CERAMIC MATERIALS MANUFACTURING

Dr. Alaa Aladdin

APPLICATIONS AND STORAGE OF CERAMICS

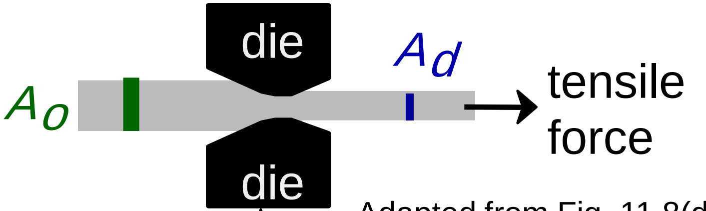
ISSUES TO ADDRESS...

- What are some applications of ceramics?
- How is processing of ceramics different than for metals?

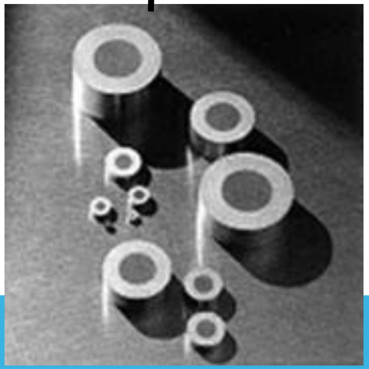
Applications Ceramics

CERAMICS APPLICATION: DIE BLANKS

- Die blanks:
  -- Need wear resistant properties!
- Die surface:
  -- 4 μm polycrystalline diamond particles that are sintered onto a cemented tungsten carbide substrate.
  -- polycrystalline diamond gives uniform hardness in all directions to reduce wear.



Adapted from Fig. 11.8(d), *Callister & Rethwisch 8e.*



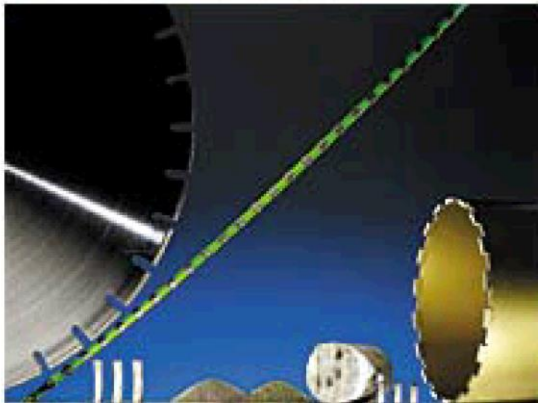
Courtesy Martin Deakins, GE Superabrasives, Worthington, OH. Used with permission.

CERAMICS APPLICATION: CUTTING TOOLS

- Tools:
  -- for grinding glass, tungsten, carbide, ceramics
  -- for cutting Si wafers
  -- for oil drilling

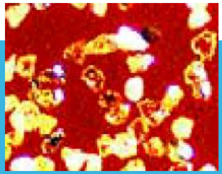
- Materials:
  -- manufactured single crystal or polycrystalline diamonds in a metal or resin matrix.
  -- polycrystalline diamonds resharpen by microfracturing along cleavage planes.

oil drill bits



blades

Single crystal diamonds

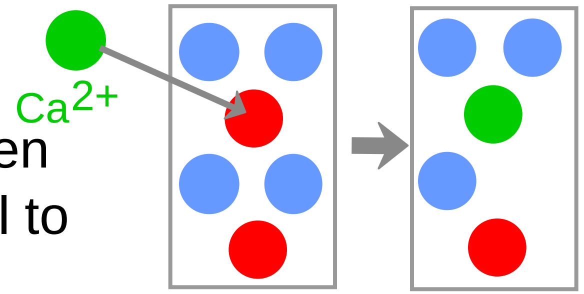


polycrystalline diamonds in a resin matrix.

