Polymeric fiber technology
lecture (3)
Fiber structure

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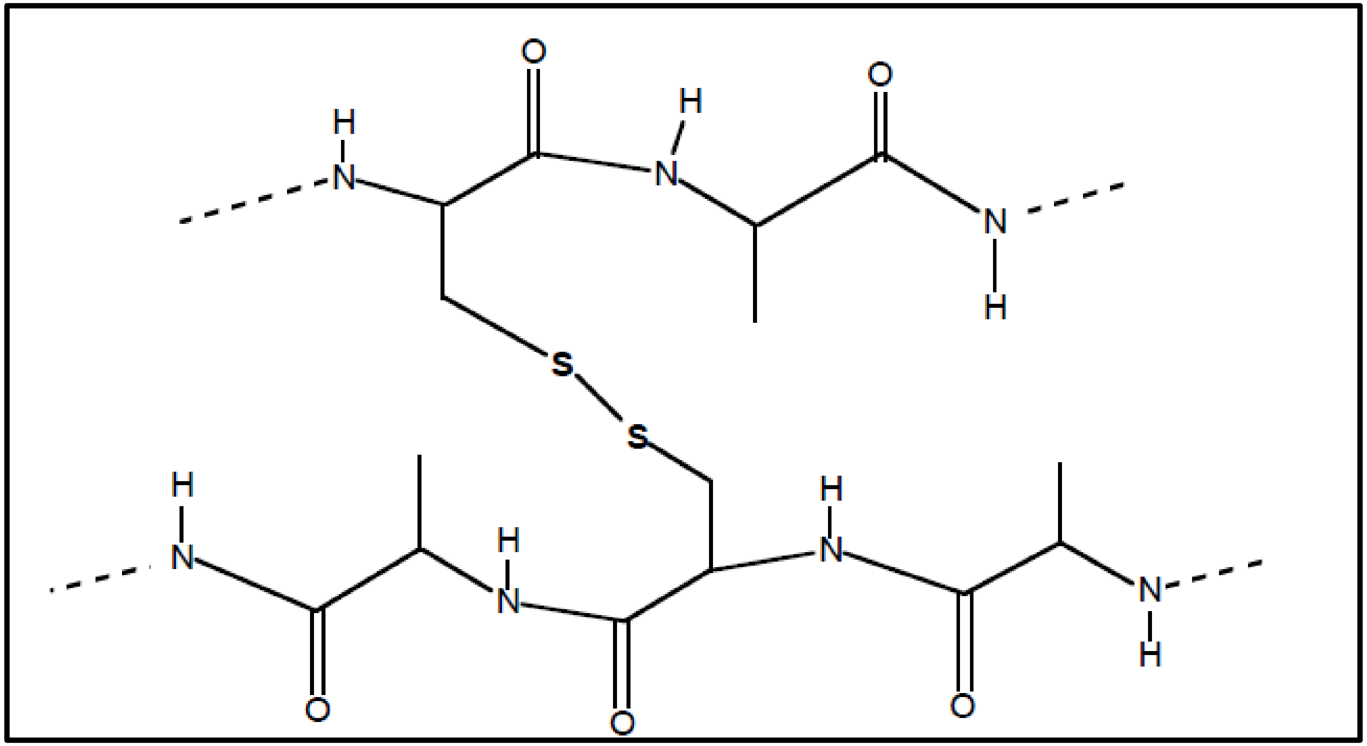
:Fiber structure

Fibers are thread formers, often used to make cloth. Silk, nylon, polyester, and cotton are all fibers. They are usually flexible, and can be tightly woven without breaking. At the molecular level, they are composed of long carbon chains with few or no branches. In a



.Fig. (1): Sulfur Bonds Cross Link Chains Of Amino Acids

- Due to the way in which polymer chains group themselves together in a fiber, fibers are endowed with unique characteristics in-between those of brittle plastics and rubber elastics. In a fiber, we have a two-phase system: Crystals contribute strength and amorphous regions give stretch. All other things being equal as we increase polymer

