University of South Australia

ENR116 Engineering Materials

Module 4 Non-metals and Corrosion

Dr Drew Evans

School of Advanced Manufacturing and Mechanical Engineering

University of South Australia

Copyright Notice

Do not remove this notice.

University of South Australia

Ceramic processing and applications

University of South Australia

Intended Learning Outcomes

At the end of this section, students will be able to:-

- Identify the classes of ceramics.
- Understand how and why ceramics are used.
- Describe ceramic processing and how it differs from that of metals.

Classes of ceramics

- **Glasses**
  - -optical
  - -composite reinforce
  - -containers/ household
- **Clay products**
  - -whiteware
  - -bricks
- **Refractories**
  - -bricks for high *T* (furnaces)
- **Abrasives**
  - -sandpaper
  - -cutting
  - -polishing
- **Cements**
  - -composites
  - -structural
- **Advanced ceramics**
  - engine
  - -rotors
  - -valves
  - -bearings
  - -sensors

Adapted from Fig. 13.1 and discussion in Section 13.2-6, *Callister & Rethwisch 8e.*

Properties:

T_m for glass is moderate, but large for other ceramics.

low toughness and ductility; large moduli and creep resistance

University of South Australia

Glasses

Glasses are noncrystalline silicates containing other oxides such as CaO, Na_2O, K_2O, and Al_2O_3. Typical applications include containers, lenses, and fibreglass.

Table 13.1 Compositions and Characteristics of Some of the Common Commercial Glasses

	Composition (wt%)						
Glass Type	*SiO_2*	*Na_2O*	*CaO*	*Al_2O_3*	*B_2O_3*	*Other*	*Characteristics and Applications*
Fused silica	>99.5						High melting temperature, very low coefficient of expansion (thermally shock resistant)
96% Silica (Vycor™)	96				4		Thermally shock and chemically resistant—laboratory ware
Borosilicate (Pyrex™)	81	3.5		2.5	13		Thermally shock and chemically resistant—ovenware
Container (soda–lime)	74	16	5	1		4MgO	Low melting temperature, easily worked, also durable
Fiberglass	55		16	15	10	4MgO	Easily drawn into fibers—glass–resin composites
Optical flint	54	1				37PbO, $8K_2O$	High density and high index of refraction—optical lenses
Glass–ceramic (Pyroceram™)	43.5	14		30	5.5	$6.5TiO_2$, $0.5As_2O_3$	Easily fabricated; strong; resists thermal shock—ovenware

Data from Table 13.1, *Callister & Rethwisch 8e.*

Glass-ceramics

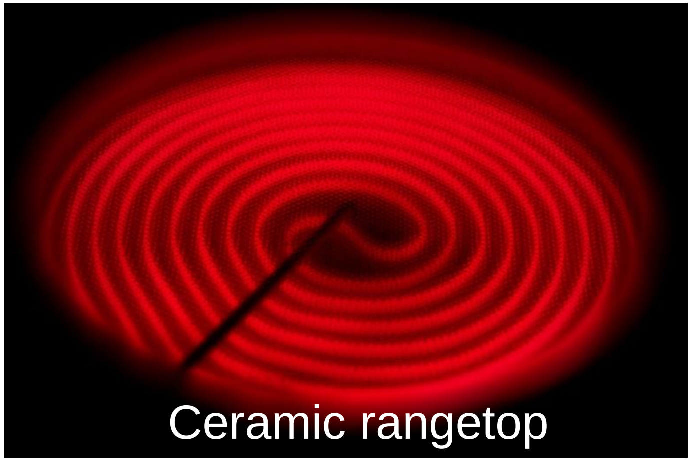
Noncrystalline to crystalline by the proper high-temperature heat treatment

University of South Australia

Glass-ceramics: properties and applications

Properties:

- Relatively high mechanical strengths
- Low coefficients of thermal expansion
- High temperature capabilities
- Good dielectric properties
- Good biological compatibility.


Ceramic rangetop

Applications:

Ovenware, tableware, oven windows, and rangetops

- Strength and excellent resistance to thermal shock

Electrical insulators, substrates for printed circuit boards, architectural cladding, heat exchangers and regenerators.

