



Cellulosic nanomaterials with preferred orientation



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und Prozesstechnik

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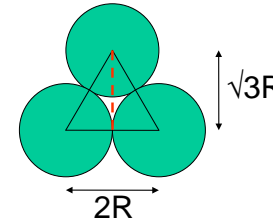
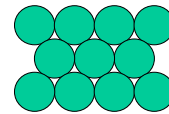
Benefits of orientation



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Higher fibre volume fraction

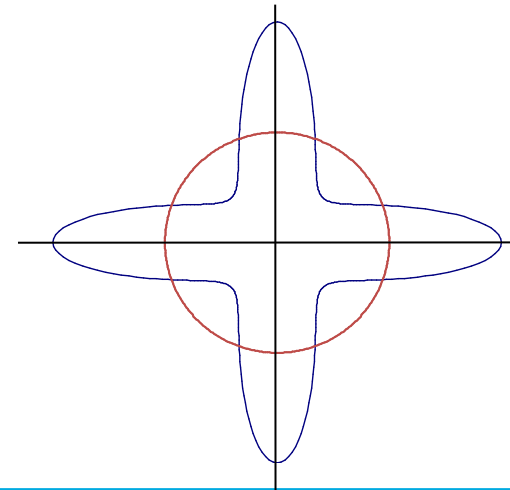
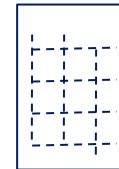
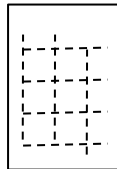
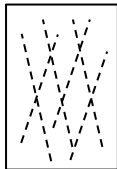
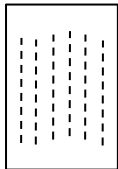
~ 50% with nonwovens, theoretical maximum 91% in UD composite