:Stiffness and diameter

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Explaining the Behavior of Micro-denier Fibers Using the Bending Stiffness and Specific Area Rules

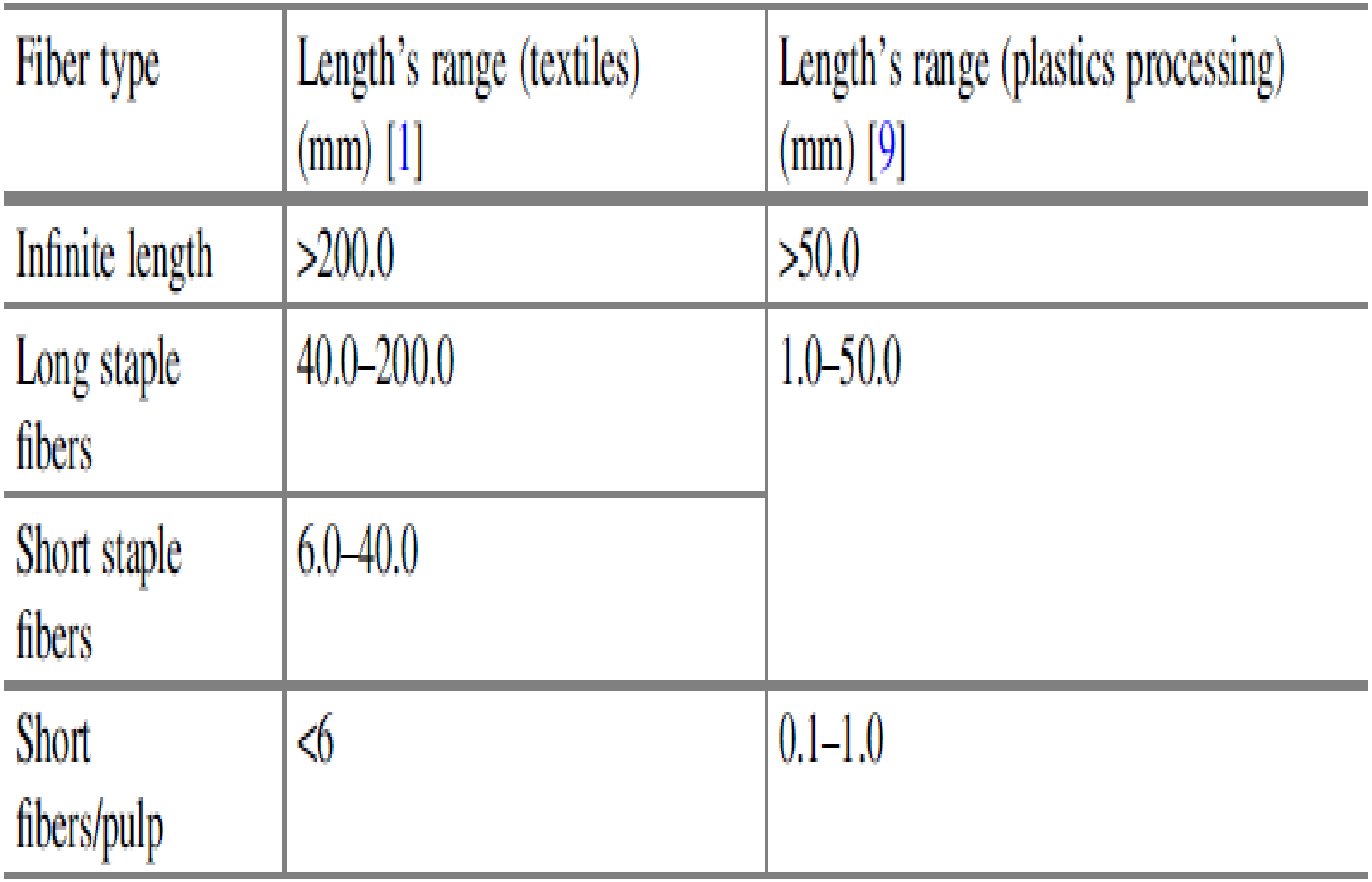
- Micro-denier fibers produce yarns and fabrics that are very soft due to the reduced bending stiffness explained by our bending stiffness diameter rule.Micro-denier fibers require more dye per unit weight than do thicker fibers to achieve the same depth of shade, a phenomenon explained by the large

