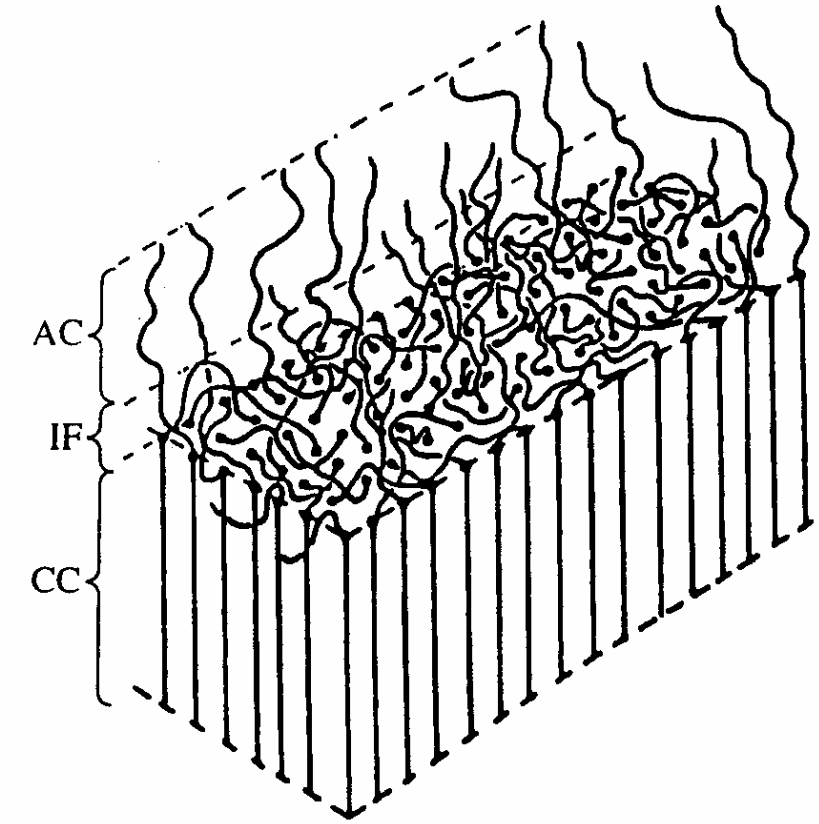
polymer structure and micromechanics

structure

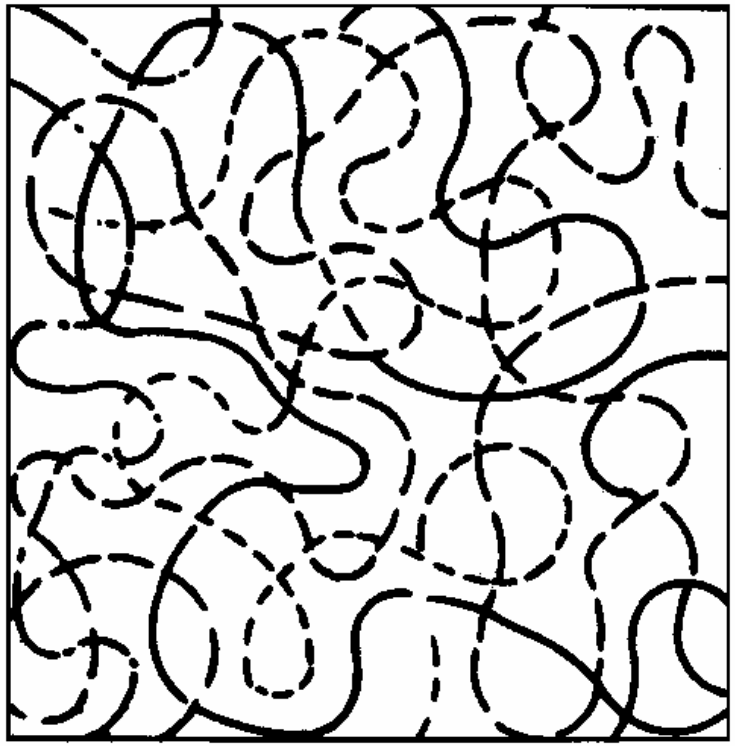
Physical structure



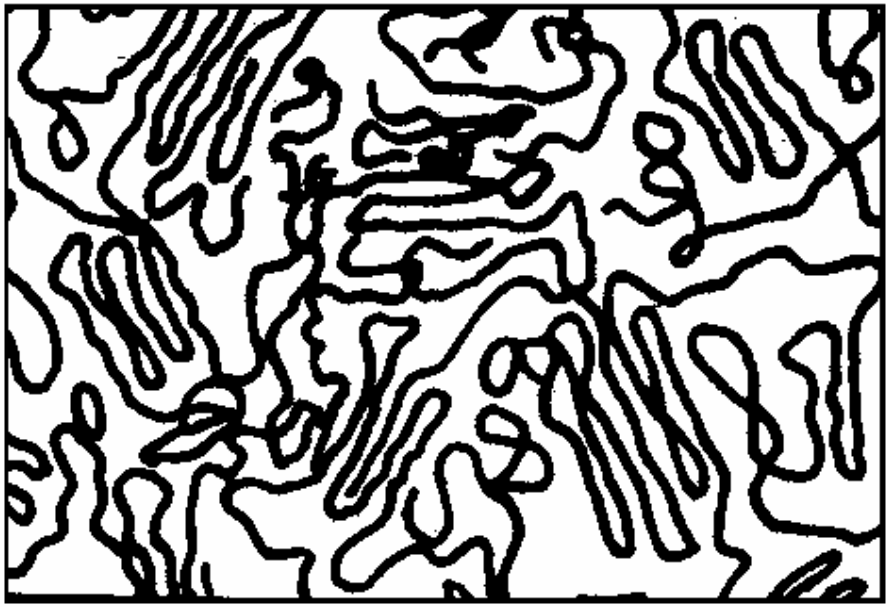
Amorphous components (AC)

Interface (IF)

Crystalline components (CC)

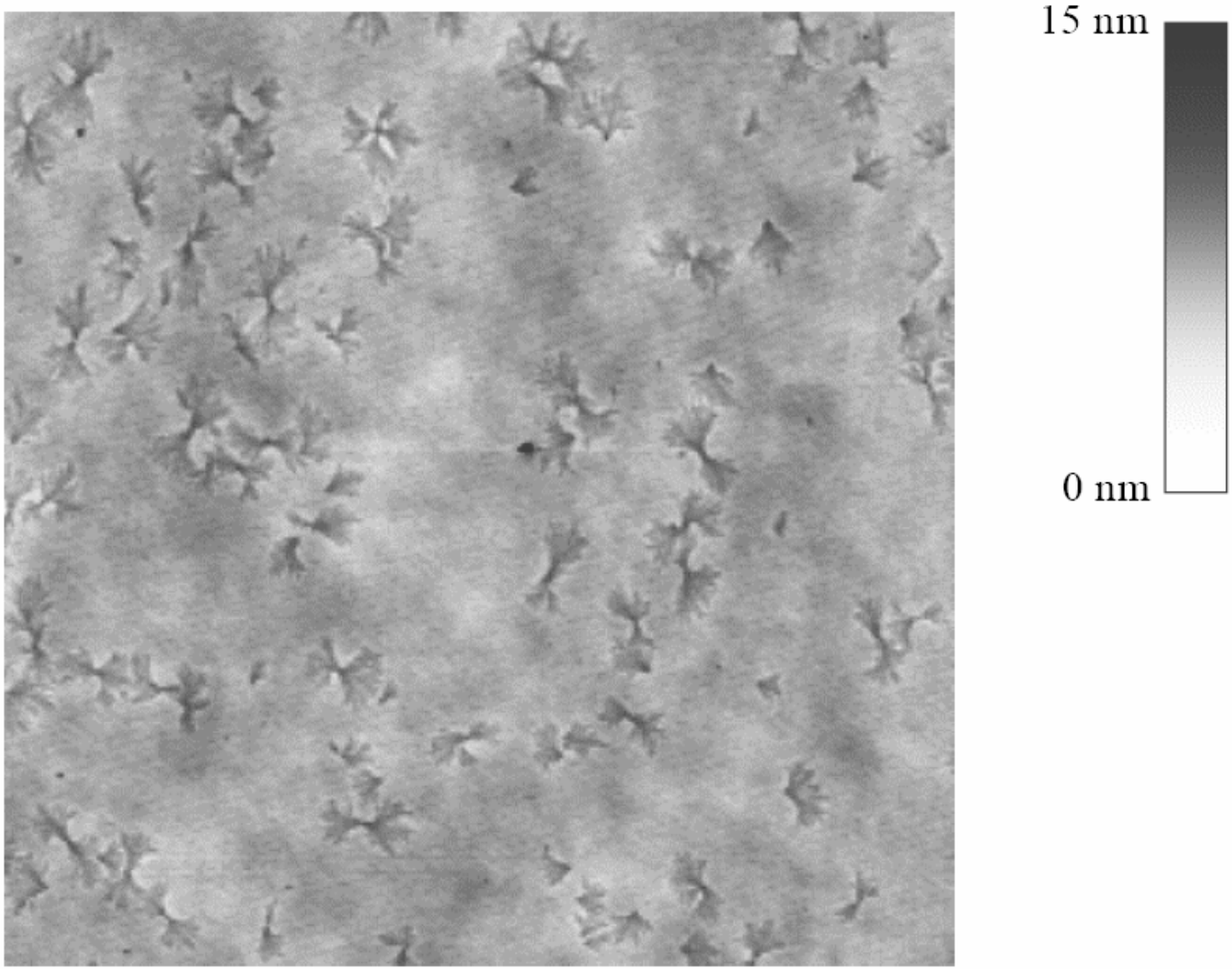


P.J. Flory, 1949



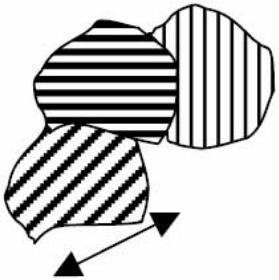
G.S.Y.Yeh, 1972

Amorphous components (AC)



