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Topic: Silicate Industries

PART 3

Comments - Read the lesson in details and complete the given assignment.

Introduction

A ceramic is an inorganic non-metallic solid made up of either metal or non-metal compounds that have been shaped and then hardened by heating to high temperatures. In general, they are hard, corrosion-resistant and brittle. Traditional ceramics are clay-based, but high-performance or advanced ceramics are being developed from a far wider range of inorganic non-metal materials. Advanced ceramics have the properties of high strength, high hardness, high durability and high toughness. 'Ceramic' comes from the Greek word meaning ‘pottery’. The clay-based domestic wares, art objects and building products are familiar to us all, but pottery is just one part of the ceramic world.

Nowadays the term ‘ceramic’ has a more expansive meaning and includes materials like glass, advanced ceramics and some cement systems as well.

Traditional ceramics

Traditional ceramics are clay–based. The categories of pottery shown here are earthenware, stoneware and porcelain. The composition of the clays used, type of additives and firing temperatures determine the nature of the end product.The major types of pottery are described as earthenware, stoneware and porcelain

Advanced ceramics – new materials(High technology ceramics)

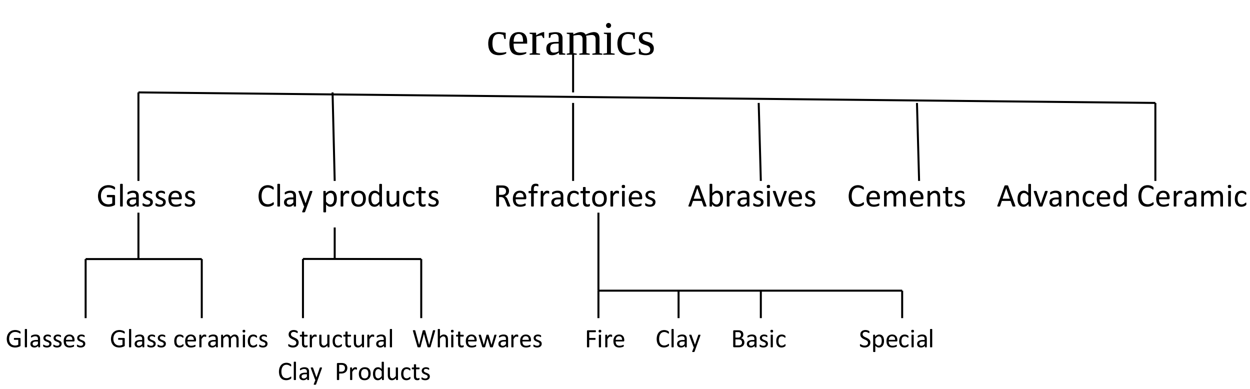
While traditional ceramics have been used for over 25,000 years, advanced ceramics have only been developed within the last 120. Advanced ceramics are also referred to as technical ceramics, high-performance ceramics, engineering ceramics, industrial ceramics or high-tech ceramics.Advanced ceramics are not generally clay-based. Instead, they are either based on oxides or non-oxides or combinations of the two:

Typical oxides used are alumina (Al_2O_3) and zirconia (ZrO_2) and Non-oxides are often carbides, borides, nitrides and silicides, for example, boron carbide (B_4C), silicon carbide (SiC)andmolybdenum disilicide ($MoSi_2$).

<u>Application of High technology ceramics</u>

- automotive (insulation rings in brake callipers, valve plates in common rail injection systems)
- electronics (semiconductors, LED substrate fabrication, ultra-high frequency signal transmission)
- biotechnology (knee replacement elements, blanks for the production of crowns, bridges and implants in dentistry)
- environmental applications (wind turbines, photovoltaic systems,
- piezo-ceramic sensors)
- industrial manufacturing (pressure sensors, moving components for precision measuring machines, ceramic screws and bolds)
- metal processing and machining (protection tubes for temperature measurement, sliding blocks for heat treatment plants)

Classification of Ceramics Based on their Applications



[clay – A hydrated Aluminum silicates with other oxides. Provides workability before firing hardens it. (eg Al2O32Si32H2O)

feldspar – A naturally occurring, industrial important, network silicate with a low melting temperature. It becomes glass upon firing and bonds the refractory components together. Some Si+4ions are replaced with Al+3 in substitional positions and some Na+, K+, Ca+, Ba+ ions are in interstitial positions. (eg K2O Al2036Si02)

silica – (aka flint or quartz) SiO2 is a polymorphic compound. (quartz, tridymite and cristobalite are some of its forms.) It acts as the refractory component of traditional ceramic]

