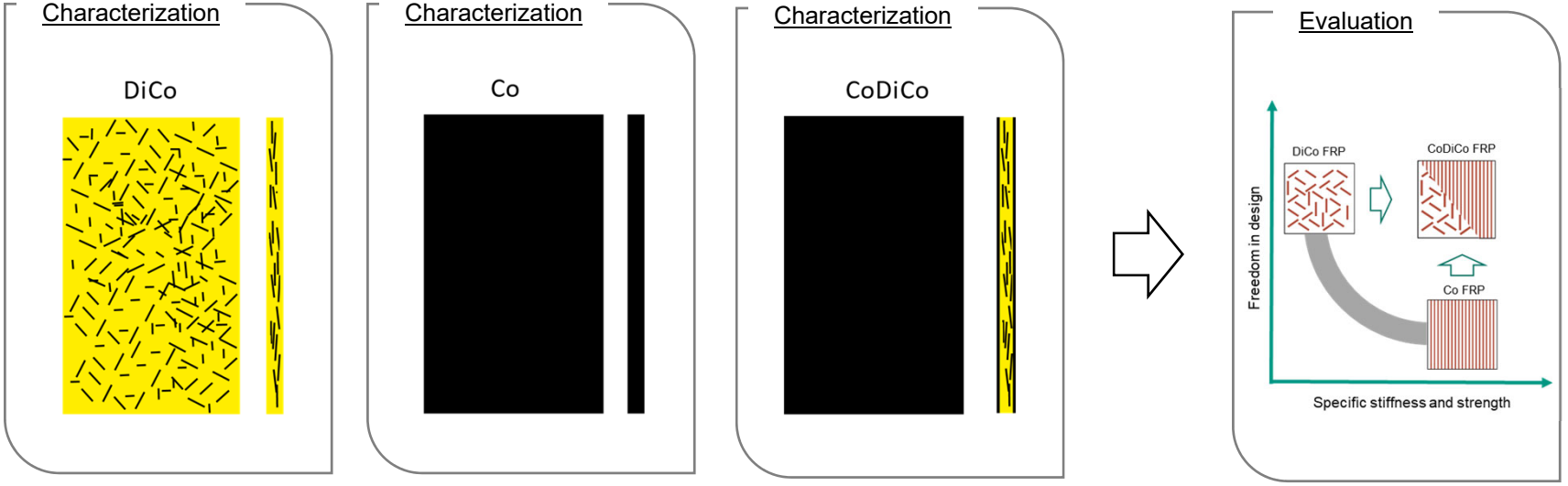
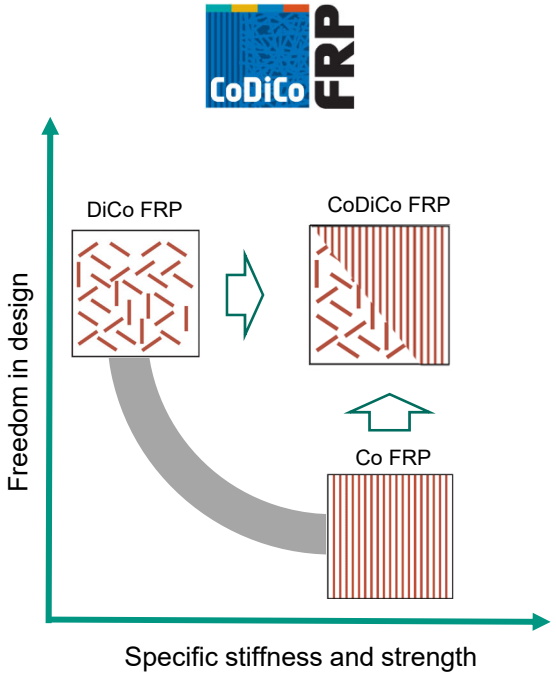
Effect of hybridization on the mechanical properties of Continuous-discontinuous-LFT

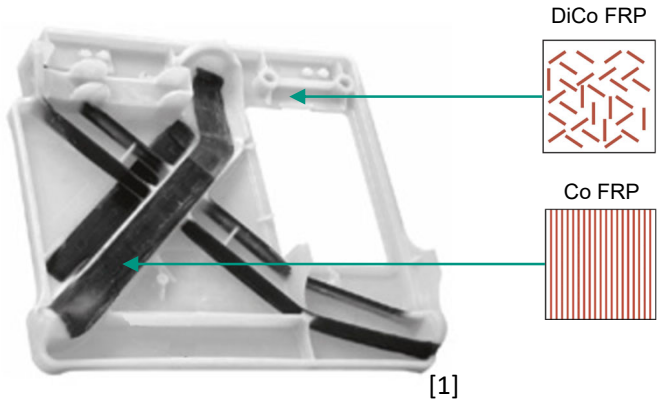
Benedikt M. Scheuring, Christoph Schelleis, Wilfried V. Liebig, John Montesano, Kay A. Weidenmann



Continuous-discontinuous fiber reinforced polymers (CoDico-FRP)

Motivation



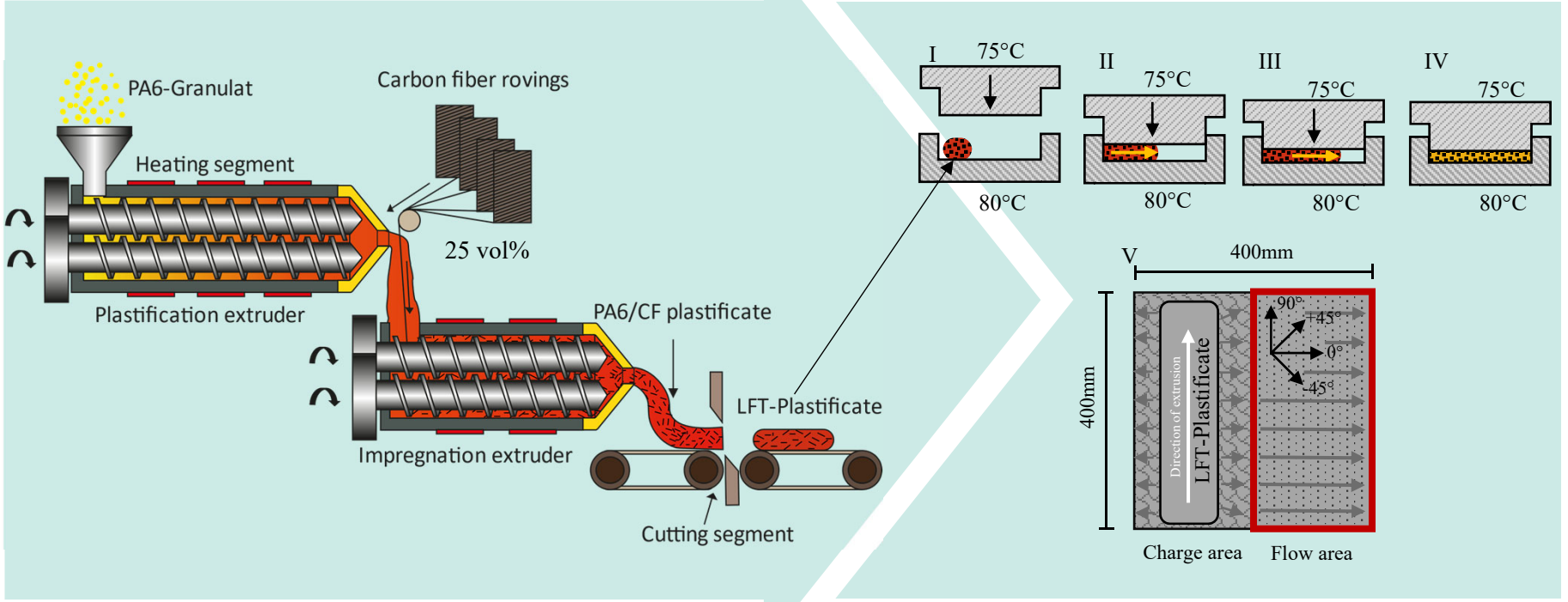


[1]

