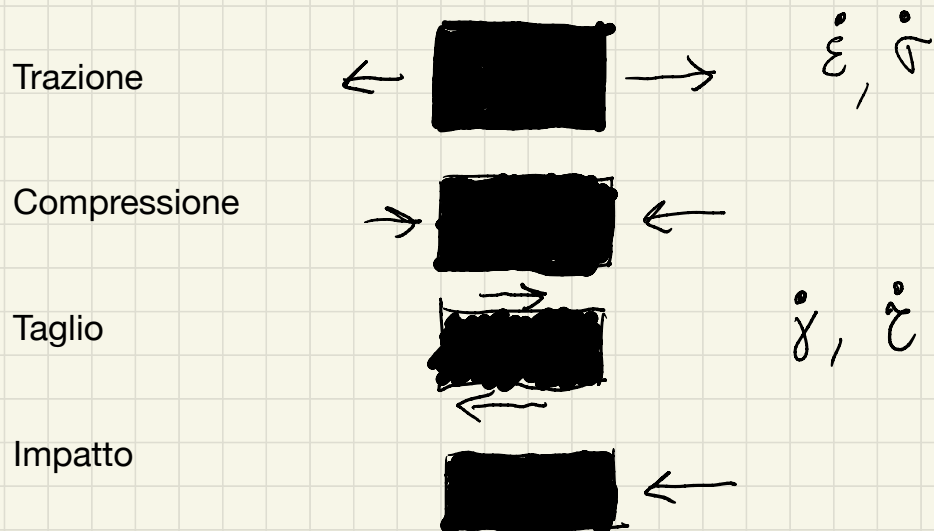


MECCANISMI DI FRATTURA DEI POLIMERI

MACROSCOPICAMENTE



Da un punto di vista macroscopico delle proprietà meccaniche:

- Curve sforzo-deformazione
- Snervamento e frattura

Da un punto di vista microscopico delle proprietà meccaniche

Meccanica della frattura

- Snervamento (**shear yielding**)
- **Crazing**

$$\Delta V = 0$$

$$\Delta V \neq 0$$

ES. PROVA A TRAZIONE

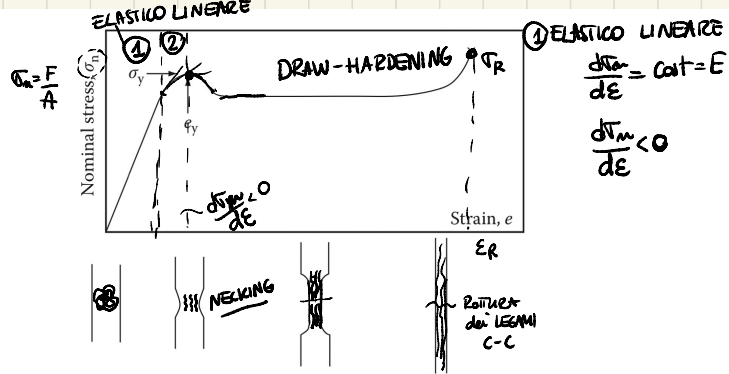


FIGURE 22.1 Schematic representation of the stress-strain behaviour of a ductile polymer and consequent change in specimen dimensions (× marks the point at which fracture occurs).