PET / AFM: M Durell, J E Macdonald, D Trolley, Europhysics Letters (2002)

Crystal "grains": crystallites of varying orientation



10 μm

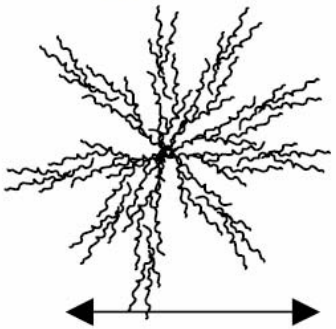
Ex: Stainless steels Fe-Ni-Cr

Depletes at grain boundaries causing corrosion

used for fracture fixation plates,etc., & angioplasty stents

Spherulites: radially oriented crystallites interspersed w/ amorphous phase

semicrystalline polymers, glass-ceramics



10 μm

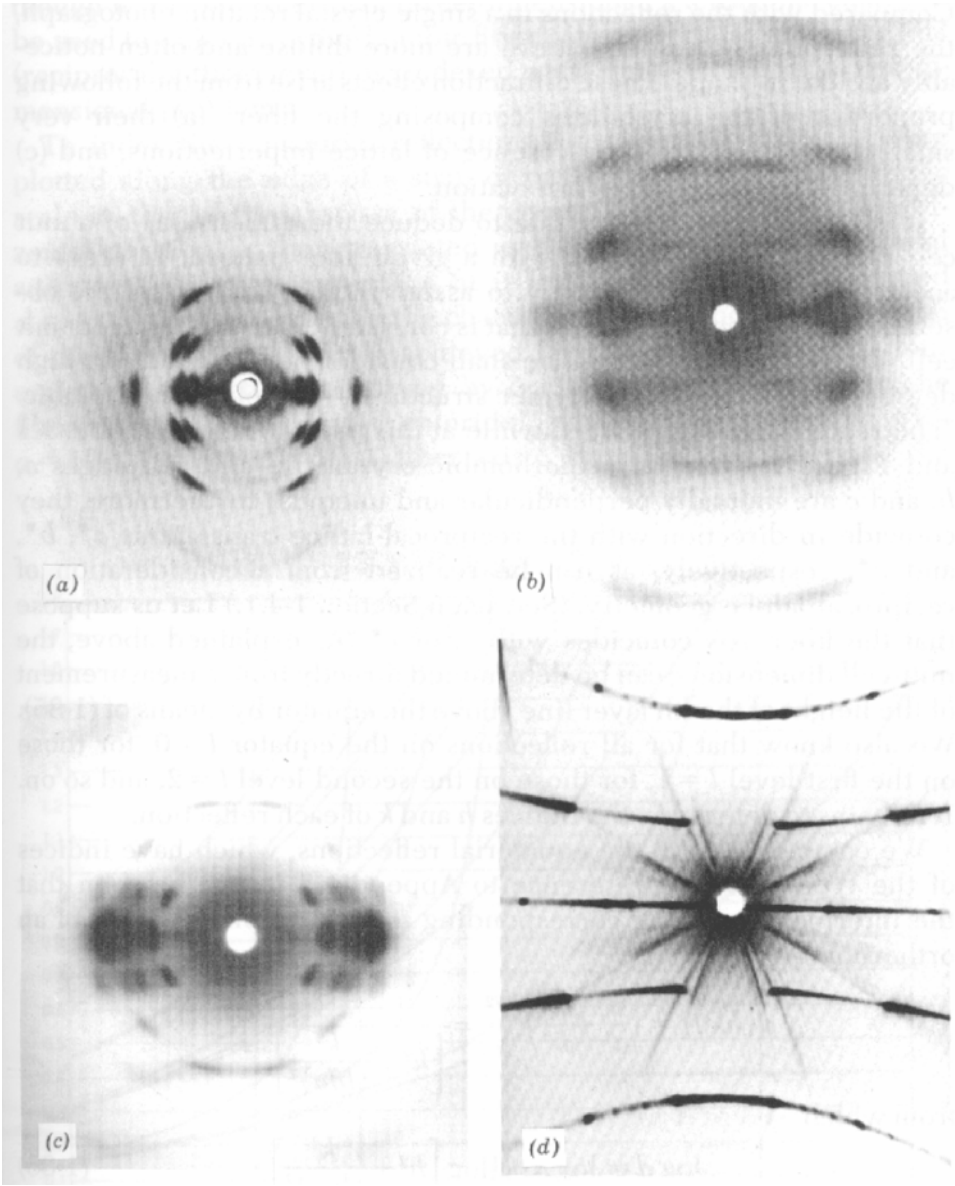
Structure

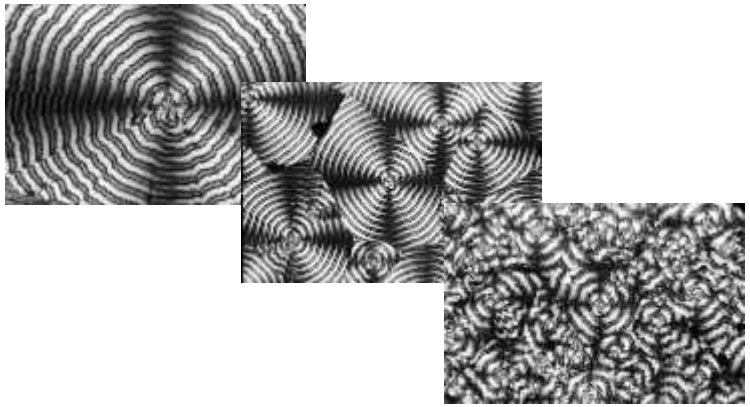
Crystalline Amorphous components (CC)

