BUDAPESTI MŰSZAKI ÉS
GAZDASÁGTUDOMÁNYI EGYETEM
GÉPÉSZMÉRNÖKI KAR

Materials Science
(BMEGEMTAMM1)

Lecturer: Dr. Ákos Pomázi
pomazi.akos@gpk.bme.hu

POLIMERTECHNIKA
TANSZÉK

Additives

- **Objective:** Modifying properties
- **Fillers (e.g., talc, $CaCO_3$, carbon black, mica)**
- **Sliders: improve workability**
- **Plasticizers:** make hard plastics flexible (e.g., PVC)
- **Antistatic agents**
- **Flame retardants:** reduce flammability and smoke production
- **Stabilizers:** ensure that the polymer's properties are maintained under processing and application conditions
- **Dyes, pigments**
- **Odorants and fragrances**
- **Nucleating agents:** regulate crystallization and crystal structure

KEEP CALM AND BE A CSILLÁMPÓNI

Aging, degradation

- **Degradation:** heat, light, oxygen (ozone) or radiation can cause chain-breaking chemical reactions, causing changes in the polymer structure.

- **Type of degradation:**
  - **Thermal degradation** – thermal energy (heat); as a result of excessively high temperatures during the processing of thermoplastic polymers
  - **Photodegradation** – under the influence of light (UV); polymers containing double bonds are particularly sensitive to this (e.g., rubbers, elastomers, HIPS)

  - **Chemical degradation** – acids, bases, solvents, reactive gases (O_3)
  - **High-energy radiation** – sufficient energy to break all bonds; chain breaking, reduction in molecular weight, cross-linking (can be utilized in the cross-linking of PE; pipes, coatings)
  - **Mechanochemical degradation** – breakage of chemical bonds due to high external stresses; not particularly significant
  - **Biodegradation** – Enzymes produced by microorganisms break down the bonds
- **Degradation effects almost never occur on their own.**
- E.g.: Window profile: sunlight (temperature), water, detergents, oxygen, ozone, and other reactive gases in the air
- **Mechanisms:**

  - Depolymerization (e.g.: PMMA)
  - Elimination (e.g.: PVC – hydrochloric acid is formed)
  - Chain-breaking
  - Cross-linking

Aging, degradation

Intensification (Overstress) for acceleration

21 days at 37° C

4 minutes at 175 ° C

Basics of mechanics

- **Force – F [N]**
- **Displacement – l [mm]**
- **Initial length of the specimen – l_0 [mm]**
- **Strain/elongation – Δl [mm]**

