

Chapter 14: Applications and Processing of Ceramics

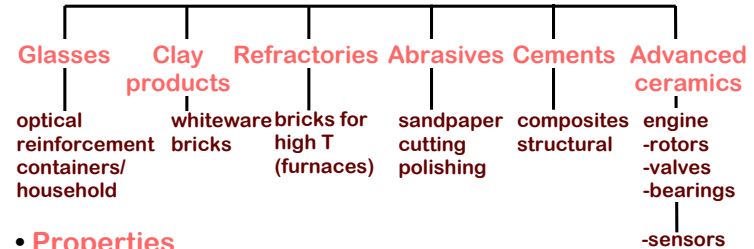
Issues to address...

- How do we classify ceramics?
- How is processing different than for metals?
- What are some typical applications?

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Taxonomy of Ceramics



- **Properties**
T_{melt}: Moderate for glasses, large for other ceramics.
Toughness, ductility: Small
- **Applications**
High T, wear resistant, novel uses from charge neutrality.
- **Fabrication**
Some glasses: forming possible
Other ceramics: cannot form or cast!

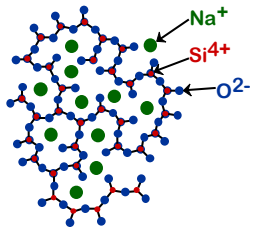
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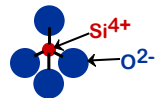
Silicate Glasses

• Glass Structure:

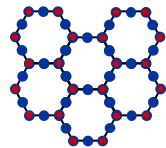
Amorphous (noncrystalline)



Basic unit: SiO₄⁴⁻ tetrahedron



• Compare to crystalline



Check: Is this charge balanced?

• Impurity elements

- Na⁺, Mg²⁺, Ca²⁺, Al³⁺
- bonds SiO₄ tetrahedra together
 - often lowers working T
 - complicates structure: makes amorphous easier to obtain
 - must achieve charge neutrality

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Glass Properties

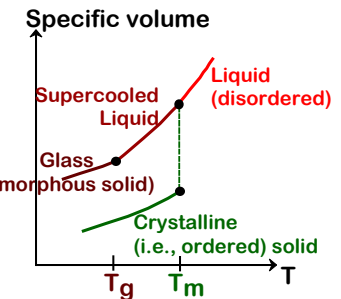
• Specific volume (1/) vs temperature (T)

Glasses:

- do not crystallize
- spec. vol. varies smoothly (amorphous solid)
- T_g: glass transition T

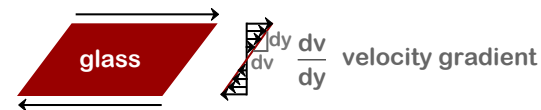
Crystals are different:

- spec. vol changes abruptly at T_m



• Viscosity () = $\frac{dv}{dy}$

units of : [Pa s]

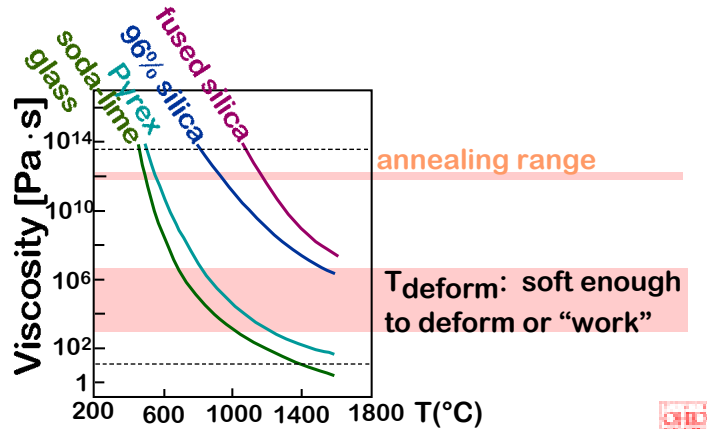


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Glass viscosity vs T, impurity content

- Viscosity decreases with T
- Impurities lower T_{deform}

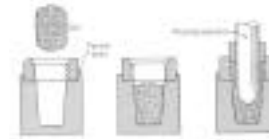


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Types of Glass Forming

- Pressing:

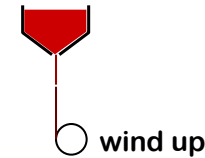


both operations are used to make jars, bottles

- Blowing:



- Fiber Drawing:



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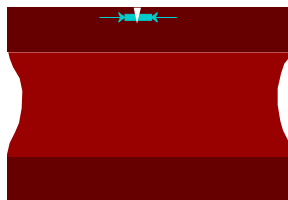


Tempered Glass

- Puts surface into compression
- Suppresses growth of surface cracks



- Surface crack growth is stopped



show
Prince
Rupert's
drops

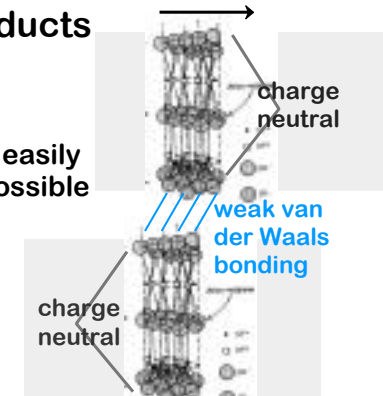
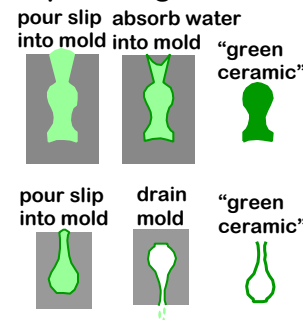
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Clay Products

