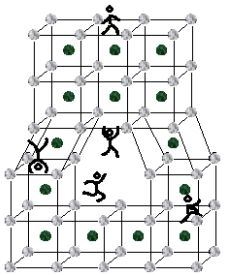
Glasses



- Long-Range and Short-Range Order
- Glass Transitions
- Viscosity
- Glass Forming Materials
- Glass Properties

Mon., Oct. 6, 2003

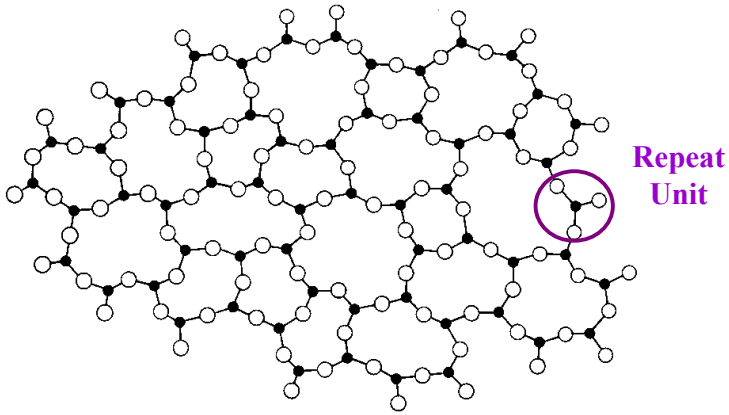
- HW : 6.2,4,18,32,42

MATS275: INTRODUCTION TO MATERIALS SCIENCE

What Makes a Glass?

- Amorphous
  - no long-range order
    - repeat units but no lattice constants
  - Ill-defined Melting Point
    - glass-transition temperature

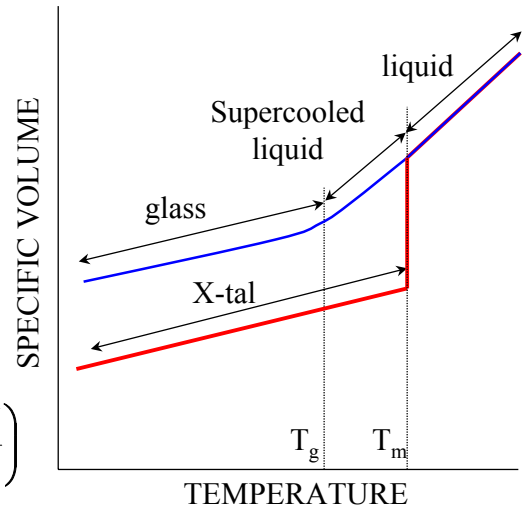
Lack of Long-Range Order



Glass-Transition

$$\text{S.V.} = \frac{\text{Volume}}{\text{Mass}}$$

$$\text{slope}: \alpha_v = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)$$



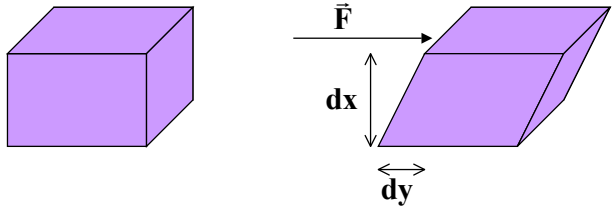
What is the Glass Transition?

- Below T_g
  - NO molecular motion at all - solid is frozen
- Between T_g and T_m
  - Reorientation and motion of connected repeat units
  - chains bend and wiggle
- Above T_m
  - Free motion of all molecules

ON THE TIME SCALE OF THE EXPERIMENT

Shear Strains

- The elastic constant for a shear strain...



$F \propto dy$

$\frac{F}{A} \propto \frac{dy}{dx}$

stress ∝ strain

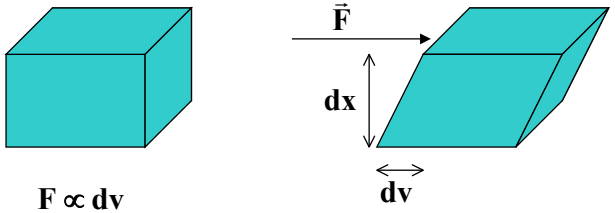
$\tau \propto \gamma$

$\tau = G\gamma$

G ≡ shear modulus

Shear in Fluids

- Now force is proportional to the rate of displacement...



