

Chapter Outline:

Applications and Processing of Ceramics

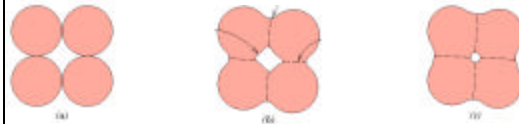
Chapter 14: Applications and Processing of Ceramics

- Short review of glass/ceramics applications and processing (14.1 - 14.4)

Optional reading: 14.3, 14.5 – 14.18

Formation and processing of Ceramics

- Ceramic materials have relatively high melting temperature and they are brittle \Rightarrow casting and processing based on plastic deformation (e.g. strain hardening) that we discussed for metals cannot be applied for ceramics.
- Some ceramics are formed by powder pressing, involve drying and firing,...



Sintering: powder pressing + firing below melting T

- Cements are formed from a fluid paste that hardens as a result of chemical reactions.
- Glasses (non-crystalline silicates) are produced by complete melting of the raw ingredients.

Applications of Ceramics

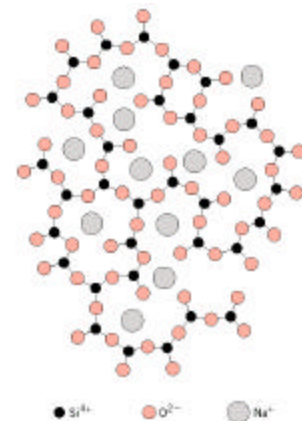
- The compressive strength is typically ten times the tensile strength. In structures, designs must be done for compressive loads.
- The transparency to light of many ceramics \Rightarrow optical applications (windows, photographic cameras, telescopes, etc)
- Good thermal insulation \Rightarrow use in ovens, the exterior tiles of the Shuttle orbiter, etc.
- Good electrical isolation \Rightarrow ceramics are used to support conductors in electrical and electronic applications.
- Good chemical inertness \Rightarrow applications in reactive environments.

Silicate Glasses

Silicate Glasses - noncrystalline silicates (SiO_2) containing other oxides (CaO , Na_2O , K_2O , Al_2O_3)

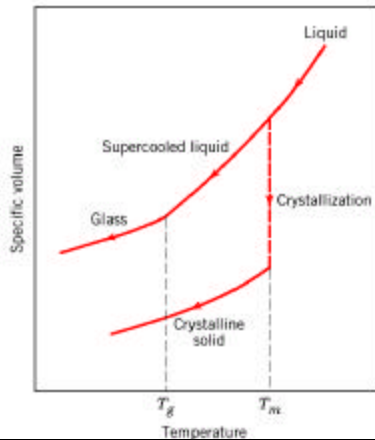
Containers, windows, lenses, fiberglass, etc.

Example:
Container/window glasses contain ~ 30 wt% oxides (CaO , Na_2O) whose cations are incorporated within SiO_4 network: *network modifiers*.



Properties of Glasses (I)

- Solidification is gradual, through a viscous stage (viscosity is increasing with decreasing T), without a clear melting temperature
- The specific volume does not have an abrupt transition at a fixed temperature but rather shows a change in slope at the glass-transition temperature



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Viscosity (from Chapter 13)

Viscosity is a measure of a non-crystalline (glass or liquid) material's resistance to deformation. High-viscosity fluids resist flow; low-viscosity fluids flow easily.

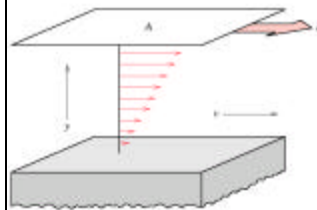
How readily a moving layer of fluid molecules drags adjacent layers of molecules along with it determines its viscosity.

Units are Pa-s, or Poises (P)

1 P = 0.1 Pa-s

Viscosity of water at room temp is ~ 10⁻³ P

Viscosity of typical glass at room temp >>> 10¹⁶ P



$$\eta = \frac{\tau}{dv/dy} = \frac{F/A}{dv/dy}$$

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Properties of Glasses (II)

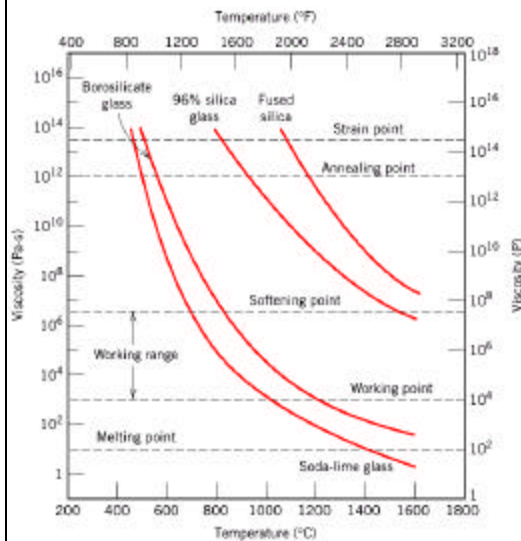
Important temperatures in glasses are defined in terms of viscosity

- > **Melting point:** viscosity = 100 P, below this temperature glass is liquid
- > **Working point:** viscosity = 10⁴ P, glass is easily deformed
- > **Softening point:** viscosity = 4×10⁷ P, maximum T at which a glass piece maintains shape for a long time
- > **Annealing point:** viscosity = 10¹³ P, relax internal stresses (diffusion)
- > **Strain point:** viscosity = 3×10¹⁴ P, above this viscosity, fracture occurs before plastic deformation

Glass forming operations - between softening and working points

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Properties of Glasses (III)



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Heat treatment of Glasses

Annealing at elevated temperatures is used to remove thermal stresses that result from inhomogeneous temperatures during cooling (similar to annealing of metals)

Tempering - heating the glass above the glass transition temperature but below the softening point and then quenched in an air jet or oil bath.

The interior, which cools later than the outside, tries to contract while in a plastic state after the exterior has already become rigid. This causes residual compressive stresses on the surface and tensile stresses inside.

In fracture, a crack has first to overcome the residual compressive stress, making tempered glass less susceptible to fracture. Tempering is used in automobile windshields, glass doors, eyeglass lenses, etc.

Summary

Make sure you understand language and concepts:

- Glass tempering
- Glass transition temperature
- Melting point (glass)

Reading for next class:

Chapter 15: Polymer Structures

- Hydrocarbon and Polymer Molecules
- Chemistry of Polymer Molecules
- Molecular Weight and Shape
- Molecular Structure and Configurations
- Copolymers
- Polymer Crystals

Optional reading: none