$$\Delta l = l - l_0$$

- **Deformation – ε [-]**

$$\varepsilon = \frac{\Delta l}{l_0}$$

- **Surface – A [mm^2]**
- **Mechanical stress – σ [MPa]**

$$\sigma = \frac{F}{A}$$

- **Engineering stress – σ [MPa]**

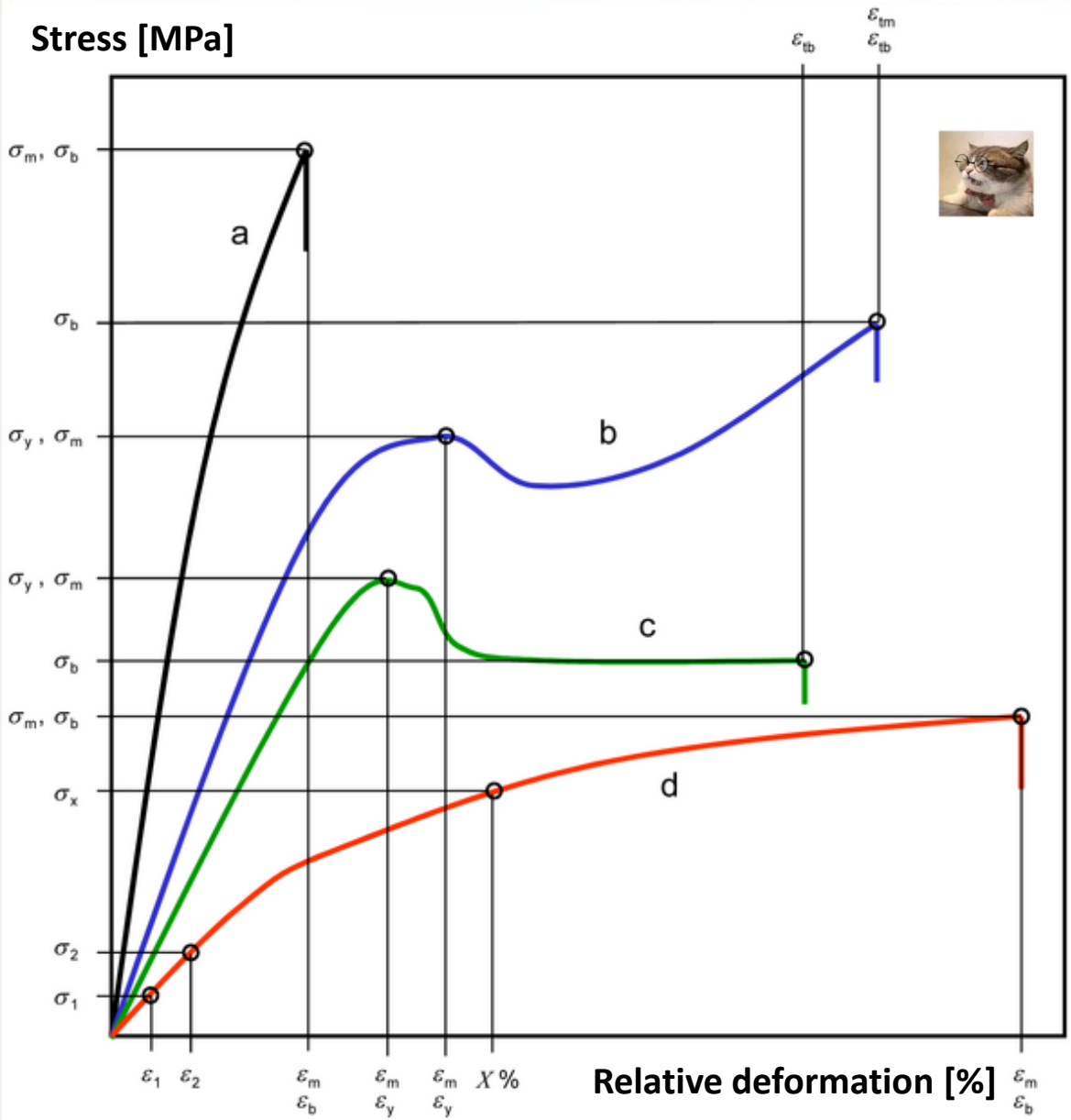
$$\sigma = \frac{F}{A_0}$$

- **Elastic modulus (Hooke's law) – E [GPa]**

$$\sigma = E\varepsilon$$

- **Strength:** the specific load-bearing capacity of a material, i.e., the amount of force that a unit cross-section of the material can withstand without failing. Depending on the type of load: tensile, compressive, bending, shear, etc.