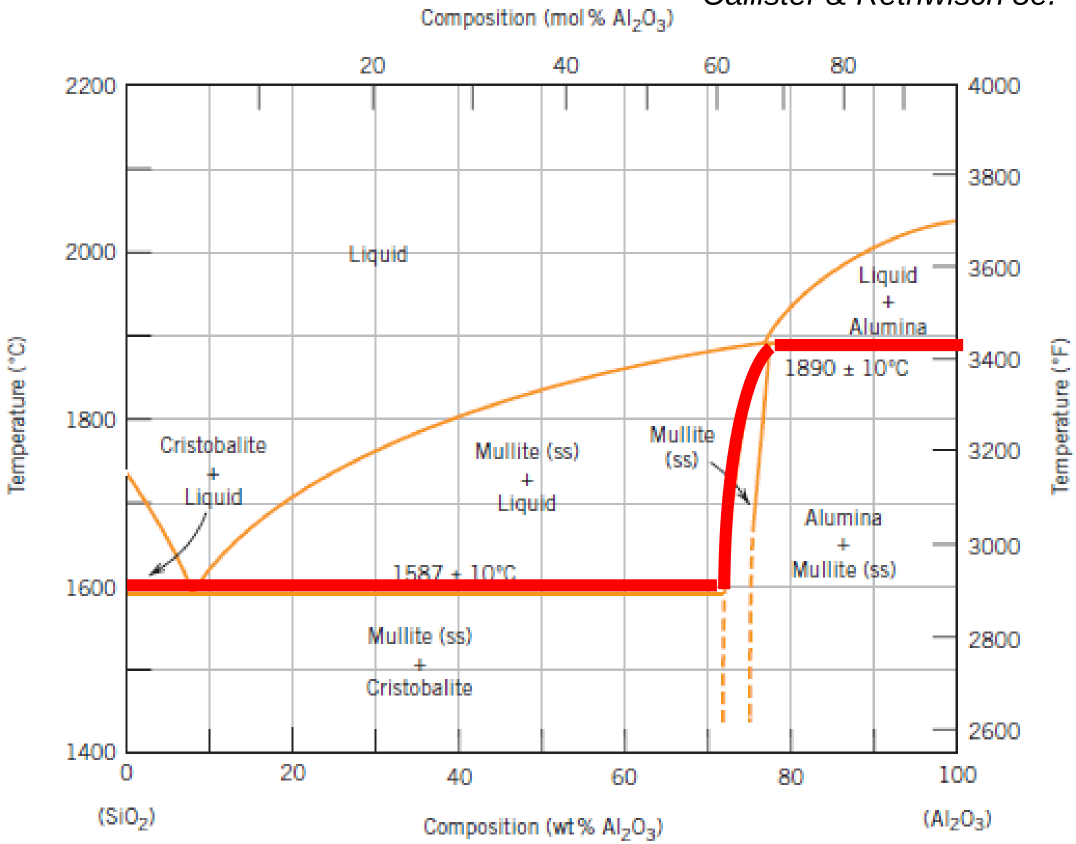
Refractories: Properties

Have the capacity to withstand high T's without melting or decomposing.

Remain unreactive and inert when exposed to severe environments.

Also able to provide thermal insulation.

Adapted from Fig. 12.27, *Callister & Rethwisch 8e.*



Upgrading the alumina content will increase the maximum service temperature.

University of South Australia

Refractories: Applications

Typical applications include furnace linings for metal refining, glass manufacturing, metallurgical heat treatment, and power generation.

Data from Table 13.2, *Callister & Rethwisch 8e.*

Table 13.2 Compositions of Five Common Ceramic Refractory Materials

Refractory Type	*Composition (wt%)* Al_2O_3	SiO_2	MgO	Cr_2O_3	Fe_2O_3	CaO	TiO_2	*Apparent Porosity (%)*
Fireclay	25–45	70–50	0–1		0–1	0–1	1–2	10–25
High-alumina fireclay	90–50	10–45	0–1		0–1	0–1	1–4	18–25
Silica	0.2	96.3	0.6			2.2		25
Periclase	1.0	3.0	90.0	0.3	3.0	2.5		22
Periclase–chrome ore	9.0	5.0	73.0	8.2	2.0	2.2		21

University of South Australia

Abrasives: Properties

Abrasive ceramics are used to wear, grind, or cut away other materials, which necessarily are softer.