RESINA EPOSSIDICA → TI → RETICOLAZIONI X-Linking

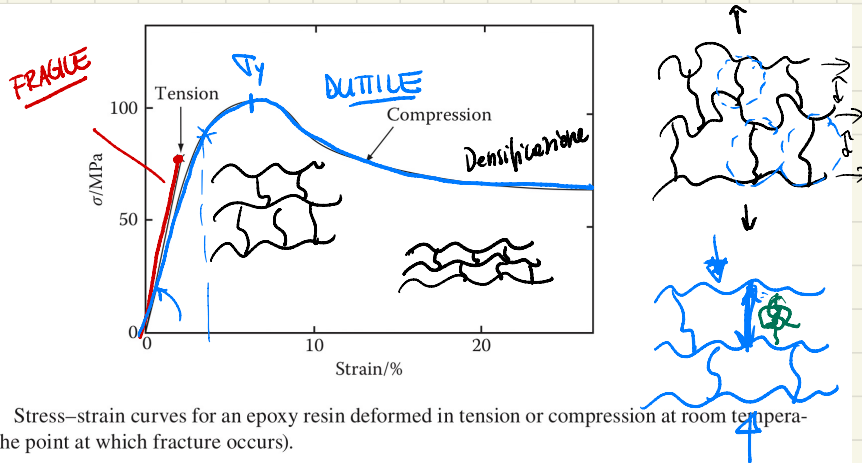
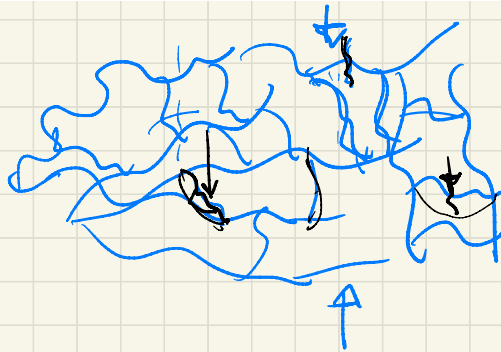


FIGURE 22.9 Stress-strain curves for an epoxy resin deformed in tension or compression at room temperature (× marks the point at which fracture occurs).



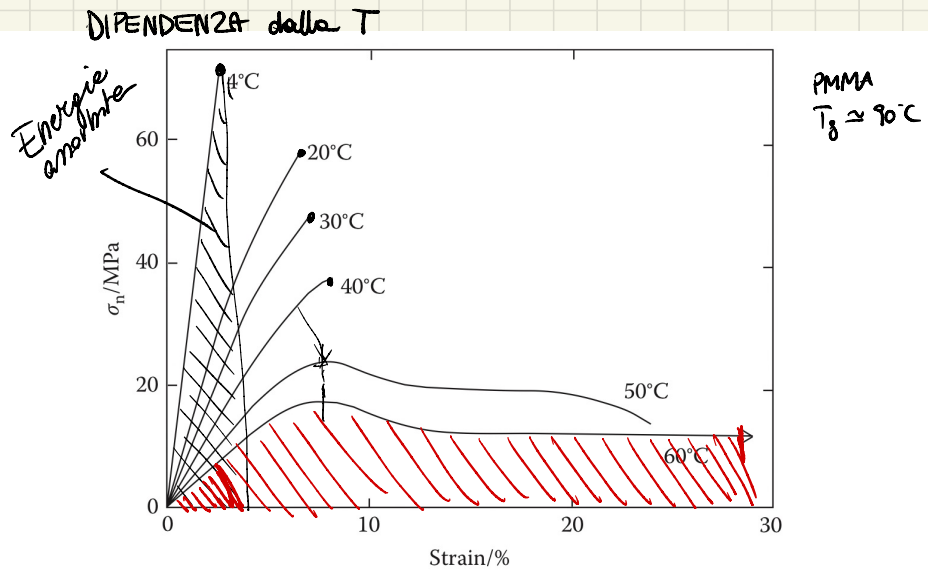


FIGURE 22.2 Variation of the stress–strain behaviour of poly(methyl methacrylate) with temperature. (Data taken from Andrews, E.H., *Fracture in Polymers*, Oliver and Boyd Ltd, London, U.K., 1968.)

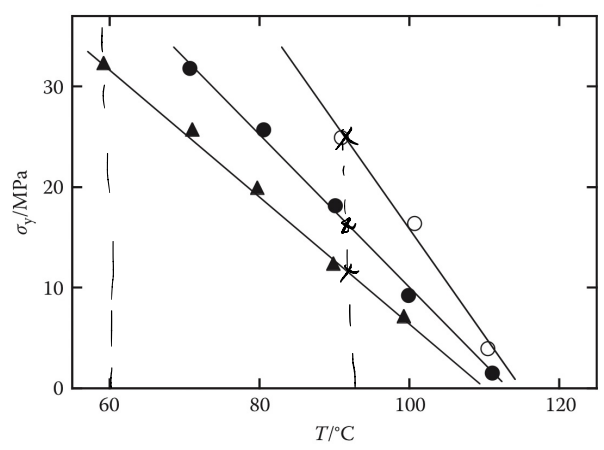
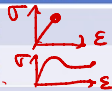
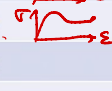


FIGURE 22.4 Variation of the yield stress of poly(methyl methacrylate) with temperature at strain-rates of: \blacktriangle , 0.002 min^{-1} ; \bullet , 0.02 min^{-1} ; and \circ , 0.2 min^{-1} . (Data taken from Langford, G. et al., *Materials Research Laboratory Report No. R63-49*, Dept. Civil Eng., MIT, Cambridge, MA, 1963.)