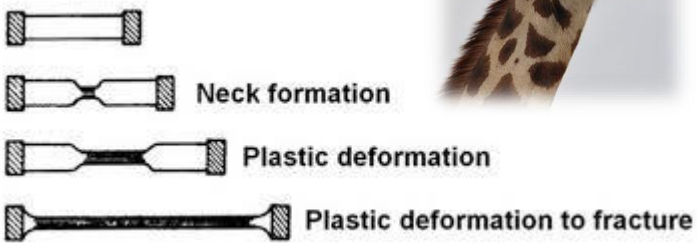
Tensile test



a) brittle (glass-like) behaviour

b) and c) demonstrating neck formation

d) soft, rubbery behaviour with high (>50%) elongation at break



Load-bearing history

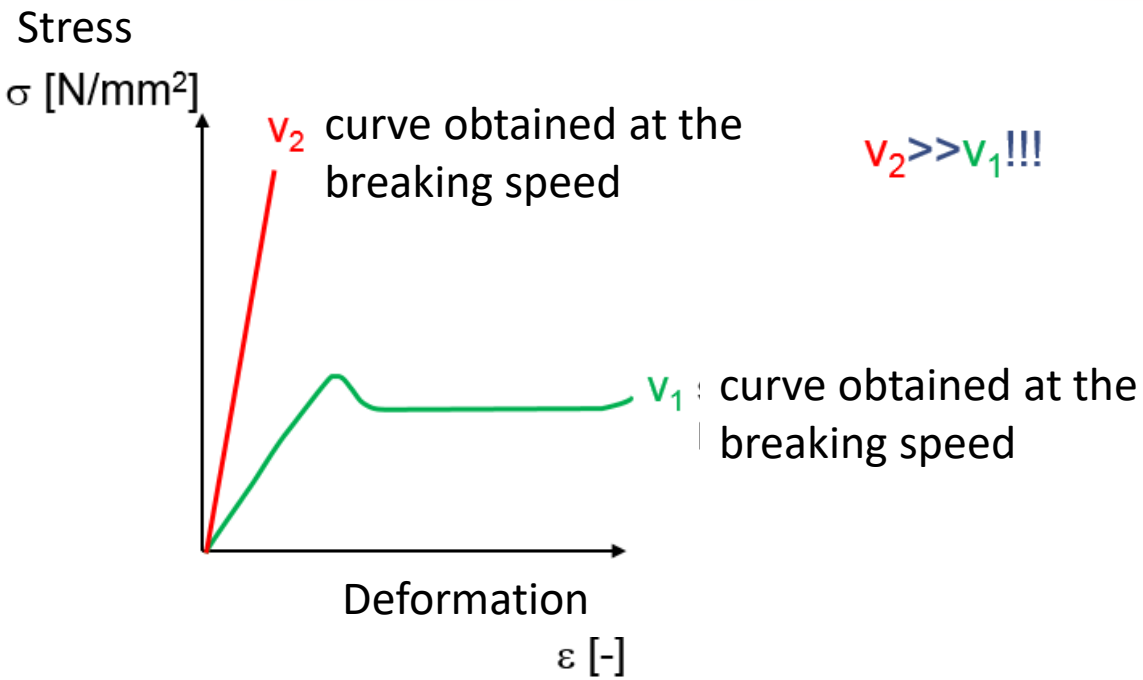
Static, constant over time

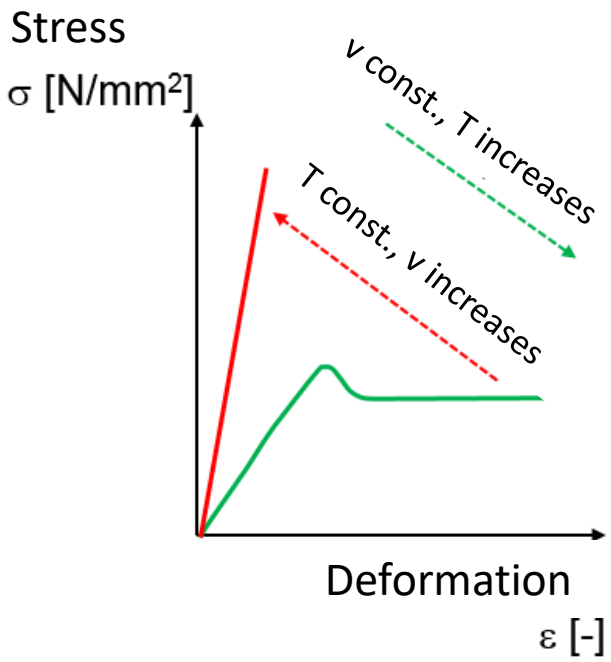
Impact-like

Periodic, cyclical

With repeated use, fatigue may occur, and in extreme cases, a fracture may result

