Interdisciplinary Field of Research [pln1]

Traditional academic disciplines

- physics
- chemistry
- biology
- engineering

Modern specializations and combinations

- biological physics
- medical physics
- biochemistry
- biomedical engineering
- materials science
- nanoscience
- *soft matter physics*

Characteristics of soft matter

- attributes of solids mixed with attributes of liquids
- materials from everyday life strongly represented
- mutable and polymorphic materials, quenched randomness
- hierarchic structures on microscopic and mesoscopic length scales
- conditions favorable for self-assembly of structures
- materials highly responsive to surroundings
- ubiquity of nonlinear effects
- response strongly dependent on time scale of perturbation
- strong fluctuations and fragile ordering
- weak stimuli with strong impact
- additives with strong impact
- relaxation times directly accessible to human senses

Major topics

- polymers
- colloids
- surfactants (amphiphiles)
- liquid crystals
- surfaces and interfaces
- elasticity, viscosity, viscoelasticity
- diffusion, permeation
- microfluidity, nanofluidity
- ionic soft matter
- biological matter
- self-assembly

Theoretical methodologies

- equilibrium statistical mechanics
  e.g. http : //digitalcommons.uri.edu/equilibrium_statistical_physics/
- nonequilibrium statistical mechanics
  e.g. http : //digitalcommons.uri.edu/nonequilibrium_statistical_physics/
- transport theory
- physical kinetics
- stochastic processes
- fluid mechanics including microfluidics and nanofluidics
- simulations: molecular dynamics, Monte Carlo
- self-consistent field theory
- density functional theory
- statistically interacting particles with shapes

Experimental Techniques

Microscopy

- Optical microscopy for colloidal particles and aggregates of polymers.
- Polarized optical microscopy for identifying birefringent structures in liquid crystals.
- Differential interference contrast (DIC) microscopy for large colloidal particles.
- Electron microscopy for structures with sub-nanometer resolution. High vacuum restricts applications to dry materials.
- Scanning electron microscopy (SEM) probes surfaces. Transmission electron microscopy (TEM) probes structure of nanoscale slices. Soft matter provides marginal electron density contrast.
- Atomic force microscopy (AFM) measures forces on piconewton scale.

Scattering

- Small-angle light scattering (SALS) probes objects much larger than the wavelength (Rayleigh regime) and objects of comparable sizes (Mie regime). Dynamic light scattering (DLS) probes temporal fluctuations in scattered light.
- Main advantage of X-ray and neutron scattering: shorter wavelengths. X-rays probe electron density distributions. Neutrons are scattered from atomic nuclei and from electron magnetic moments.

Spectroscopy

- Nuclear magnetic resonance (NMR) probes local microstructures. Molecular motion broadens NMR lines.
- Infrared (IR) spectroscopy and Raman spectroscopy probe vibrational and rotational motions of molecules. IR dichroism measurements extract information on bond orientations.
- Dielectric spectroscopy probes response to time-dependent electric field. Complex dielectric function measured over wide range of frequencies.
- Fluorescent spectroscopy probes location of specific molecules or specific parts of macromolecules in heterogeneous environment (e.g. biological tissue).
- Circular dichroism (CD) spectroscopy detects presence of chiral ordering (e.g. α-helix). Oriented circular dichroism (OCD)also detects spatial orientation of helical structures.

Rheology

- Mechanical response to dynamic stress or strain.
- Variety of responses to shear stress (for example):
  - *solid matter*: shear stress causes deformation, described by shear strain.
    Phenomenon: elasticity.
    Material property: shear modulus.
  - *liquid matter*: shear stress causes flow, described by shear rate.
    Phenomenon: viscous flow.
    Material property: viscosity.
  - *soft matter*: shear stress causes (reversible) deformation on short time scale and (irreversible) flow on longer time scale.
    Phenomenon: viscoelasticity.
    Material property: relaxation modulus.

Calorimetry

- Heat transfer at constant pressure measures change in enthalpy. Differential scanning calorimetry (DSC) locates phase transitions in soft matter.

[extracted in part from Hamley 2007]