Polimero	Tipo di deformazione/T	Proprietà meccaniche caratteristiche	Meccanismo di frattura
Polistirene	Trazione a RT	Fragile 	Crazing
	Compressione a RT	Duttile 	Shear Band
PMMA	Trazione a T < 40°C	Fragile	Crazing
	Trazione a T > 50°C	Duttile	Shear Band

Policarbonato

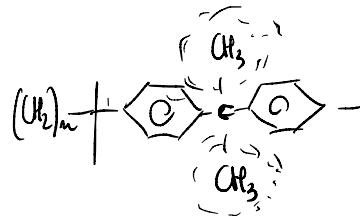
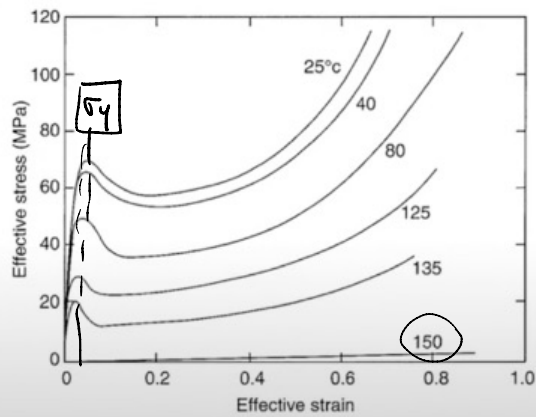
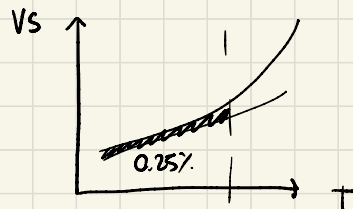
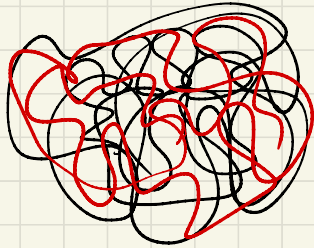


Figure 12.23 Stress-strain behavior of polycarbonate in uniaxial extension at various temperatures. (Reproduced from G'Sell, C., Hiver, J.M., Dahoun, A., and Souahi, A., *J. Mater. Sci.*, 27, 5031, 1992. With permission.)

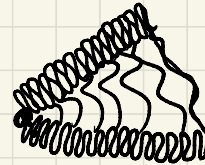


POLIMERO AMORFO



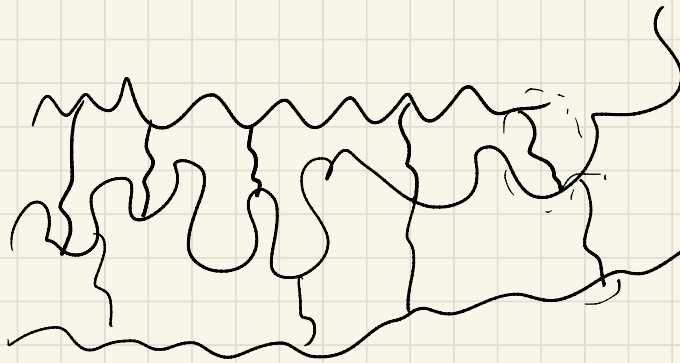
RANDOM COIL

POLIMERO SEMICRISTALLINO
(SFERULITE)



