Rheological Characterization of Wood & Wood Composites

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Outline

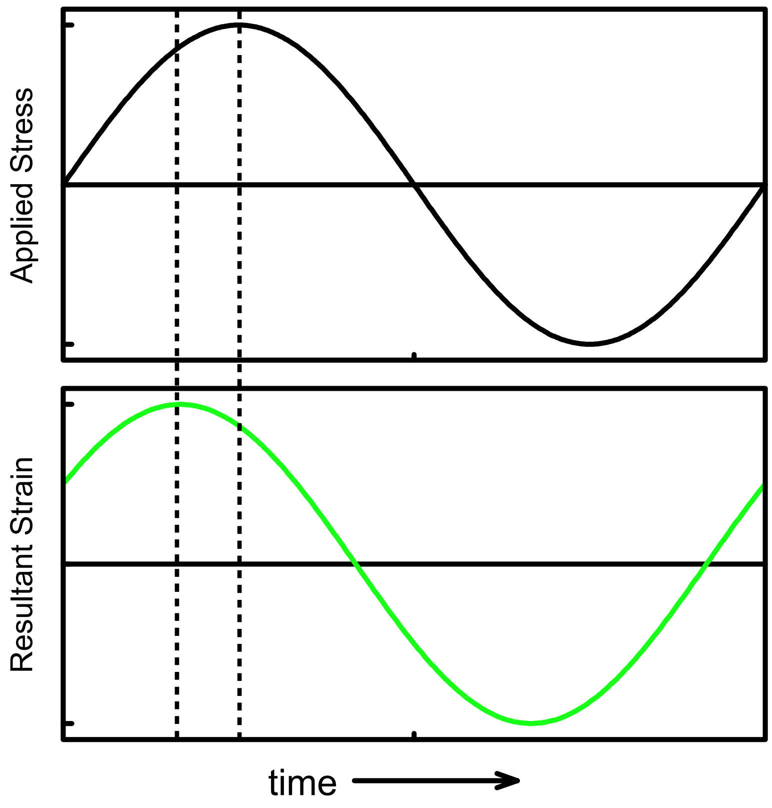
- Wood rheology
- Force mode
- Instrumentation
- Sample preparation
- Moisture control
- Linear viscoelastic response (LVR)
- Example Data

Wood Rheology

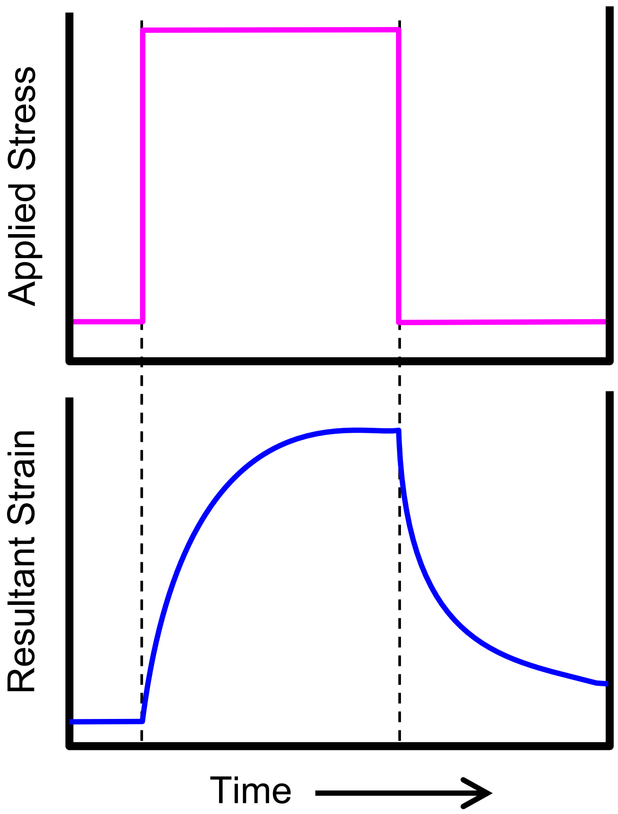
Rheology: Study of the flow and deformation of materials.

Reflecting chemical structure, molecular and supramolecular ordering

Static & Dynamic Force Modes



Oscillatory perturbation



Static perturbation

Instrumentation

Instrumentation

Modern instrumentation requires a choice between:

- Strain controlled machines
- Stress controlled machines

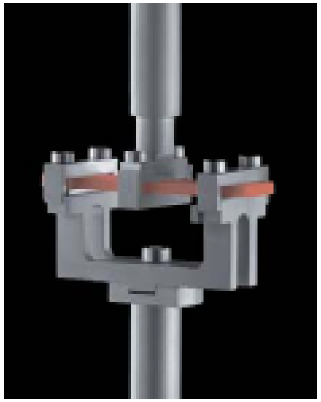
Strain Control: Apply displacement, and
use a load cell to measure the stress.

Stress Control: Apply a force, and use an interferometer to
measure the displacement.

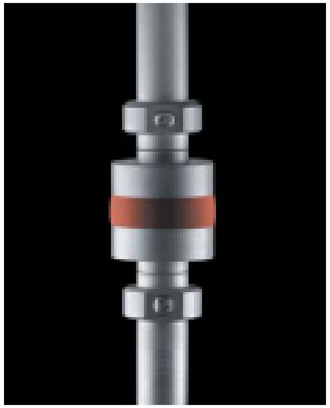
Sample Preparation

1. Machine a geometry that suits your needs.
   - Grain orientation
   - Specimen size
   - Clamp modes & clamp sizes

3-point bending



cantilever bending



parallel plate

2. Hygro-thermal history (Solvent extraction?) is extremely important.

Sample Preparation

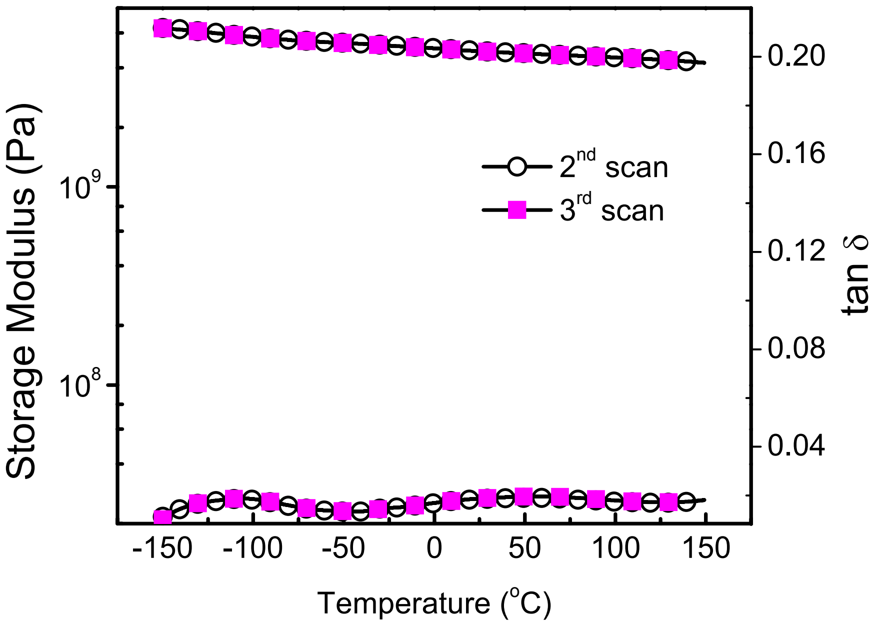
Moisture Control

As always, moisture control during analysis is critical.