[1] Kärger L, Hrymak A, Henning F, Weidenmann KA, Böhlke T, Wood JT. Continuous-Discontinuous Fiber-Reinforced Polymers - An Integrated Engineering Approach. Carl Hanser Verlag; 2020

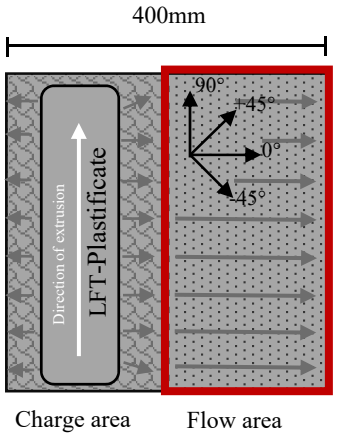
Manufacturing process Dico

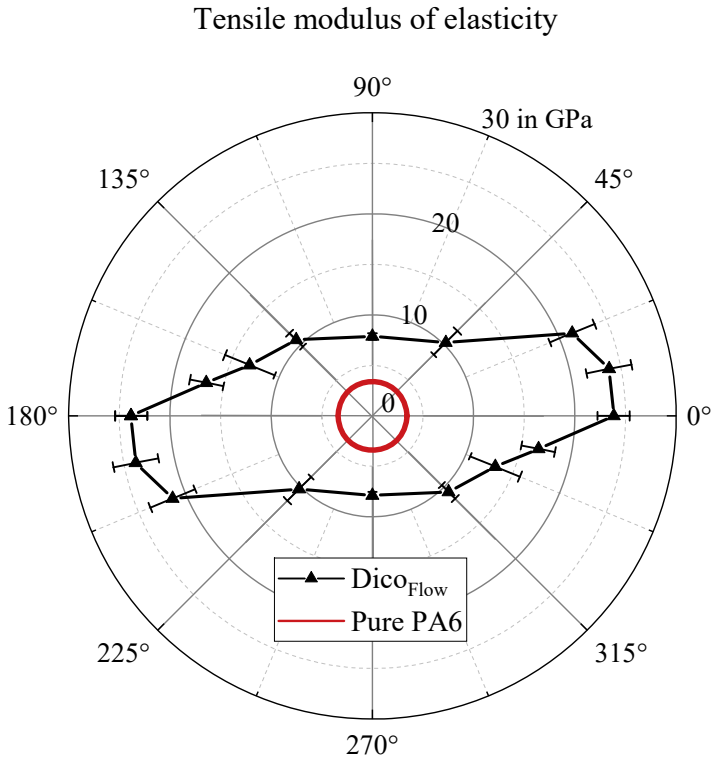
Long Fiber reinforced Thermoplastics (LFT)



Reinforcement effect Dico

Orientation-dependent stiffness



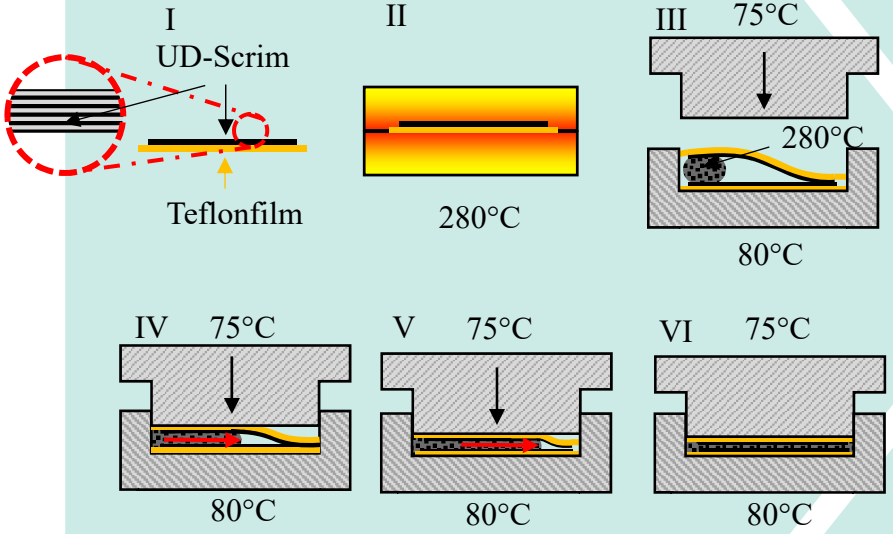


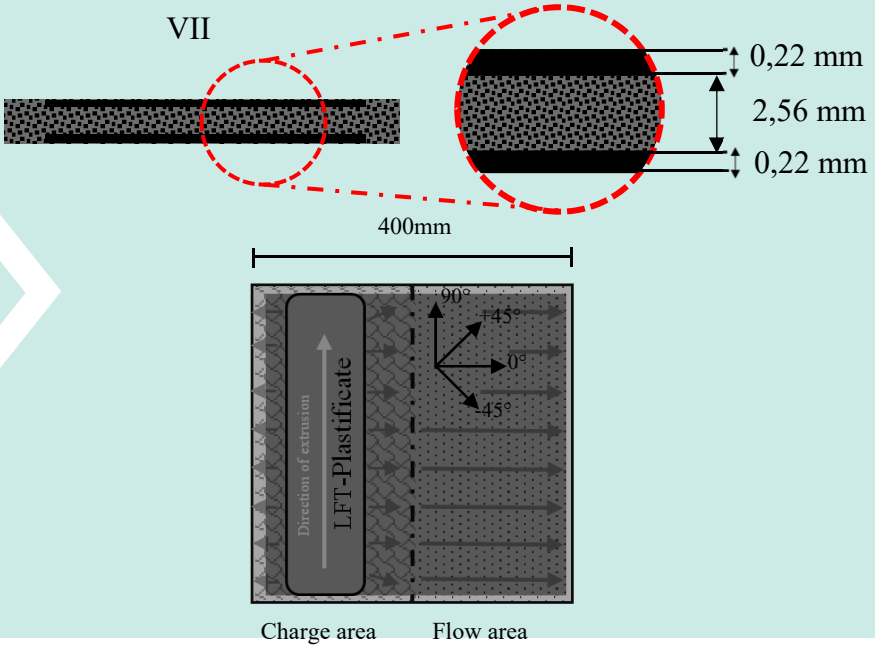
Results

- Significantly reinforcing effect through the fibers
- Clear directional dependence of the stiffness
  - Strong orientation of the fibers in the flow direction