Clays:

♣Aluminosilicates (A2O3 and SiO2 and chemically bound H2O)
♣ Broad range of compositions, structures, impurities
♣ Usually the structure is layered with water between the sheets making it plastic (hydroplasticity)
♣ Can be mixed with water and easily formed and then dried and fired to increase strength

Whitewares and Structural Clay Products

♣ Made from clay, flint and feldspar
♣ Flint is finely ground quartz, a filler that is hard and chemically unreactive with a high melting temperature.
♣ Feldspar is an aluminosilicate mineral that contains K+, Na+ and Ca+. It acts as a fluxing agent. (i.e. it spreads out heat and helps things to flow.)

Refractories:

♣ Materials that are able to withstand high temperatures without melting or decomposing.

♣ They are able to maintain insulative properties at high temperatures.

♣ They remain inert and unreactive at high temperatures.

♣ The four main categories: fireclay, silica (acid), basic and special.

♣ A decrease in the porosity of refractories will

1. increase strength
2. increase corrosion resistance
3. increase load-bearing capacity
4. decrease insulativeness
5. resistance to thermal shock

Abrasives

♣ Extremely hard materials used for cutting, grinding, and polishing other materials.

♣ Due to high heat generated during the process, these materials also must have some refractory
properties.

♣ Examples are diamond, SiC, WC, Corundum, and silica sand.

Cements

♣ materials that form a paste when mixed with water and then hardenedby chemical reactions

♣ examples include cement, plaster of paris and lim

Characteristics of Ceramics

- Low density compared to metals..
- High melting point or decomposition temperature
- High hardness and very brittle.
- High elastic modulus and moderate strength .
- Low toughness.

- High electrical resistivity.
- Low thermal conductivity.
- High temperature wear resistance .
- Thermal Shock resistance .
- High corrosion resistance.
- In crystalline ceramics the crack propagation is usually through the grains (transgranular) and along specific crystallographic (or cleavage) planes, which are planes of high atomic density.

Semiconducting and superconducting oxide :

Some ceramics are semiconductors. Most of these are transition metal oxides that are II-VI semiconductors, such as zinc oxide. While there are prospects of mass-producing blue LEDs from zincoxide,Semiconducting ceramics are also employed as gas sensors. When various gases are passed over a polycrystalline ceramic, its electrical resistance changes. With tuning to the possible gas mixtures, very inexpensive devices can be produced.

Ceramics are amongst the most electrically insulating materials known. However, discoveries in the late 20th century have also shown some ceramics to be the most electrically conducting.The discovery of high temperature (above the temperature of liquid nitrogen) ceramic superconductors has changed superconductivity from an interesting curiosity to a useable technology, with particular applications in the medical field as a superconducting magnet in MRI scanners. Superconductors are also used in NMR and mass spectrometers and in particle accelerators such as the large Hadron Collider.Typical materials include YBCO (a mixture of the oxides of yttrium, barium and copper) and BiSSCO (a mixture of the oxides of bismuth, strontium and copper).

Carbon nanotube :

New techniques for thermal management in ceramics at the nanoscale level have been investigated using low percentages of carbon nanotubes to reduce thermal conductivity of bulk ceramics. Samples of yttriam-stabilized zirconia containing purified single-walled carbon nanotubes (SWNT) or vapor grown carbon fibers (VGCF) have been prepared by tape casting and analyzed using the laser flash method to evaluate reductions in thermal conductivity at high temperatures. New features in the samples due to the presence of carbon nanotubes have been characterized using Raman, SEM, TEM and, in the case of VGCFs, are related to significant reductions in thermal conductivity (>25%). The inclusion of a low percentage of nanoscale carbon fibers, the intimate relationship between the fibers and ceramic particles, and the indication that the fibers possess a crystalline overcoating, all contribute to the lowering of the thermal conductivity.

Ceramic Crystalline Structures

Crystal structures of ionic compounds tend to maximize packing efficiency. (This lowers the overall energy.) The limitations to dense packing are the radius ratio and the need to maintain charge neutrality. The radius ratio can help to predict the CN (and hence the crystal structure.) If the bonding has some covalent character, then the packing will be less efficient. You can determine the amount of ionic character in a bond by knowingthe electronegativities, XA & XB,of the elements in the bond and the following equation: % ionic character = [1 – e -1/4(XA-XB)] x 100%A tetrahedral position is an interstitial site that if occupied, would have 4 neighbors. An octahedral position is an interstitial site that if occupied, would have 6 neighbors .