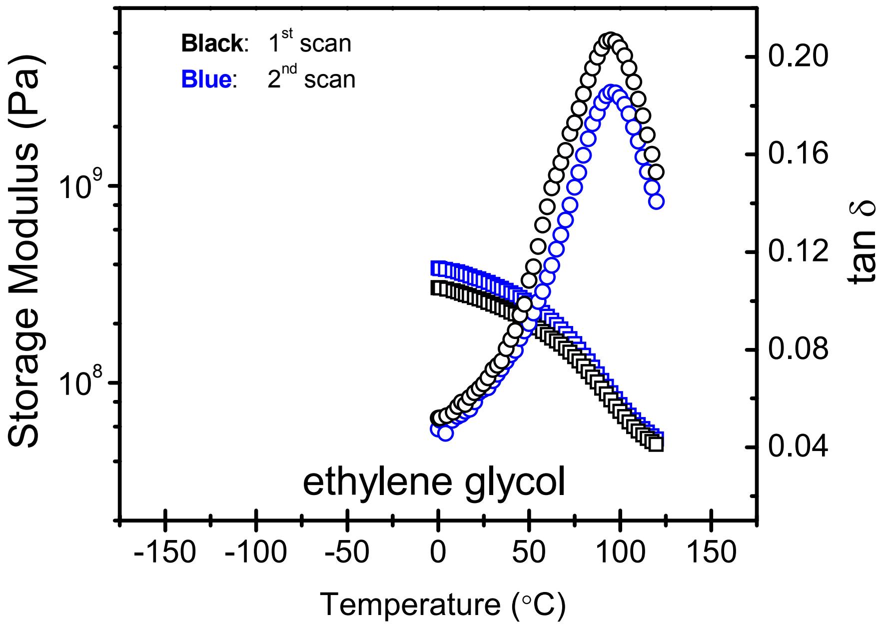
We have 3 choices:

1. **Completely dry**
   - Simple
   - Reveals weak, secondary relaxations
   - Thermal decomposition may be a concern
2. **Completely saturated**
   - Somewhat simple to dificult
   - Reveals strong, primary relaxations
   - Thermal decomposition of **<u>less</u>** concern
3. **RH control**
   - Difficult and very expensive

Moisture Control

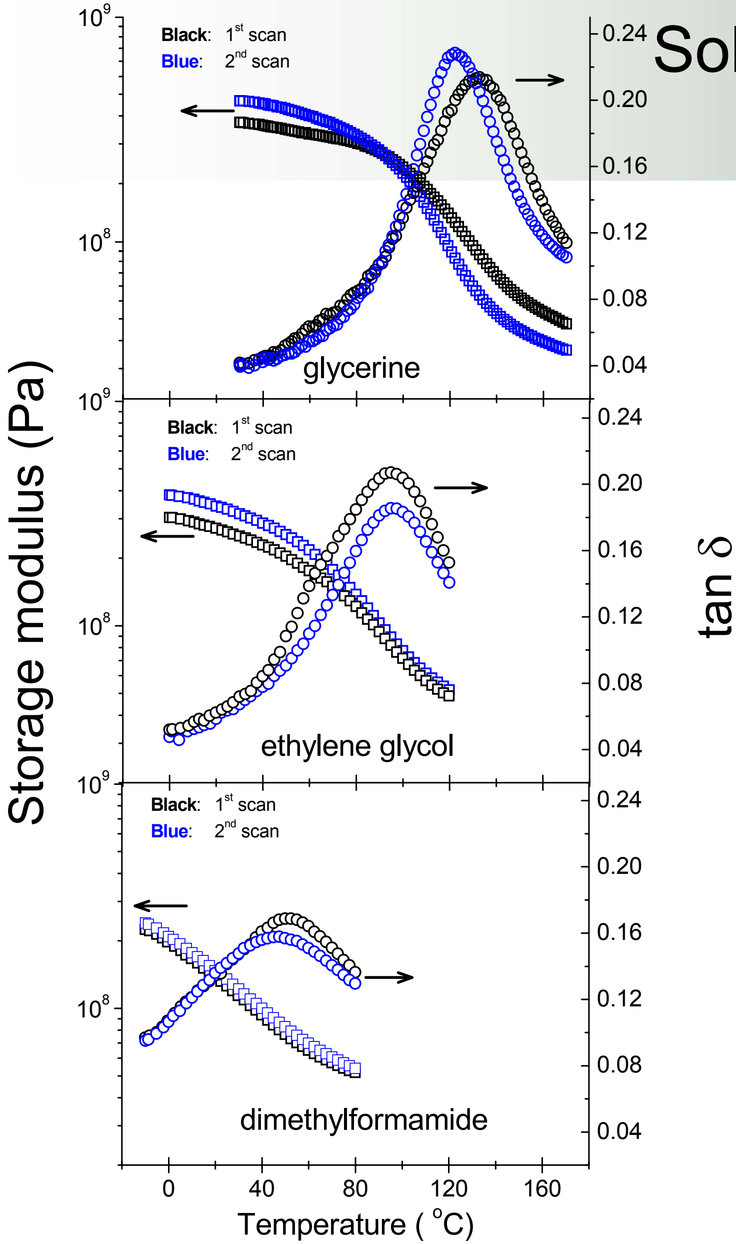


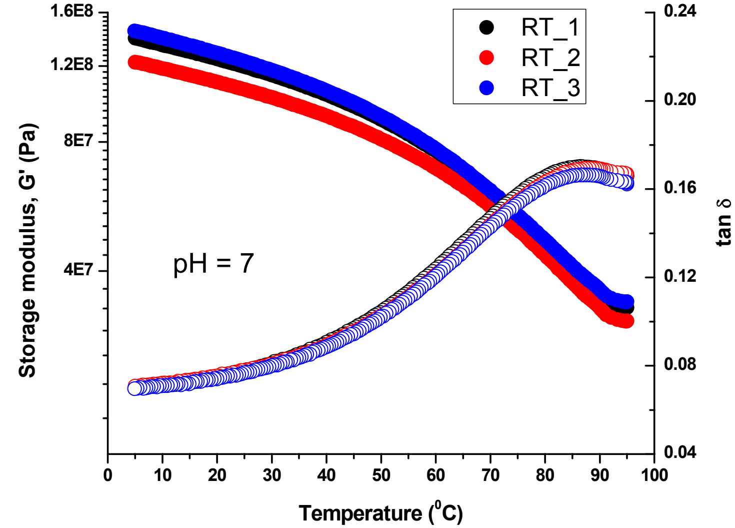
Completely dry pine in single cantilever bending