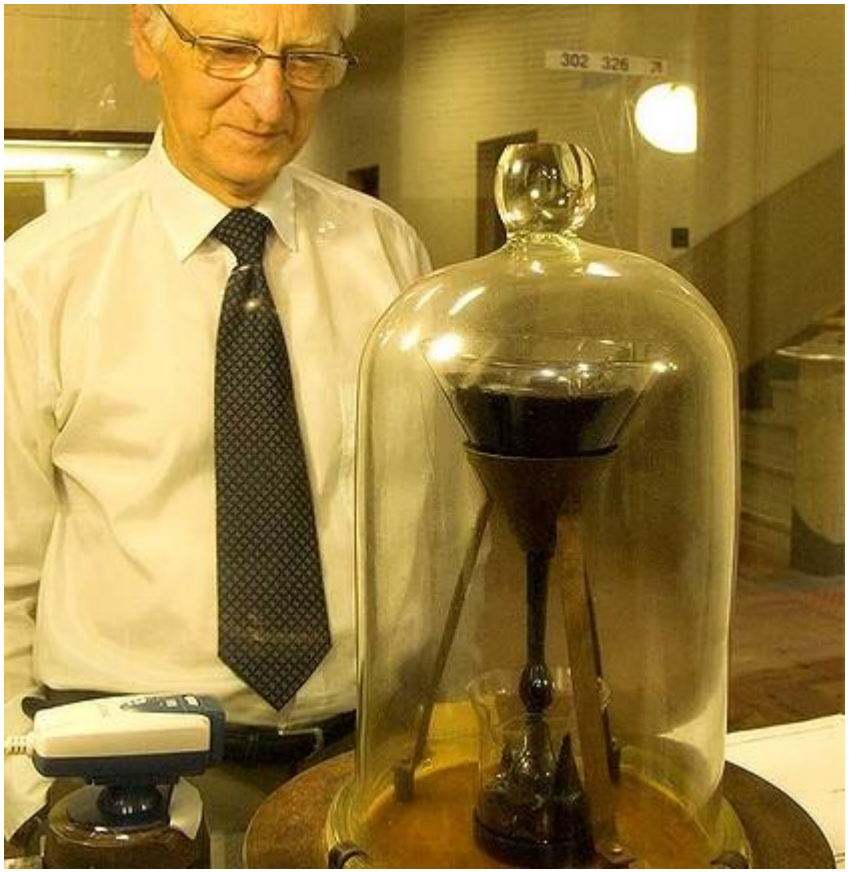
Temperature-time equivalence





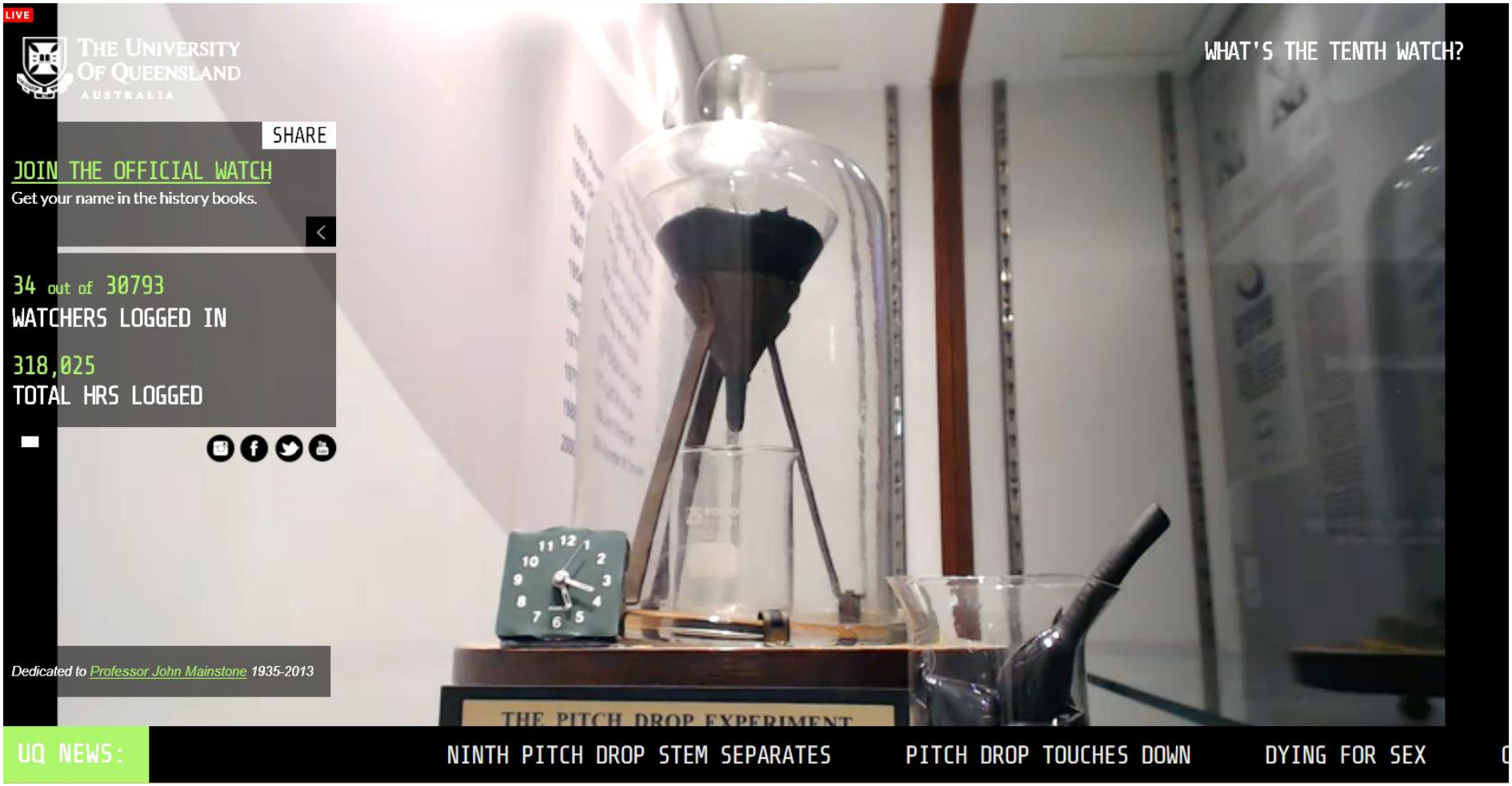
- **The loading speed and temperature have a significant influence on the material's mechanical response**