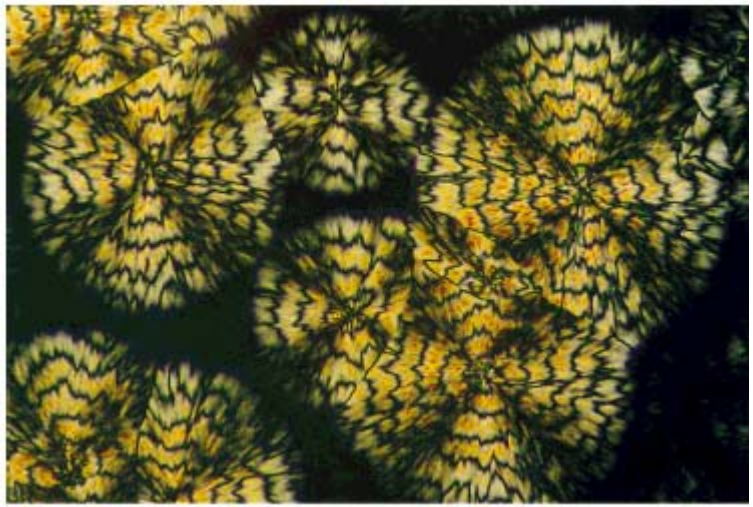
- **Single crystalline**

A.Keller, 1953

Structure, scales, partially crystalline polymers







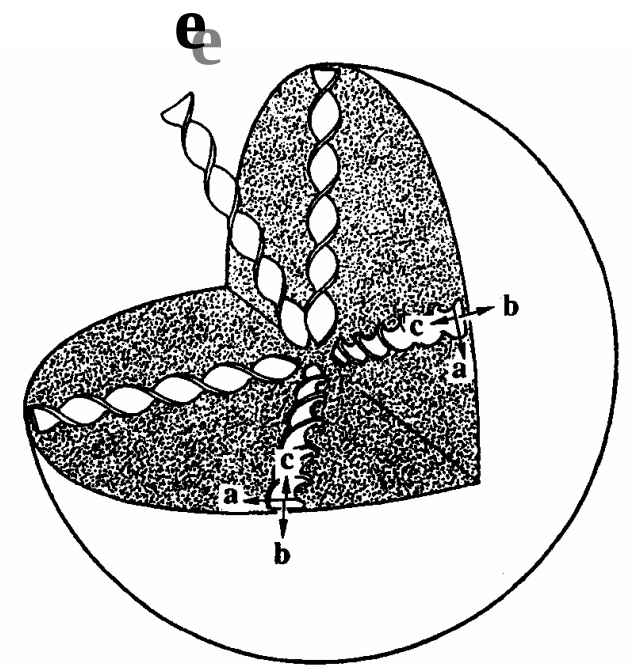
1 millimeter square, OM

Bamford, Nature 173 (1954) p. 27; Astbury, Endeavor 1(1942) p. 70

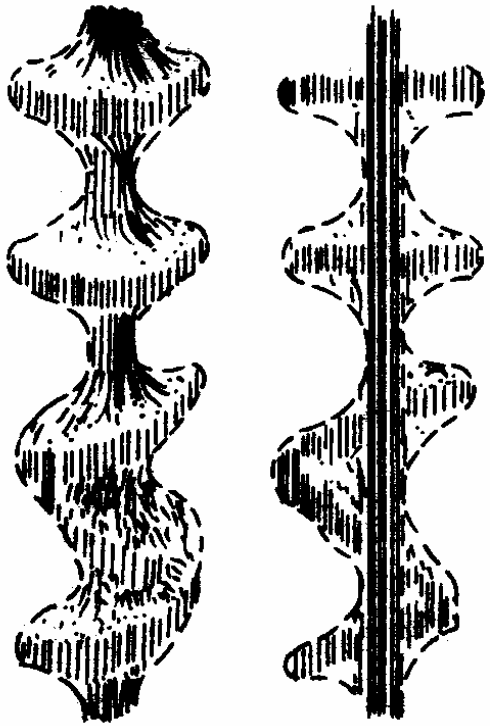
Structure

Crystalline Amorphous components (CC)