Manufacturing process

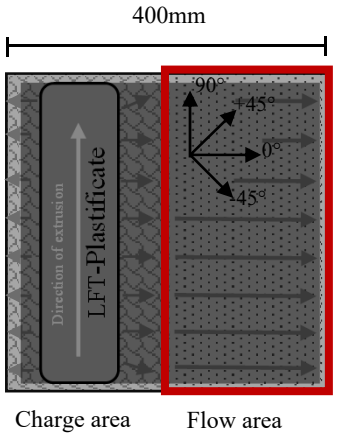
CoDiCo-Materials

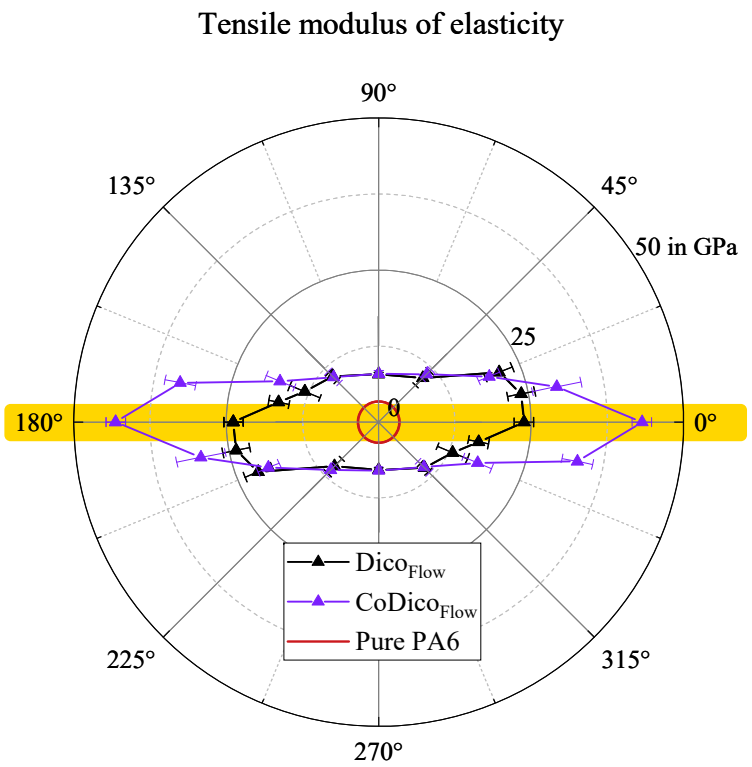




Reinforcement effect CoDico

Orientation-dependent stiffness





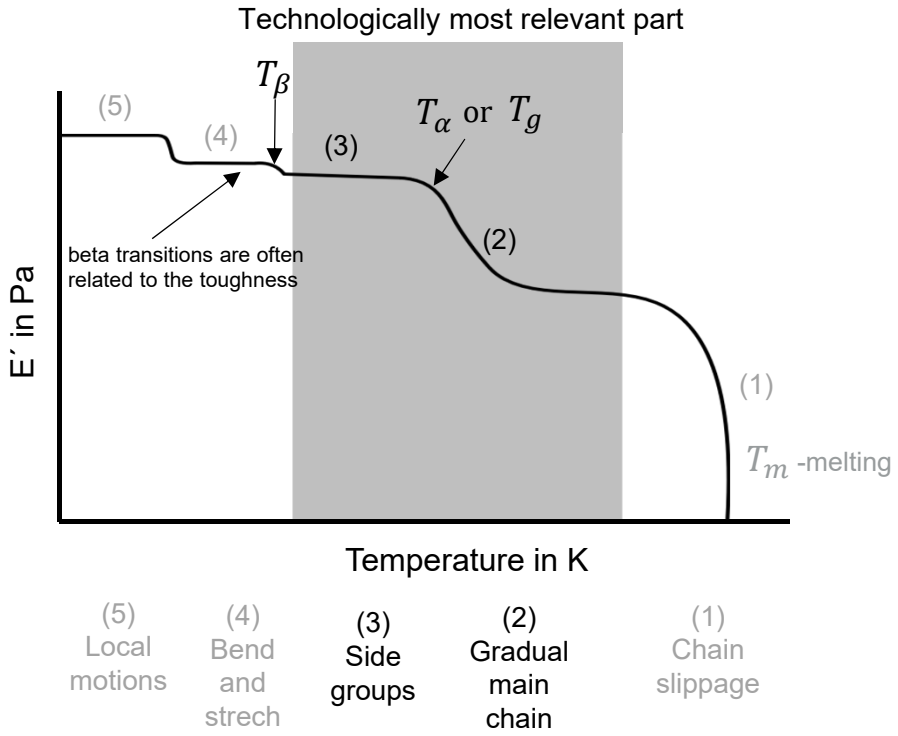
Results

- Further stiffening only in small angles to the orientation of the Co-phase
  - No reinforcement effect from an angle greater than +- 45°.

→ for further investigations

Temperature-dependent stiffness behavior

Thermoplastics



Effects

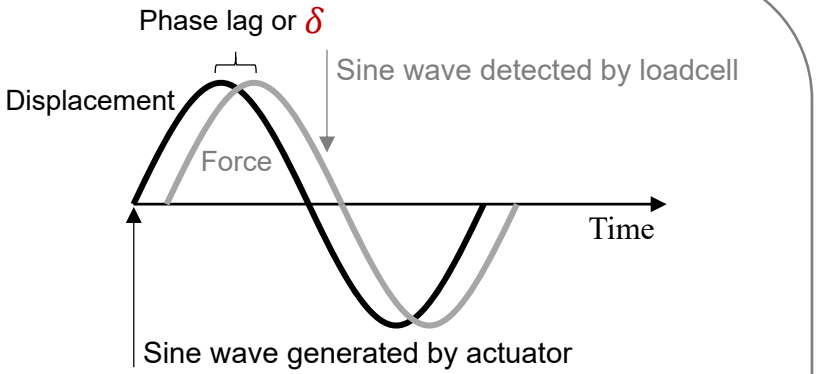
- Strong reduction of stiffness over temperature range
- Technology most relevant part
  - After T_β movements of side groups
  - After T_g movements of main chain

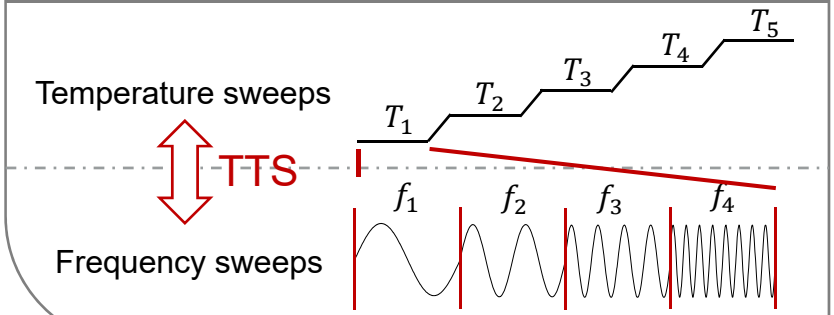
In adaption to: Kevin P. Menard - Dynamic Mechanical Analysis_ A Practical Introduction, -CRC Press (2008).