Essential properties of fibers for :composite applications

- **Geometrical Properties:**
- The geometrical aspects of fibers are mainly defined by their length L and diameter D, resulting in the so-called aspect ratio L/D. Concerning the fiber’s diameter, different shapes of fibers beside a round shape are possible. Furthermore, the so-called fineness or titer T, which is the mass per length unit, is an important factor to describe the fibers geometry, since it takes into account differences in density of the specific fiber types.

- The most common synthetic reinforcement fibers have a round cross-section, since it provides a uniform mechanical loading of the fiber material. This leads to a higher specific strength of the materials compared to other fiber shapes. However, different cross-sections can be found in fibrous materials for composite applications.
- For the fiber’s length, short or staple fibers ($L/D < \infty$) and fibers with infinite length ($L/D = \infty$) have to be taken into account. In the following Table 1, the classification of fibers length for textiles and plastics processing is displayed.

Table 1 Classification of fiber length for textiles and plastics processing



Fiber type	Length's range (textiles) (mm) [1]	Length's range (plastics processing) (mm) [9]
Infinite length	>200.0	>50.0
Long staple fibers	40.0–200.0	1.0–50.0
Short staple fibers	6.0–40.0	
Short fibers/pulp	<6	0.1–1.0

- The fineness (or titer T) of a fiber describes the mass per unit length. Therefore, it depends on the diameter d of the fiber and its density ρ. The unit for fiber fineness is tex (grams per 1,000 m) or den (grams per 9,000 m). The following equation can be used to calculate the fineness from filament diameter or vice versa:

$$D = \sqrt{\frac{4}{\Pi \cdot \rho} \cdot T}$$

- **Mechanical Properties:**
- A high tenacity σ (or strength, stress at maximum elongation) is necessary for acting as a reinforcement of the matrix material. The strength of the fibers is usually one or two orders of magnitude higher than the strength of the matrix material. If mechanical load is transferred completely from the matrix to uniaxially oriented fibers, the composite strength can reach the fiber strength multiplied by the fiber volume content. For reinforcement fibers, tenacity is usually measured in the unit of MPa or GPa. For lightweight construction, the specific tenacity (tenacity divided by the fiber's

