04 Properties of materials: 2. Ceramics

The commercial and technological importance of ceramics is best demonstrated by the variety of products and applications that are based on this class of material. The list includes:

1. **Clay construction products**, such as bricks, clay pipe, and building tile

2. **Refractory ceramics**, which are capable of high temperature applications such as furnace walls, crucibles, and molds

3. **Cement used in concrete**, used for construction and roads (concrete is a composite material, but its components are ceramics)

4. **Whiteware products**, including pottery, stoneware, fine china, porcelain, and other tableware, based on mixtures of clay and other minerals.

5. **Glass** used in bottles, glasses, lenses, window panes, and light bulbs

6. **Glass fibers** for thermal insulating wool, reinforced plastics (fiberglass), and fiber optics communications lines

7. **Abrasives**, such as aluminum oxide and silicon carbide

8. **Cutting tool materials**, including tungsten carbide, aluminum oxide, and cubic boron nitride.

9. **Ceramic insulators**, which are used in applications such as electrical transmission components, spark plugs, and microelectronic chip substrates.

10. **Magnetic ceramics**, for example, in computer memories.

11. **Bio ceramics**, which include materials used in artificial teeth and bones.

For purposes of organization, we classify ceramic materials into three basic types:

(1) **Traditional ceramics**—silicates used for clay products such as pottery and bricks, common abrasives, and cement;

(2) **New ceramics**—more recently developed ceramics based on nonsilicates such as oxides and carbides, and generally possessing mechanical or physical properties that are superior or unique compared to traditional ceramics; and

(3) **Glasses**—based primarily on silica and distinguished from the other ceramics by their nanocrystalline structure. In addition to the three basic types, we have glass ceramics— glasses that have been transformed into a largely crystalline structure by heat treatment.

Physical Properties

Several of the physical properties of ceramics are presented in Table 7.2. Most ceramic materials are *lighter* than metals and *heavier* than polymers. *Melting temperatures* are higher than for most metals, some ceramics preferring to decompose rather than melt.

TABLE 7.2 Selected mechanical and physical properties of ceramic materials.

Material	Hardness (Vickers)	Elastic modulus, E		Specific Gravity	Melting Temperature	
		Gpa	(lb/in^2)		°C	°F
Traditional ceramics						
Brick-fireclay	NA	95	14×10^6	2.3	NA	NA
Cement, Portland	NA	50	7×10^6	2.4	NA	NA
Silicon carbide (SiC)	2600 HV	460	68×10^6	3.2	27,007[a]	48,927[a]
New ceramics						
Alumina (Al_2O_3)	2200 HV	345	50×10^6	3.8	2054	3729
Cubic boron nitride (cBN)	6000 HV	NA	NA	2.3	30,007[a]	54,307[a]
Titanium carbide (TiC)	3200 HV	300	45×10^6	4.9	3250	5880
Tungsten carbide (WC)	2600 HV	700	100×10^6	15.6	2870	5198
Glass						
Silica glass (SiO_2)	500 HV	69	10×10^6	2.2	7[b]	7[b]

Electrical and thermal conductivities of most ceramics are lower than for metals; but the range of values is greater, permitting some ceramics to be used as insulators while others are electrical conductors.

Thermal expansion coefficients are somewhat less than for the metals, but the effects are more damaging in ceramics because of their brittleness.

Ceramic materials with relatively high thermal expansions and low thermal conductivities are especially susceptible to failures of this type, which result from significant temperature gradients and associated volumetric changes in different regions of the same part.