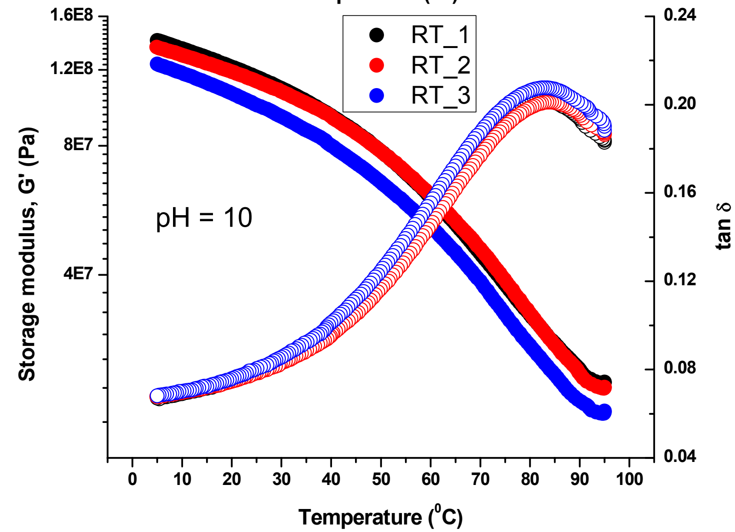


Saturated yellow-poplar in parallel-plate torsion

Solvent Submersion



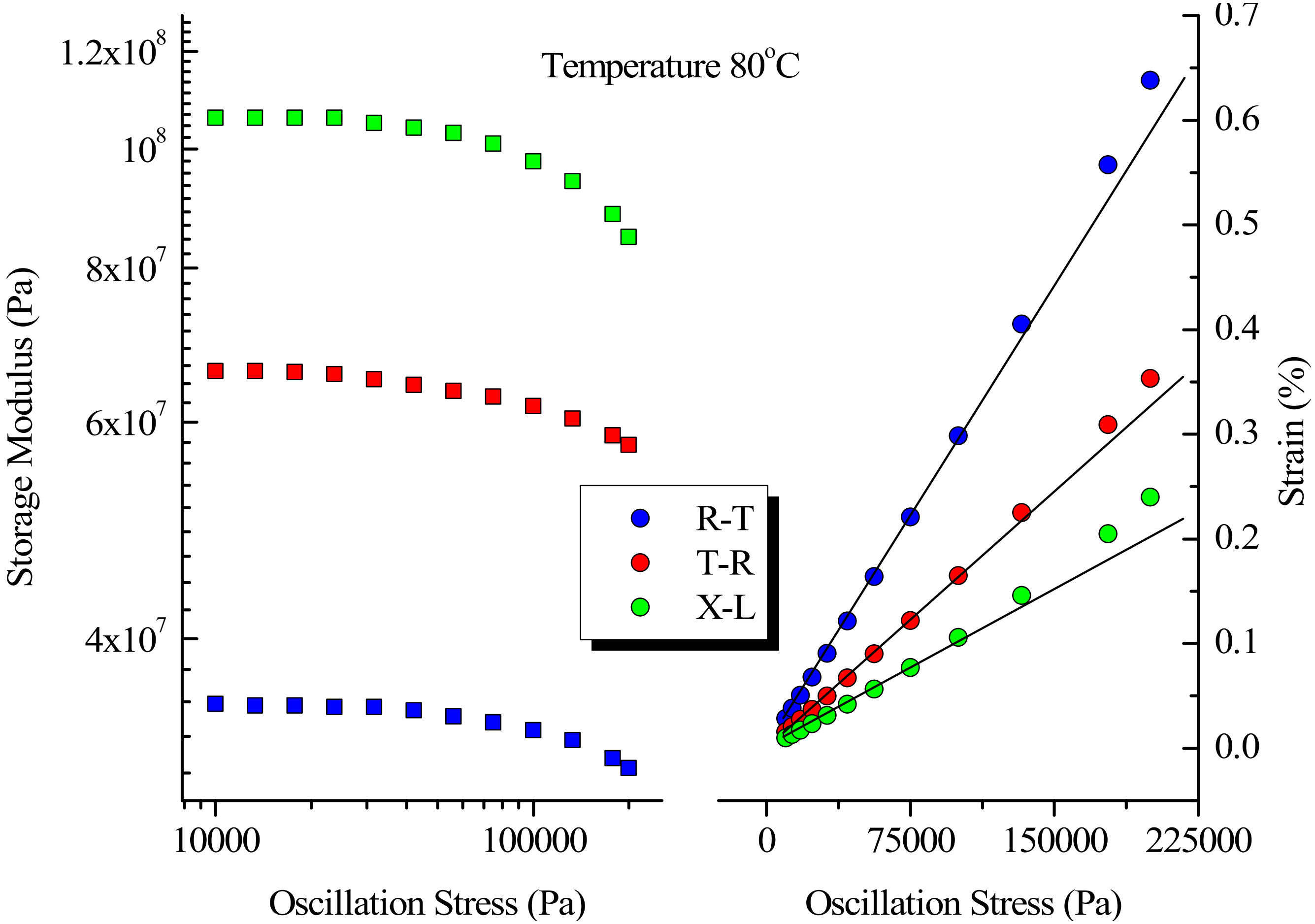




Linear Viscoelastic Response (LVR)

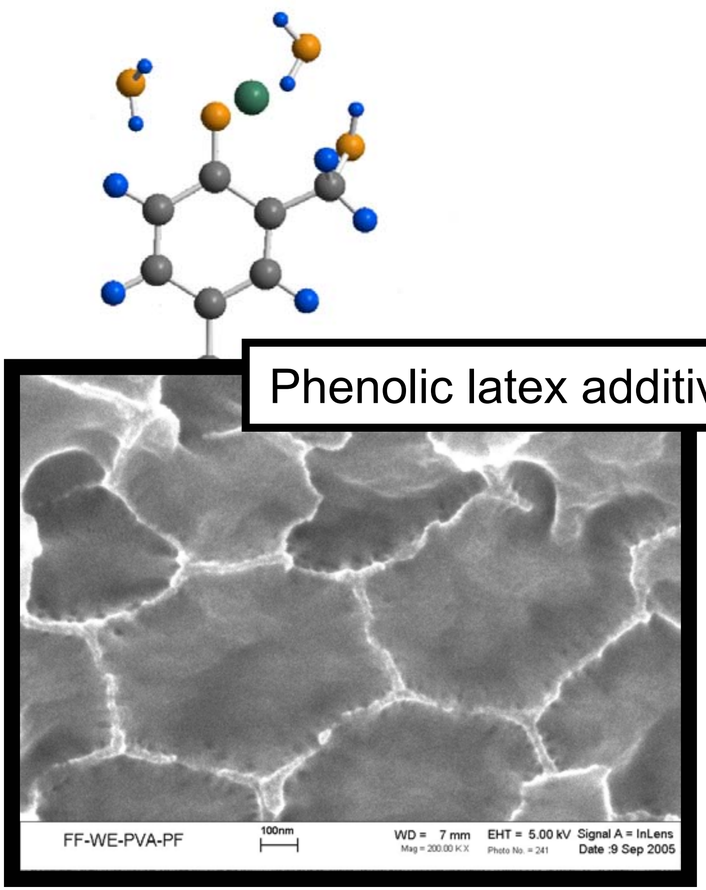
- The response (e.g. strain) is directly proportional to the mechanical input (stress).
- Within the LVR, polymer packing is not altered and the response is independent of the input level.
- Data within the LVR is easiest to describe mathematically.
- Experiments are generally performed at the highest stress/strain within the LVR, optimizing signal/noise ratio without causing an erroneous response.

Linear Viscoelastic Response (LVR)