Dynamic mechanical analysis

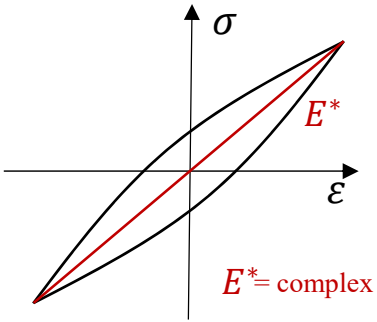
Procedure

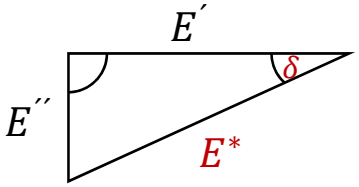
Testing





Evaluation





$E^* = E' + i\,E''$

$= E'(1 + i\tan\delta)$

$\Downarrow$

$E' = \frac{E^*}{1+tan\delta}$

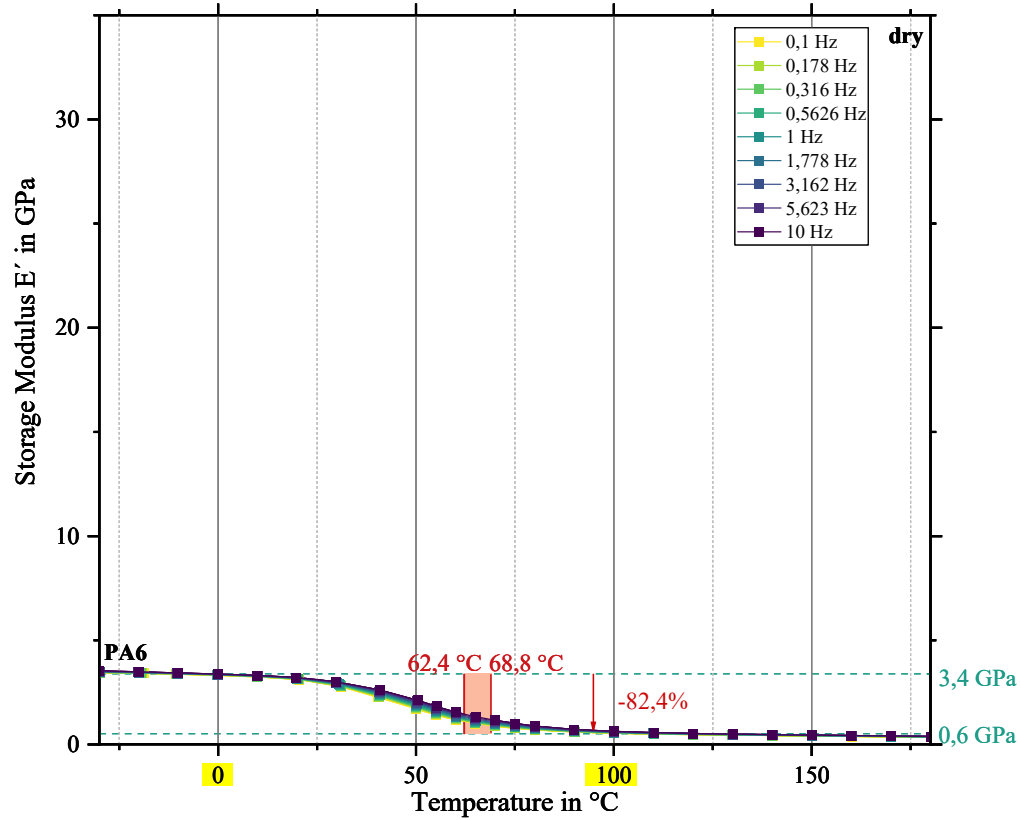
E' = storage modulus

E'' = loss modulus

$\tan\delta$ = Damping factor = $\frac{E''}{E'}$

Dynamic mechanical analysis

Under tensile load

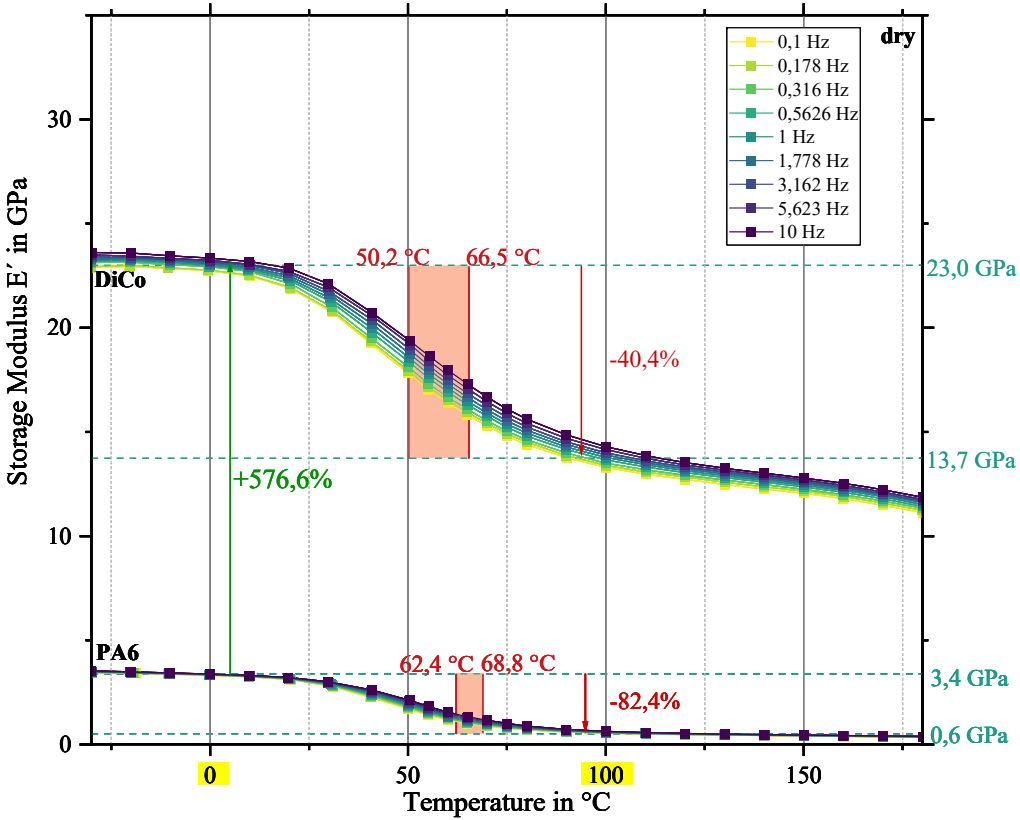


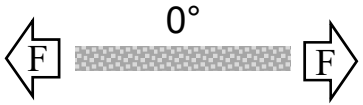
PA6

- Significant drop in stiffness in the area around Tg
- Tg = peak of phase lag δ
- Drop of over 80%

