A **ceramic** is any of the various hard, brittle, heat-resistant and corrosion-resistant materials made by shaping and then firing an inorganic, nonmetallic material, such as clay, at a high temperature. Common examples are earthenware, porcelain, and brick.

The earliest ceramics made by humans were pottery objects (*pots* or *vessels*) or figurines made from clay, either by itself or mixed with other materials like silica, hardened and sintered in fire. Later, ceramics were glazed and fired to create smooth, colored surfaces, decreasing porosity through the use of glassy, amorphous ceramic coatings on top of the crystalline ceramic substrates. Ceramics now include domestic, industrial and building products, as well as a wide range of materials developed for use in advanced ceramic engineering, such as in semiconductors.

The word **"*ceramic*"** comes from the Greek word κεραμικός (*keramikos*), **"of pottery"** or **"for pottery"**, from κέραμος (*keramos*), **"potter's clay, tile, pottery"**.The earliest known mention of the root **"ceram-"** is the Mycenaean Greek *ke-ra-me-we*, workers of ceramic written in Linear B syllabic script. The word ceramic can be used as an adjective to describe a material, product or process, or it may be used as a noun, either singular, or more commonly, as the plural noun "ceramics"

This article is about the material properties of ceramics. For other uses, see Ceramic (disambiguation).

Short timeline of ceramic in different styles

Ceramic material is an inorganic, non-metallic oxide, nitride, or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension. They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments. Ceramics generally can withstand very high temperatures, ranging from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).

The crystallinity of ceramic materials varies widely. Most often, fired ceramics are either vitrified or semi-vitrified as is the case with earthenware, stoneware, and porcelain. Varying crystallinity and electron composition in the ionic and covalent bonds cause most ceramic materials to be good thermal and electrical insulators (researched in ceramic engineering). With such a large range of possible options for the composition/structure of a ceramic (nearly all of the elements, nearly all types of bonding, and all levels of crystallinity), the breadth of the subject is vast, and identifiable attributes (hardness, toughness, electrical conductivity) are difficult to specify for the group as a whole. General properties such as high melting temperature, high hardness, poor conductivity, high moduli of elasticity, chemical resistance and low ductility are the norm, [8] with known exceptions to each of these rules (piezoelectric ceramics, glass transition temperature, superconductive ceramics). Many composites, such as fiberglass and carbon fiber, while containing ceramic materials are not considered to be part of the ceramic family. [9]

Highly oriented crystalline ceramic materials are not amenable to a great range of processing. Methods for dealing with them tend to fall into one of two categories – either make the ceramic in the desired shape, by reaction *in situ*, or by "forming" powders into the desired shape, and then sintering to form a solid body. Ceramic forming techniques include shaping by hand (sometimes including a rotation process called "throwing"), slip casting, tape casting (used for making very thin ceramic capacitors), injection molding, dry pressing, and other variations.

Many ceramics experts do not consider materials with amorphous (noncrystalline) character (i.e., glass) to be ceramics even though glassmaking involves several steps of the ceramic process and its mechanical properties are similar to ceramic materials. However, heat treatments can convert glass into a semi-crystalline material known as glass-ceramic.[10][11]

Traditional ceramic raw materials include clay minerals such as kaolinite, whereas more recent materials include aluminum oxide, more commonly known as alumina. The modern ceramic materials, which are classified as advanced ceramics, include silicon carbide and tungsten carbide. Both are valued for their abrasion resistance and hence find use in applications such as the wear plates of crushing equipment in mining operations. Advanced ceramics are also used in the medicine, electrical, electronics industries, and body armor.

Properties

The physical properties of any ceramic substance are a direct result of its crystalline structure and chemical composition. Solid-state chemistry reveals the fundamental connection between microstructure and properties, such as localized density variations, grain size distribution, type of porosity, and second-phase content, which can all be correlated with ceramic properties such as mechanical strength σ by the Hall-Petch equation, hardness, toughness, dielectric constant, and the optical properties exhibited by transparent materials.

Ceramography is the art and science of preparation, examination, and evaluation of ceramic microstructures. Evaluation and characterization of ceramic microstructures are often implemented on similar spatial scales to that used commonly in the emerging field of nanotechnology: from tens of ångstroms (Å) to tens of micrometers (µm). This is typically somewhere between the minimum wavelength of visible light and the resolution limit of the naked eye.

The microstructure includes most grains, secondary phases, grain boundaries, pores, micro-cracks, structural defects, and hardness micro indentions. Most bulk mechanical, optical, thermal, electrical, and magnetic properties are significantly affected by the observed microstructure. The fabrication method and process conditions are generally indicated by the microstructure. The root cause of many ceramic failures is evident in the cleaved and polished microstructure. Physical properties which constitute the field of materials science and engineering include the following:

Cutting disks made of silicon carbide

Mechanical properties

Mechanical properties are important in structural and building materials as well as textile fabrics. In modern materials science, fracture mechanics is an important tool in improving the mechanical performance of materials and components. It applies the physics of stress and strain, in particular the theories of elasticity and plasticity, to the microscopic crystallographic defects found in real materials in order to predict the macroscopic mechanical failure of bodies. Fractography is widely used with fracture mechanics to understand the causes of failures and also verify the theoretical failure predictions with real-life failures.

Ceramic materials are usually ionic or covalent bonded materials. A material held together by either type of bond will tend to fracture before any plastic deformation takes place, which results in poor toughness in these materials. Additionally, because these materials tend to be porous, the pores and other microscopic imperfections act as stress concentrators, decreasing the toughness further, and reducing the tensile strength. These combine to give catastrophic failures, as opposed to the more ductile failure modes of metals.

These materials do show plastic deformation. However, because of the rigid structure of crystalline material, there are very few available slip systems for dislocations to move, and so they deform very slowly.

To overcome the brittle behavior, ceramic material development has introduced the class of ceramic matrix composite materials, in which ceramic fibers are embedded and with specific coatings are forming fiber bridges across any crack. This mechanism substantially increases the fracture toughness of such ceramics. Ceramic disc brakes are an example of using a ceramic matrix composite material manufactured with a specific process.