The flow of tar at room temperature



John Mainstone
http://www.thetenthwatch.com/
Experiment started in 1927

The flow of tar at room temperature



2014

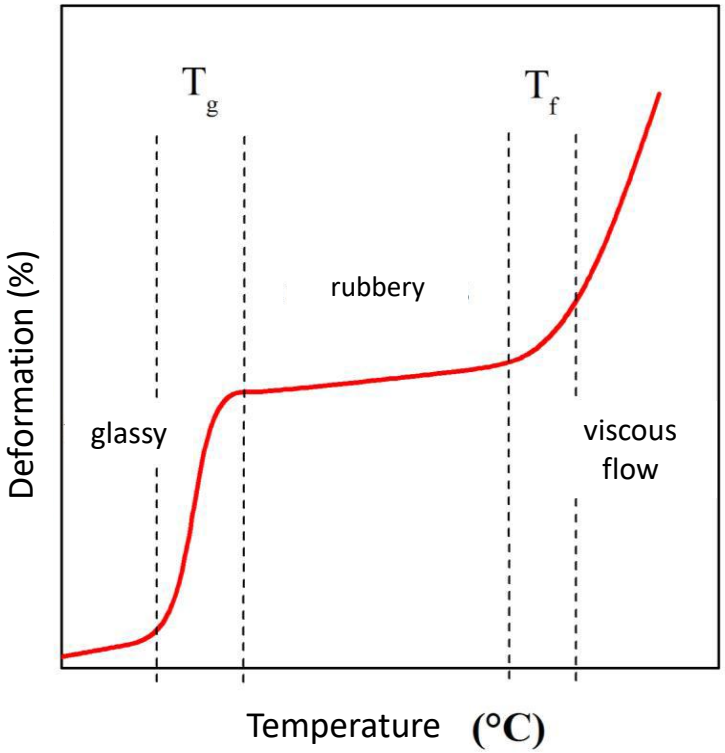
The flow of tar at room temperature

2015

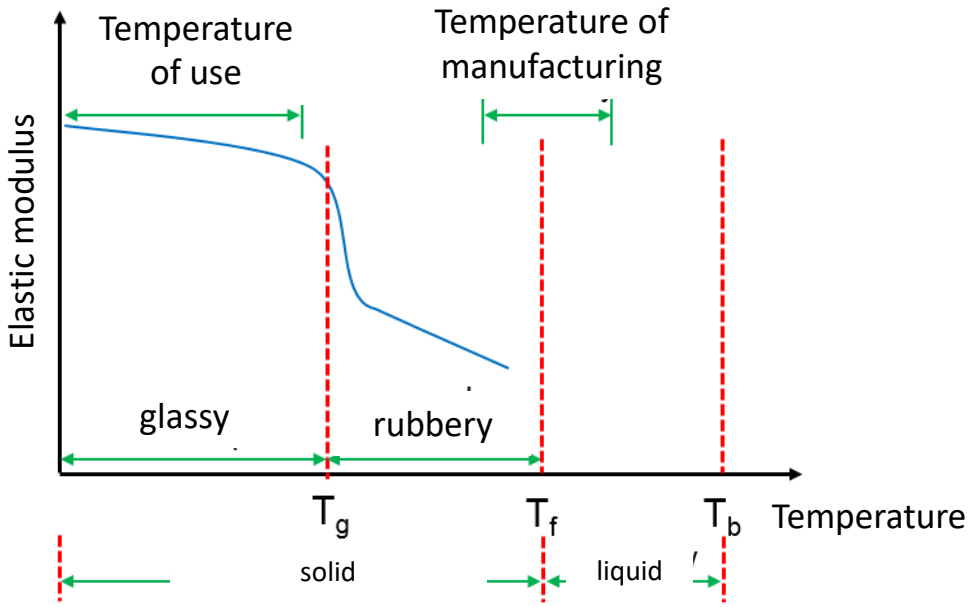