Dynamic mechanical analysis

Under tensile load





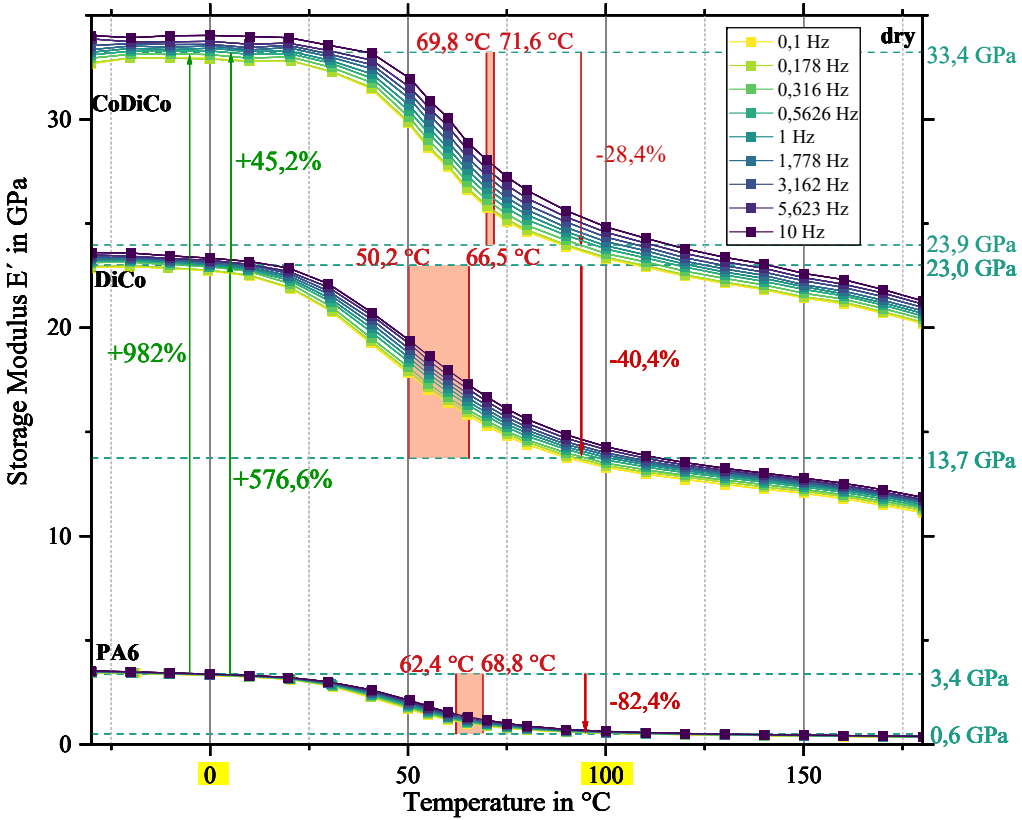
Karlsruhe Institute of Technology

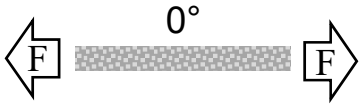
Dico

- strong reinforcing effect through the fibers
  - +576% to PA6
- reduction of temperature sensitivity
  - Over 50% in comparison to PA6

Dynamic mechanical analysis

Under tensile load





Karlsruhe Institute of Technology

Dico

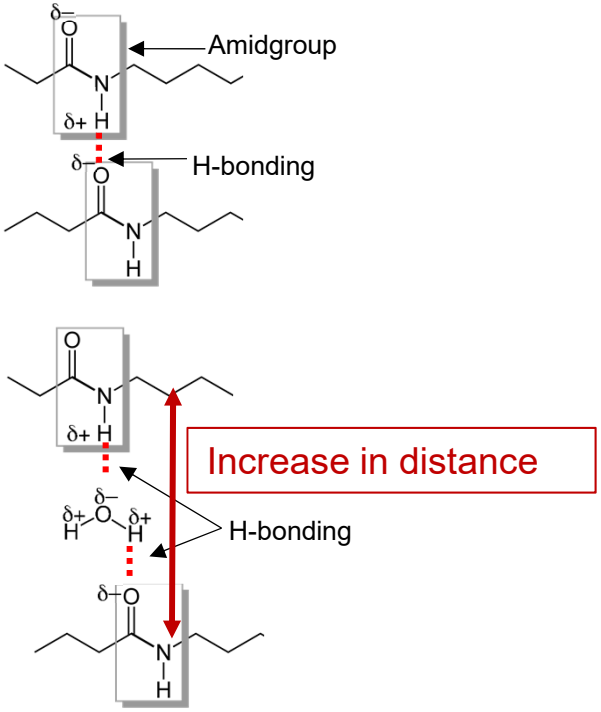
- strong reinforcing effect through the fibers
  - +576%
- reduction of temperature sensitivity
  - Over 50% in comparison to PA6

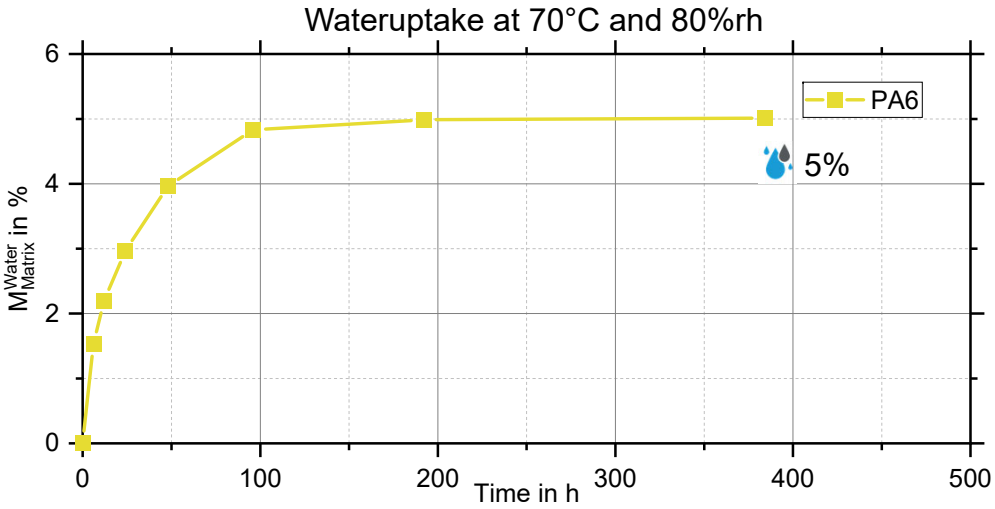
CoDico

- further reinforcement effect
  +45% in comparison to Dico
- Further reduction of temperature sensitivity
  - -30% in comparison to Dico