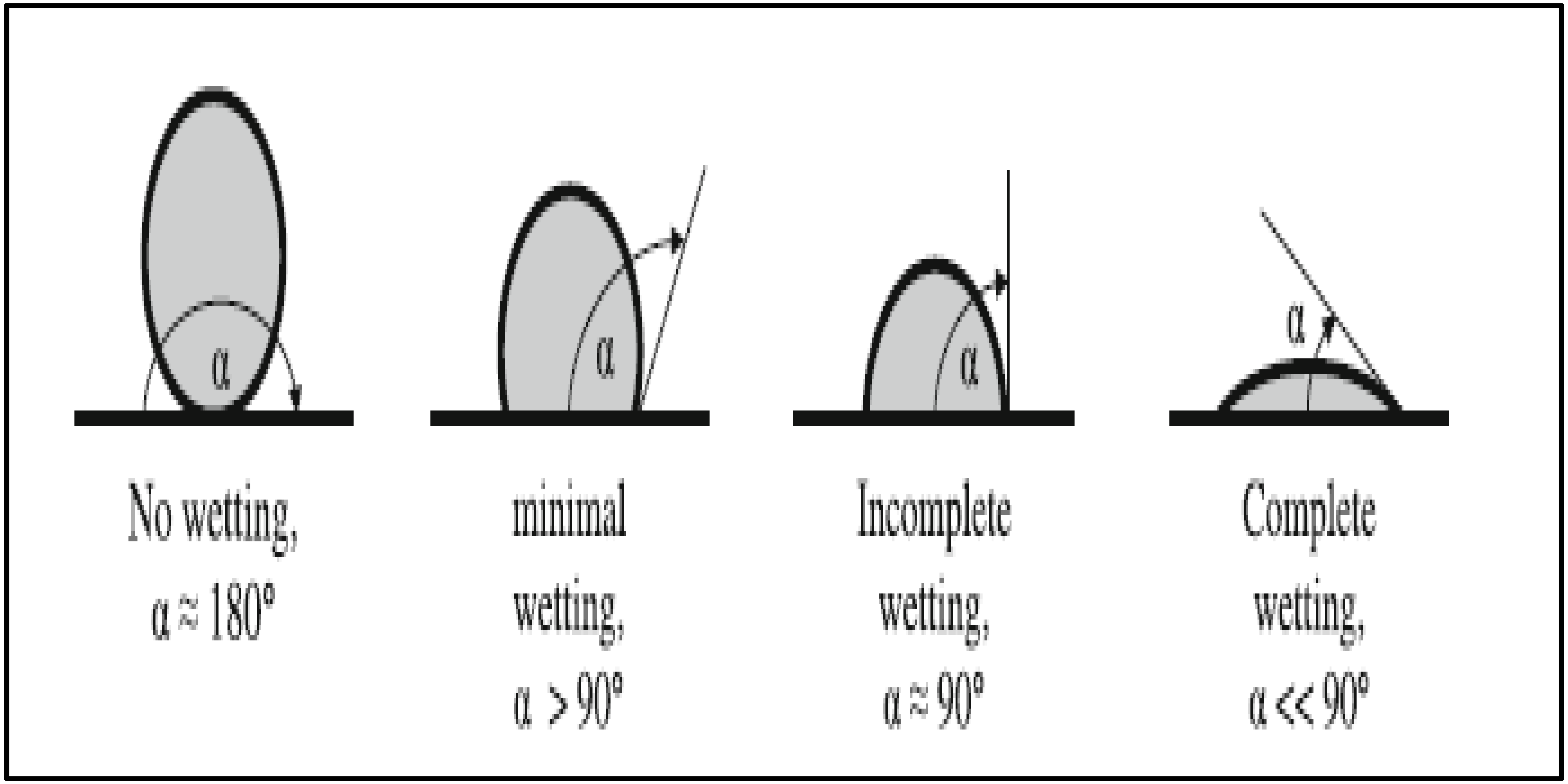
- The maximum elongation εmax of reinforcement fibers is usually low compared to the possible elongation of the matrix material. In case of good load transfer, composite failure takes place at the level of maximum fiber elongation due to fiber breakages. The failure behavior of the composite is usually brittle. By adjusting fiber matrix adhesion, a more ductile failure behavior can be achieved if cracks propagate slowly between the single filaments.
- Young’s modulus E describes the stiffness of the fiber measured in the region of linear elastic deformation and is indicated usually in GPa. Fibers with high Young’s modulus

- **Surface Properties:**
- **Surface area and surface roughness:** The most common synthetic reinforcement fibers have a diameter in the range of less than 50 µm, while pores and fibrils in the range of nm contribute to the surface which is later bound to the matrix material. Apart from the adhesion properties, the surface area and roughness have an impact on the fibers' tribological properties. These properties are important when it comes to fiber-fiber-interaction and friction with machinery elements during textile processing. If the surface is too rough and a protection is missing, a lot of fiber breakage and hence a

- **Surface Energy and Contact Angle:** As an indicator for the ability of a liquid to wet a material, the contact angle of a droplet of this liquid on a plain horizontal solid surface can be measured. The contact angle α is very small when the droplet immediately loses its form after contact with the surface. Hence, the wettability of the surface with the liquid is very high. If the wettability is not good, the contact angle α lies in the range between 180 and 90°. The wettability and hence the contact angle α depends on surface energies of the materials involved in the wetting process. The surface energy σ is defined as the amount of energy ΔW which has to be overcome in order to increase the surface by

$$\sigma = \Delta W/\Delta A$$

- The work ΔW which has to be overcome is due to the intermolecular cohesion within the liquid. If a liquid is brought on a surface, then the tension of the boundary layer σLS becomes important. Following the equation:
- $\sigma L. \cos \alpha = \sigma s - \sigma LS$
- good wettability is achieved when the surface energy of the solid (fibers) is higher than the surface energy of the wetting liquid (e.g. matrix material).