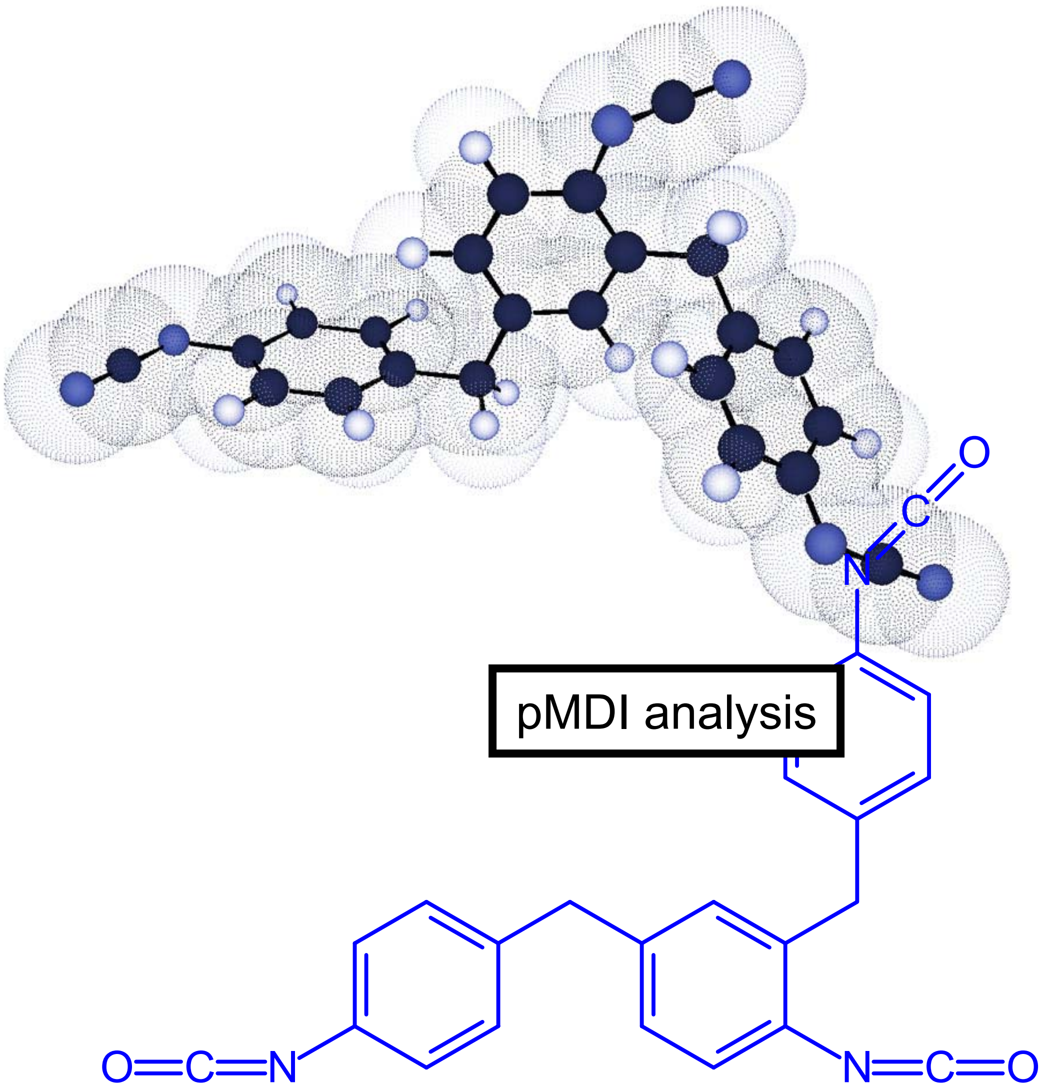


Yellow-poplar submerged in DMF under parallel-plate torsion

Example Data

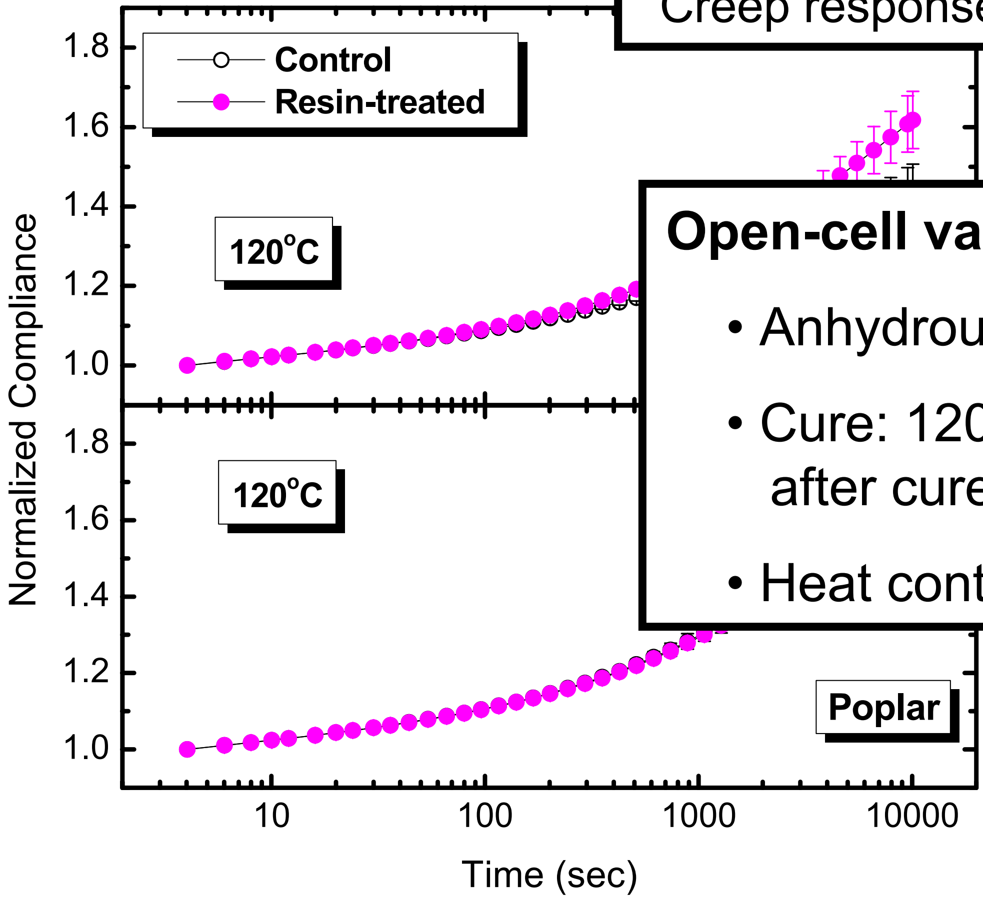


Phenolic latex additives



pMDI analysis

Species Dependence of pMDI Performance

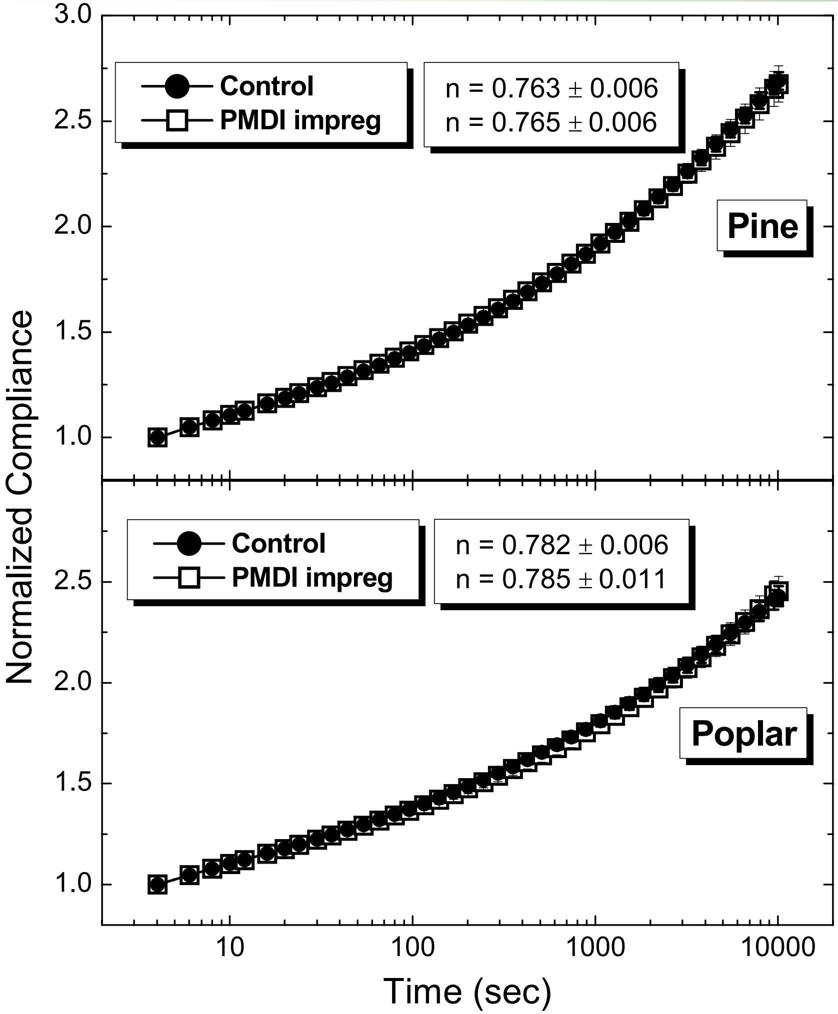


Creep response of dry wood

Open-cell vacuum impregnation:

- Anhydrous acetone/pMDI solutions.
- Cure: 120°C, 2 hrs, (3 – 5 % weight gain after cure).
- Heat control samples in the same fashion.