Anisotropy

At the same Vf, E-random is at best 1/3 of EI-UD

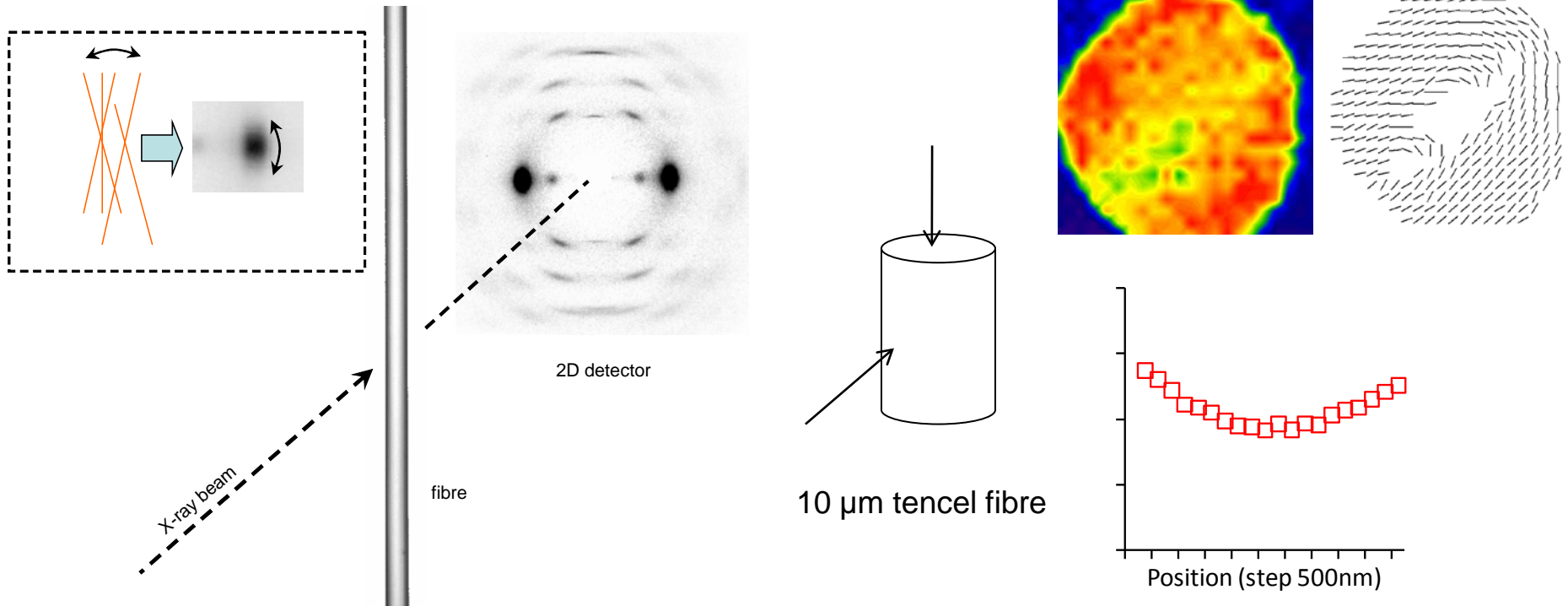
More design options



Ways to quantify orientation in cellulose

Orientation of crystalline domains by WAXS

Beam size from several 100 μm down to 200 nm



Ways to quantify orientation in cellulose



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Average orientation from birefringence measurement using polarized light microscopy



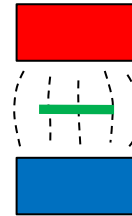
Polarized Raman microscopy => average orientation

Microscopy + image analysis for discrete objects

Overview of possible approaches

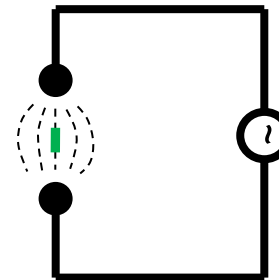
Strong magnetic field (7T)

Sugiyama et al. *Macromolecules* 1992

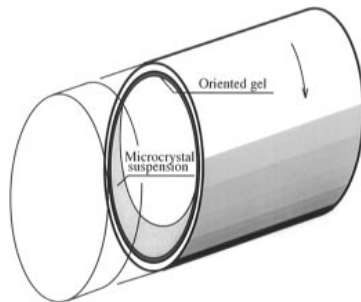


Strong AC field (1kHz, 1kV/cm)

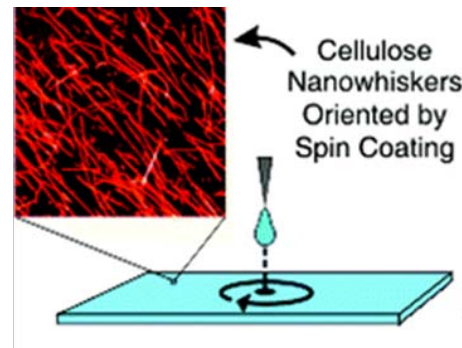
Bordel et al. *Langmuir* 2006



Shear



Nishiyama et al.
Macromolecules
1997



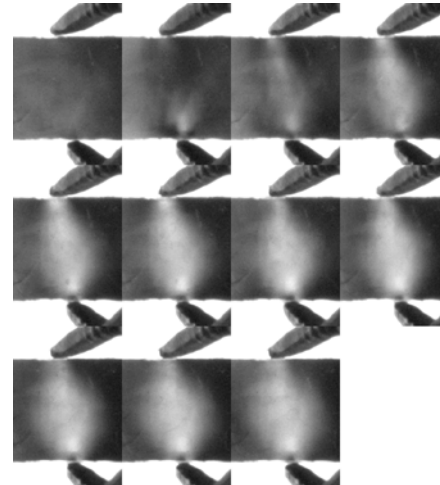
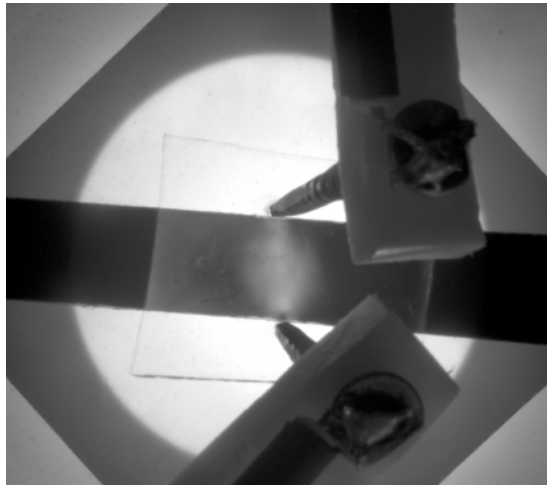
Dugan et al.
Biomacromolecules 2010

