Polymer Classification

Chemical Structure

- copolymer
  - graft
  - random
  - alternating
  - graft terpolymer
- Homopolymer

Structure

- Linear
- Branched
- Crosslinked

Tacticity

- Isotactic
- Syndiotactic
- Atactic

Intermolecular forces

- Elastomer
- Fiber

Thermal behavior

- Thermoplastic
- Thermoset (no change)

Synthesis

- Condensation polymerization
- Addition polymerization
  - Free radical
  - Catalist
  - Cationic/Anionic polymerization

Source

- Natural ocurring
  - Cellulose
  - Starch
  - Proteins
- Synthetic
  - Plastics

Monomer arrangement

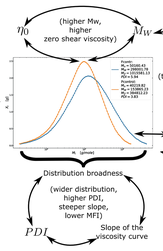
- Block copolymer
- graft copolymer

Polymerization

- Is a random process
- prone to mistakes in the spatial conformation
- molecules with different molecular weight

Molecular weight distribution (MWD)

- Number average molecular weight
  - number of individual chains
  - $M_n = \frac{\sum X_i}{\sum \frac{X_i}{M_i}}$
- Weight average molecular weight
  - mass fraction
  - $M_W = \frac{\sum X_i M_i}{\sum X_i}$
- Higher average molecular weight
  - Amount of high molecular weight chains
  - $M_Z = \frac{\sum X_i M_i^2}{\sum X_i M_i}$
- Polydispersity Index
  - $PDI = \frac{M_W}{M_n}$



Rheological test

Chemical and Physical Properties

Chemical stability

- Temperature
- Strain
- Double bonds Free radicals
- Ultraviolet exposure
- Oxygen

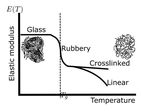
Avoid chain rupture with:

- Avert high temperatures
- Avoid frequent heating cycles
- Additives
  - Thermal stabilizers
  - UV stabilizers
  - Antioxidant stabilizers

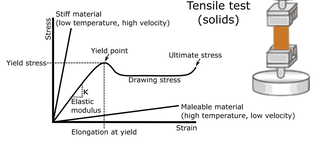
Processability

- Polymerization
- Degradation
- Molecular weight distribution
- Viscoelasticity
  - DPM
  - Temperature
  - Additives

Thermal behavior (Glass tansition temperature)



Tensile test (solids)



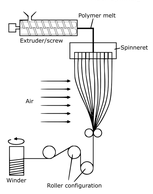
Polymer Processing

Injection molding Defects

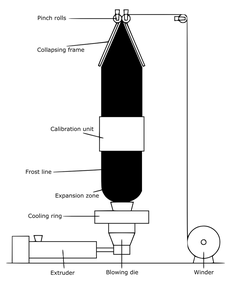
- Warpage (unstructured design)
- Jetting (high fill rate)
- Splashes (clamp failure)
- Charcoal-like edges (diesel effect)
- Flash (high pressure)
- Weld lines (uneven temperatures)
- Ejector pin marks (early eject)
- Sink marks (thick wall sections)
- Short Shot (low pressure)
- Silver-like surface (moisture)

Extrusion

- Extrusion defects
  - Shrinkage (too much stress)
  - Surging (speed variations)
  - Lumpy surface (too cold)
  - Bubbles (moisture)
  - Pimples (resin gels)
  - Shark skin (overheating)
- Processing conditions
  - Polymer rheology
  - Cooling conditions
  - Die dimensions
  - Screw design
  - Relative draw speed to extrusion speed
- Fiber Spinning

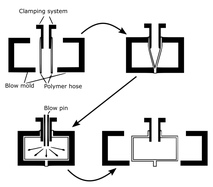


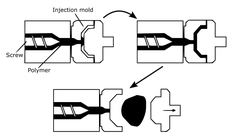
- Blown Film



Injection

- Processing conditions
  - Screw design
  - Injection Pressure
  - Mold layout
  - Shot size
  - Clamping force
- Injection Molding
- Blow molding



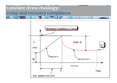


Parameters derived from $G'(\omega)$ and $G''(\omega)$

- Complex moduli: $|G^*(\omega)| = \left[G'(\omega)^2 + G''(\omega)^2\right]^{\frac{1}{2}}$
- Tan delta: $\tan\delta = G''(\omega) / G'(\omega)$
- Complex viscosity: $\eta^*(\omega) = \frac{\sqrt{G'^2(\omega) + G''^2(\omega)}}{\omega}$
- by Cox Mertz Rule: $\eta^*(\omega) = \eta(\dot{\gamma})$ where $\dot{\gamma}(\omega) = \omega(\omega)$

Oscillatory rheometry

- $G'(\omega) = G'(\omega) + G''(\omega)$

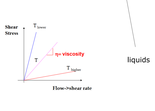


Other rheological tests:

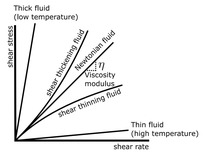
- Constant shear rate (viscous modulus)
- Constant stress (creep and recovery compliance)
- Constant strain (relaxation modulus)

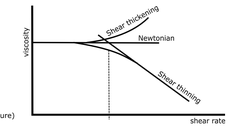
Plot data

Steady State Behavior

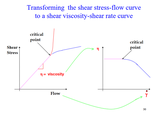


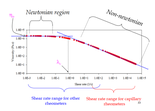
liquids

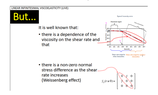




Transforming the shear stress-flow curve to a shear viscosity-shear rate curve





parallel plates

Non-Linear behavior