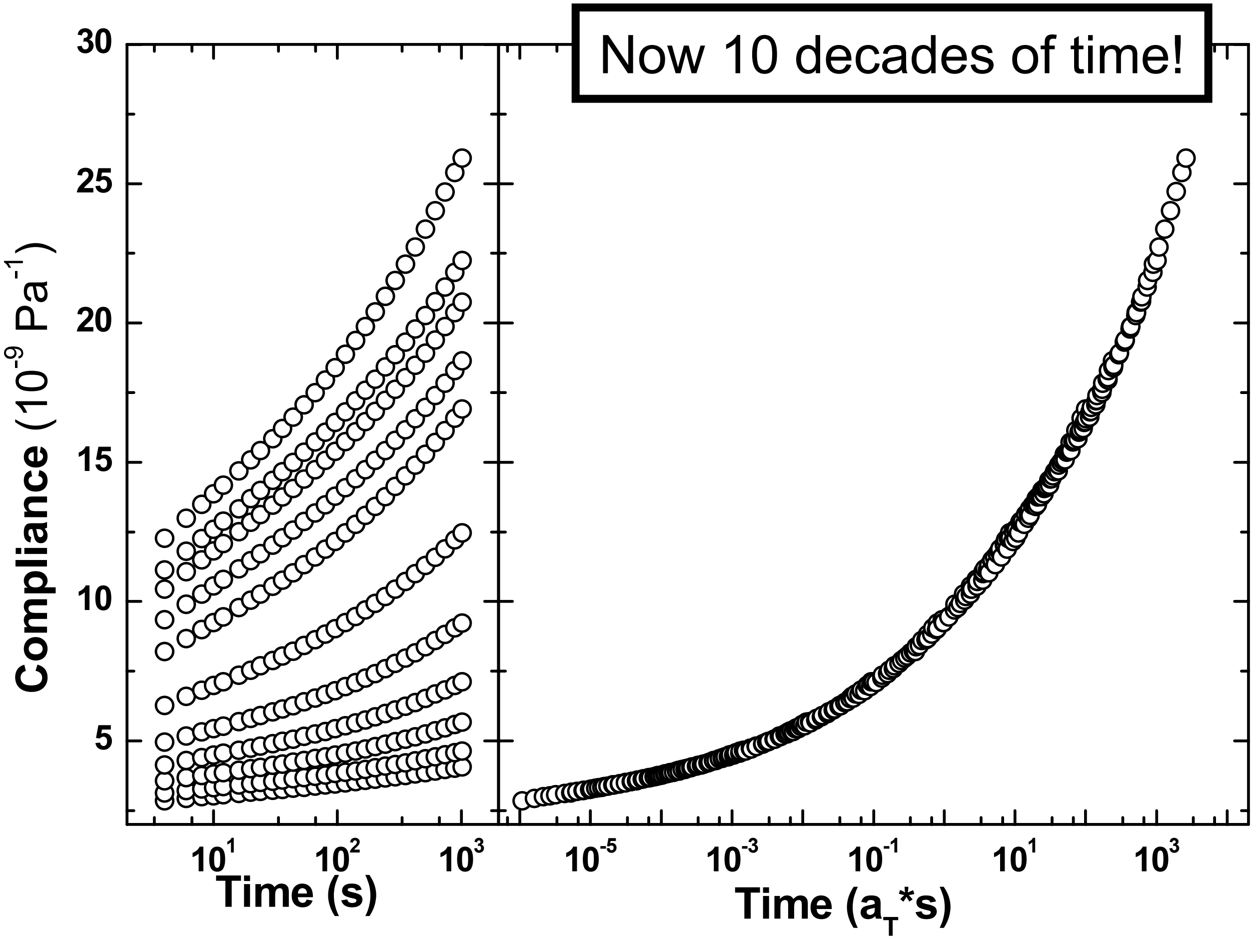
Now… Ethylene Glycol (EG) Plasticized Wood



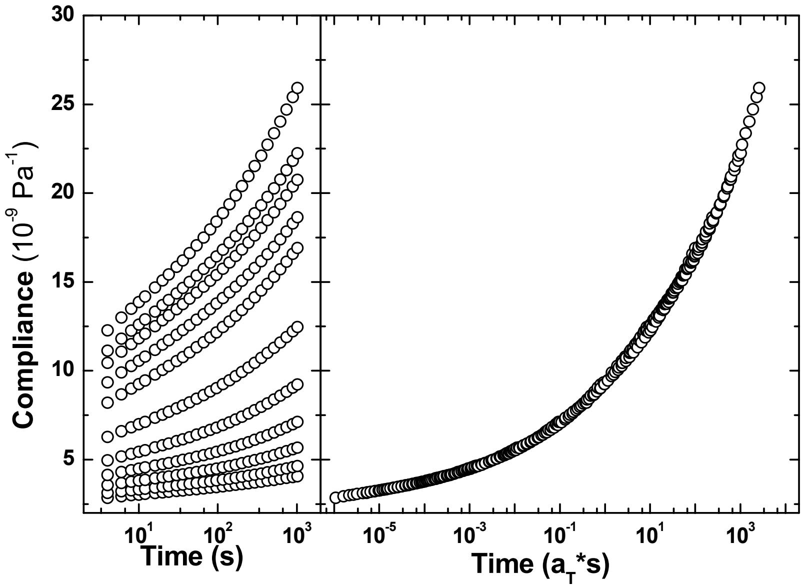
- pMDI-treated and control specimens (impregnations as before but resin concentration 13% for poplar, 20% for pine).
- Post-cure resin content 5.5% for poplar, 5.3% for pine.
- Saturated in EG and subjected to 3 hour creep at 50°C (initially heated 90°C for 30 min., cooled (20°C/min) to 50°C; held at 50°C for 30 min).
- 5 replications each.

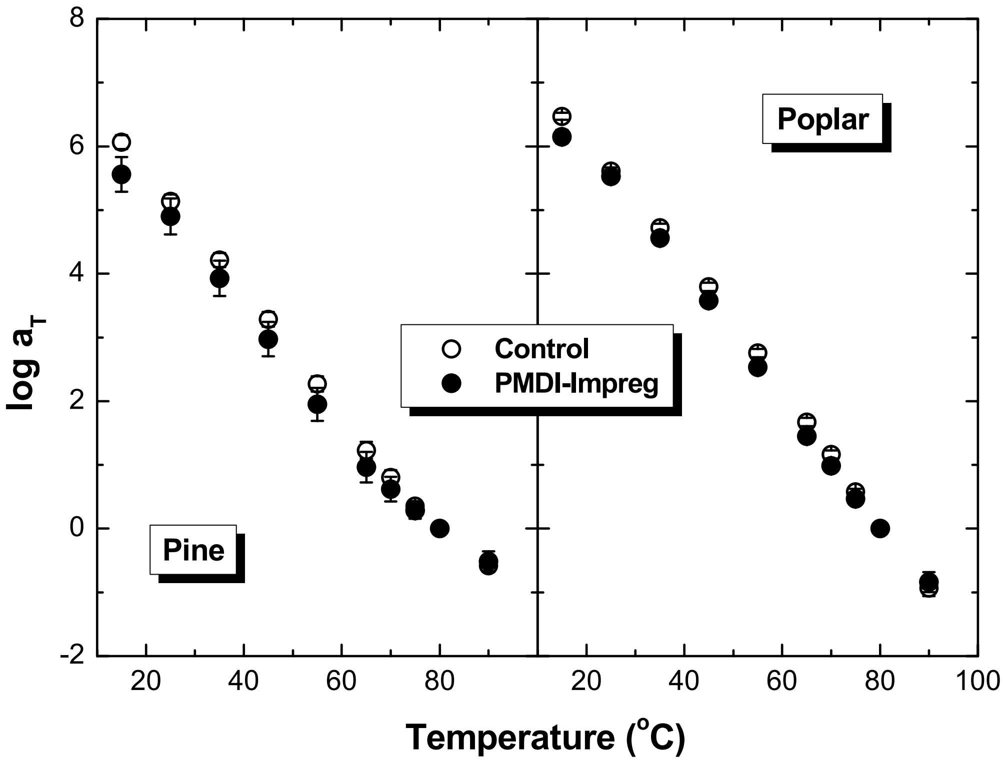
$$D(t) = D_u + (D_r - D_u) \times \left[1 - \exp\left\{ -\left(\frac{t}{\tau} \right)^{1-n} \right\} \right]$$