- Fibre spinning
- Spinning disc
- Rotating drum
- Post-drawing

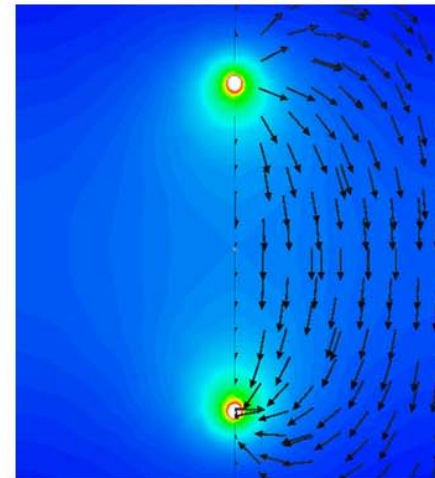
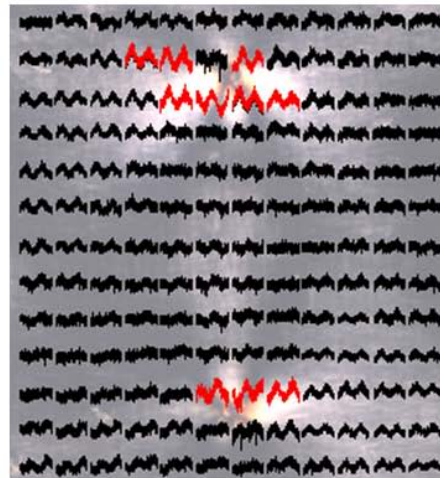
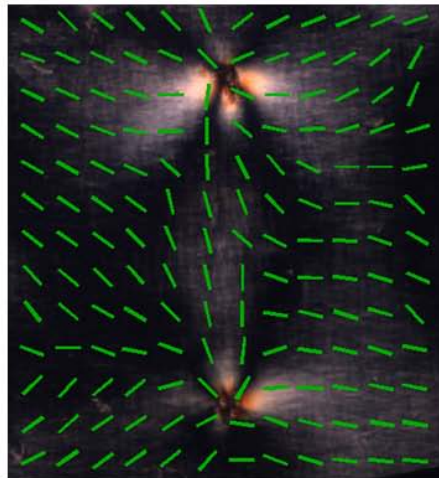
Orientation by an AC electric field



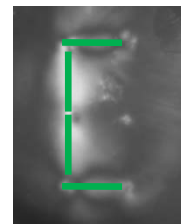
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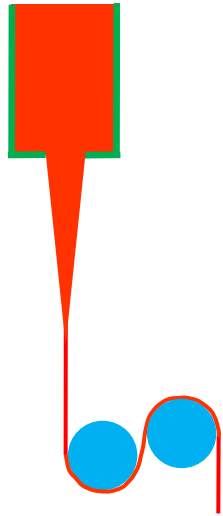
Gindl et al. *Biomacromolecules* 2009