Properties:	Materials:
Hardness	Diamond (both natural and synthetic)

University of South Australia

Abrasives: Applications

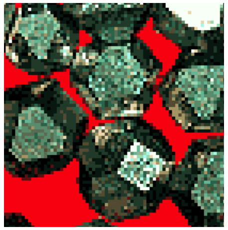
Tools for:

grinding

polishing

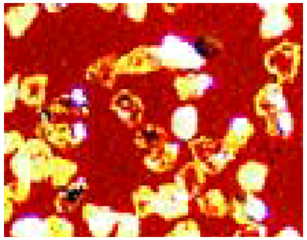
cutting

drilling

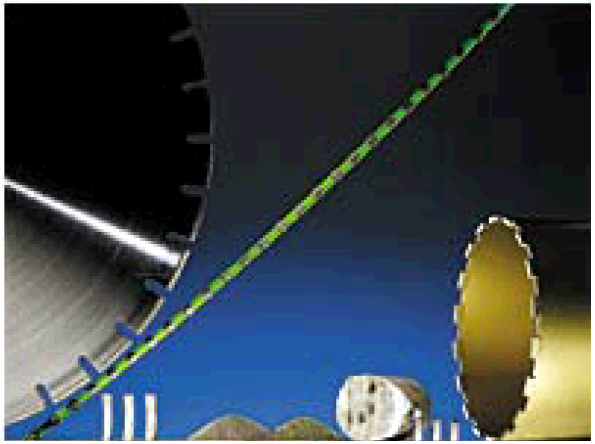


Coated single crystal diamonds

Oil drill bits



Polycrystalline diamonds in a resin matrix.



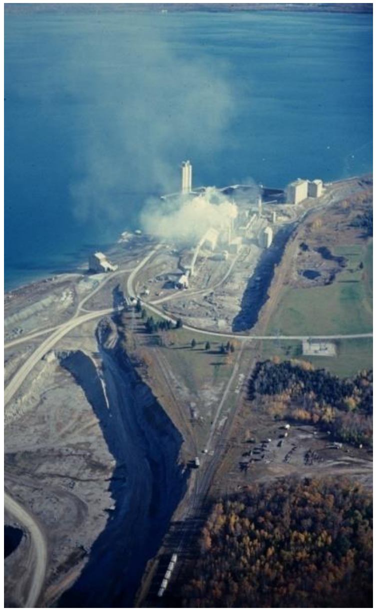
Cutting blades

Photos courtesy Martin Deakins, GE Superabrasives, Worthington, OH. Used with permission.

University of South Australia

Cements

Characteristic feature of these materials is that when mixed with water they form a paste that subsequently sets and hardens.



Portland cement is consumed in the largest tonnages.

The principal constituents are tricalcium silicate ($3CaO–SiO_2$) and dicalcium silicate ($2CaO–SiO_2$).

Cements

Produced by:

University of South Australia

Fabrication and processing of ceramics

A classification scheme for ceramic forming techniques.