The flow of tar at room temperature

2017

Termomechanical curves

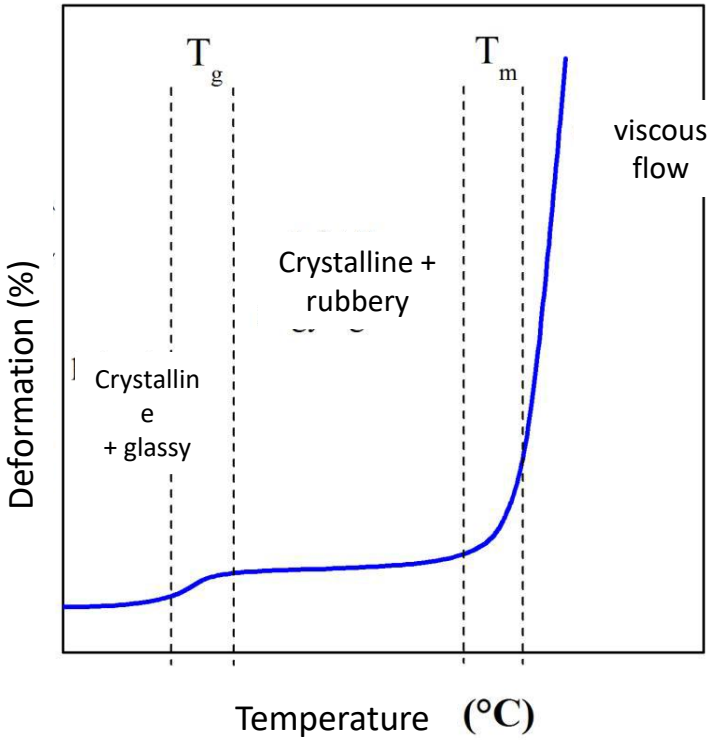


Linear, amorphous polymers

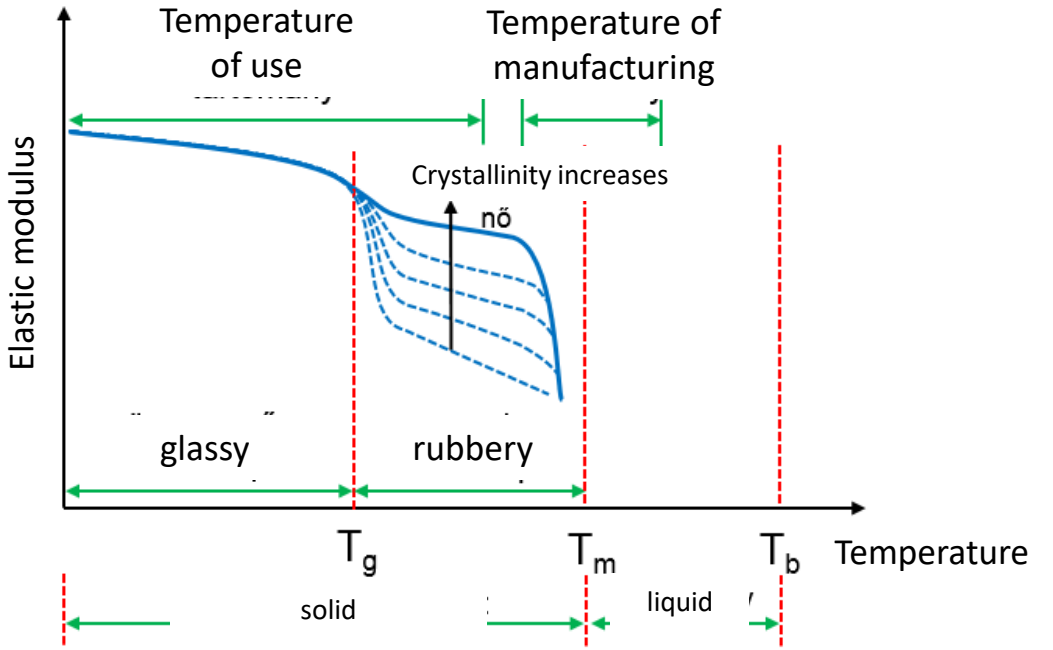


T_g: glass transition temperature
T_f: flow temperature
T_b: temperature of degradation

