Composition and Manufacture
Polycrystalline Alumina

- Sintering and Grain Growth[3,4,15]
  - Bond Grains Together Below Melting Temperature (2051.0 +/- 9.7°C)

NOTE
- Changes in Grain Size and Shape
- Changes in Pore Shape
- Changes in Pore Size

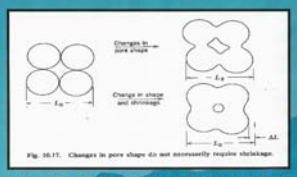


Fig. 10.17. Changes in pore shape do not necessarily require shrinkage.

Kingery WD, Bowen HK, Uhlmann DR (1976). Introduction to ceramics. 2d ed. New York: Wiley.

Sintering and Grain Growth
Purpose of Sintering Additives (i.e. MgO)

- Sintering Rate Acceleration Advantages
  - **Prevents Discontinuous Grain Growth**
  - **Increases Mechanical Strength**
  - **Increases Density**
  - **Produces a Fine-grained Microstructure**
    - **Directly Affects Strength and Hardness**
    - **Finer Grain Size is ALWAYS Superior to Coarser Grain Size (Cahoon)**

What is Discontinuous Grain Growth?
- **Grain Boundaries Break Away From Pores**
- **Larger Pores**
- **Larger Grains**
- **Less Density**

Sintering and Grain Growth
Influence of Atmospheres

Important!
- Control Oxygen Pressure
- Control Number of Defects
- Control the Rate of Sintering

Sintering and Grain Growth
Influence of Atmospheres

Important!
- Control Atmospheric Pressure
- Control Porosity

Fig. 10.16. A specimen of alumina (a) sintered 1 hr at 1800°C and (b) heated 1 hr at 1900°C to give secondary recrystallization. Note that the pore spacing has not changed. Courtesy J. E. Burke.

Kingery WD, Bowen HK, Uhlmann DR (1976). Introduction to Ceramics. 2nd Ed. New York: Wiley.

Composition and Manufacture

Alumina Crystal Structure and Unit Cells

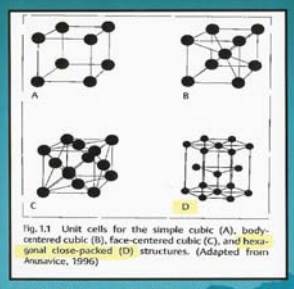


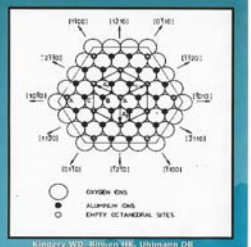
Fig. 1.1 Unit cells for the simple cubic (A), body-centered cubic (B), face-centered cubic (C), and hexagonal close-packed (D) structures. (Adapted from Anusavice, 1996)

Brantley WA, Eliades T (2001). Orthodontic materials : Scientific and clinical aspects. Stuttgart ; NY, NY: Thieme.

Composition and Manufacture

Chemical and Crystalline Structure of Alumina [3,4,8,14,15,16,22]

- Many Phases
  - Alpha Phase Aluminum Oxide (α-Al_2O_3)-structural phase
- Corundum
  - Multi-Crystalline Form
- Sapphire
  - Single-Crystalline Form
- Structure
  - Hexagonal Closed-Packed
  - 3rd Hardest Substance



Kingery WD, Bowen HK, Uhlmann DR (1976).Introduction to ceramics. 2nd ed. New York: Wiley.

Composition and Manufacture

Monocrystalline Alumina

- Grown as one large crystal
  - Less Impurities than Polycrystalline->No Sintering
  - Aluminum oxide 2100°C
  - Slow Cooled Bar or Rod
  - Optical Clarity->No Grains
- Milled
  - Diamond Blades
  - Lasers
  - Ultrasonics
- Heat Treated
  - Removes imperfections and stresses due to milling
- Extremely High Hardness

Monocrystalline
Inspire Ice Ormco

Composition and Manufacture

Polycrystalline Alumina

- 3µm Al_2O_3 Particles Mixed with a Binder
  - Molded
  - Heated to 1800°C to remove Binder
  - Sintering of Particles
- With Grain Boundaries
  - Grain Size <30µm for
  - Strength
  - More Opaque
  - Machine Slots/Heat Treat
  - Prevent Grain Growth > 30µm

Polycrystalline	
Mystique	GAC
Clarity	3M Unitek
Transcend	3M Unitek