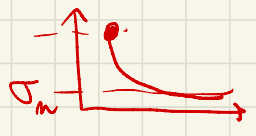
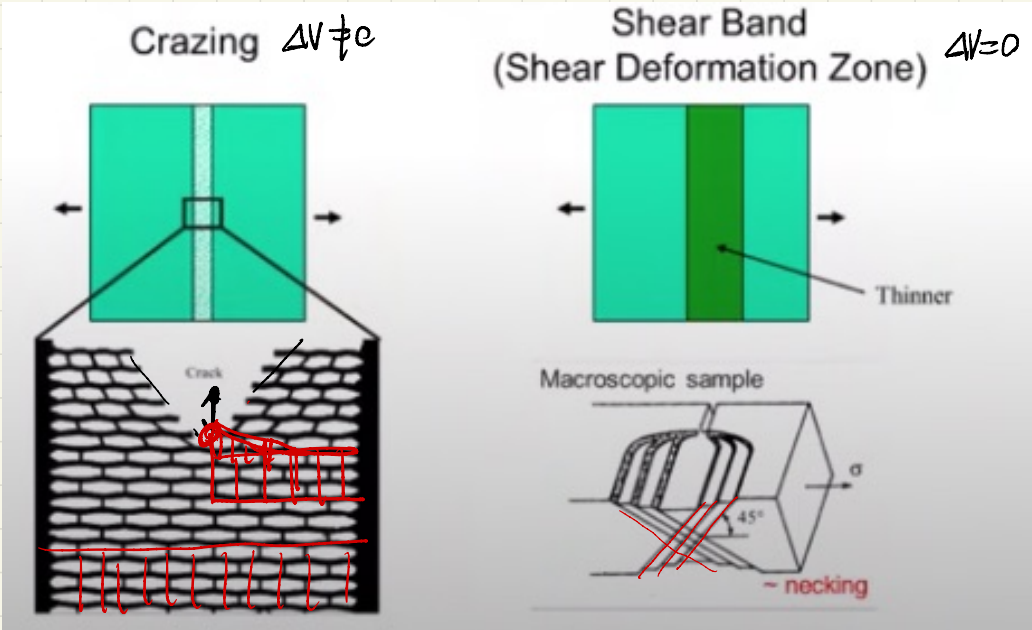
POLIMERO RETICOLATO

FRAGILE (A TRAZIONE)