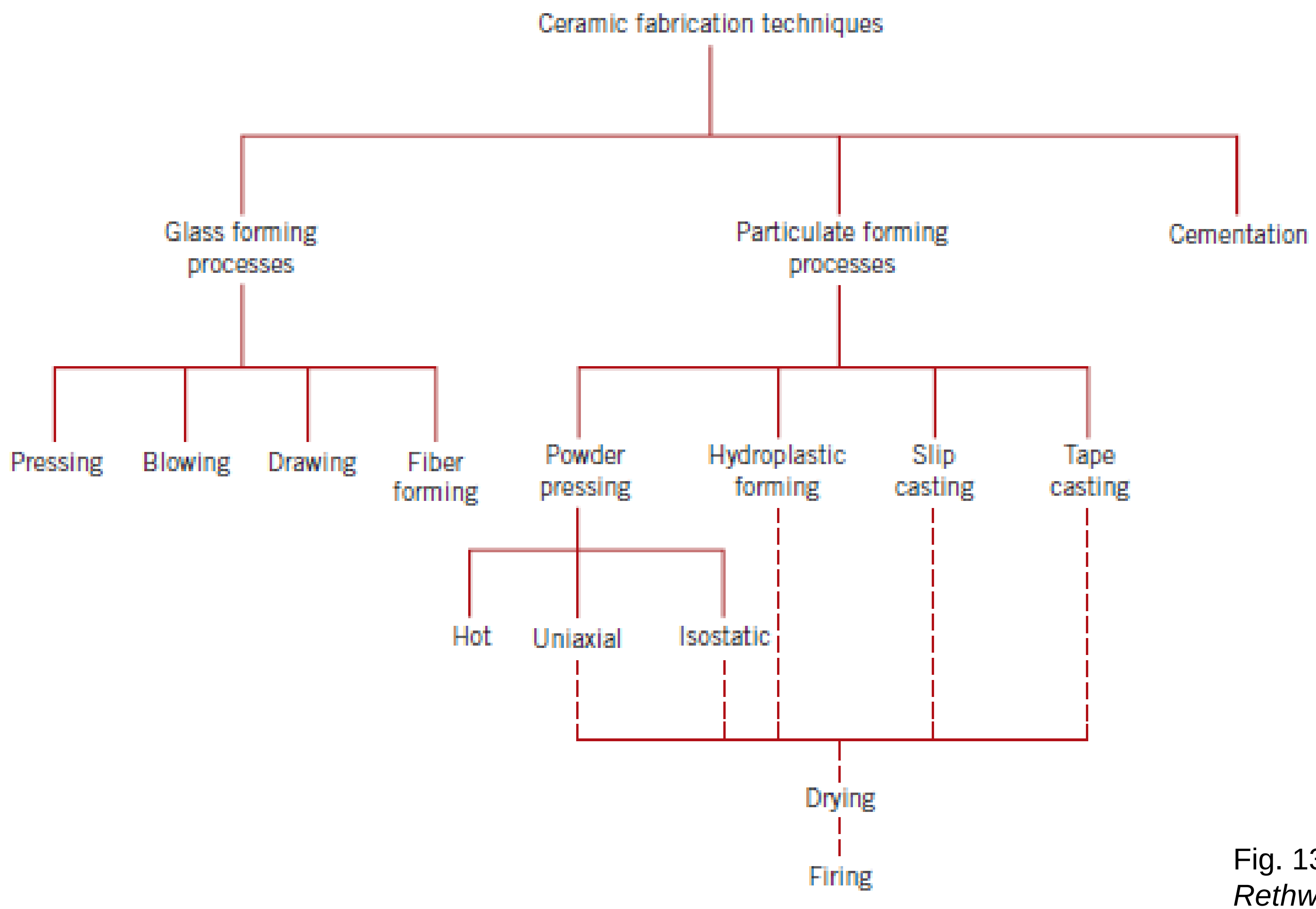


Fig. 13.05, *Callister & Rethwisch 8e.*

University of South Australia

Glass properties: viscosity–temperature characteristics

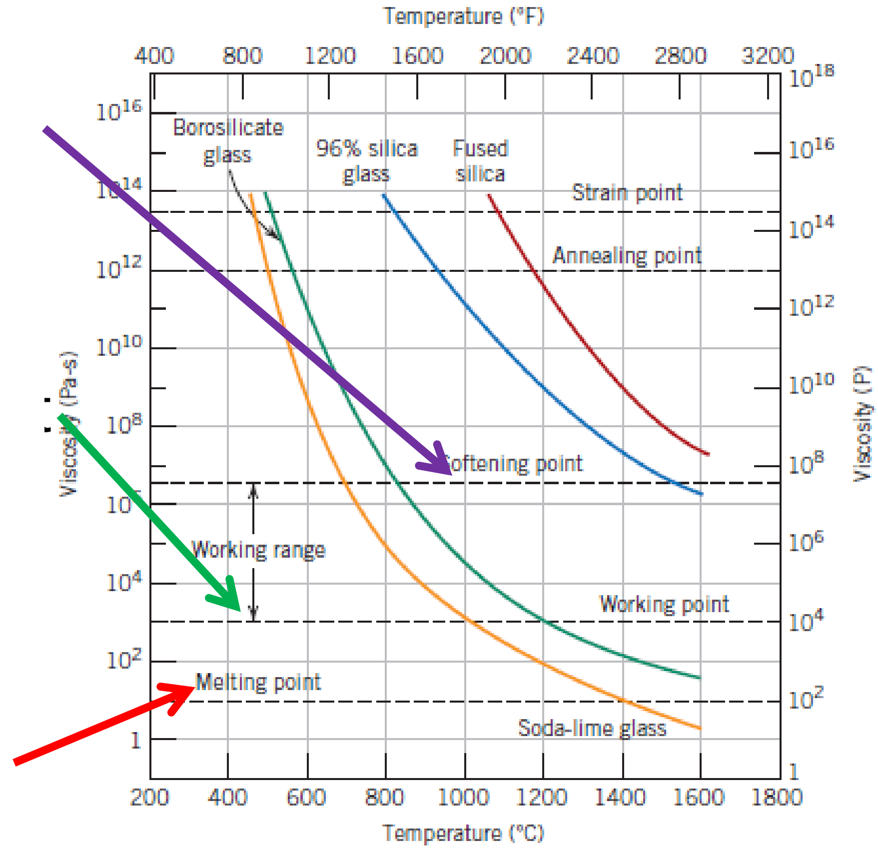


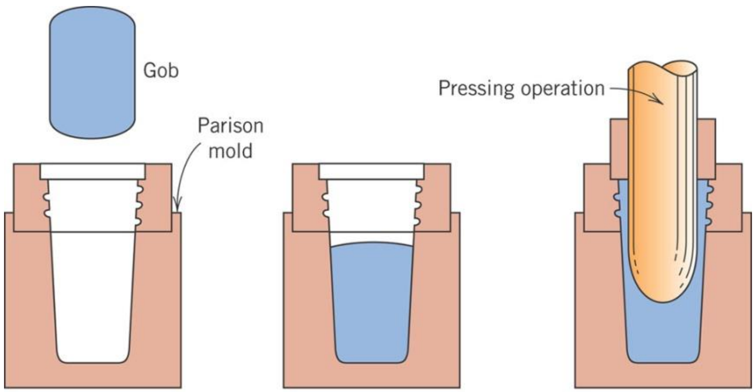
Fig. 13.07, *Callister & Rethwisch 8e.*

University of South Australia

Ceramic fabrication methods: glass forming

Pressing: plates, dishes, (relatively thick objects)

mold is steel with graphite lining