- **Pherulit**

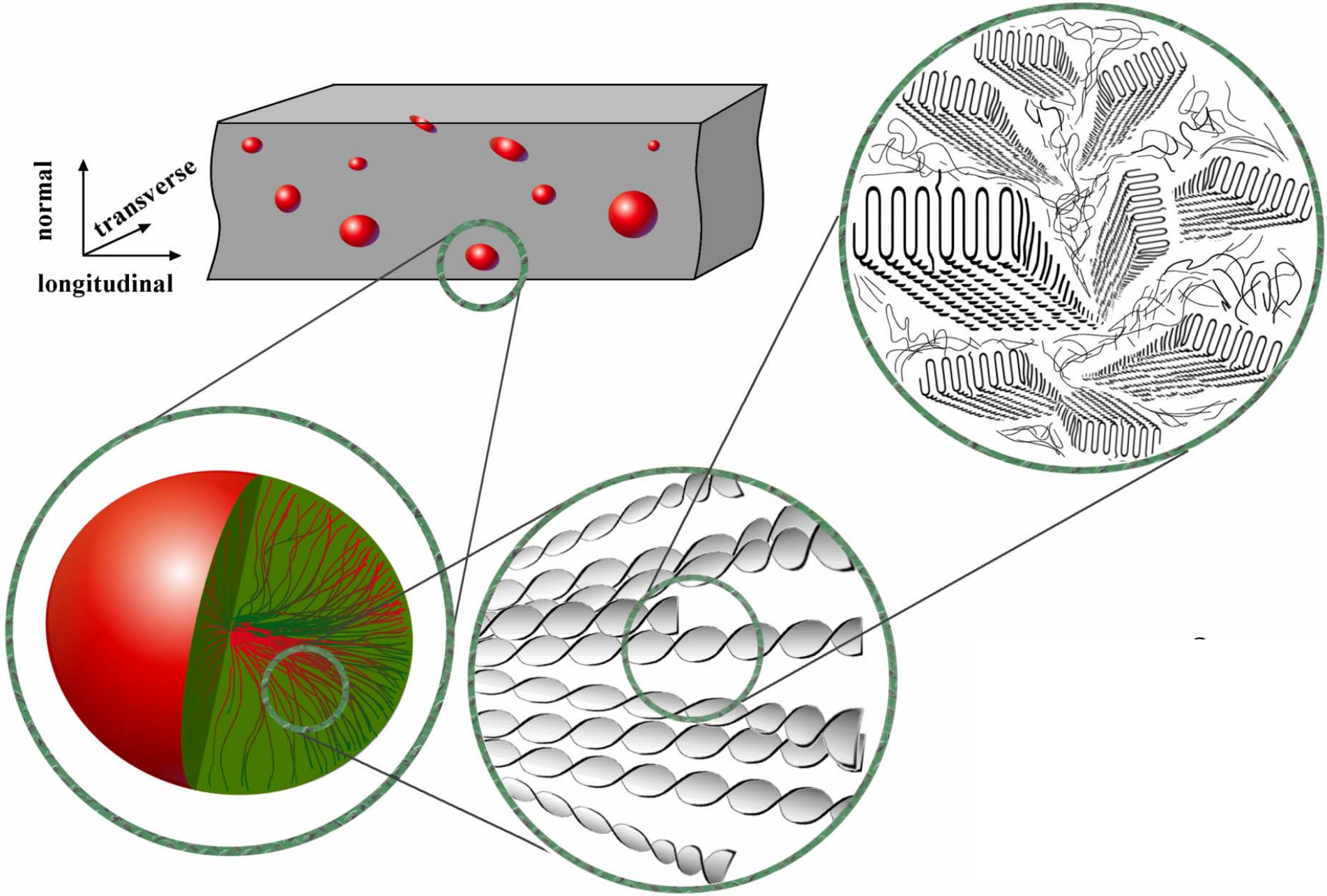


Schultz, J.M., 1984

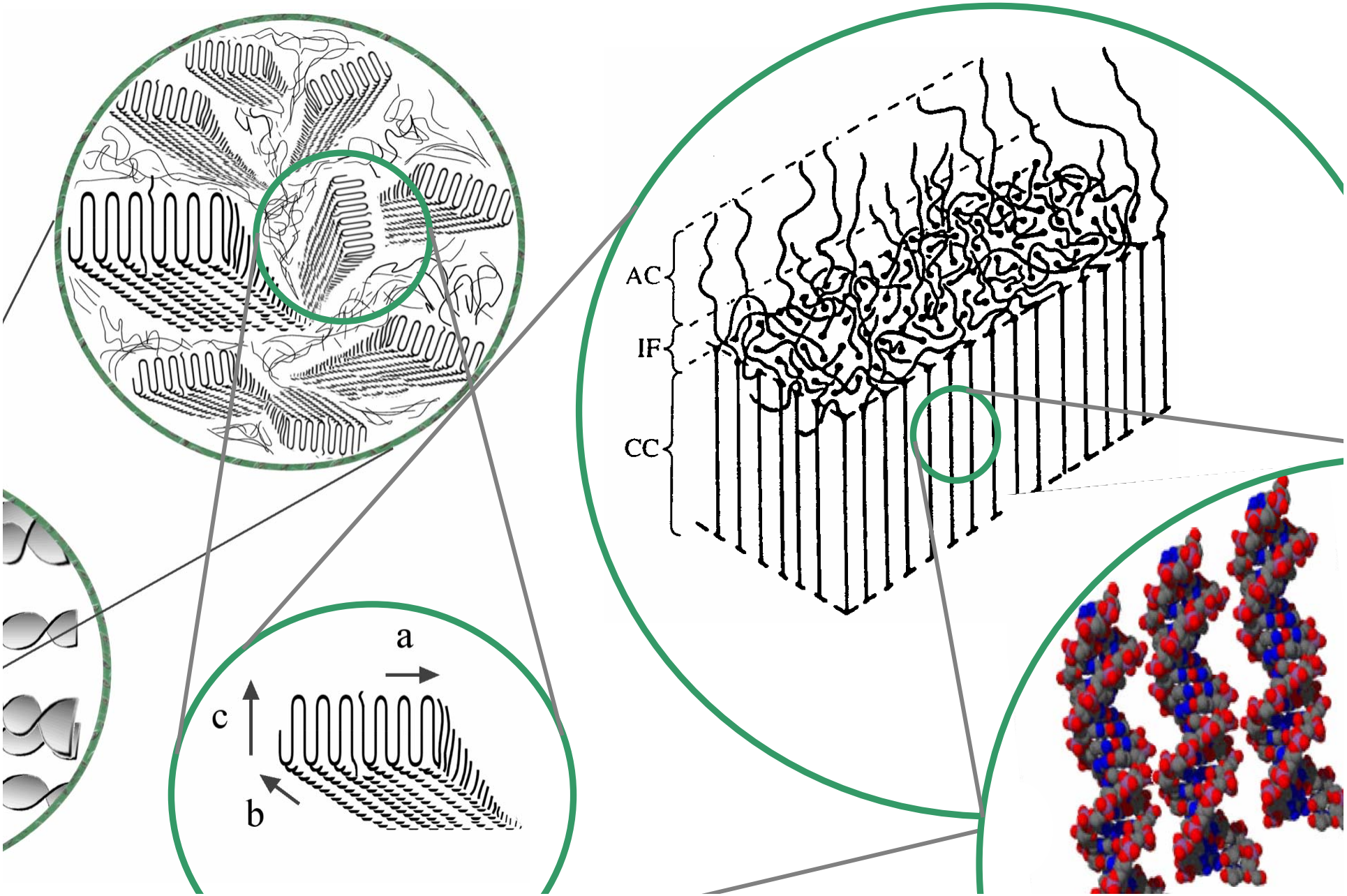


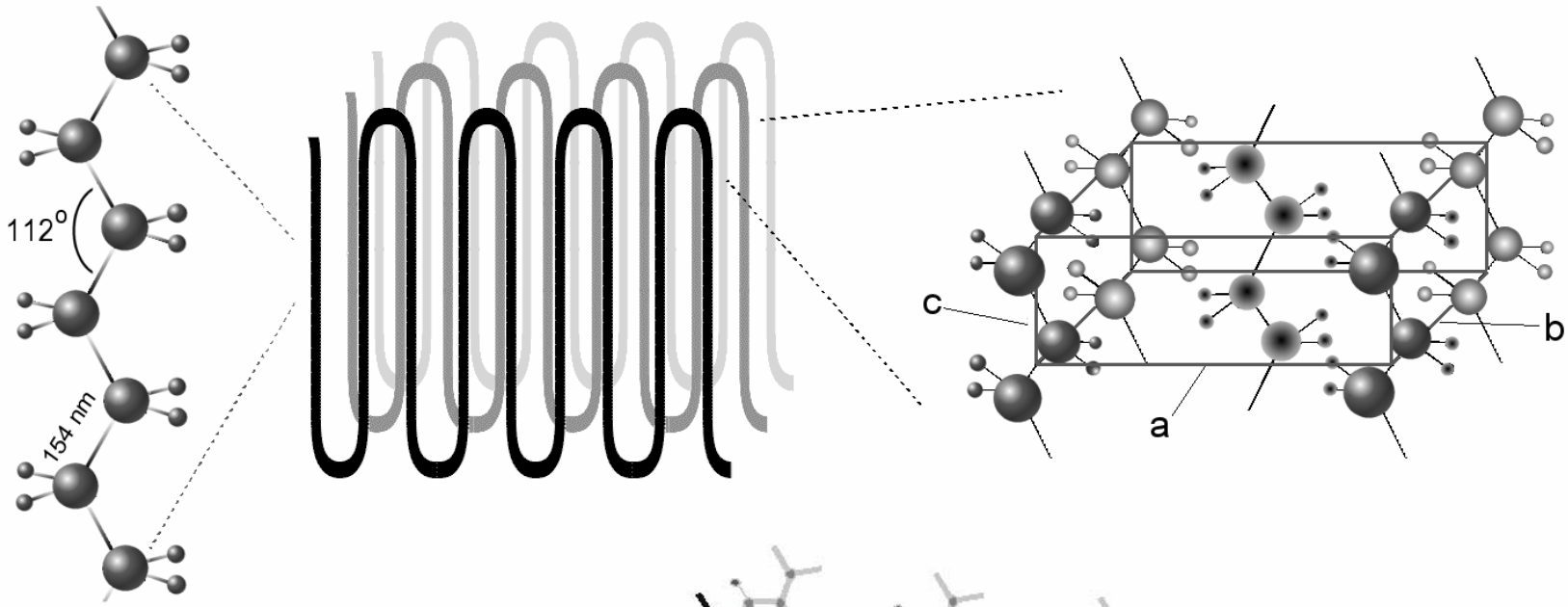
- **Shish kebab**

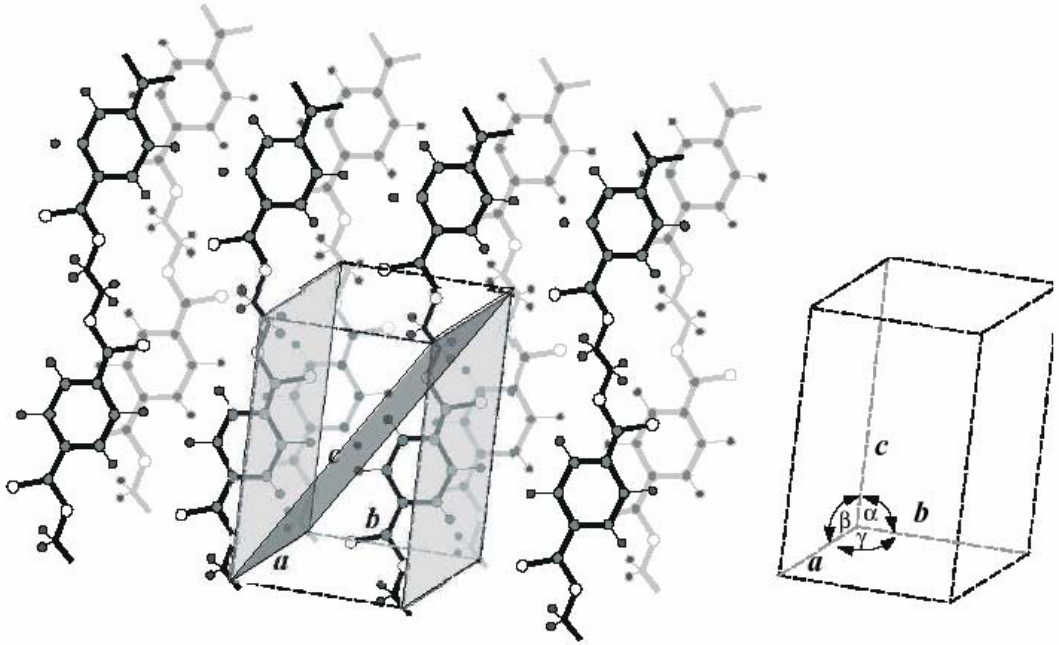
Structure, scales, partially crystalline polymers



Structure, scales, partially crystalline polymers



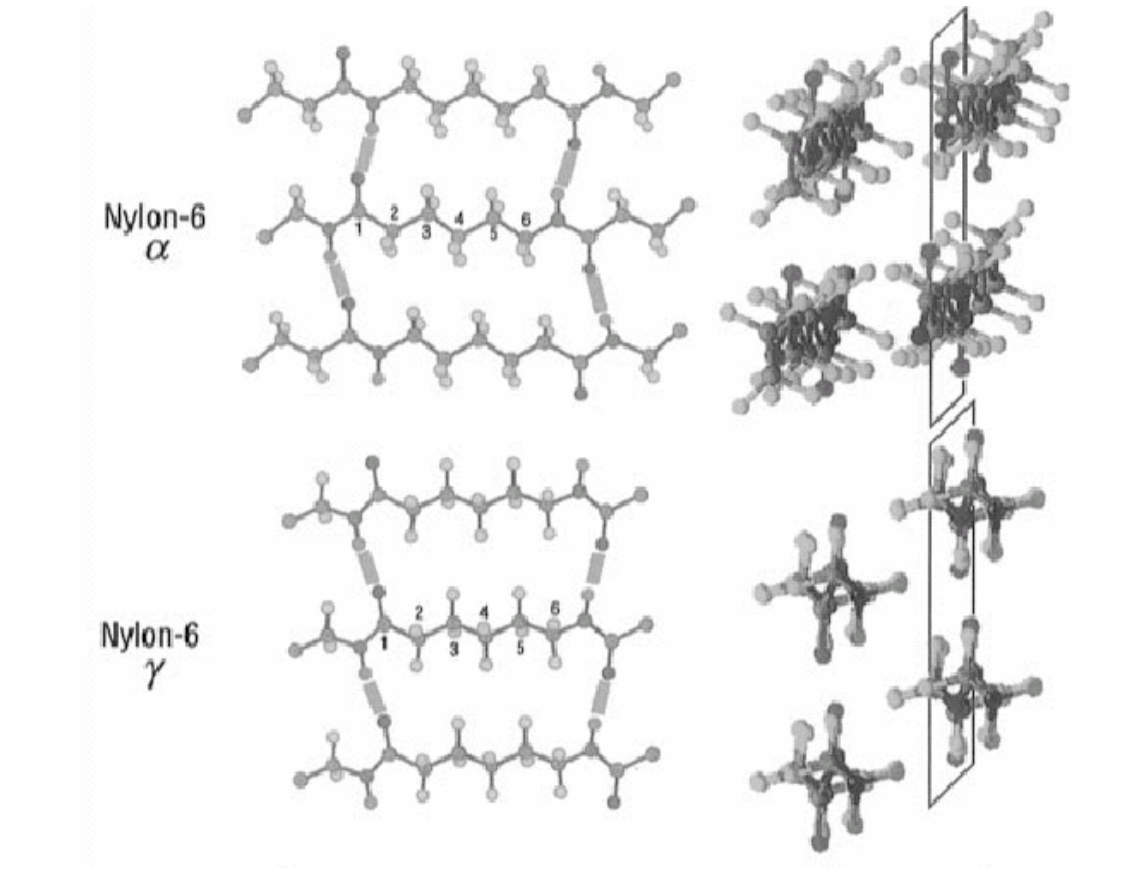




The crystalline unit cell for PET (a = 4.56 Å, b = 5.94 Å, c = 10.75 Å; α = 98.5°, β = 118°, γ = 112°),