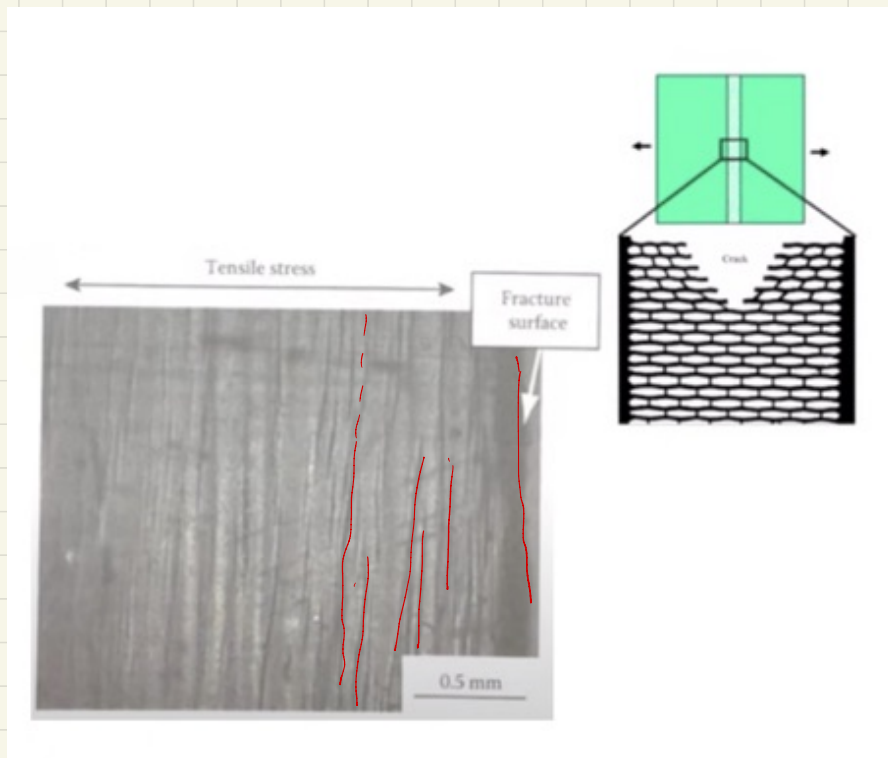


FRATTURA

Proprietà meccaniche a grandi deformazioni: meccanismi microscopici



Crazing



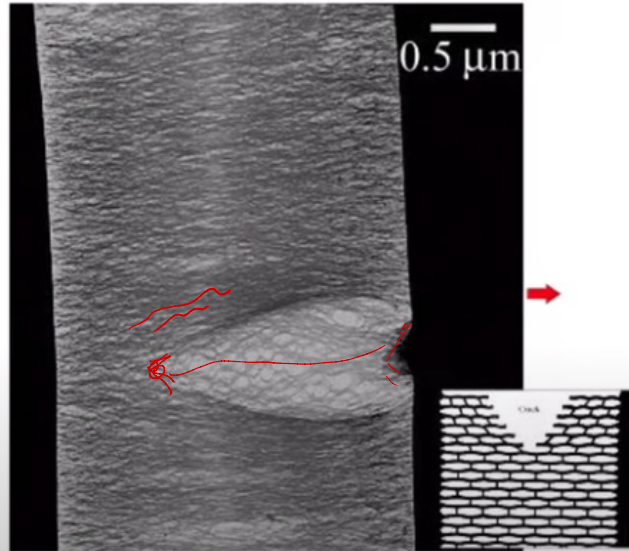
- Polystyrene
- PMMA
- PCHE

PCHE homopolymer
M = 283,000 g/mol

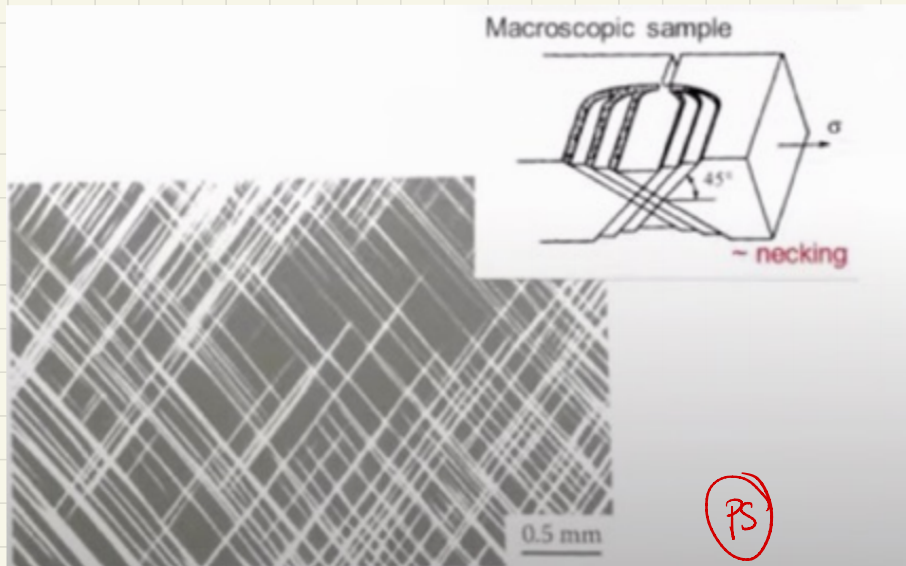


TEM

Ryu et al. *Macromolecules* (2002)