Blowing: jars, bottles, bulbs

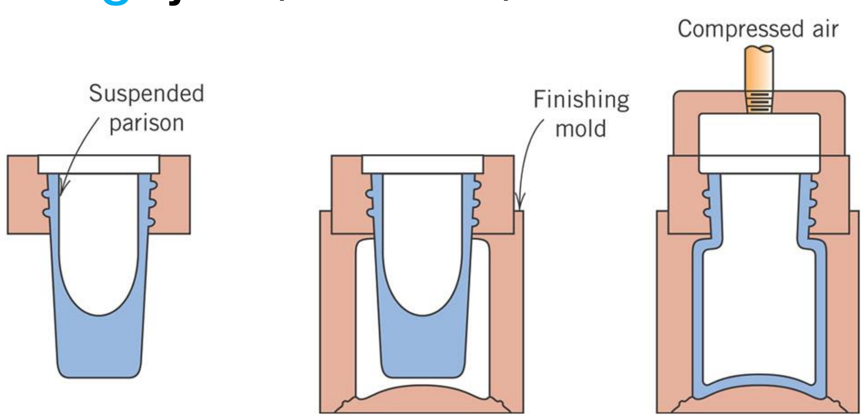


Fig. 13.8, *Callister & Rethwisch 8e*. (Fig. 13.8 is adapted from C.J. Phillips, *Glass: The Miracle Maker*, Pittman Publishing Ltd., London.)

University of South Australia

Ceramic fabrication methods: sheet glass forming

Sheet forming: Continuous draw - for making sheet, rod, tubing, fibers.

Sheets are formed by floating the molten glass on a pool of molten tin.

