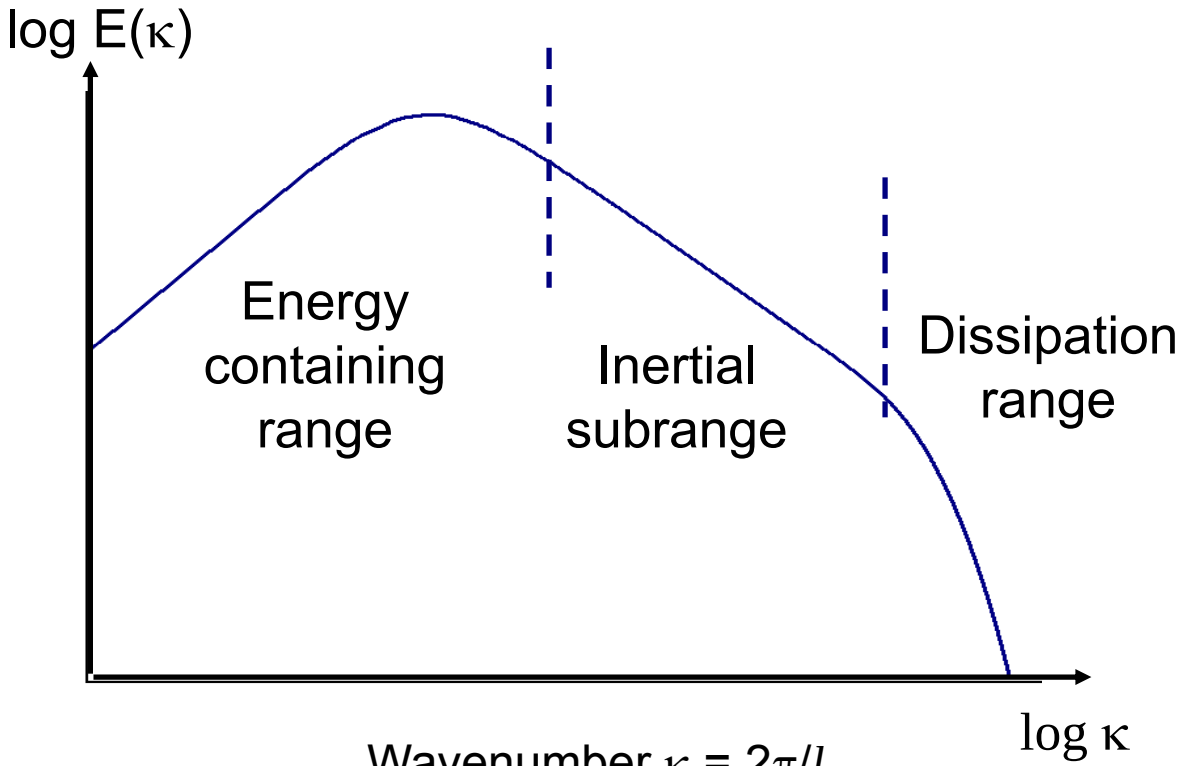

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where l is the eddy size

Conclusions

- NFC will probably (at least so some degree) behave as other elongated nano-particles
- Maybe some characterstics from non-nano fibre suspensions (pulp) will also be present?
- Strong effect of concentration in various processes
  - Pumping
  - Mixing
  - Fractionation
  - Dewatering
  - Drying
- All data seem to show shear thinning behaviour = good!
- New material forming processes needed!