Shear banding



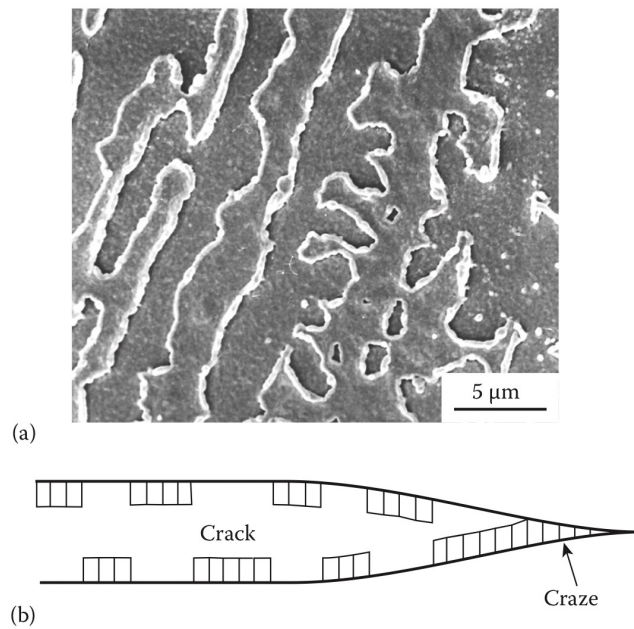


FIGURE 23.10 (a) Scanning electron micrograph of the fracture surface of a sample of poly(methyl methacrylate) showing craze debris on the surface. (Courtesy of M.N. Sherratt, University of Manchester, Manchester, U.K.) (b) A schematic representation of a crack growing through a craze with craze breakdown at the craze-polymer interface.

❖ Proprietà meccaniche: meccanismi di frattura

DIPENDENZA dal PESO MOLECOLARE della ϵ_R .

ϵ_R — STRUTTURA < COMPOSIZIONE
 M_w / M_n

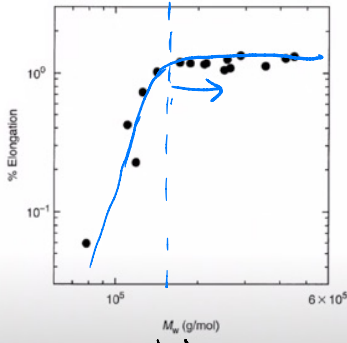
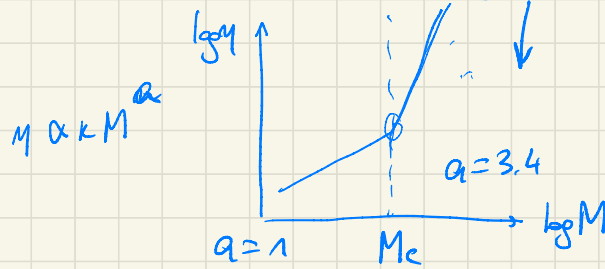
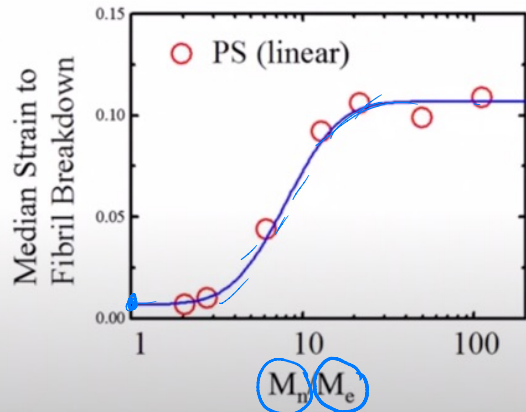
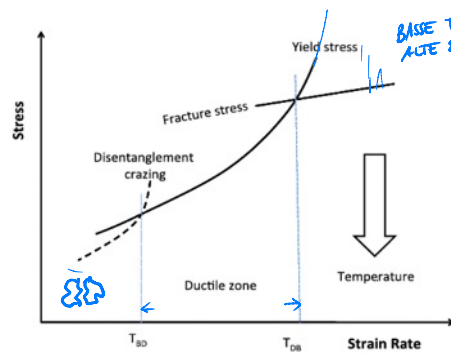
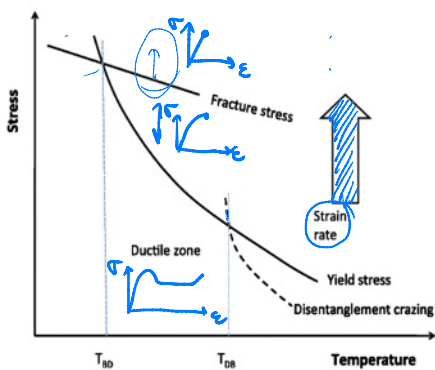


Figure 12.24 Elongation at break in polystyrene as a function of weight average molecular weight. (Data reported in McCormick, H.W., Brower, F.M., and Kim, L., *J. Polym. Sci.*, 39, 87, 1959.)
 (Figure 12.24 from Polymer Chemistry, Paul C. Hiemenz and Timothy P. Lodge (2nd Edition), CRC Press.)