Termomechanical curves

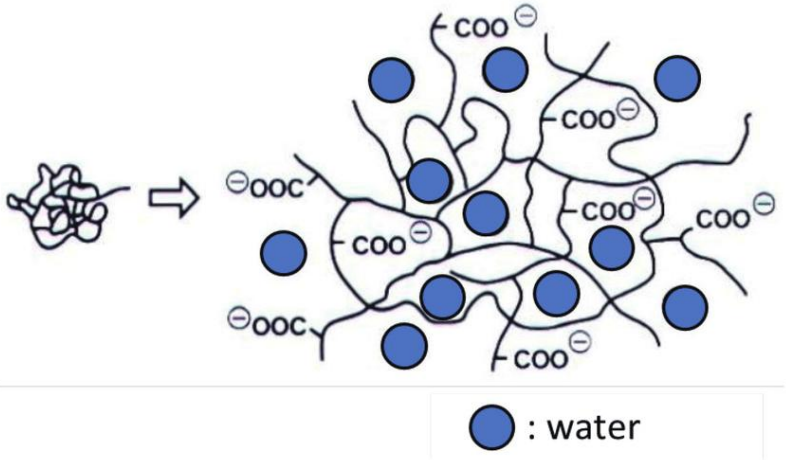


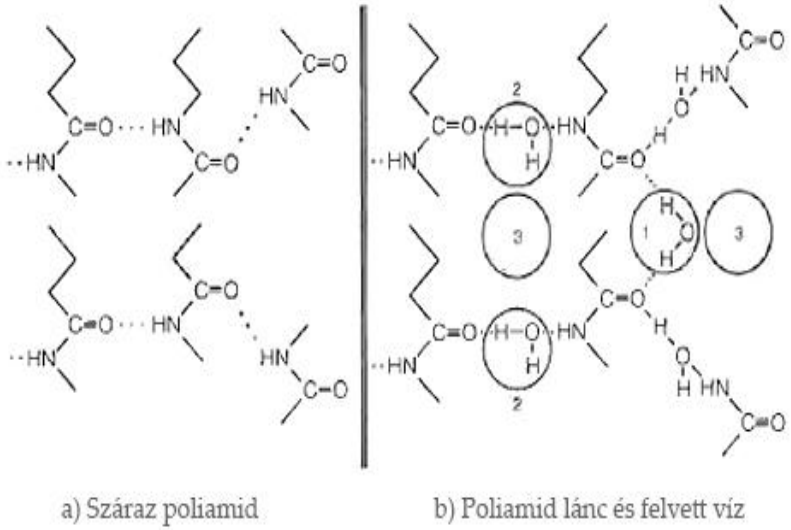
Linear, semicrystalline polymers



T_g: glass transition temperature
T_m: melting temperature
T_b: temperature of degradation

The effect of moisture on the mechanical prop.



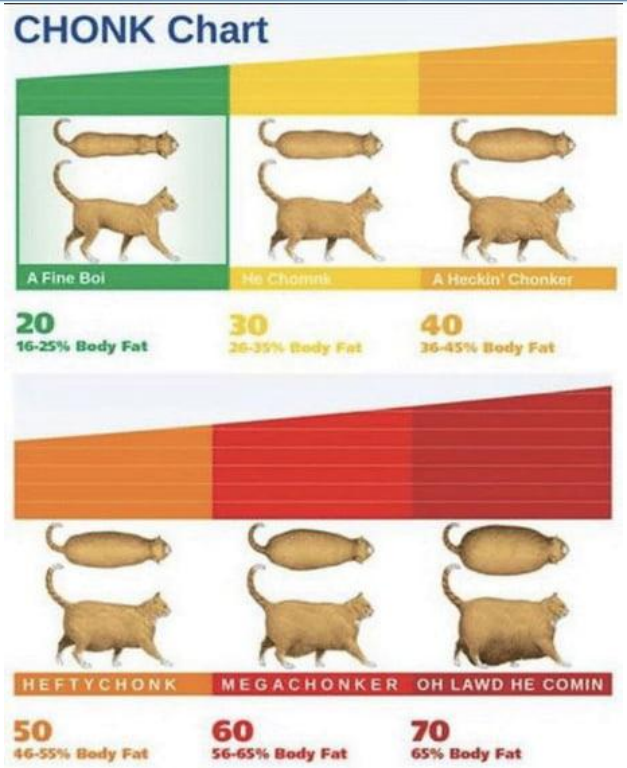


- **Hydrophobic materials :** no water uptake (PE, PP)
- **Hydrophilic materials :** they absorb or release water until the equilibrium moisture content corresponding to the given temperature and relative humidity is reached (PET, PA, PLA)

- Water molecules reduce the number of secondary bonds through swelling → When subjected to a load, the material's mechanical behavior changes and it becomes more ductile

- **Generally a disadvantage ↔ It could also be an advantage**
- **Disadv.:** degradation, foaming, etc. (the materials must be dried)
- **Adv.:** the use of polymer gels (e.g., controlled drug release)

The effect of moisture on the mechanical prop.



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Thank you for your attention!

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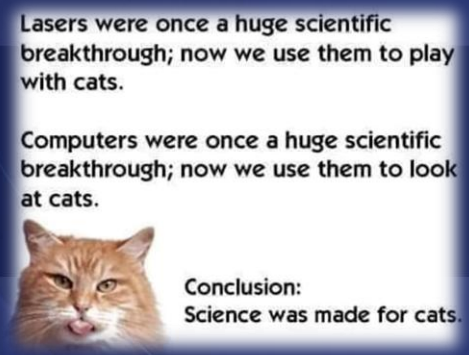

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