Fractography

• Macroscopic features
  – Brittle fracture: smooth, shiny fracture surface, chevron markings
  – Ductile fracture: rough fracture surface, flat or slant, cup-and-cone

• Microscopic features
  – Brittle fracture: transgranular (river lines), intergranular
  – Ductile fracture: dimples, voids
Dimple fracture

• For tougher materials, plastic deformation accompanies the crack growth.
• Dislocations emanate from the crack tip.
• Voids grow and coalesce to form cracks, leading to rough fracture surfaces with dimples.

Equiaxed dimples
Shear dimples
Tear dimples
Equiaxed dimples

FIGURE 7.16  Microvoid coalescence under tensile loading, which leads to "equiaxed dimple" morphology: (a) TEM fractograph shows "dimples" as mounds; (b) SEM fractograph shows "dimples" as true depressions.
Shear dimples

FIGURE 7.17  Microvoid coalescence under shear loading, which leads to "elongated dimple" morphology: (a) TEM fractograph shows "dimples" as raised parabolas; (b) SEM fractograph shows "dimples" as true elongated troughs.
Fatigue crack: striation

- Regularly spaced ridges
- The location of crack fronts at successive cycles under cyclic loading-fatigue crack.
- Convex in the direction of crack growth.
- The spacings reflect the rate of crack growth.
Fracture in polymers

- Crazing: localized yielding leads to formation of small and interconnected microvoids.
- Molecular chains are stretched and oriented in the fibrillar bridges between the voids.
- Cracks form when the fibrils are broken and the voids coalesce.

**Figure 15.9** Schematic drawings of (a) a craze showing microvoids and fibrillar bridges, and (b) a craze followed by a crack. (From J. W. S. Hearle, Polymers and Their Properties, Vol. 1, Fundamentals of Structure and Mechanics, Ellis Horwood, Ltd., Chichester, West Sussex, England, 1982.)
Crack patterns

FIGURE 7.24 Crack advance from left to right along alternate craze-matrix interfaces in polystyrene. (a) Patch pattern. Note decreasing patch size in crack propagation direction. (Courtesy of Clare Rimmac, Lehigh University.) (b) Stereoscan micrograph showing bands of craze separated by areas where the craze has been stripped off. Mackerel pattern. Fully detached craze regions appear darker in this photograph. (Murray and Hull27, with permission from John Wiley & Sons, Inc.)
Banded hackle markings

FIGURE 7.25  Banded hackle markings in fast fracture region.  (a) Crack advances in jumps through craze bundles.  (b) Patch appearance on hackle band surface. Crack propagation from left to right.  (Courtesy of Clare Rimnac, Lehigh University.)
Tear dimples

FIGURE 7.26 Tear dimples in Noryl polymer. Microvoid nucleation at butadiene-polystyrene duplex particles. (Courtesy of Clare Rimnac, Lehigh University.)
Fracture in crystalline polymers

FIGURE 7.27 Fracture associated with spherulites in crystalline polymers. (a) Schema showing possible crack paths through a spherulite. (b) Orientation of crystal lamellae in spherulite. Lamellae are believed to be randomly oriented in core region, radially oriented in midregion, and tangentially oriented along surface of spherulite. (c) Fast running crack fracture surface in polypropylene revealing the four crack paths as outlined in (a). (d) Interspherulitic fracture in polypropylene associated with slow crack velocity. (From Friedrich\textsuperscript{35}; reprinted with permission from Fracture 1977, Vol. 3, 1977, p. 1119, Pergamon Press.)
Fracture in ceramics

FIGURE 7.28 Fracture surface appearance in glassy ceramic revealing mirror, mist, and hackle regions. (a) Plate-glass fracture surface. Tensile fracture stress = 28.3 MPa, or 4.1 ksi. (From Orr.) Arrow indicates approximate crack origin. (b) Schematic diagram showing different fracture regions and approximate textural detail. (From Mecholsky et al.) Copyright, American Society for Testing and Materials, Philadelphia, PA. Reprinted with permission.)
Fracture in composites-1

FIGURE 7.30 Fracture surface appearance in short glass-fiber reinforced nylon 66. (a) Fast fracture appearance revealing matrix adhesion to glass fibers. (b) Fatigue fracture revealing fiber–matrix debonding (A and B) and matrix drawing (C). (Courtesy R. Lang.)
Fracture in composites-2

FIGURE 7.31 Fracture surface in hollow glass sphere-filled epoxy resin. (a) Glass particles located at A, detached at D, and cracked at C. (b) Silicon X-ray map showing location of glass spheres. (Courtesy M. Breslaur.)
FIGURE 7.32 Fracture surface appearance in graphite fiber-reinforced epoxy. (a) Tensile failure revealing cleavage-like pattern. Arrow indicates crack direction. (b) Shear failure reveals presence of hackle markings in epoxy resin.47 (Reprinted with permission Copyright ASTM).