.Fig. (3): Liquid droplets showing a different wetting behaviors

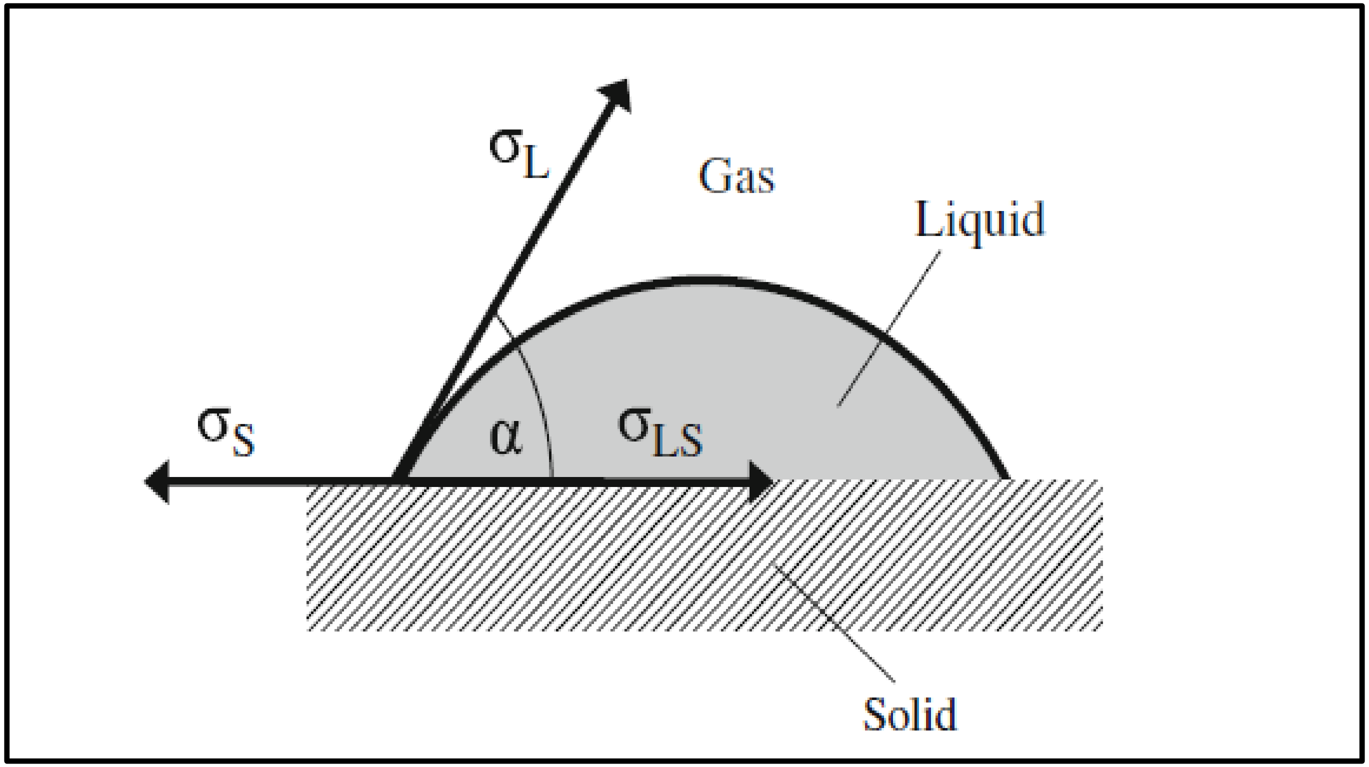


Fig. (4): Relations Between The Surface Energies Of Liquid And .Solid Determine The Contact Angle And The Resulting Wettability