Parameter humidity in PA6

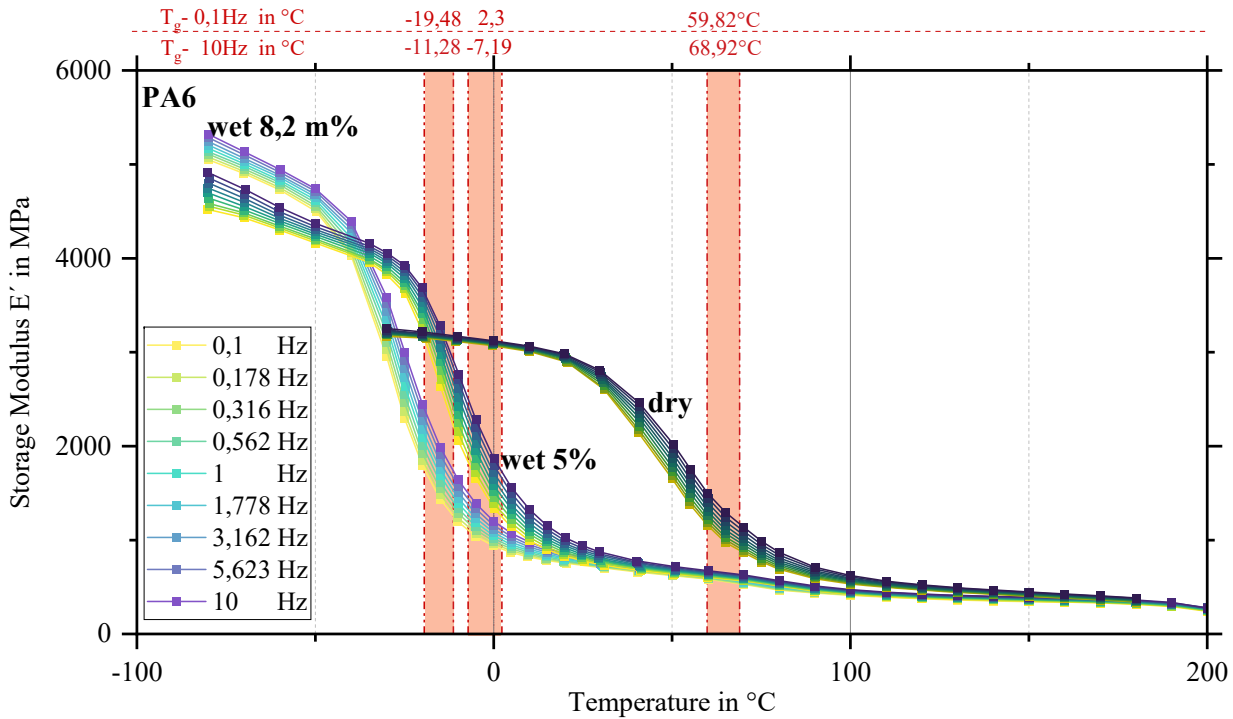
Influence on mechanical properties





Influence of water on the mech. properties of PA6

Dynamic mechanical analysis

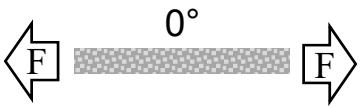


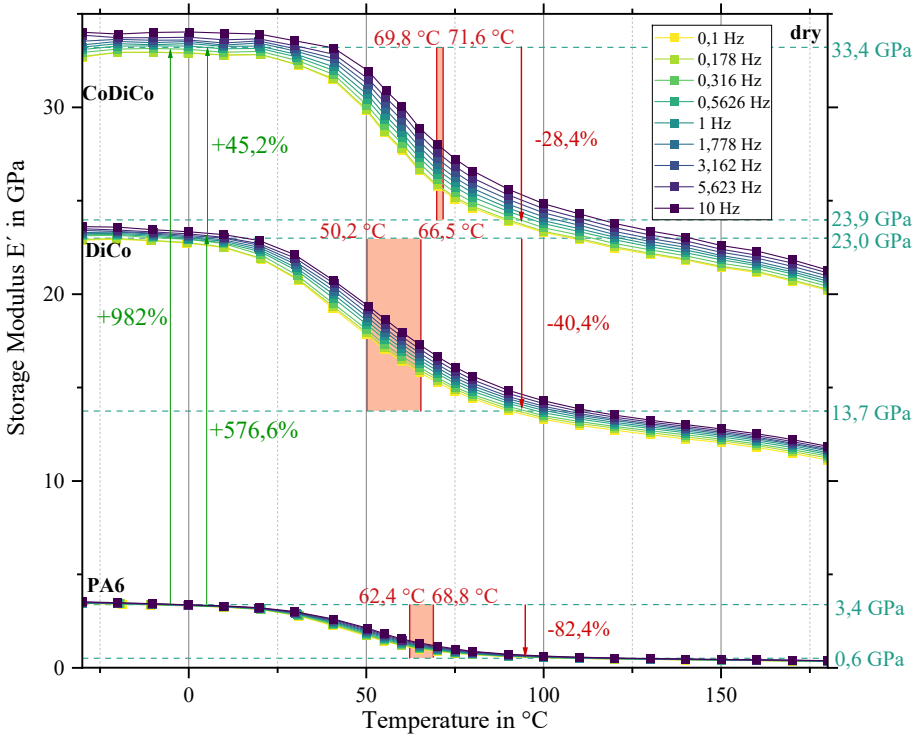
Results

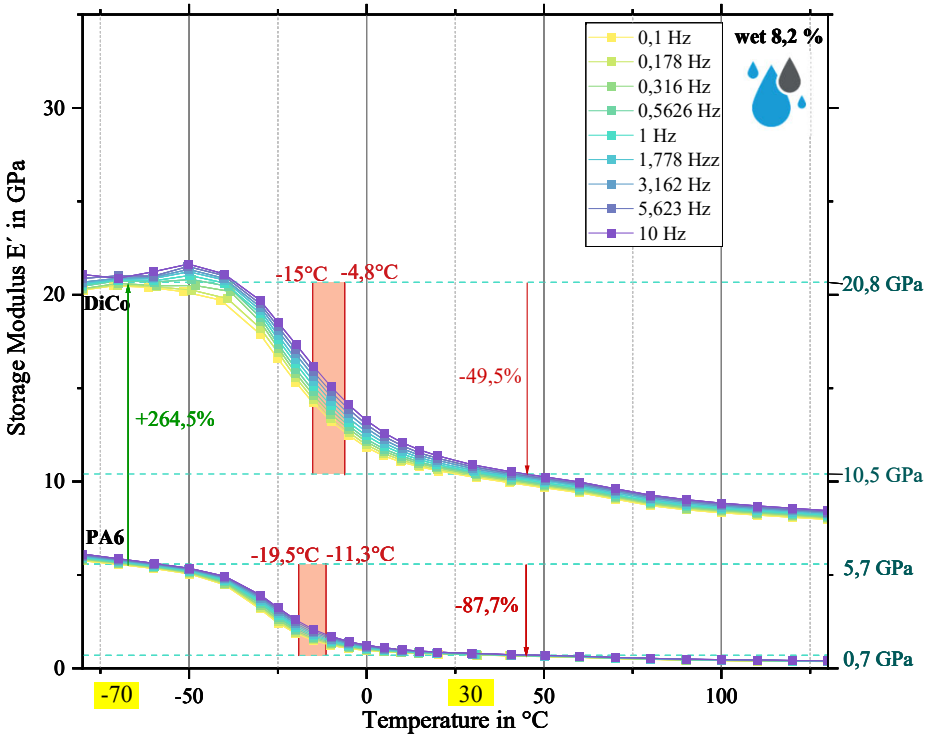
- Water leads to:
  - **α** softening
    - a shift of Tg by up to approx. 80°C
  - ➡ Bigger distance in main chain
  - **β** stiffening
    - solidification at low temperatures
  - ➡ Water limits movement of the side groups