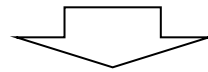
(V cm⁻¹)
 2000
 1000
 500
 50



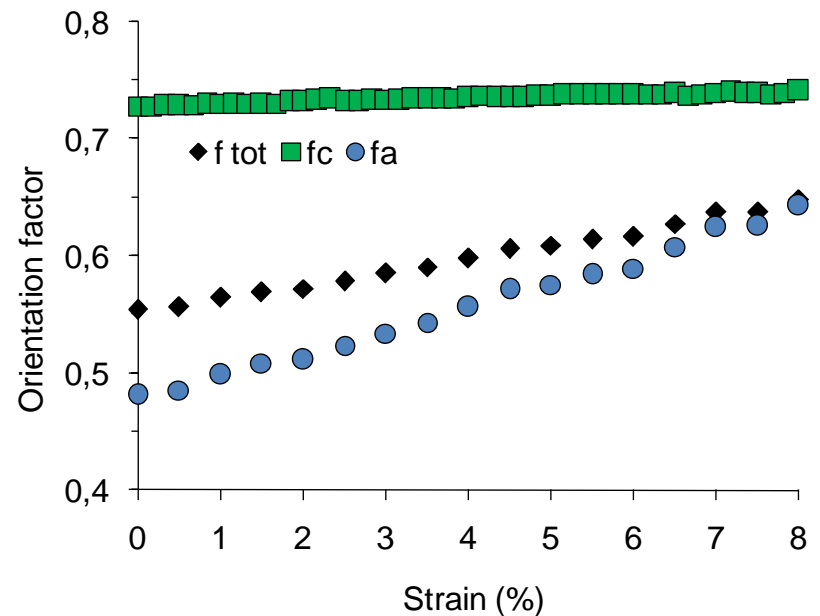
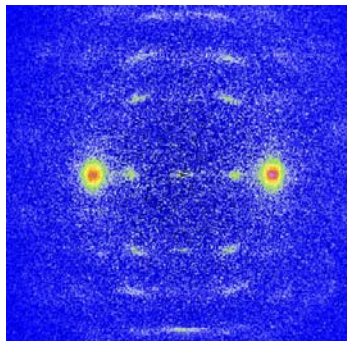
Spun cellulose fibres



Take-up speed > extrusion speed

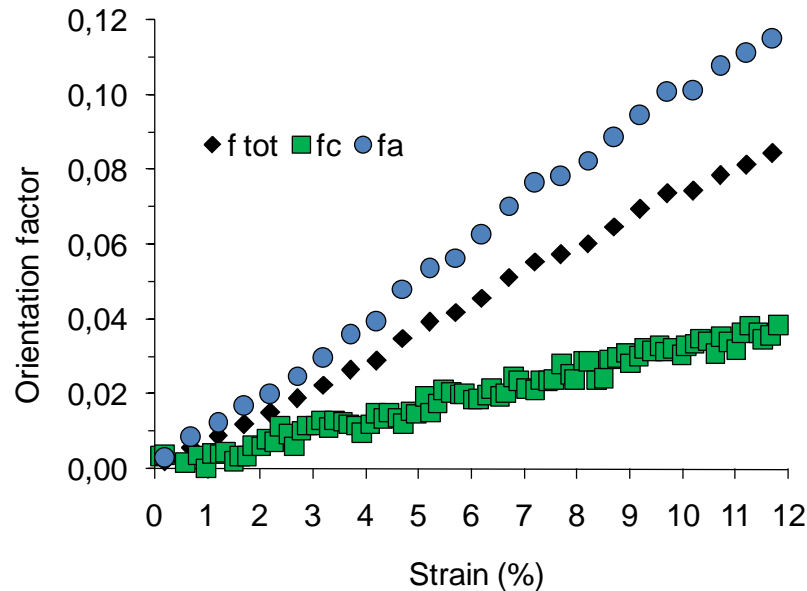
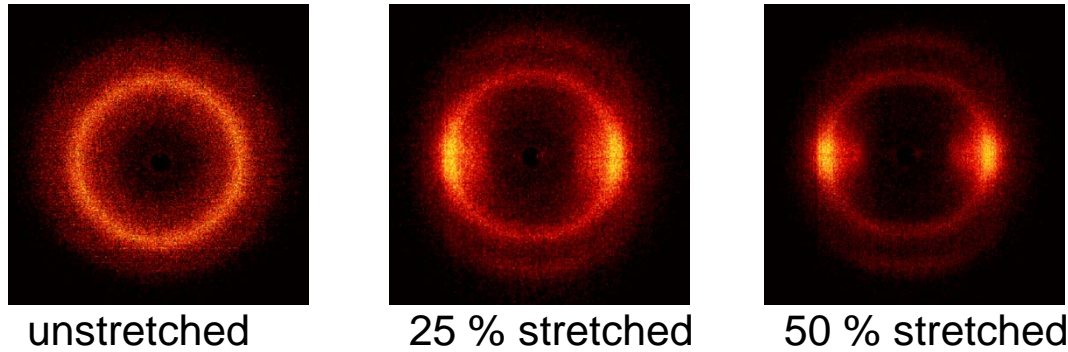