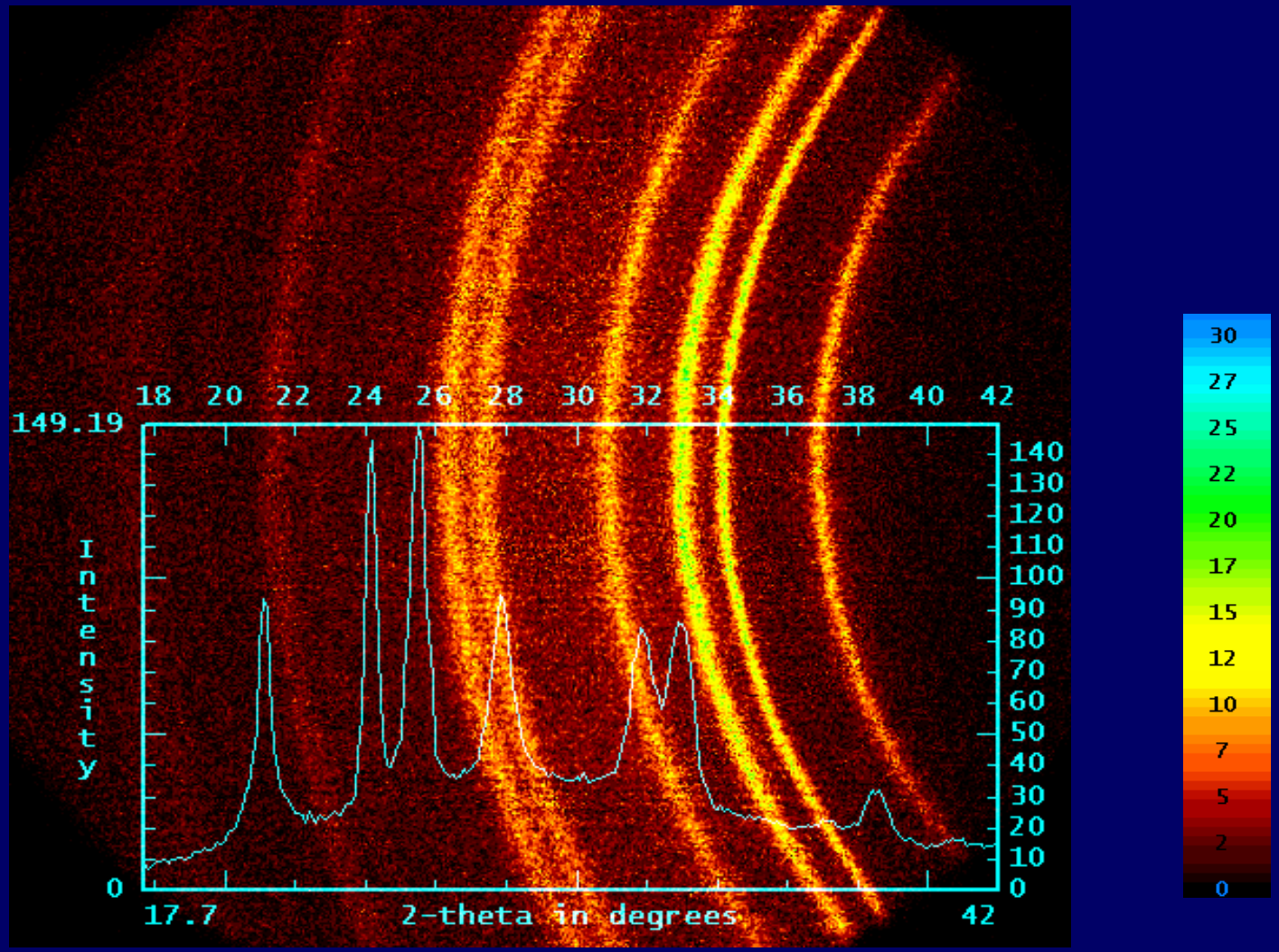
M Durell (2002)

Nylon



Nylon exists in three forms, noncrystaline, α crystal and γ crystal. γ crystal is the most interested one. It is monoclinic, but could be more precised described as pseudo-orthorhombic lattice with a=0.482nm, b= 0.782nm and c = 1.67nm. And α crystal is monoclinic lattice with a=0.478nm, b= 0.400nm, c=1.724nm and angle γ = 67.5°.