- Clay is inexpensive
- Add water to clay:
 - allows material to shear easily
 - extrusion, slip casting possible

- Slip casting:



Sheet structure of kaolinite clay

show slip demo

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Drying and Firing

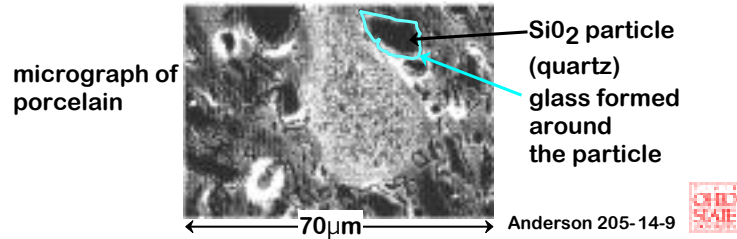
- Drying: layer size and spacing decreases



wet slip partially dry "green" ceramic

- Firing:

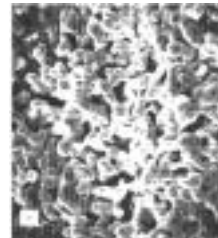
- T raised to (900-1400°C)
- glass forms from clay and flows between SiO₂ particles



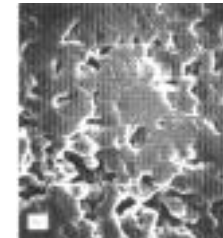
Sintering Powders

- Grind to produce ceramic and/or glass particles
- Inject into mold
- Sinter (i.e., press at elevated T to reduce pore size)

- Aluminum oxide powder



sintered at 1700°C for 2.5 minutes

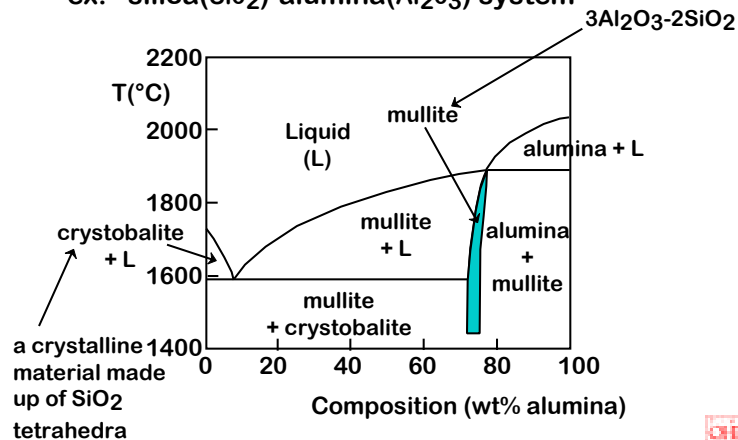


at 1700°C for 6 minutes

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Refractories

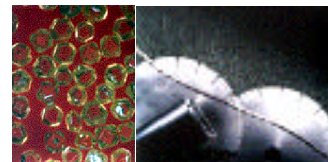
- High T phases (e.g., furnaces)
- ex: silica(SiO₂)-alumina(Al₂O₃) system



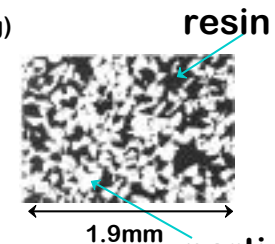
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Abrasives

- Particles are...
 - held together w/ glass or polymer resin (ex: sandpaper or grinding wheels)
 - used in abrasive slurry (ex: wire saws, polishing)



Diamond-based abrasive manufactured by GE Superabrasives, Worthington, OH
<http://www.ge.com/superabrasives/>



particles

- silicon carbide
- tungsten carbide
- aluminum oxide
- silica sand

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Sensors

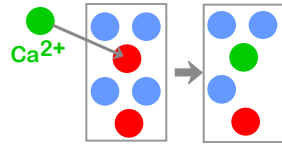
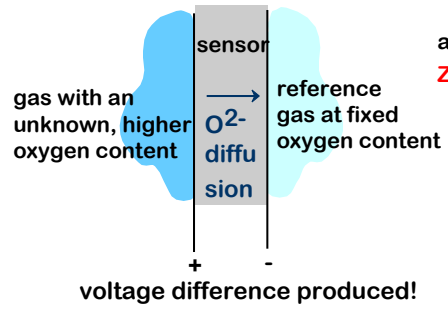
- Principle: Make diffusion of ions fast

- Oxygen sensor: ZrO_2

- Ca impurity

 - increases O^{2-} vacancies

 - increases O^{2-} diffusion



a Ca^{2+} ion removes a Zr^{4+} and a O^{2-} ion.

You can also make an oxygen pump!

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