Time/Temperature Superposition w/ EG Plasticized Wood

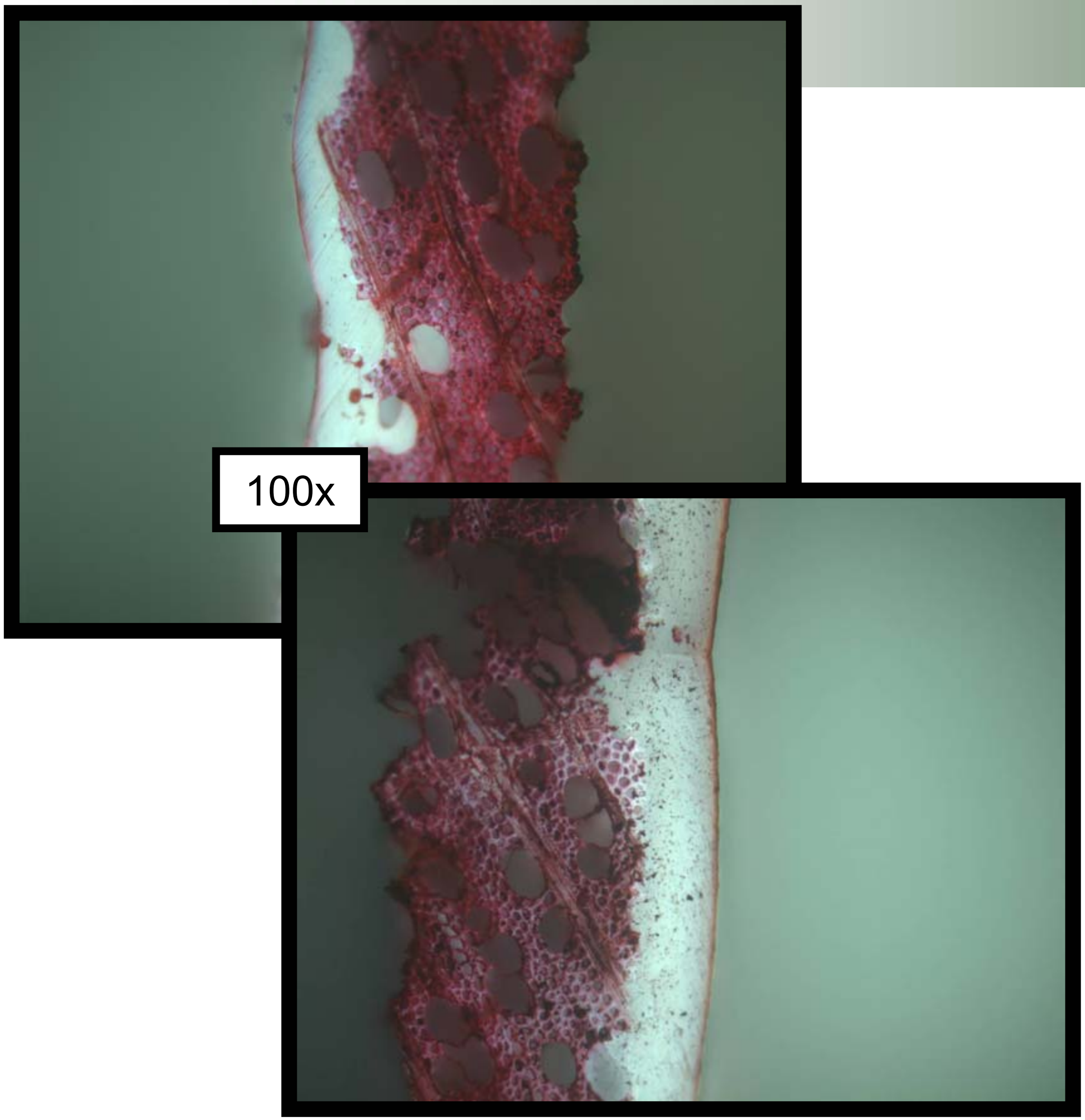


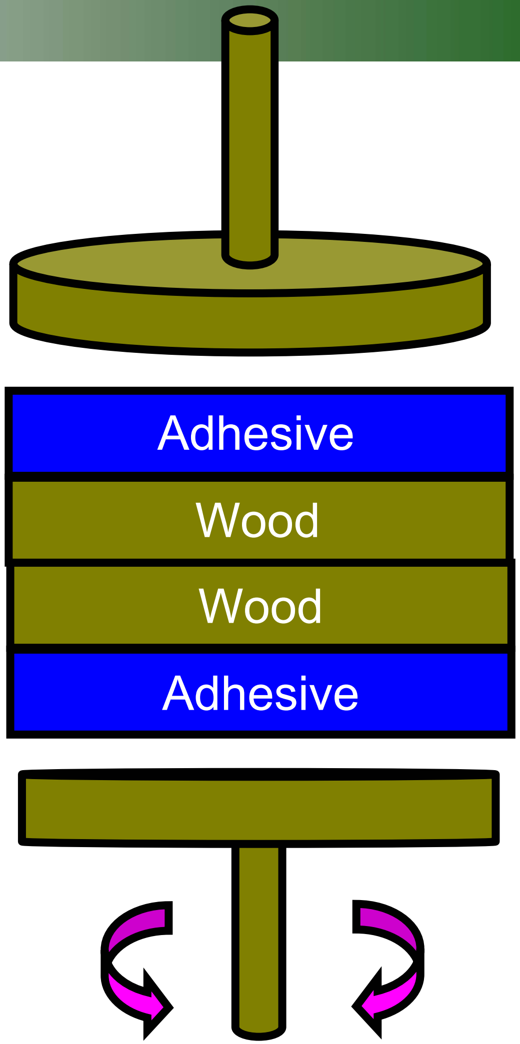
Time/Temperature Superposition w/ EG Plasticized Wood



