Ceramics, Glasses, Superconductors Processing and Equipment

Text Reference: “Manufacturing Engineering and Technology”, Kalpakjian & Schmid, 6/e, 2010 Chapter 18

FIGURE 18.1 (a) Examples of typical glass parts. (b) Examples of ceramic parts. Source: (a) Courtesy of Commercial Optical Manufacturing, Inc. (b) Courtesy Kyocera.

TABLE 18.1 General Characteristics of Ceramics Processing

<table>
<thead>
<tr>
<th>Process</th>
<th>Advantages</th>
<th>Limitations</th>
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</thead>
<tbody>
<tr>
<td>Slip casting</td>
<td>Large parts, complex shapes, low equipment cost</td>
<td>Low production rate, limited dimensional accuracy</td>
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<td>Extrusion</td>
<td>Hollow shapes and small diameters, high production rate</td>
<td>Parts have constant cross section, limited thickness</td>
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<td>Dry pressing</td>
<td>Close tolerances, high production rate (with automation)</td>
<td>Density variations in parts with high length-to-diameter ratios, fine grain structure can be difficult</td>
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<tr>
<td>Wet pressing</td>
<td>Complex shapes, high production rate</td>
<td>Limited part size and dimensional accuracy, tooling costs can be high</td>
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<td>Hot pressing</td>
<td>Strong, high-density parts</td>
<td>Temperature can be high</td>
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<td>Isostatic pressing</td>
<td>Uniform density distribution</td>
<td>Equipment can be costly</td>
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<tr>
<td>Jigging</td>
<td>High-production rate with automation, low tooling cost</td>
<td>Limited to isostatically parts, limited dimensional accuracy</td>
</tr>
<tr>
<td>Injection molding</td>
<td>Complex shapes, high production rate</td>
<td>Tooling can be costly</td>
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</tbody>
</table>

FIGURE 18.2 Processing steps involved in making ceramic parts.

FIGURE 18.3 Sequence of operations in slip casting a ceramic part. After the slip has been poured, the part is dried and fired in an oven to give it strength and hardness. Source: After F.H. Norton.

(a) (b) (c) (d) (e)

FIGURE 18.4 Production of ceramic sheets through the doctor-blade process.
Finishing Operations

- May be employed to
  - Give final shape
  - Improve surface finish & tolerances
  - Remove surface flaws
- Possible Finishing Operations:
  - Grinding
  - Lapping & honing
  - Ultrasonic machining
  - Drilling
  - Electrical-discharge machining
  - Laser-beam machining
  - Abrasive water-jet cutting
  - Tumbling

Forming & Shaping of Glass

General process for glass:

- Melt
  - 1000° to 1200°C
  - A red-hot, viscous, syrup
- Shape
  - in Molds
  - with Tools
  - by Blowing
- Improve strength by
  - Chemical & thermal treatments
  - Lamination with thin layer of tough plastic
FIGURE 18.9 Manufacturing process for glass tubing. Air is blown through the mandrel to keep the tube from collapsing. Glass tubes for fluorescent bulbs are made by this method.


FIGURE 18.11 Manufacturing a glass item by pressing glass into a mold. Source: Courtesy of Corning Glass Works.

FIGURE 18.12 Pressing glass into a split mold. Source: After E.B. Shand.

FIGURE 18.13 Centrifugal casting of glass. Large telescope lenses and television-tube funnels are made by this process. Source: Courtesy of Corning Glass Works.

FIGURE 18.14 (a) The stages involved in inducing compressive surface residual stresses for improved strength.
(b) Residual stresses in a tempered glass plate.
Design Considerations for Ceramics and Glasses

- Balance limitations (poor tensile strength, sensitivity to internal & external defects, low impact toughness) against advantages (hardness, scratch resistance, compressive strength both cold & hot)
- Important to control processing parameters and the quality & amount of impurities in raw materials
- Consider relative costs of quantity, tooling, equipment, labour
- Consider dimensional changes, warping, possibility of cracking during processing & service life
- Compatibility with other materials in an assembly
- Allow for static fatigue (failure over time under static loading)

Superconductors

- Superconductivity is the phenomenon of near zero electrical resistivity that occurs in some materials below a critical (very cold) temperature
- Superconductors have major energy-saving potential, but difficult to achieve in ceramics due to brittleness and anisotropy
- Metals: LTSC – Low Temperature Superconductors
- Ceramics: HTSC – High Temperature Superconductors
- HTSC available in powder form

Processing of Superconductors

- Prepare powder: mix it by grinding in ball mill to grain size 0.5 to 10 μm
- Form powder to desired shape
- Heat treat the product

Summary

- Ceramic products made by casting, plastic forming, pressing; then dried & fired
- Glass products made by several shaping processes similar to those for ceramics, plastics
- Continuous glass processing methods: Drawing, Rolling, Floating
- Discrete glass processing methods: Blowing, Pressing, Centrifugal casting
- Design considerations: low tensile strength, low toughness, sensitivity to defects, warping, cracking
- Manufacturing superconductors difficult: brittleness, anisotropy