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

CERAMICS APPLICATION: SENSORS

- **Example:** ZrO_2 as an oxygen sensor
- **Principle:** Increase diffusion rate of oxygen to produce rapid response of sensor signal to change in oxygen concentration



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

- **Approach:**

  Add Ca impurity to ZrO_2:

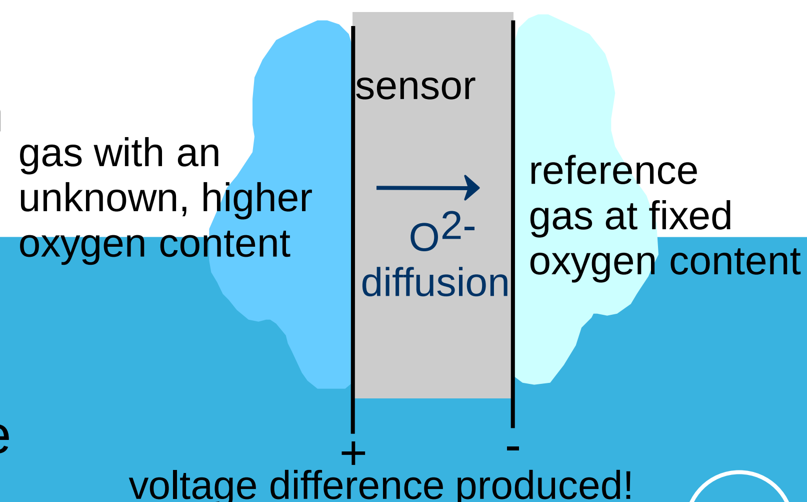
  -- increases O^{2-} vacancies

  -- increases O^{2-} diffusion rate

- **Operation:**

  -- voltage difference produced when O^{2-} ions diffuse from the external surface through the sensor to the reference gas surface.

  -- magnitude of voltage difference ∝ partial pressure of oxygen at the external surface



REFRACTORIES

- Materials to be used at high temperatures (e.g., in high temperature furnaces).
- Consider the Silica (SiO_2) - Alumina (Al_2O_3) system.
- Silica refractories - silica rich - small additions of alumina depress melting temperature (phase diagram):