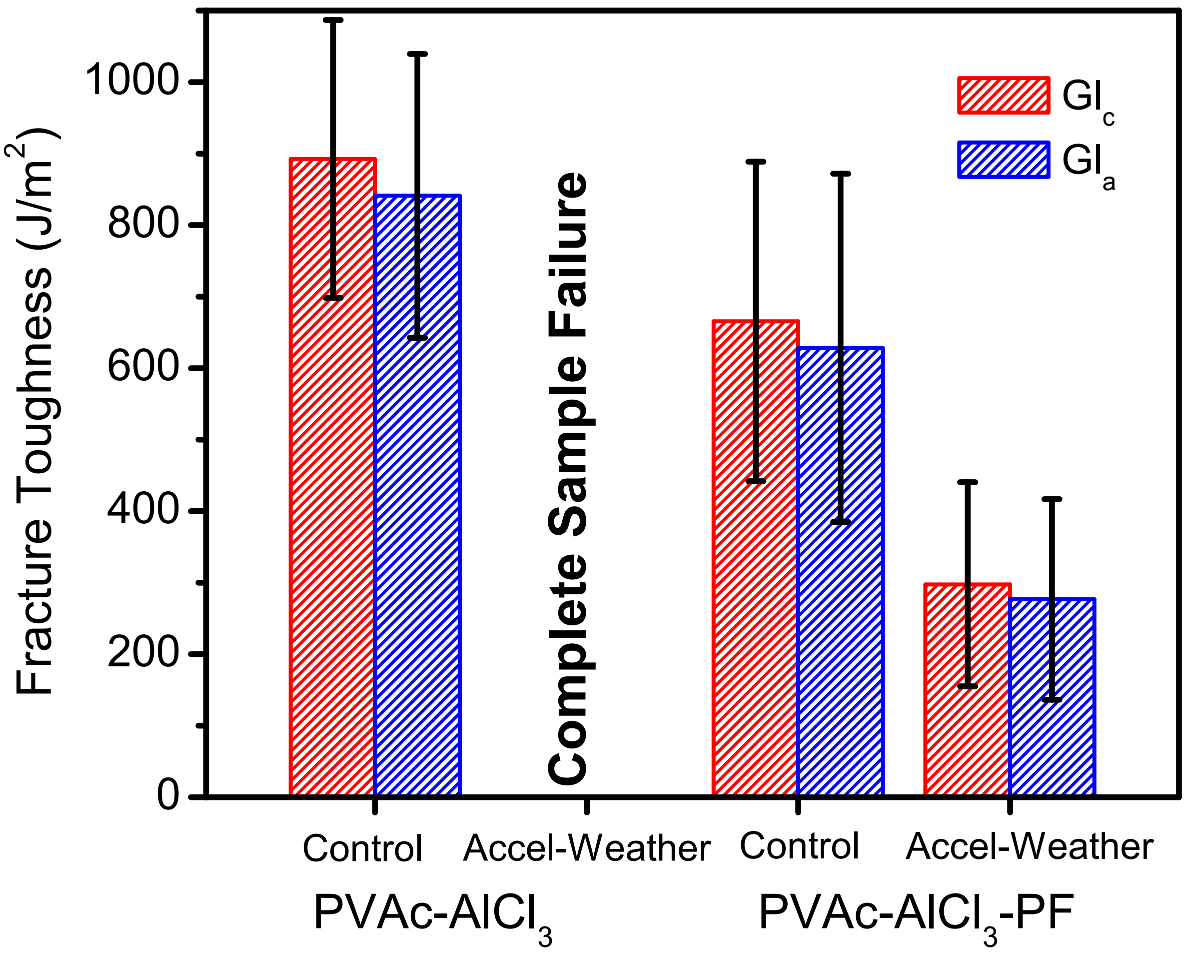


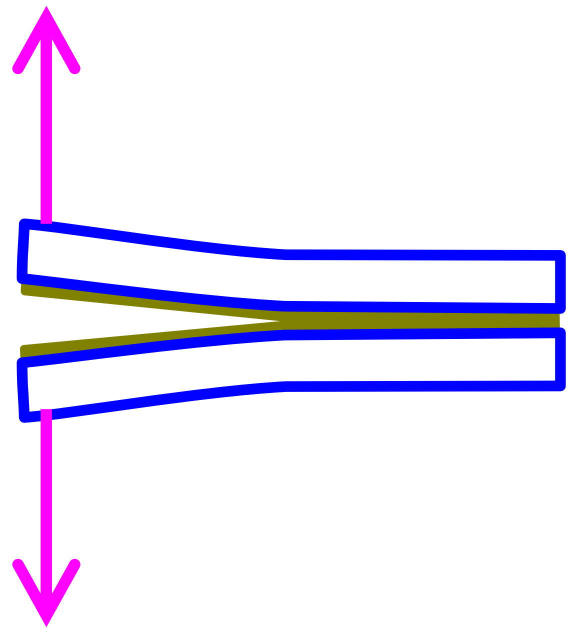
Composite Specimens with Latex Adhesive





Influence of Resol Fortifiers on Latex Durability





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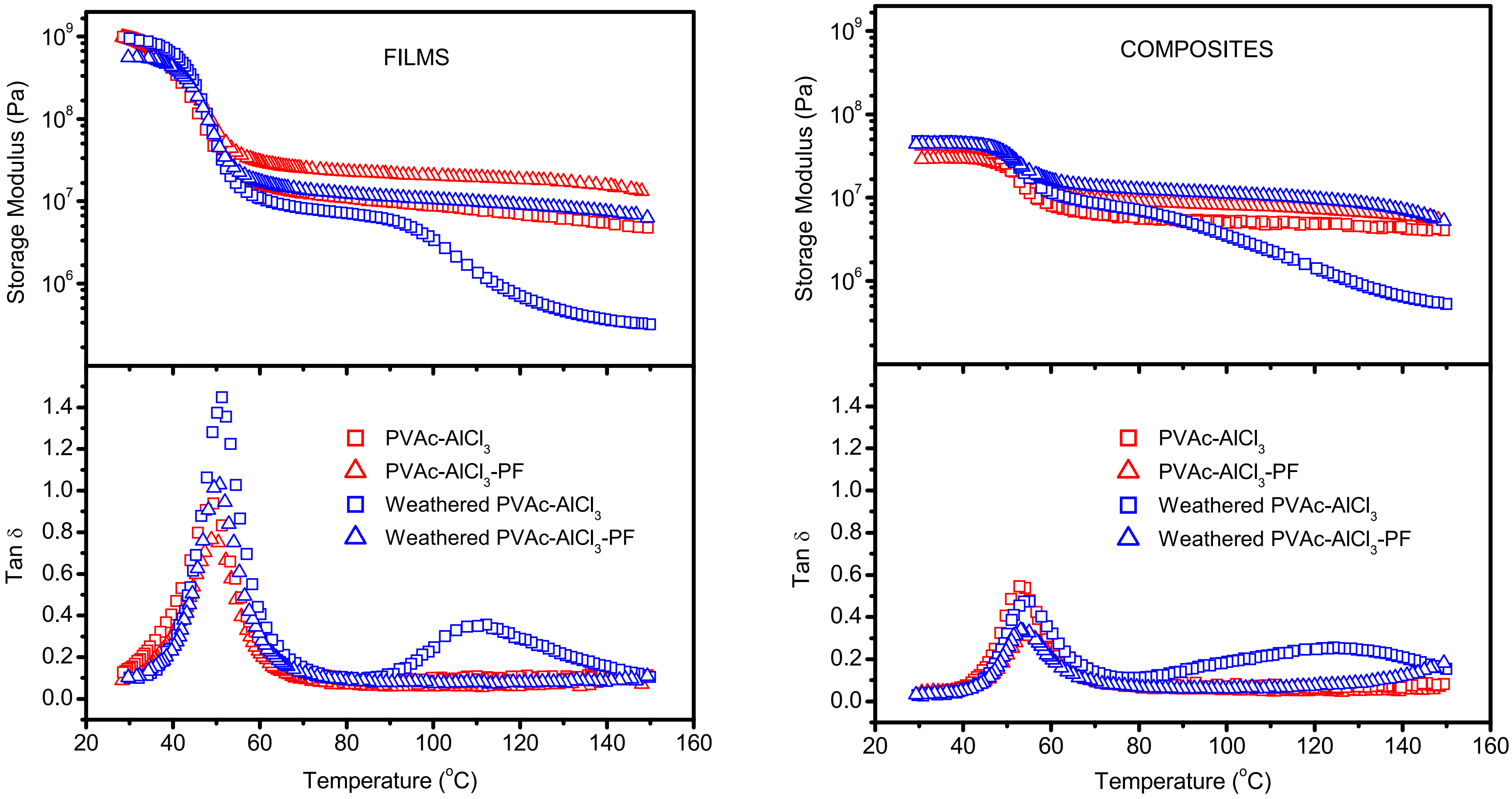