High f_c ; f_a improved by post-drawing



Gindl et al. *J Polym Sci B Polym Phys* 2008

Wet-drawn cellulose II films with undissolved cellulose I crystals



E: 10 => 32 Gpa
 σ : 200 => 400 Mpa
 ϵ : 16 => 3 %

Gindl et al. *J Polym Sci B Polym Phys* 2008

Oriented sheets of MFC

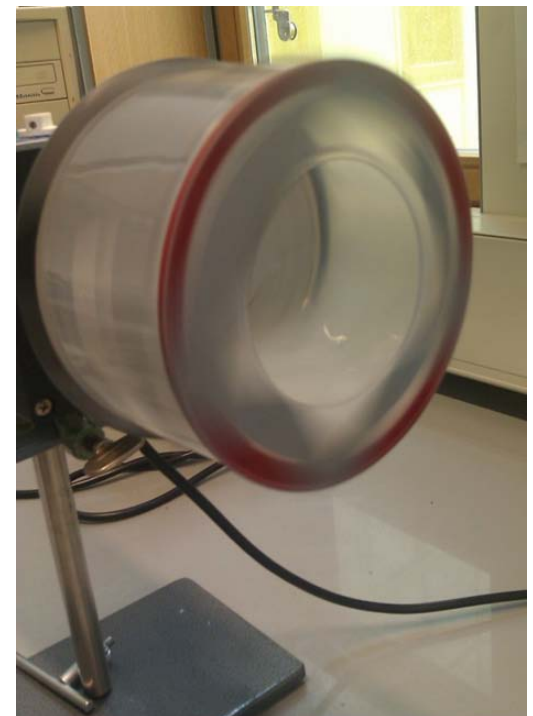


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Rotating drum method: rotation speed,
fibril content, entanglement of fibrils,

Post drawing: Strong interfibril bonds in
once consolidated films – network
formation