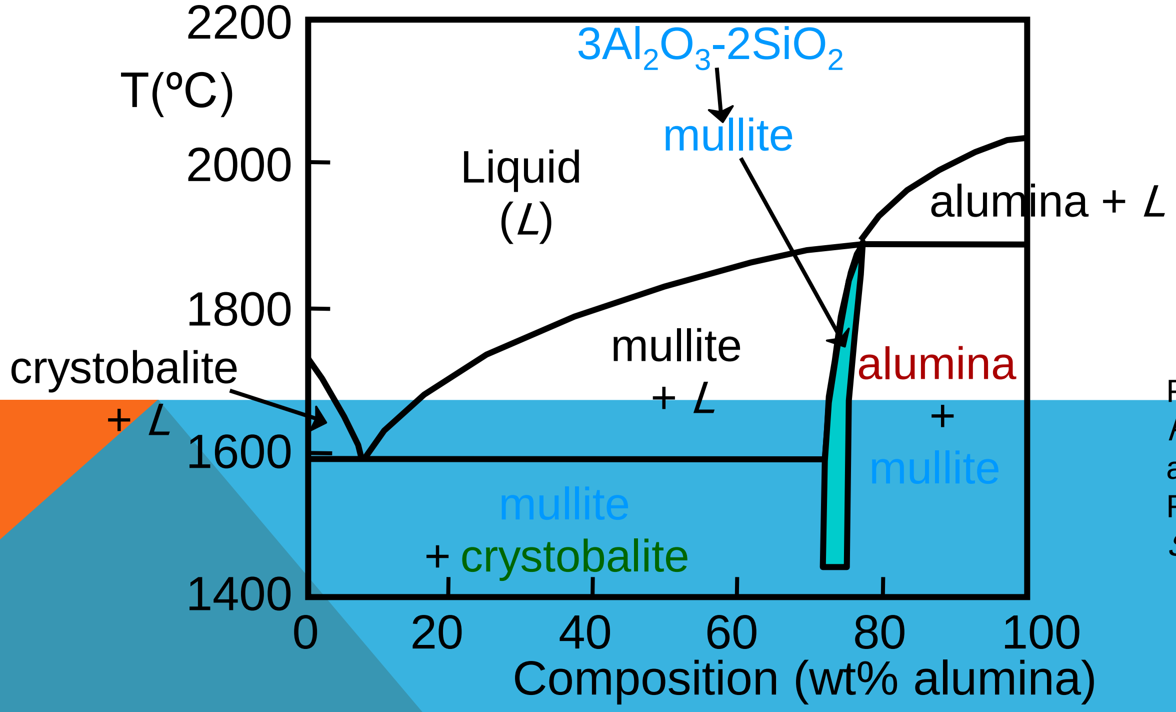


Fig. 12.27, *Callister & Rethwisch 8e.* (Fig. 12.27 adapted from F.J. Klug and R.H. Doremus, *J. Am. Cer. Soc.* **70**(10), p. 758, 1987.)

ADVANCED CERAMICS: MATERIALS FOR AUTOMOBILE ENGINES

Advantages:

- Operate at high temperatures – high efficiencies
- Low frictional losses
- Operate without a cooling system
- Lower weights than current engines

- Disadvantages:
  - Ceramic materials are brittle
  - Difficult to remove internal voids (that weaken structures)
  - Ceramic parts are difficult to form and machine

- Potential candidate materials: Si_3N_4, SiC, & ZrO_2
- Possible engine parts: engine block & piston coatings

ADVANCED CERAMICS: MATERIALS FOR CERAMIC ARMOR

Components:

-- Outer facing plates

-- Backing sheet

Properties/Materials:

-- Facing plates -- hard and brittle

— fracture high-velocity projectile

— Al_2O_3, B_4C, SiC, TiB_2

-- Backing sheets -- soft and ductile

— deform and absorb remaining energy

— aluminum, synthetic fiber laminates

Storage of Ceramics

GENERAL CHARACTERISTICS OF SILOS USED FOR STORING POWDER AND GRANULAR MATERIALS ARE AS FOLLOWS:

1. Granular materials can be collected, distributed, and stored in bulk efficiently.

2. Transportation costs, which influence the costs of raw materials and products, can be

reduced.

3. Compared with storage on a flat surface such as a floor, a silo's storing capacity is several

times greater in the same space.

4. Equipment cost per unit of storage capacity is small.

5. Automatic loading, unloading, and control of storage volume are possible.
6. Operations such as pressurization, heat insulation, moisture proofing, and fumigation are
easily accomplished.
7. Quality change, decomposition, breakage, and damage of stored materials by insects and
rats can be prevented.
8. A silo can be incorporated easily as a part of an industrial production syste

Classification of Silos

Shallow Bins and Deep Bins

When studying static powder pressure acting on silo walls, silos are classified into shallow bins and deep bins.

The classification is based on the following formulas:

Deep bins: $h > 1.5d(h > 1.5a)$

Shallow bins: $h \leq 1.5d(h \leq 1.5a)$

where *h is the height of the silo (meters), d is the inside diameter of a circular silo (meters), and a is* the length of a short side of a rectangular silo (meters).

Single Bins and Group Bins

Closed and O pen T ypes

Most bulk silos are of the closed type, equipped with a roof onto which loading equipment is installed. Some silos are airtight to permit the fumigation of imported grains, for example, using poisonous gas to exterminate vermin. Vacuum silos are also used to prevent powder clogging.

Calculation of Silo Capacity

In designing a silo, its capacity should be determined from the total storing weight of the materials, the types of the materials to be stored, and the conditions of use. Silo capacity has two components:

total capacity (geometric capacity) and the capacity of loaded stored materials (effective capacity).

Geometric capacity, also called water capacity, is used as a standard value for calculating the fumigation gas to be employed in treating imported grains.