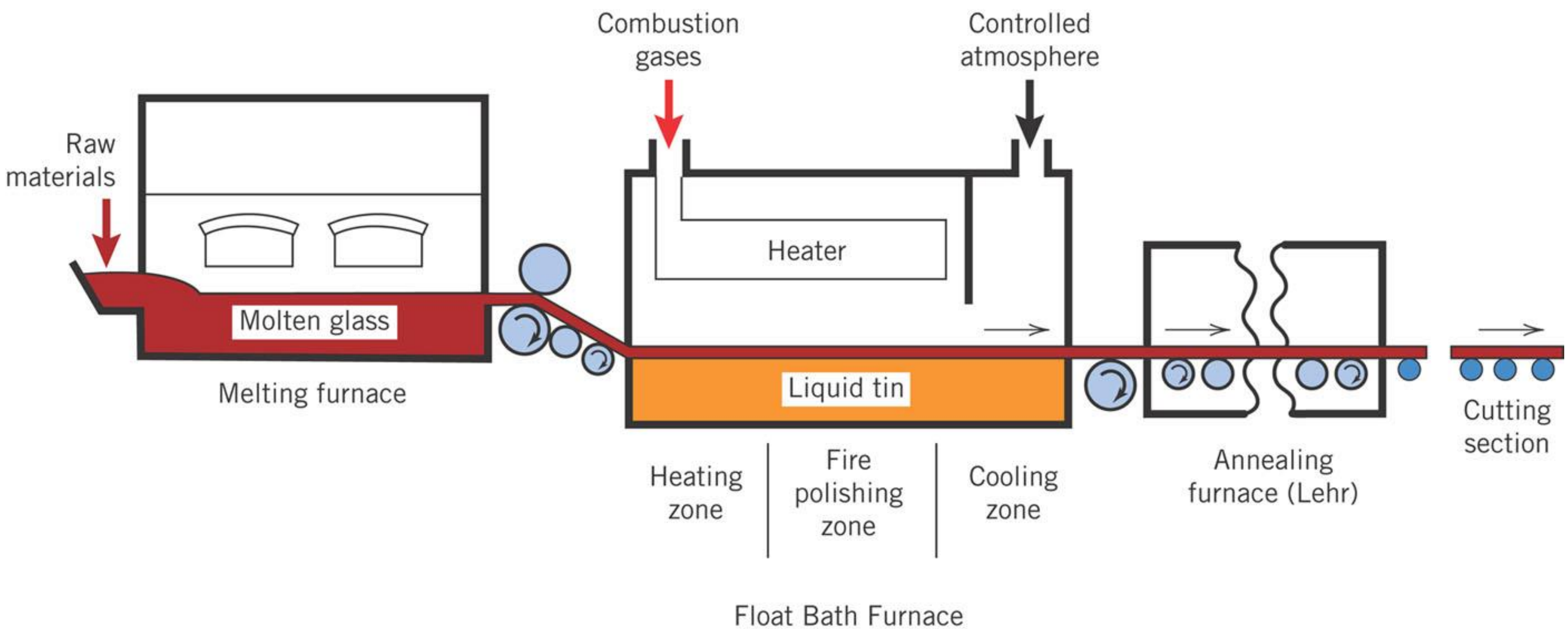


Fig. 13.9, *Callister & Rethwisch 8e*.

University of South Australia

Heat treating glass

Annealing: Removes internal stress caused by uneven cooling.

Tempering: Puts surface of glass part into compression, suppressing surface crack propagation

University of South Australia

Fabrication and processing of clay products: Clay composition

A mixture of components used i.e. typical porcelain:

University of South Australia

Characteristics of clays

Hydroplasticity: Becomes plastic when water is added.

University of South Australia

Ceramic fabrication methods

Hydroplastic forming:

Mill (grind) and screen constituents: desired particle size.

Extrude this mass (e.g., into a brick).

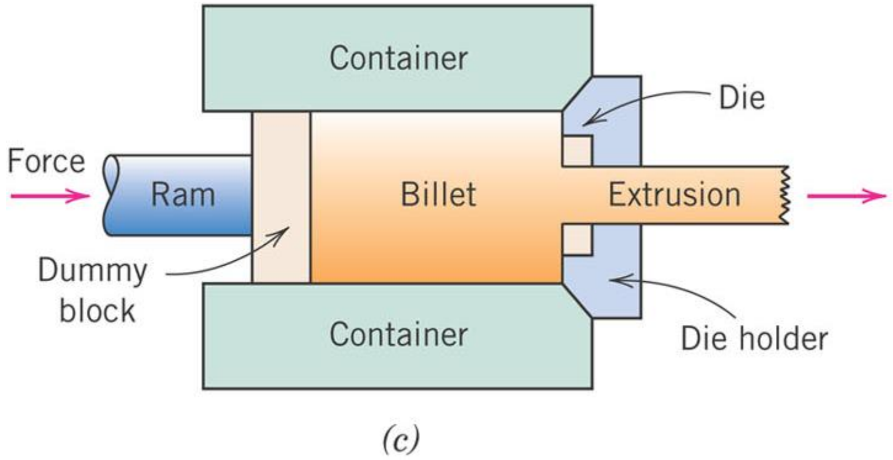


Fig. 11.8(c), *Callister & Rethwisch 8e*.

Dry and fire the formed piece.

University of South Australia

Ceramic fabrication methods

Slip casting:

Mill (grind) and screen constituents: desired particle size.

Mix with water and other constituents to form slip.

Dry and fire the formed piece.

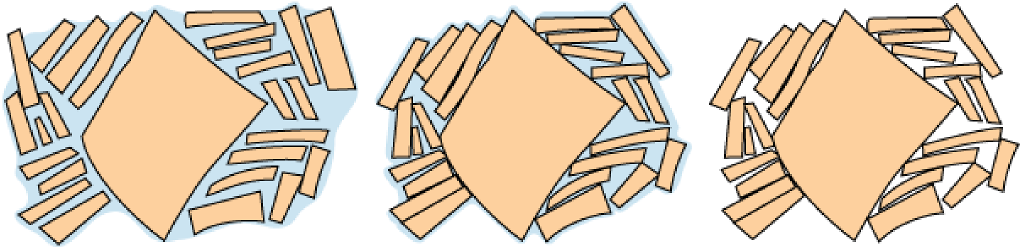
University of South Australia

Drying and firing

Drying: Layer size and spacing decrease.