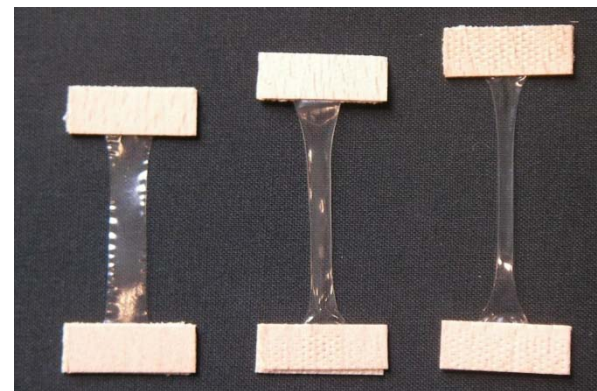
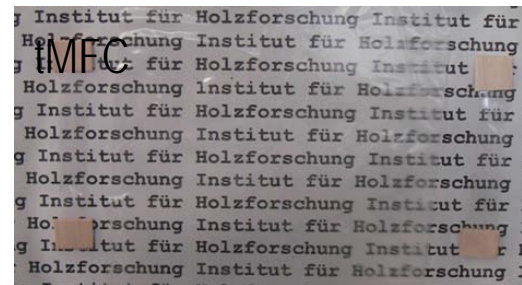
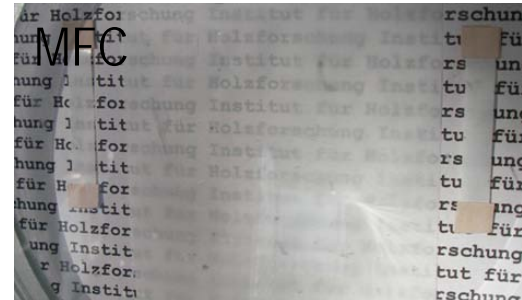
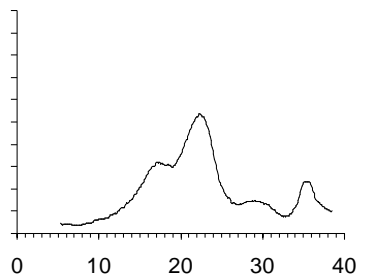
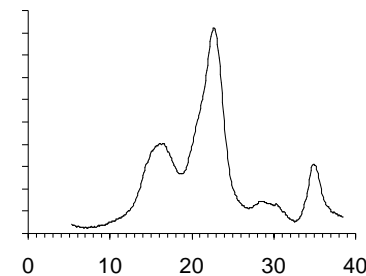
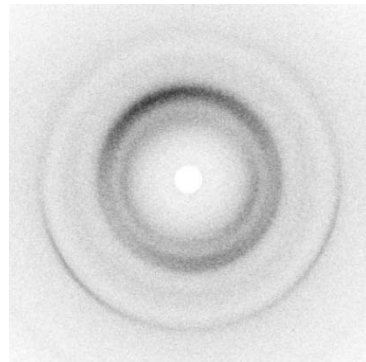
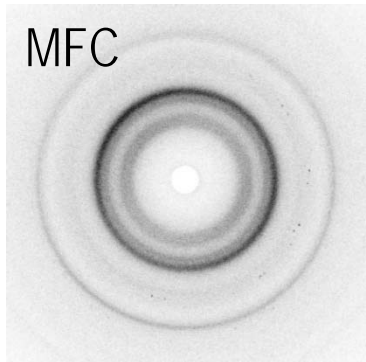
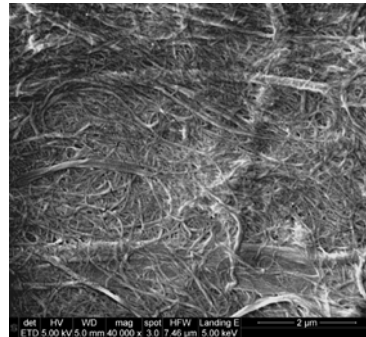
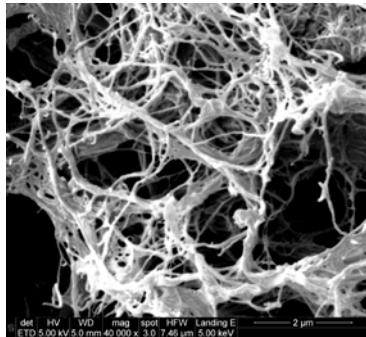
No results so far




TEMPO-oxidated cellulose



TEMPO: (2,2,6,6-tetramethylpiperidine-1-oxyl)