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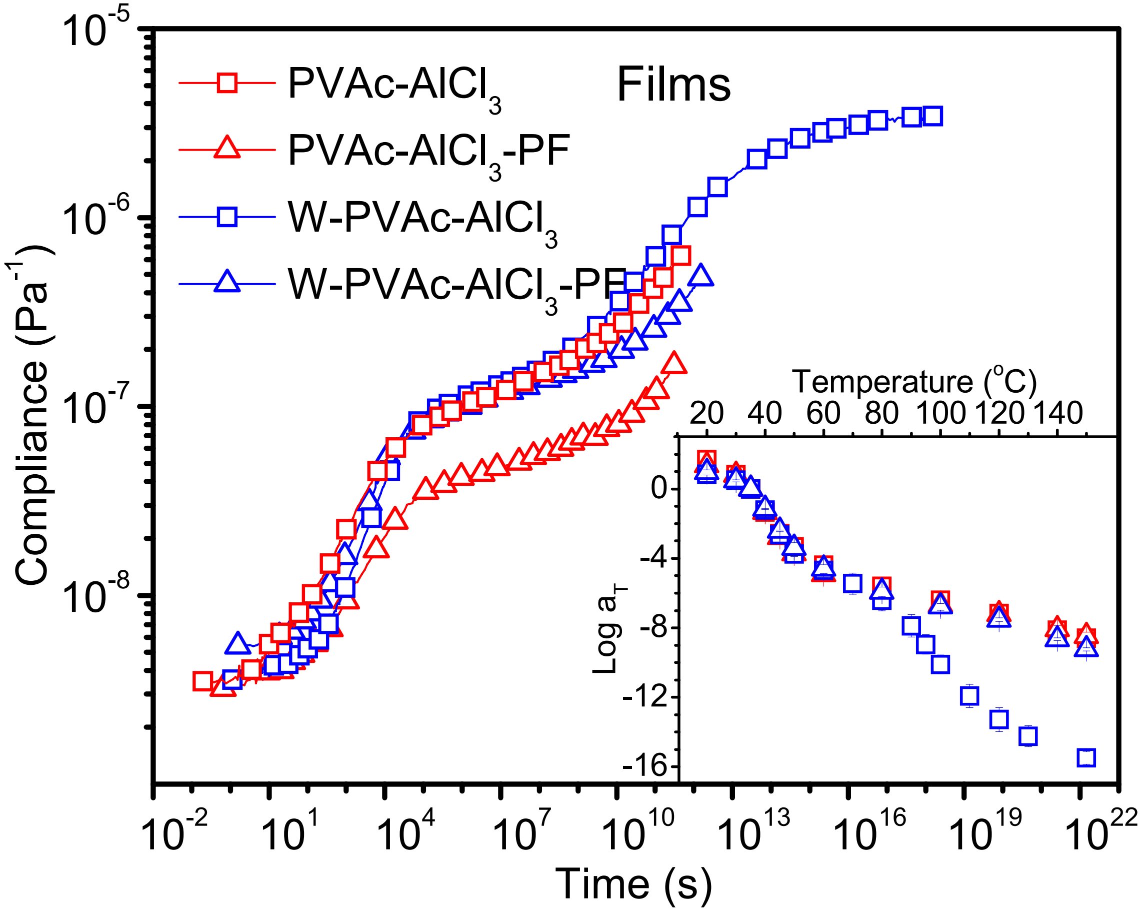
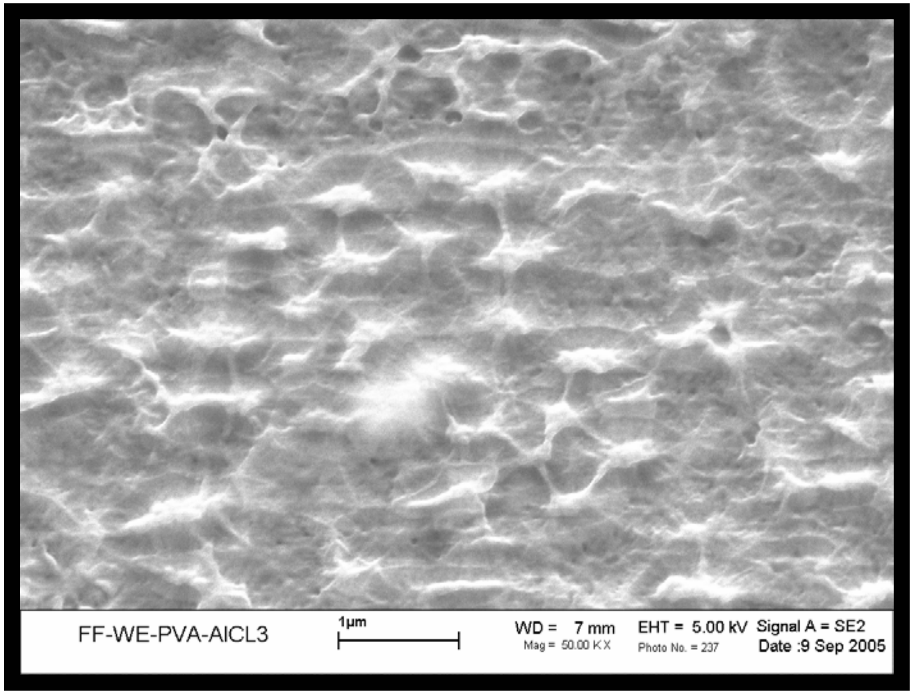


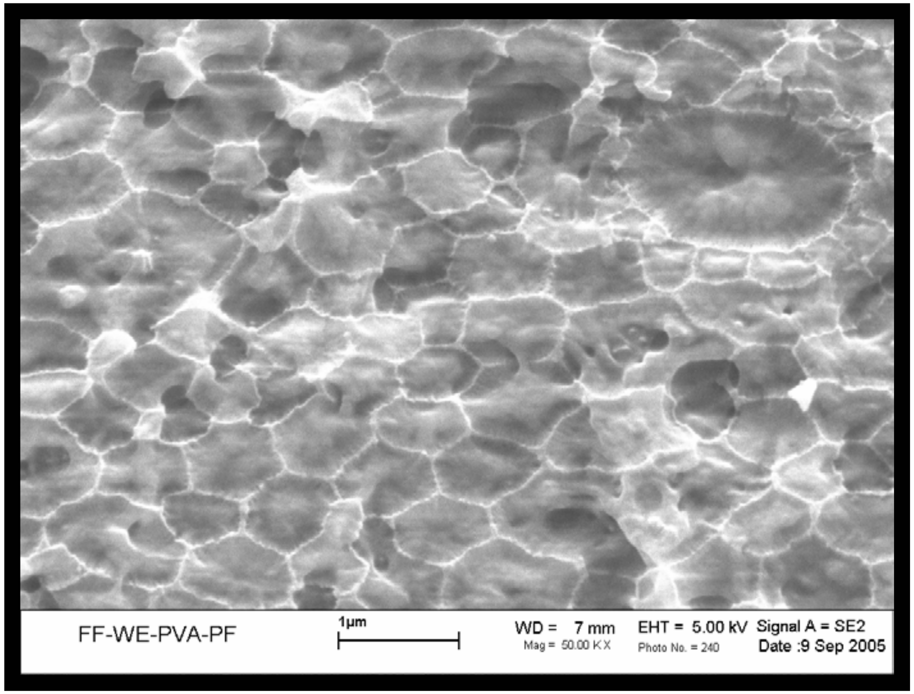
Creep master curves from time/temperature superposition

Influence of Resol Fortifiers on Latex Durability

Weathered PVAc-$AlCl_3$-50k x



Weathered PVAc-$AlCl_3$-PF-50k x



Summary

- Wood rheology deals with amorphous wood polymer relaxations.
- These relaxations reflect chemical structure, and morphology, as well as changes caused by chemical, thermal and other treatments.
- Such methods require a significant investment of funds and time, but they’re worth it.

Acknowledgements