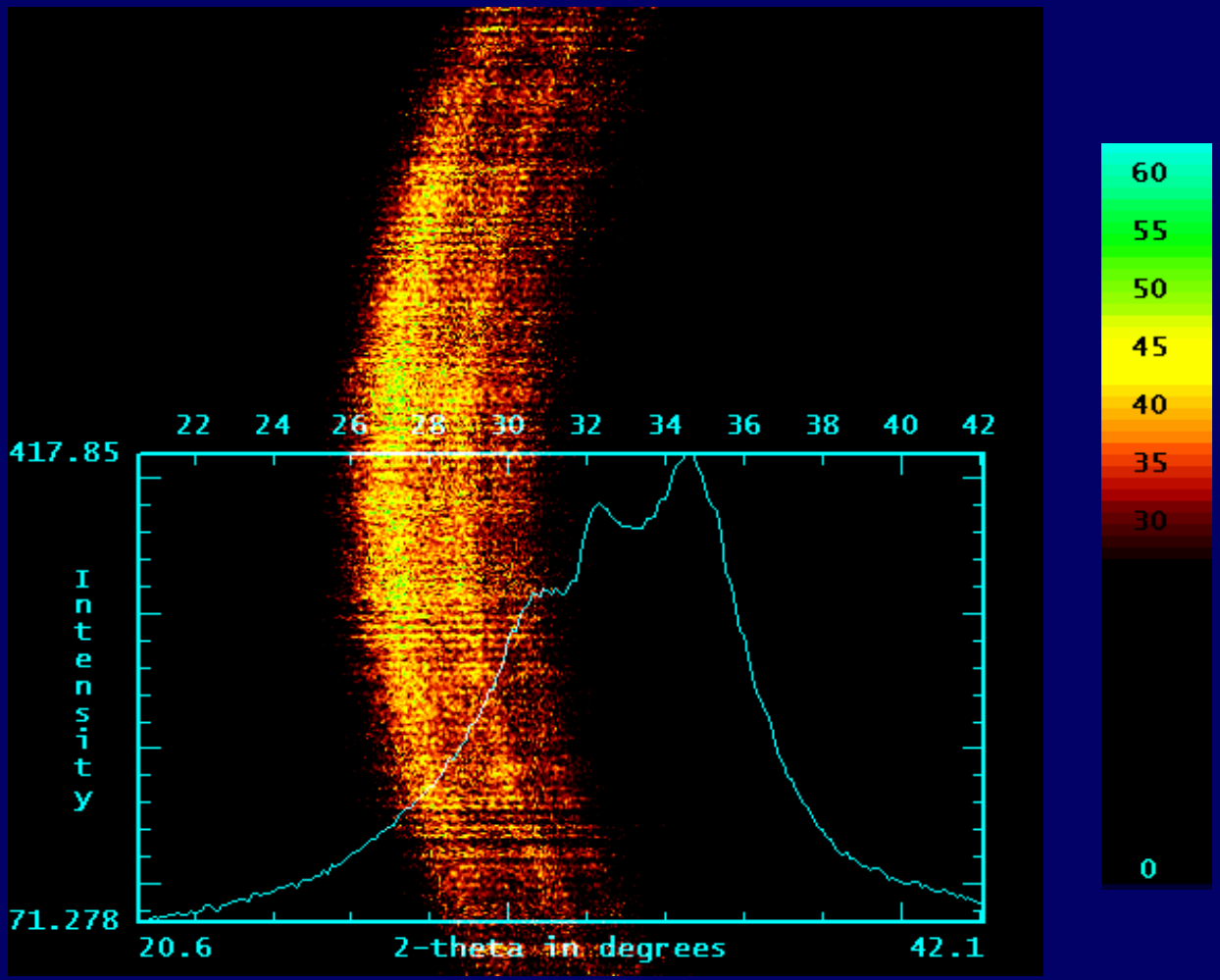
PP



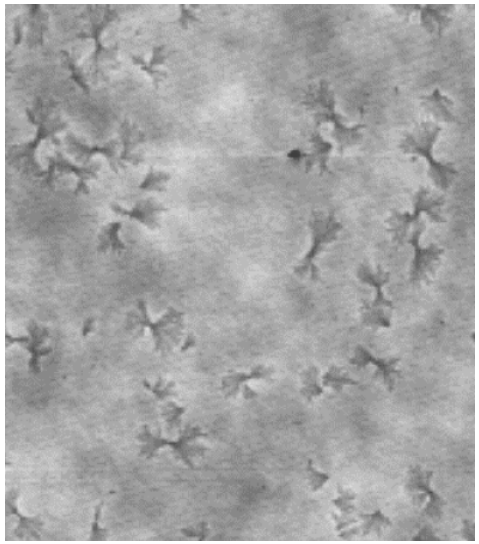
Polypropylen (PP), Cr-Kα1, 40KV 40mA

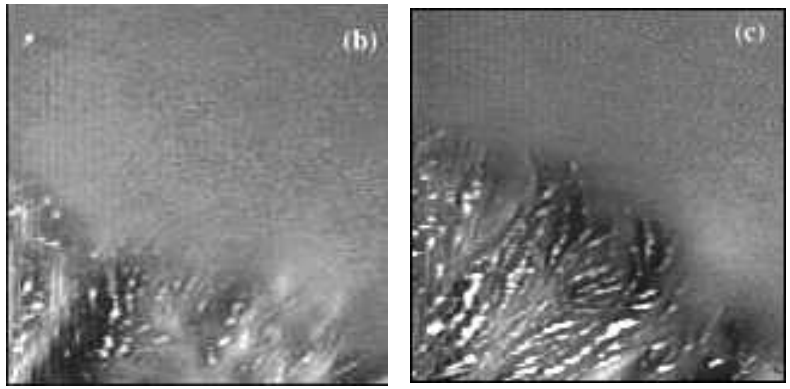
Nylon

α		
4,489	(–131)	29,6
	(13–1)	29,6
4,416	**(200)**	**30,1**
4,278	(210)	31,1
	(2–10)	31,1
4,219	(–12–1)	31,54
	(121)	31,54
4,098	**(–221)**	**32,5**
	(22–1)	**32,5**
4,007	(–102)	33,26
3,93	(–220)	33,92
	(220)	33,92
3,903	**(–1–12)**	**34,18**
	(–112)	**34,18**
3,705	(002)	36,06
γ		
4,599	**(11-1)**	**28,88**
	(-111)	**28,88**
4,159	**(-121)**	**32,02**
	(12-1)	**32,02**
4,109	**(-102)**	**32,42**
4,097	**(100)**	**32,5**
3,999	**(002)**	**33,34**
3,992	**(-1-12)**	**33,38**
	(-112)	**33,38**
3,982	**(110)**	**33,48**
	(-110)	**33,48**
3,891	**(0-12)**	**34,28**
	(012)	**34,28**
3,694	**(12-2)**	**36,18**

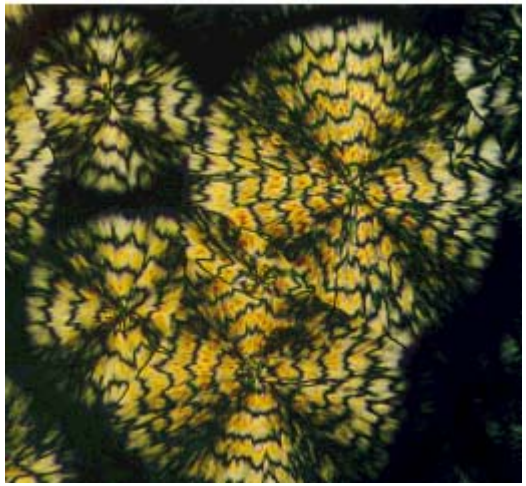


Nylon 6, Cr-Kα1, 40KV 40mA





1 micron square, AFM



1 millimeter square, OM

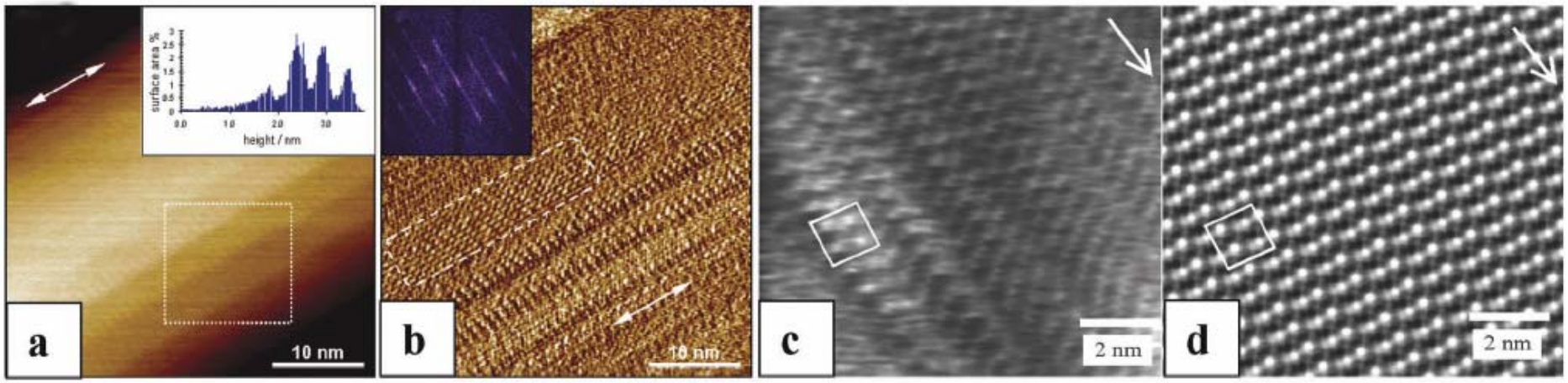
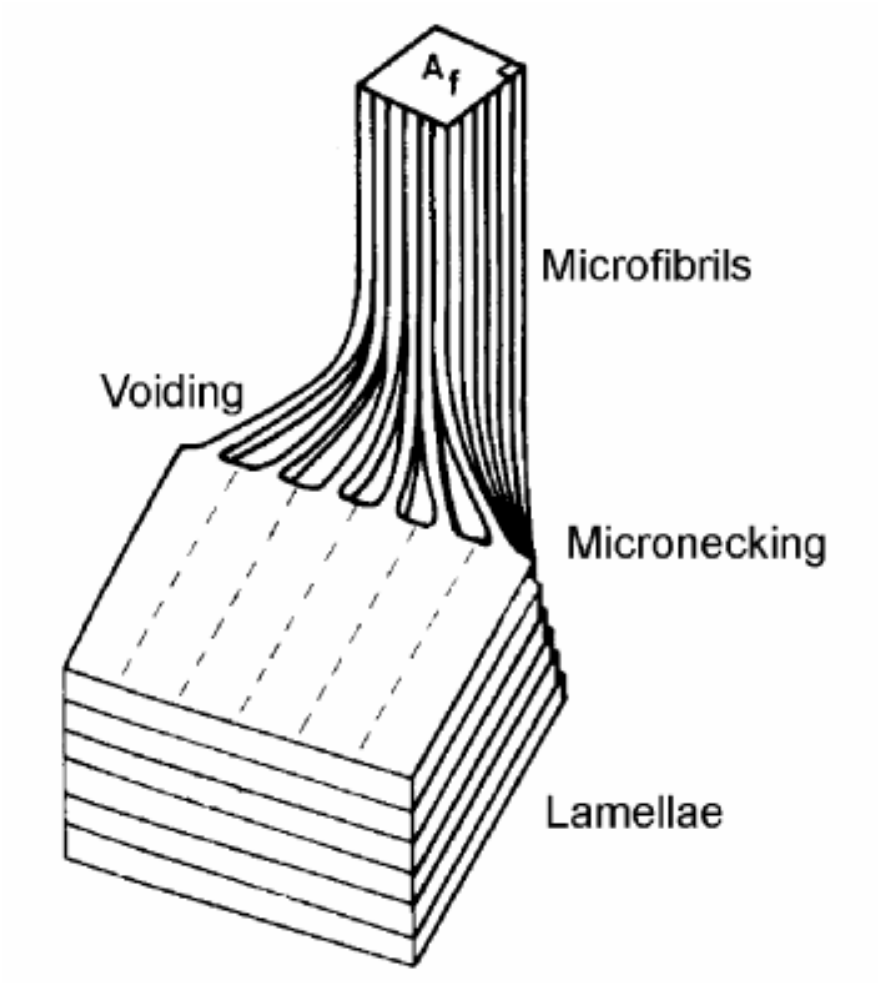


Fig. 2 AFM contact mode images. Cellulose molecules in micro-fibril crystal: (a) topographic image; and (b) error-signal image. Polybutene-1 molecules: (c) topographic image; and (d) simulated AFM image based on crystallographic data.