Drying too fast causes sample to warp or crack due to non-uniform shrinkage.

Adapted from Fig. 13.13, *Callister & Rethwisch 8e*. (Fig. 13.13 is from W.D. Kingery, *Introduction to Ceramics*, John Wiley and Sons, Inc., 1960.)



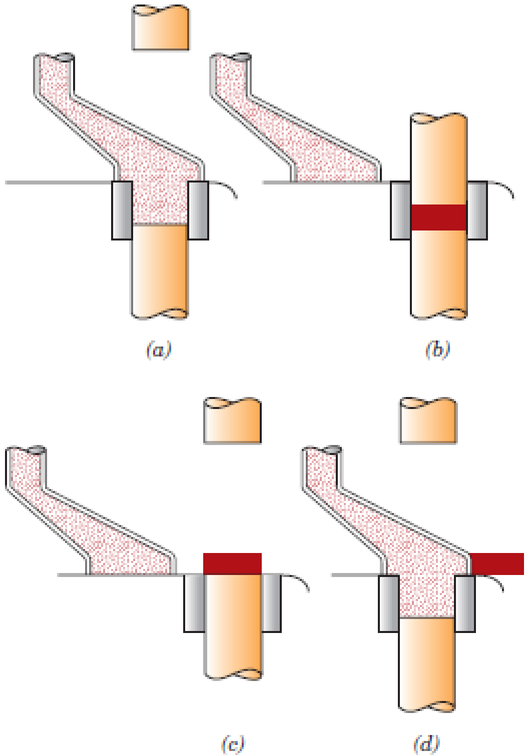
University of South Australia

Powder pressing

Uniaxial compression: Compacted in single direction.

Isostatic (hydrostatic) compression: Pressure applied by fluid - powder in rubber envelope.

Hot pressing: Pressure + heat.



Adapted from Fig. 13.15, *Callister & Rethwisch 8e*.

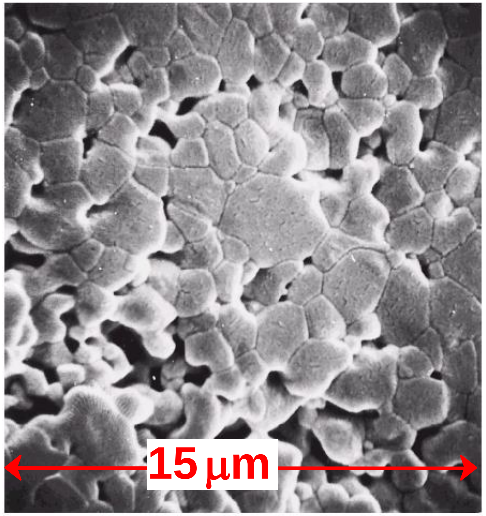
Sintering

Sintering: Coalescence of the particles in a more dense mass.

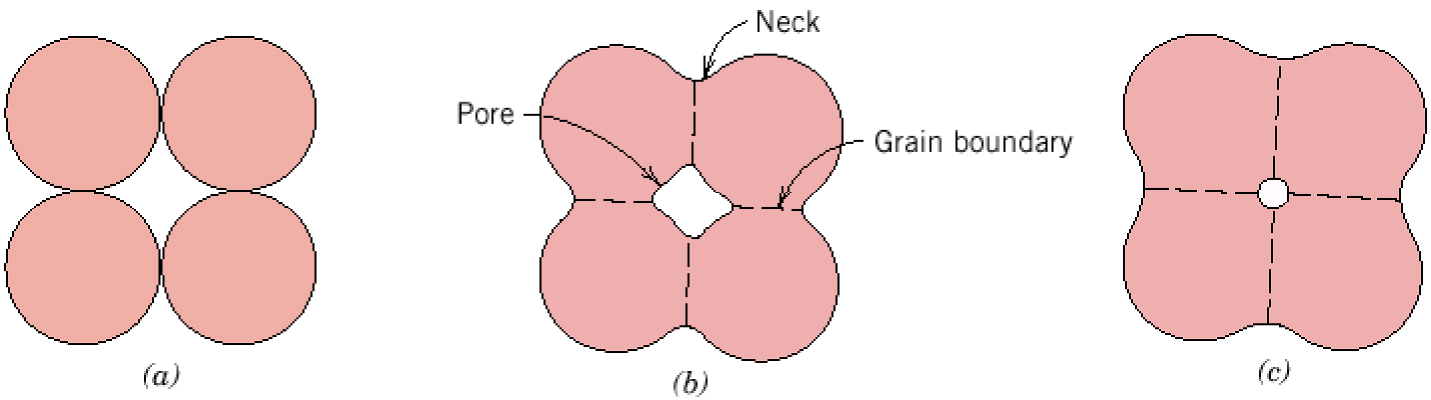
Powder touches, forms neck & gradually neck thickens.