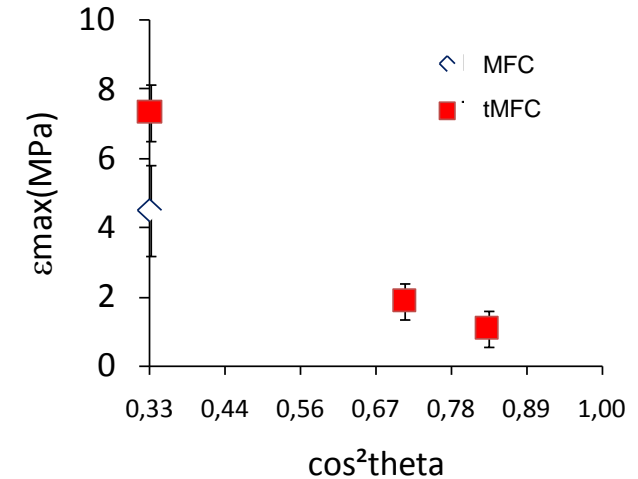
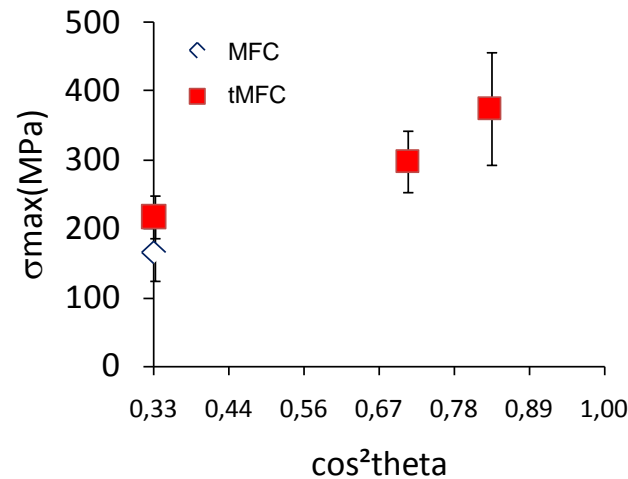
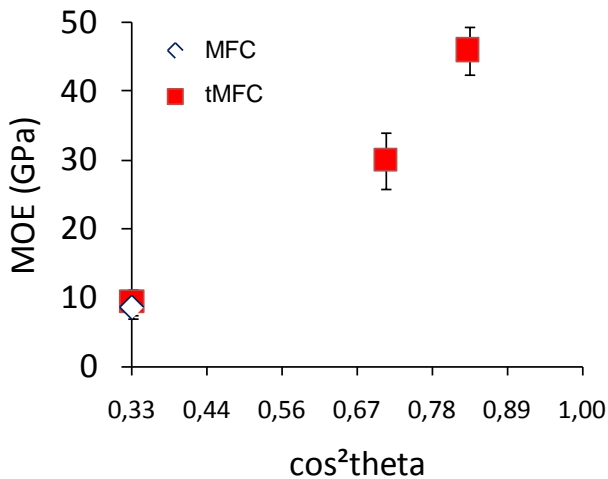
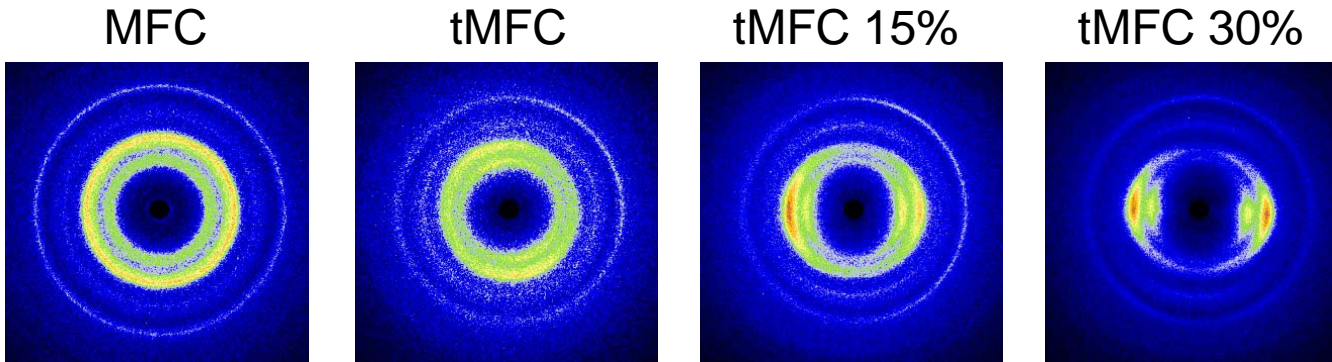



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Stretched TEMPO-oxidated cellulose



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Veigel et al. 2011

Conclusions



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Magnetic and electric fields interesting for small-scale applications

Post-drawing of consolidated films plasticised by moisture is feasible for regenerated cellulose and for surface-modified MFC

Need for a method to obtain orientation during film formation!