M. Miles, M. Antognozzi, H. Haschke, J. Hobbs, A. Humphris, T. McMaster
H.H. Wills Physics Laboratory, University of Bristol, Materials Today, Feb. 2003

deformation

Tensile and drawing



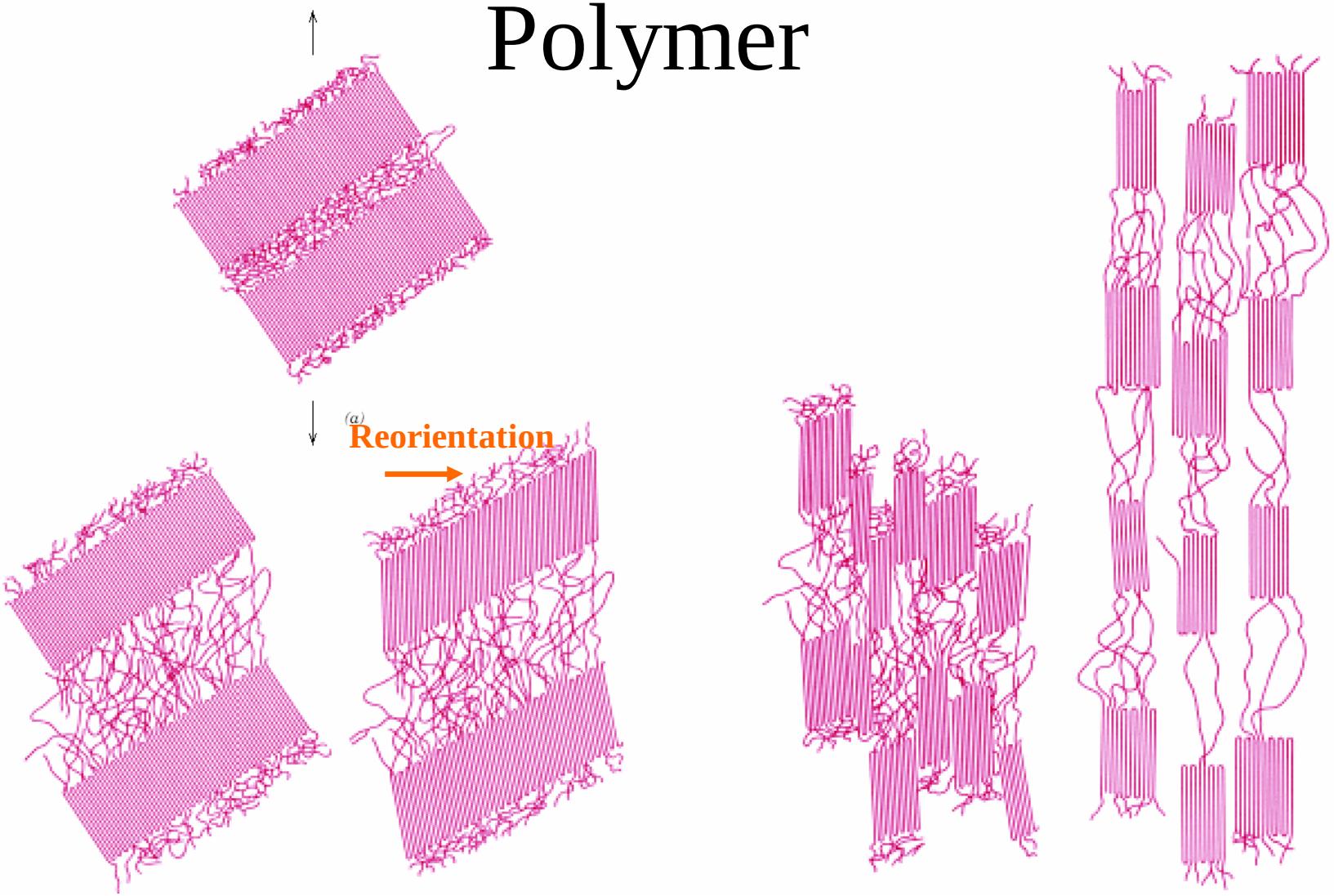
Schematic model of a cavitating semi-crystalline polymer under tensile deformation

A.Galeski, Progress in Polymer Science, (2003)

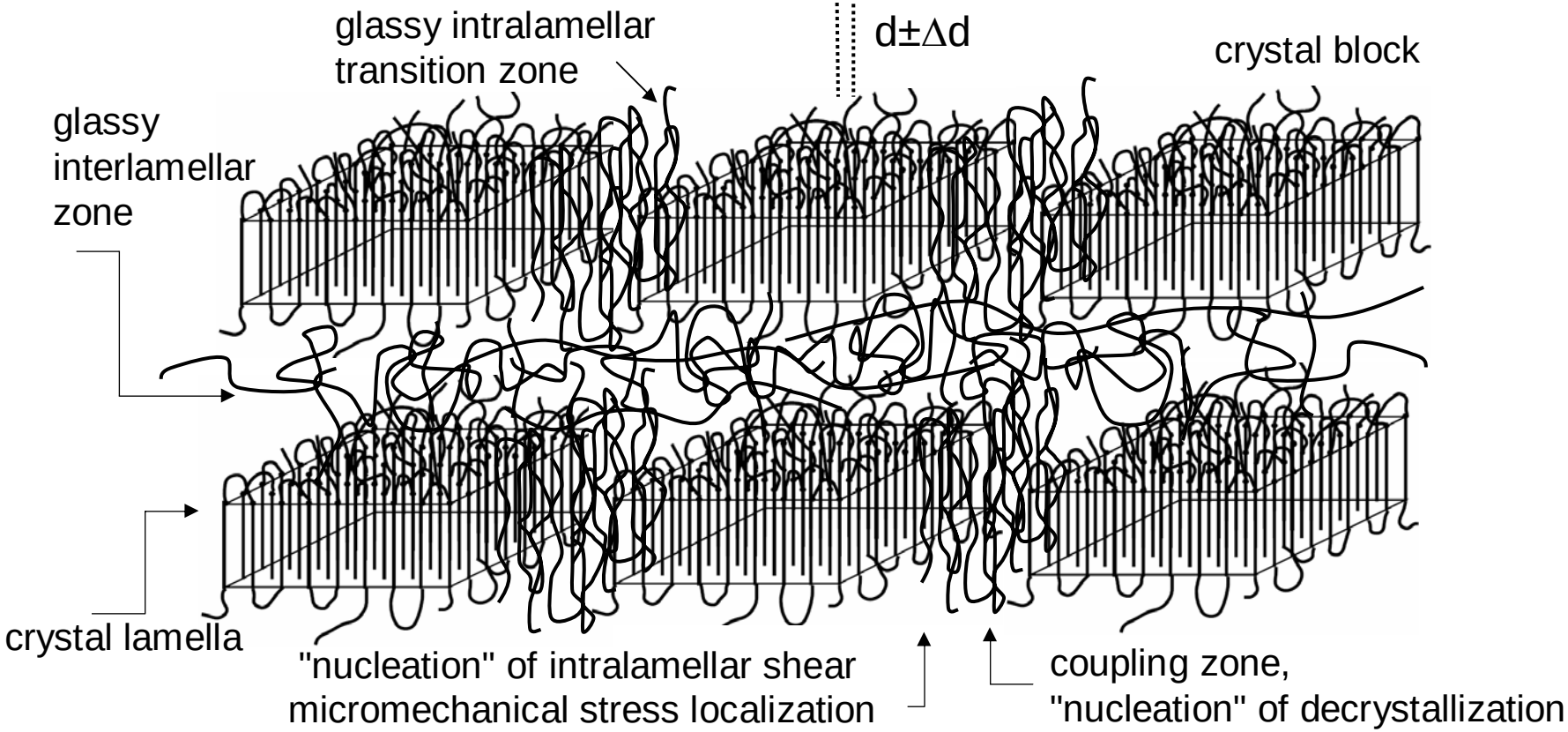
Peterlin: internal cavitation-micronecking