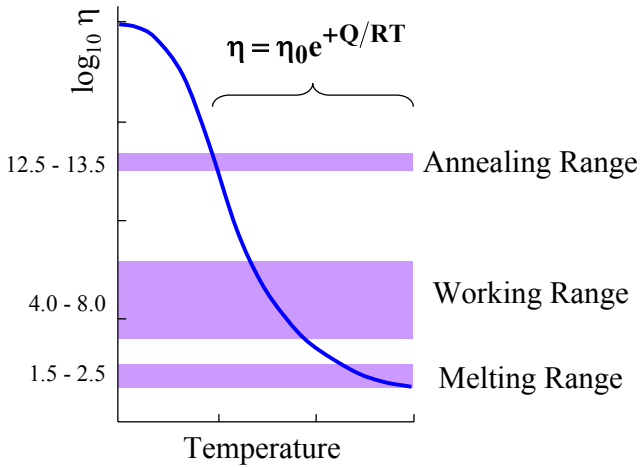
$F \propto dv$

$$\frac{F}{A} \propto \frac{dv}{dx} = \frac{d\left(\frac{dy}{dt}\right)}{dx}$$

$$\tau \propto \frac{d\left(\frac{dy}{dx}\right)}{dt}$$

$$\tau = \eta\frac{d\gamma}{dt} = \eta\frac{dv}{dx}$$

Viscosity



What Forms a Glass?

- Anything, but usually
  - oxides THE MOST IMPORTANT
  - sulfides
  - selenides
  - tellurides
  - polymers

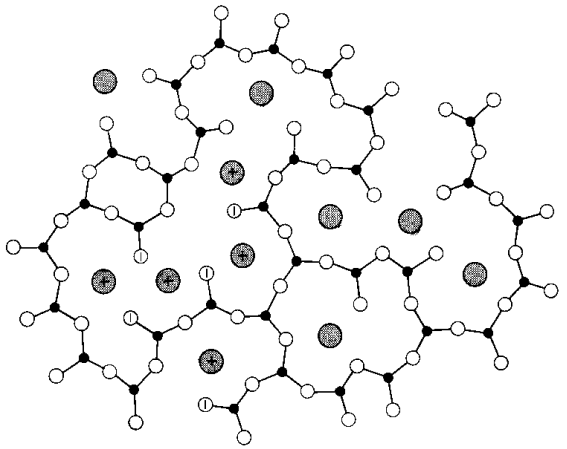
What Forms a Glass?

- Zachariasen's Rules
  - oxide glass networks are composed of oxide polyhedra
  - CN(O) = 2
  - CN(M) = 3 or 4 (tetrahedra or triangles)
  - Polyhedra share corners not edges or faces
  - Polyhedra must share at least 3 corners

Network Formers/Modifiers

Formers	Intermediates	Modifiers
SiO_2	Al_2O_3	Na_2O
B_2O_3	TiO_2	K_2O
GeO_2	ZrO_2	CaO
P_2O_5		MgO
		BaO
		PbO
		ZnO

Na_2O Network Modifiers



Important Glass and Ceramic Props

- Brittle Fracture
  - almost no slip
- Static Fatigue
  - chemical induced degradation (Si-OH)
- Creep
  - Sliding of grains, crack growth
- Thermal Shock
  - Thermal expansion problems