→ Add processing aids to help form neck.

→ Little or no plastic deformation.



Adapted from Figs. 13.16 & 13.17, *Callister & Rethwisch 8e*.



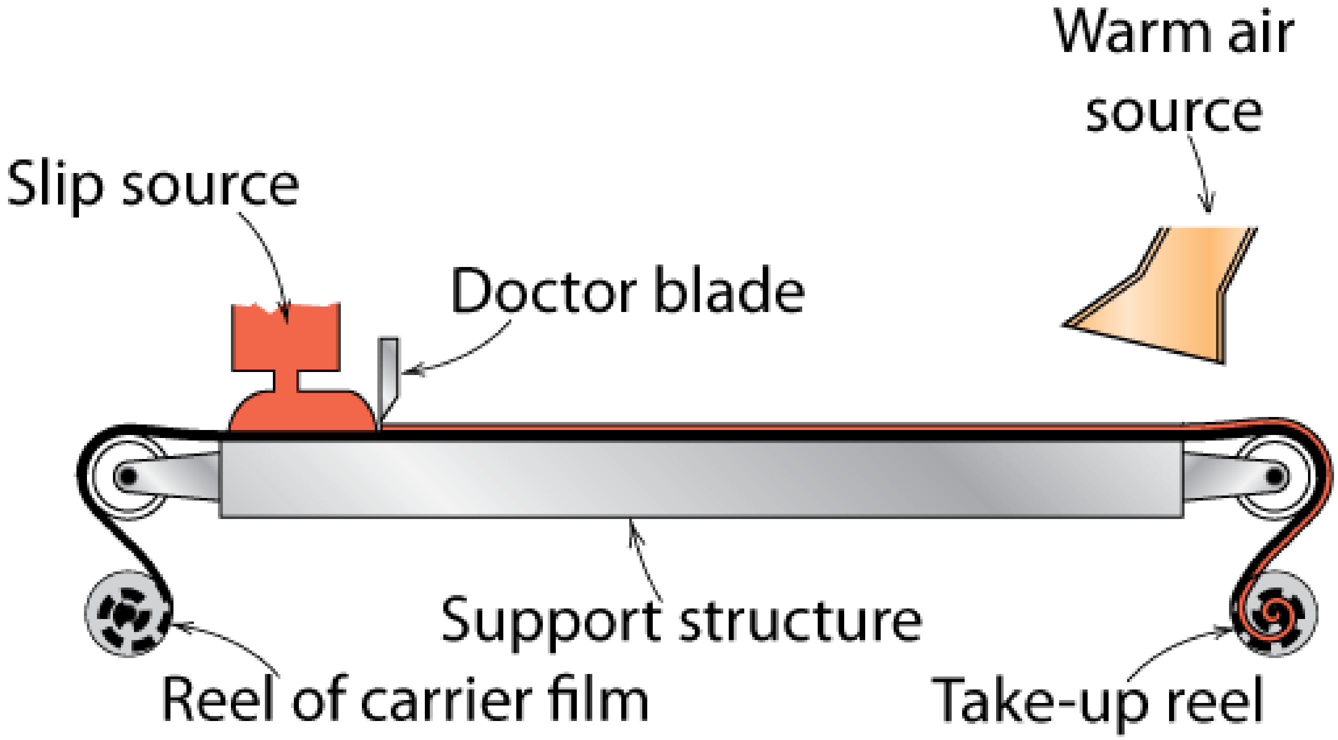
University of South Australia

Tape casting

Thin sheets of green ceramic cast as flexible tape.

Used for integrated circuits and capacitors.

Cast from liquid slip (ceramic + organic solvent).



Adapted from Fig. 13.18, *Callister & Rethwisch 8e*.

Summary

- Ceramics are classified by both structure and application.

- Ceramics are processed as a glass (at high temperatures) and as powders under high pressures.

Thank you