A. Peterlin, Journal of Materials Science , (1971)

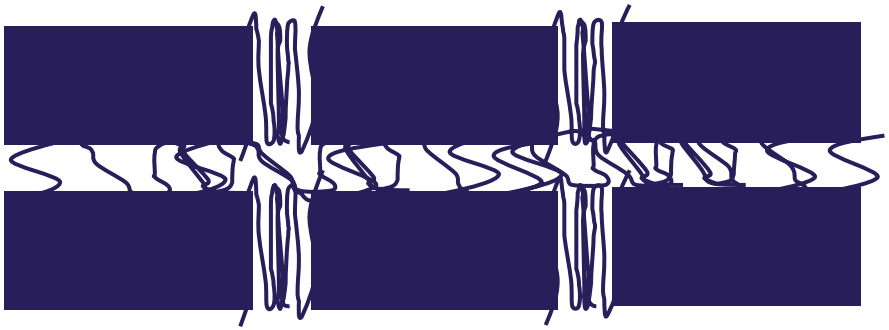
Polymer



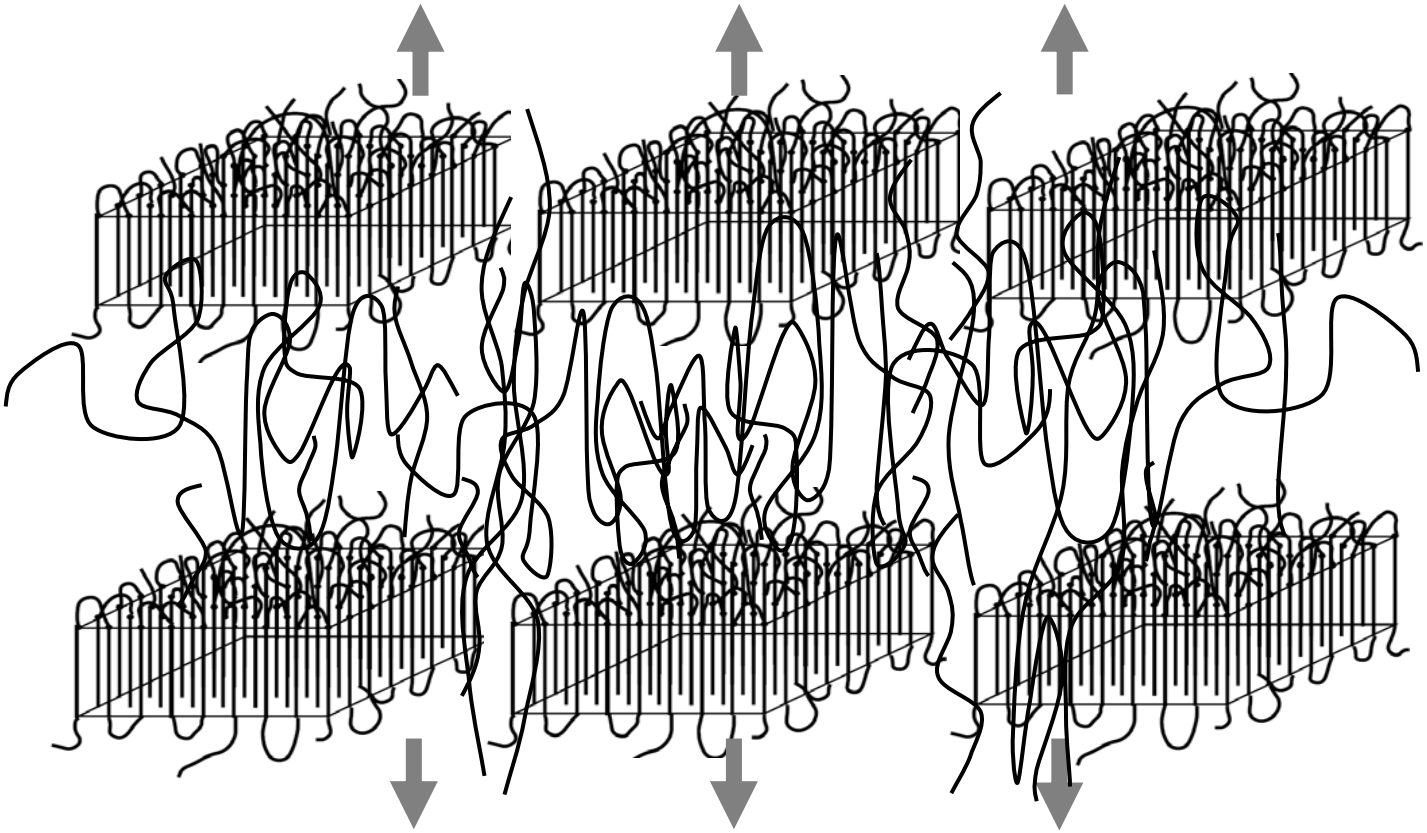
texture-relevant lattice defects, a tensorial view



tensorial nature of polymer deformation



orientation dependence, elongation of soft phase

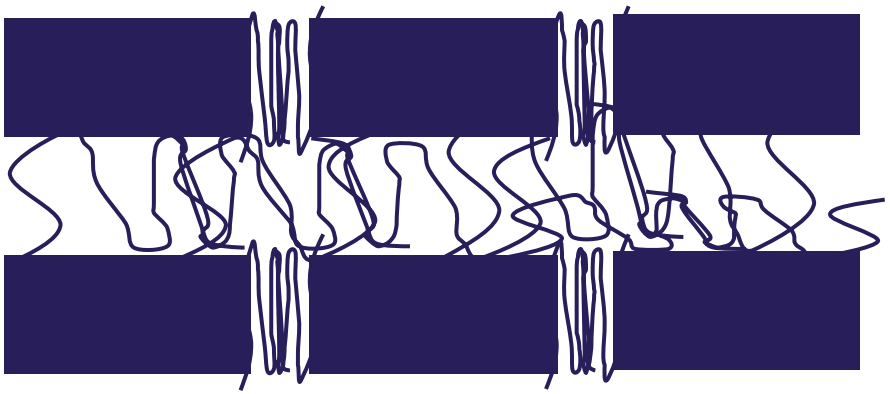


$+\sigma_{11}$

soft phase strained ..... (coupling important)

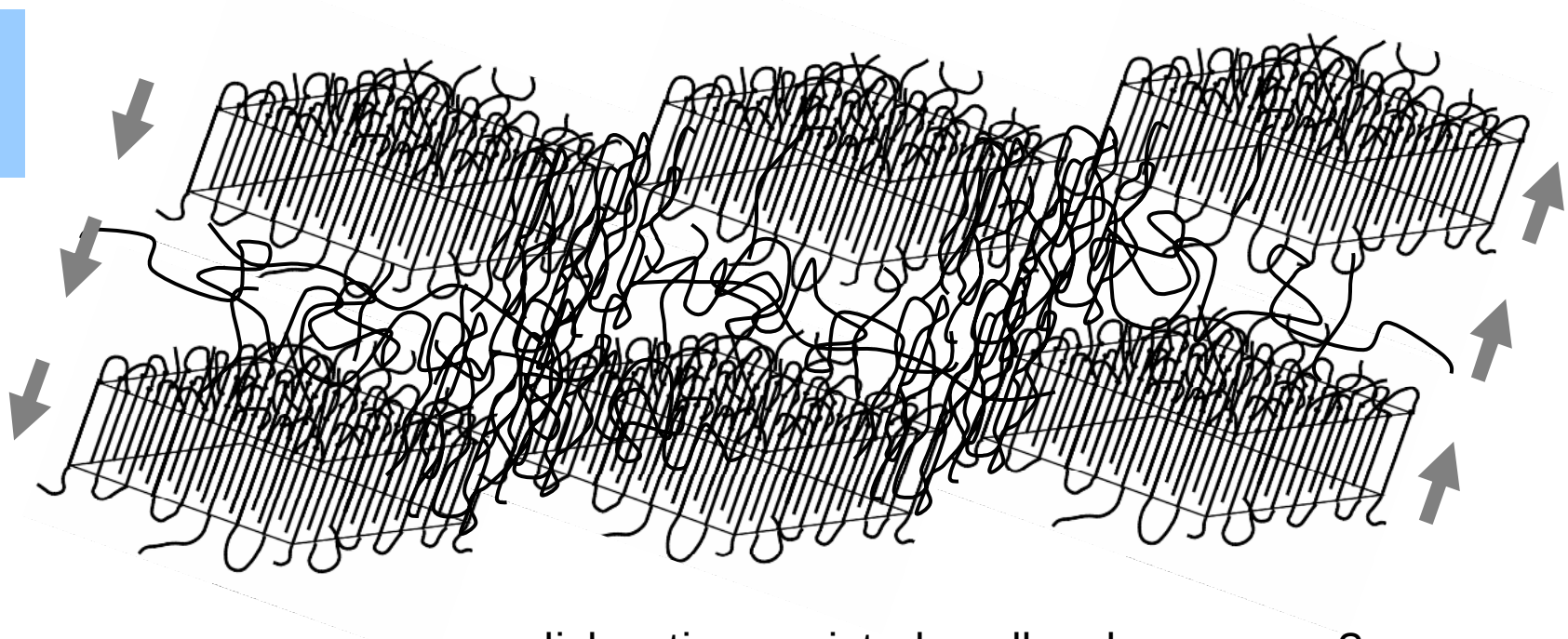
tensorial nature of polymer deformation

σ_{11}



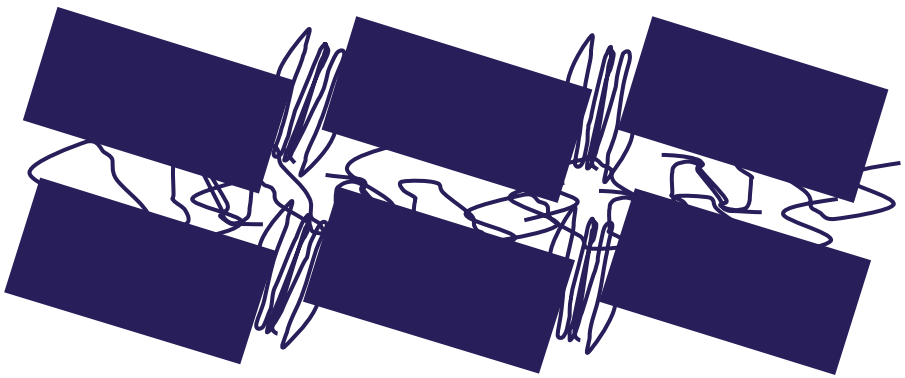
orientation dependence, shear of crystal phase #1

σ_{12}



screw dislocations or intralamellar shear zones ?

tensorial nature of polymer deformation



σ_{12}