Effective capacity is the base for calculating the storing weight and location for taking in materials whose angle of repose should be taken into consideration.

If geometric capacity is represented by *VW (m3) and effective capacity by VE (m3), the loss*

volume *VL (m) becomes*

$$V_L = V_W - V_E \ (m^3)$$

The loss volume of a cylindrical silo, illustrated in Figure 3.1, can be determined from the formula 3:

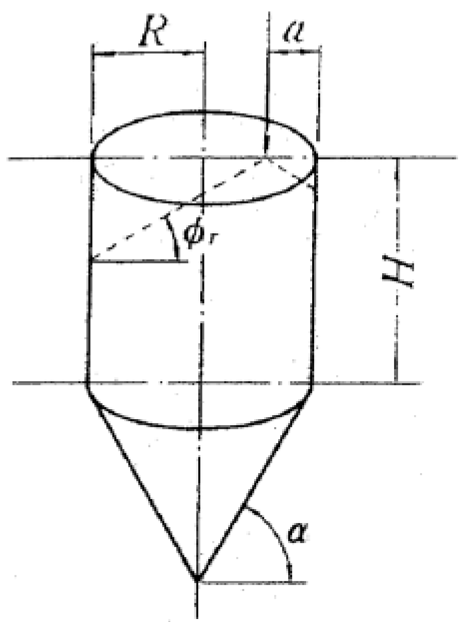
$$V_L = \frac{4}{3}R^3\left\{3F\int_0^{\pi/2}\cos^2 x\sqrt{(1-F)+F\cos^2 x\, dx}\right.$$
$$\left.+\int_0^{\pi/2}\left[(1-F)+F\cos^2 x\right]^{3/2}dx\right\}\tan\phi_1 = cf_L\ R^3\tan\phi_1$$

where

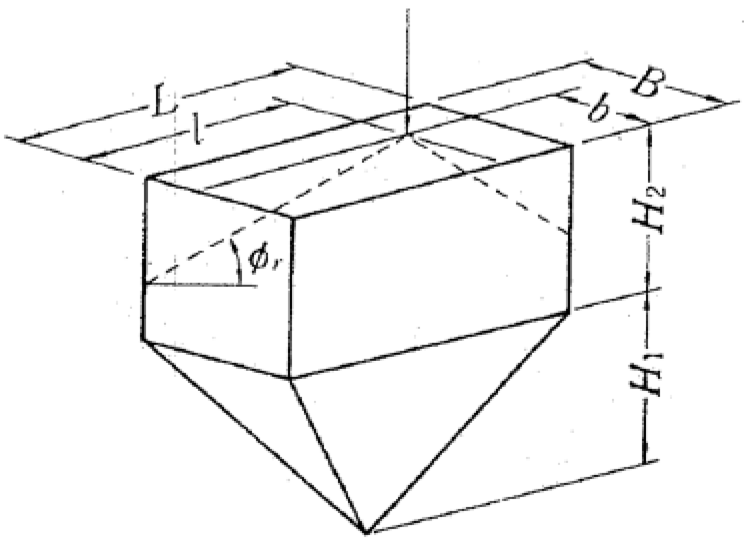
$$F = \left(1-\frac{a}{R}\right)^2$$

For a cylindrical container, Figure 3.1 symbols are used to calculate the effective capacity of silos:

$$V_E = \pi R^2 H + \frac{1}{3}\pi R^3 \tan\alpha$$



cylindrical container



square container

Design L oad

Design Recommendation for Storage Tanks and Their Supports:

The design methods described include, for the first time, Japan's new earthquake-proofing requirements.

According to the *Design Recommendation,1 the following loads should be considered: (1) dead load,*

(2) live load, (3) snow load, (4) wind load, (5) earthquake load, and (6) loads appropriate to the containers,

such as impact and absorption due to the movement of bulk materials inside the containers.