Influence of water on the mech. properties Dico and CoDico

Dynamic mechanical analysis

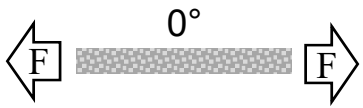


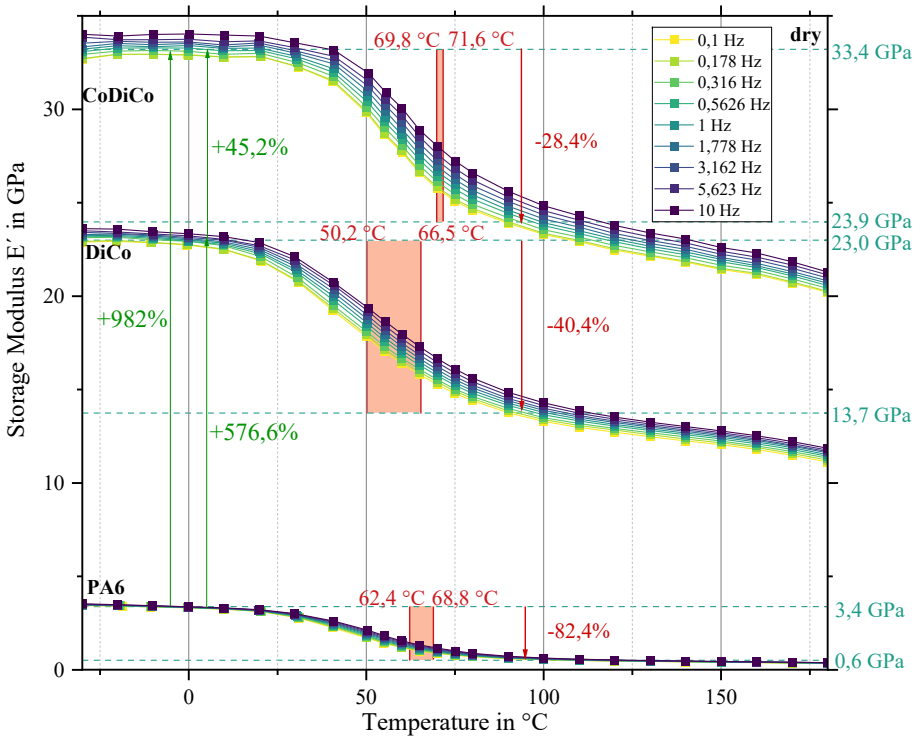


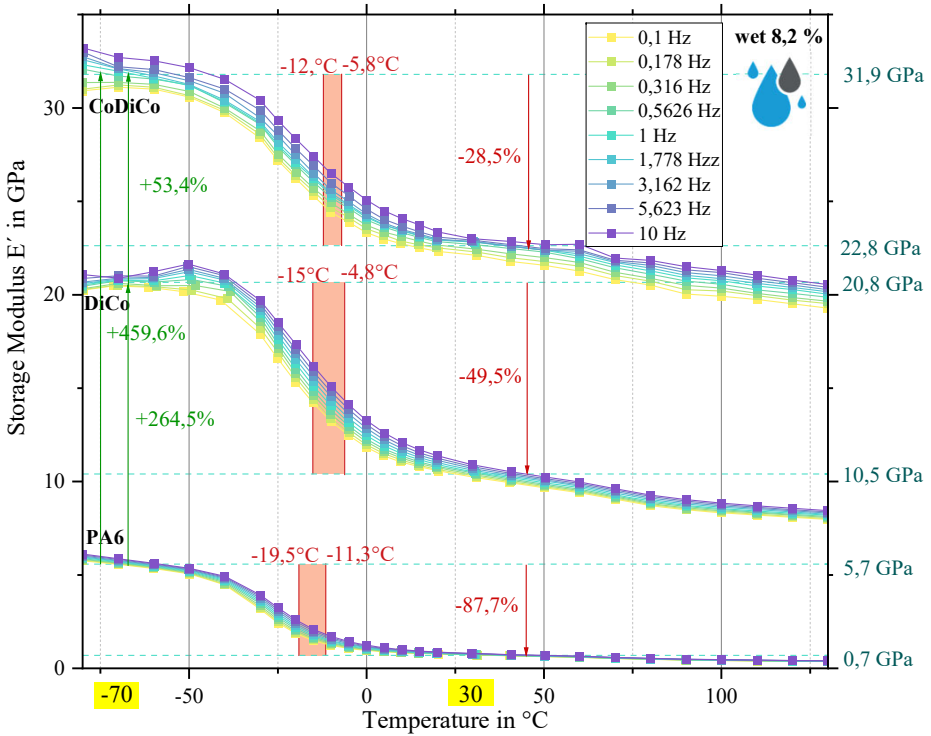


Influence of water on the mech. properties Dico and CoDico

Dynamic mechanical analysis

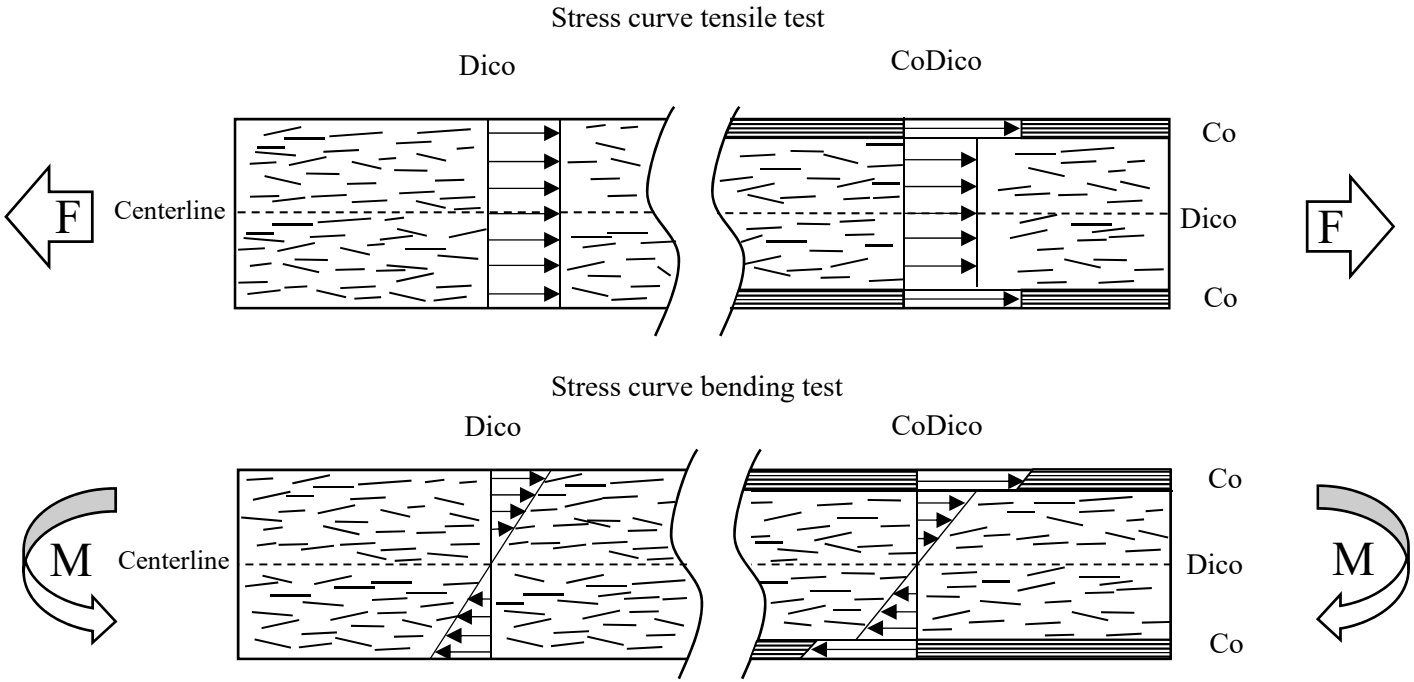






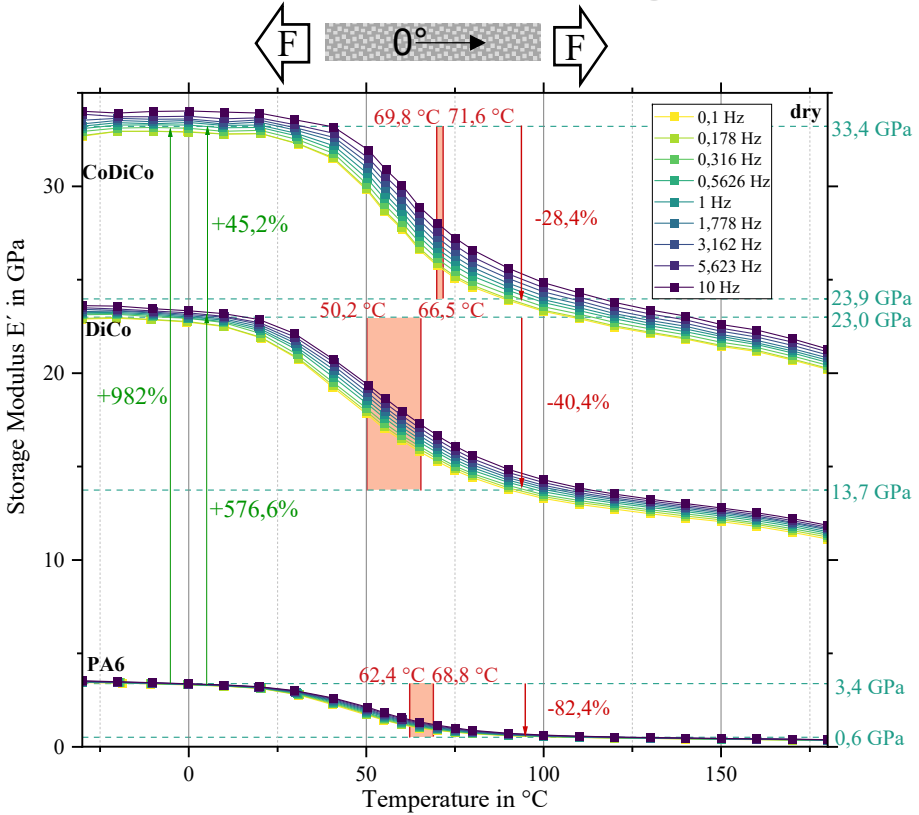
Influence of water on the mech. properties Dico and CoDico

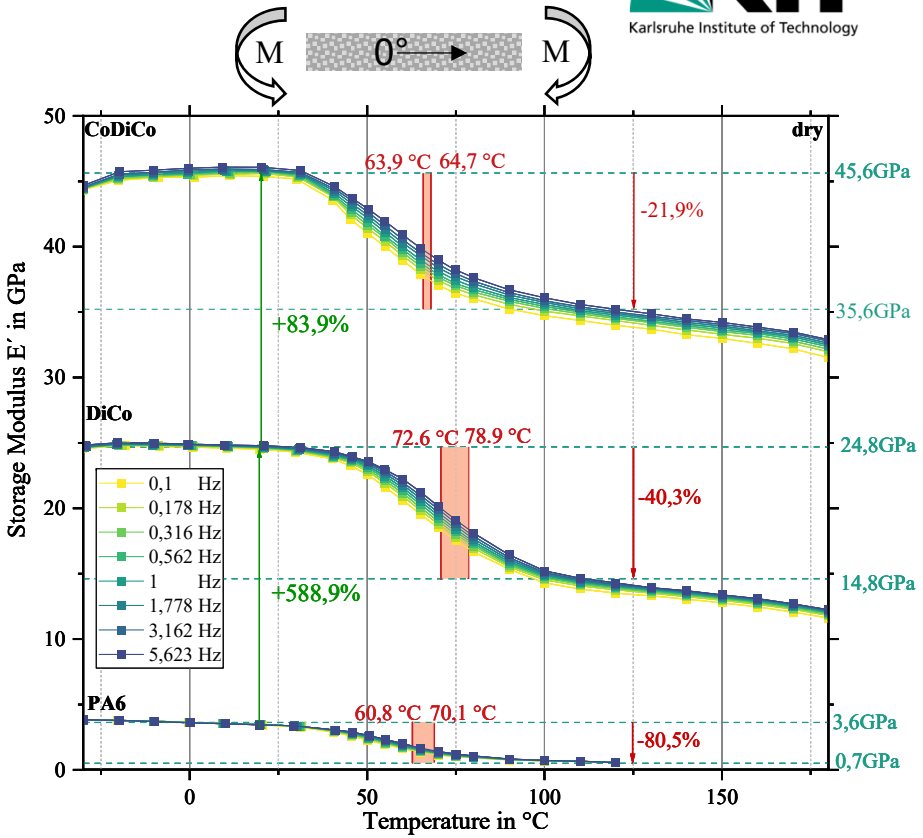
Dynamic mechanical analysis



Dynamisch mechanical analysis

Tensile vs. three point bending





Summary and Outlook

Effect of hybridization in CoDico-LFT

- **Summary:**
- Dico fibre reinforcement leads to:
  - Significant reduction in sensitivity to temperature
  - But shows sensitivity to absorbed water
    - Damage to interface fibre matrix
- CoDico fibre reinforcement leads to:
  - Further reduction of sensitivity to temperature
  - Low sensitivity to absorbed water
  - Even more pronounced hybridisation effect under bending load
- **Outlook:**
  - Is damage to the interface reversible?
  - What is the sensitivity to absorbed water under bending load?
  - How is the Temperature-Time-Superposition applicable

Thank you for your attention!

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