❖ Proprietà meccaniche: meccanismi di frattura

$$G_{1c} \propto (\sum_e f_s)^2$$



RIPASSO PROPRIETÀ MECCANICHE

RISPOSTA MECCANICA dei POLIMERI ad una SOLLECITAZIONE
DIPENDE da:

- IL TIPO di SOLLECITAZIONE
- T di PROVA
- VELOCITÀ di $\dot{\epsilon}$

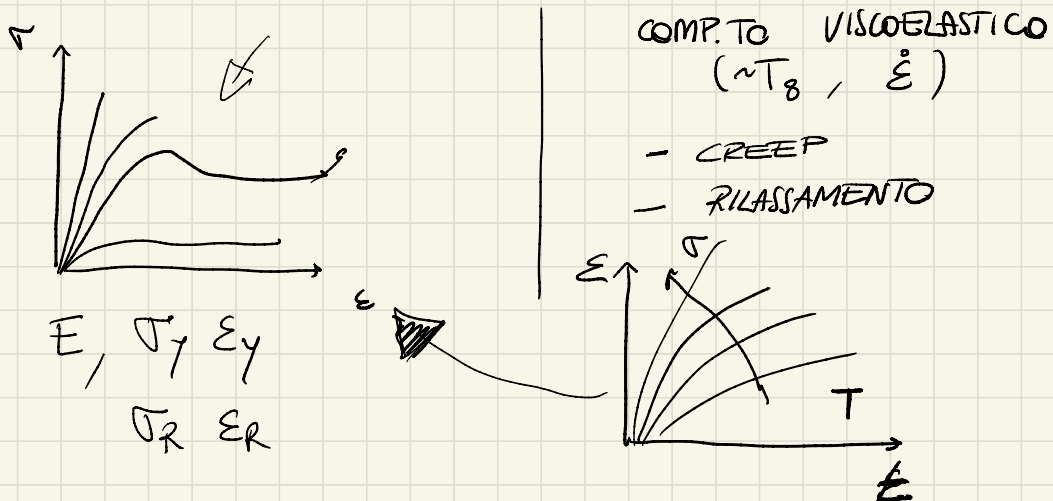
A PARITÀ di COMPOSIZIONE

- \bar{M}_w , \bar{M}_n
- Se TP dipende dalla % CRISTALLINITÀ
- Se TI dipende dal grado di RETICOLAZIONE

CARATTERIZZAZIONE dei POLIMERI

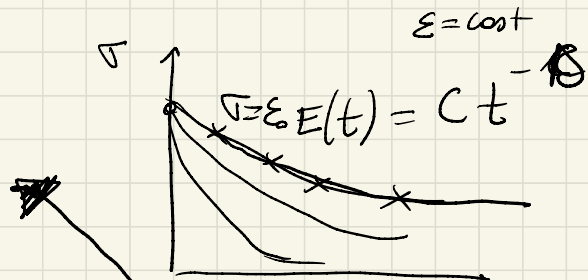
→ PROVE a CARICO VARIABILE → in controllo di σ
DEF. NE " " " ϵ

→ TRAZIONE, COMPRESIONE, FLESSIONE ...



$$\varepsilon(t) = \sigma_0 D(t)$$

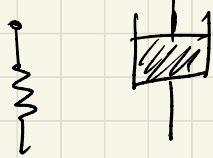
$$\sigma(t) = \varepsilon_0 E(t)$$



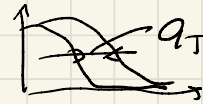
DMA

$$\left\langle \begin{matrix} E, G \\ D \end{matrix} \right\rangle \rightarrow E^* = \underbrace{E'}_{(E)} + i \underbrace{E''}_{(\eta)} t$$

$D(t)$
 $E(t)$ > MODELLI VISCOELASTICI



— PRINCIPIO di $Eg. 29$ $t-T$ (WLF)
 $T_g < T < T_g + 150^\circ C$



— PRINCIPIO di SOVRAPPORZIONE di
 BOLTZMANN

$$\varepsilon(t) = \sum_{i=1}^{\infty} \Delta \sigma_i D(t - \tau_i)$$