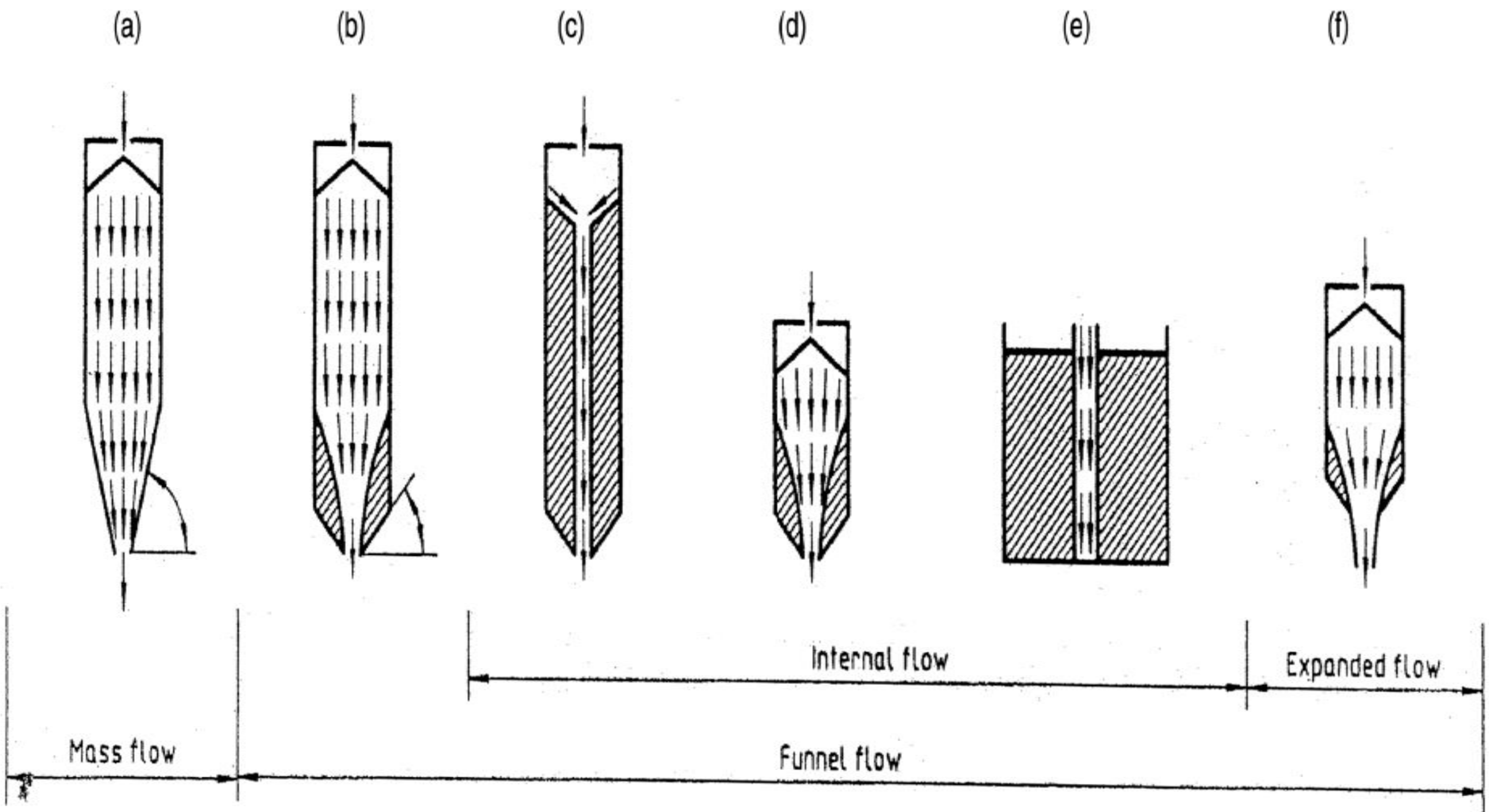


Figure 3.2 Flow patterns.