Thermal Effects

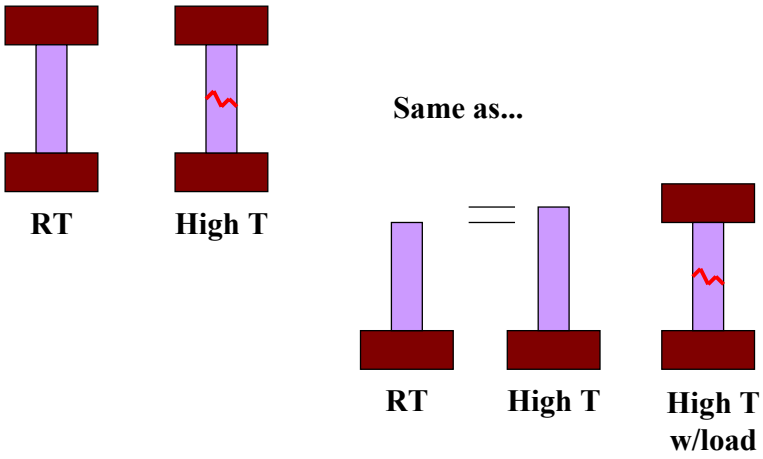
- Coefficient of Expansion

$$\alpha = \frac{1}{L}\frac{dL}{dT}$$

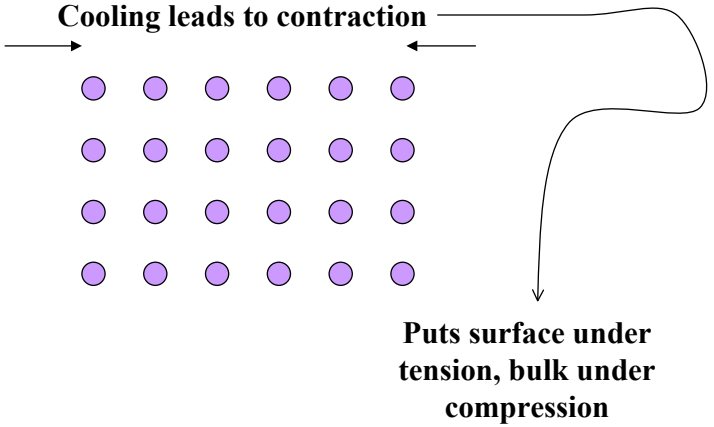
- Thermal Conductivity (Fourier's law)

$$k = -\frac{1}{A}\frac{dQ/dT}{dT/dx}$$

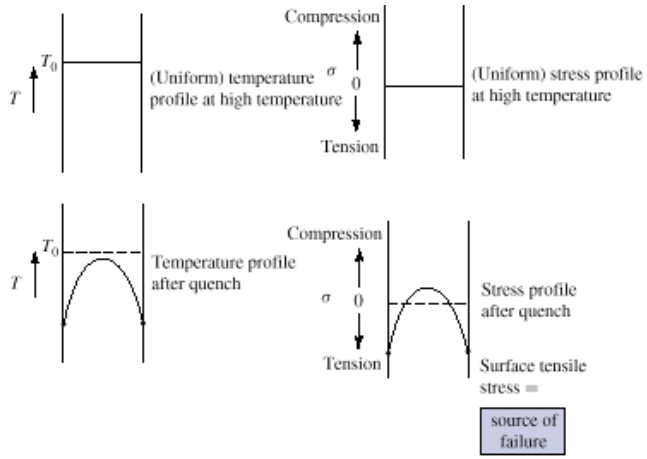
Constrained Expansion



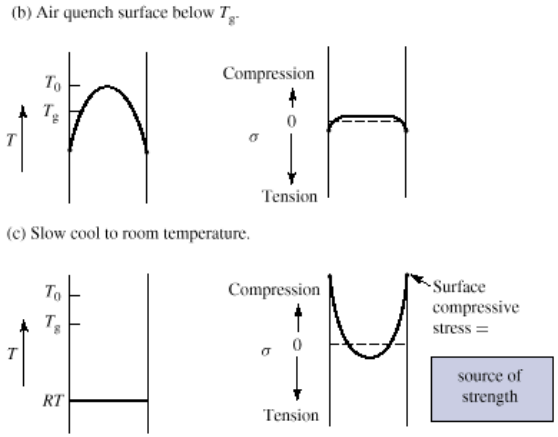
Thermal Shock



Surface in Tension



Tempering Glass



A Few Crystals

- We can also add a nucleating agent (ex., TiO2) that forms small crystallites.
- Can reduce thermal expansion - increase thermal shock strength
  - CorningWare - based on Li_2O-Al_2O_3-SiO_2.

What Forms a Glass?

- Anything, but usually
  - oxides
  - sulfides
  - selenides
  - tellurides
  - polymers THE MOST IMPORTANT

Polymers
Tacticity

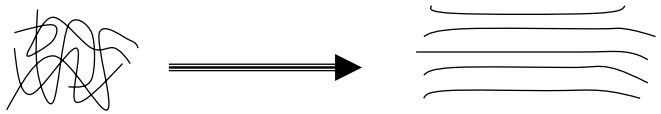
- Attach Side Groups
  - one side = isotactic
  - alternate sides = syndiotactic
  - randomly = atactic

Some Glass Transition Temps

	T_g	T_m
PP (iso)	-10	176
PMMA (syn)	115	>200
PMMA (iso)	45	160
PTFE	126	327

Polymers
Other Factors

- Size of Side Groups
- Chain Branching
- Complexity/Length of Chain
- Secondary Bonding



MetGlass

- Metals can be induced to form glasses if cooled rapidly enough.
- Must be used at low temperatures
- High strength (no dislocation motion)
- No grain boundaries - corrosion resistant
- Good magnetic properties
  - transformer cores
  - recording heads

Icoshedral Crystals