Some relatively simple ceramic structures:

- ♦ Sodium Chloride structure (NaCl)
- ♦ Cesium Chloride structure (CsCl)
- ♦ Zinc Blende structure (ZnS and Compound Semiconductors) ?
- ♦ Fluorite structure (CaF_2)
- ♦ Perovskite structure ($CaTiO_3$)
- ♦ Diamond Cubic structure (Carbon and Elemental Semiconductors)
- ♦ Graphite (Carbon)
- ♦ Fullerenes (Carbon)
- ♦ Cristobalite structure (SiO_2)
- ♦ Corundum Structure (Al_2O_3)
- ♦ Spinel Structure ($MgAl_2O_4$)/Inverse Spinel

Silicate Structures

Silica (SiO_2) has half ionic and half covalent character. (The percent of ionic character is about 50% as calculated from the above equation.) A CN of 4 is predicted for the radius ratio of 0.29 for ionic compounds. A bond angle of 105degreeis predicted for covalent bonding. Silica is allotropic with at least five different crystalline forms depending on temperature and pressure conditions. However, each form has every corner of an SiO_4tetrahedra (every oxygen atom) shared. The sharing of oxygen atoms between the tetrahedra give the overall formula of SiO_2.
The structures are not dense and have high melting temperatures.
Silicates (or silicate ceramics) are Silica (SiO_2) based ceramic clays that contain SiO_4 4-tetrahedra in various arrangements. Many naturally occurring minerals such as clays, feldspars and micas are silicates. Many ceramic materials contain silicate structures. They include glass, cement, brick, electrical insulative materials, etc.The general nature of silicate structures is the connection of the SiO_4 4-tetrahedra. Additional oxides tend to break up the continuity of these tetrahedra. The remaining connectedness may be in the form of islands, chains or sheets:

♦ Network silicate structures – these structures connect all 4 corners of the SiO_4 4-tetrahedra to form a network. The Oxygen atoms are shared which accounts for the overall chemical formula of SiO_2 not SiO_4.

♦ Island silicate structures – when positive ions bond with the oxygens of the SiO_4 4- tetrahedra

♦ Chain or ring silicate structures – when 2 corners of each SiO_4 4-tetrahedra are bonded with corners of other tetrahedra with unit chemical formula SiO_3 -2.

♦ Sheet silicate structures – when 3 corners in the same plane of a silicate tetrahedron are bonded to the corners of 3 other silicate tetrahedra with chemical unit Si_2O_5 -2

Manufacturing process

Step 1: Milling & Raw Material Procurement – The raw materials used in the process are milled materials typically found in mining sites that have been reduced from a large size to smaller sizes or even in some cases, pulverized depending upon the end product. The idea is to liberate any impurities in the materials allowing for better mixing and forming which in essence produces a more reactive material when firing.

Step 2: Sizing – During this step in the processing sequence, the materials that have undergone the milling and procurement process must be sized to separate desirable material from non-usable material. By controlling the particle size, the result will give proper bonding and a smooth surface on the finished product. This can be accomplished using Fine Mesh Vibratory Sifting Equipment such as HK Single Motor Sifter when dealing with dry, fine powder mixes in ceramics.

Step 3: Batching – This part of the process can also be known as"blending" which calculates amounts, weighing and initial blended of the raw materials. For consistent material flow into a pub mill hopper, If it has a light load capacity and a dusty hazardous environment, CF-A Air Powered Feeders are a great option.

Step 4: Mixing – To obtain a more chemically and physically homogeneous material for forming, the constituents of the ceramic powder are combined using the method of mixing or blunging. It is also important to add binders or plasticizers as well. For wet slurry mixtures, a filter press would remove the water from the slurry and yield the clay body from the mix. For these wet mixtures, deflocculants and antifoaming agents are added to improve the processing of the materials.

Step 5: Forming – For this step, the materials such as dry powders, pastes or slurries are consolidated and molded to produce a cohesive body of whatever end product is desired. In the particular case of dry forming, vibratory compaction can be used to achieve the desired shape.

Step 6: Drying – The formed materials hold water and binder in its mix that can in turn cause shrinkage, warping or distortion of the product. Generally, convection drying is the mostcommonly used method in which heated air is circulated around the ceramic piece that alleviates the risk of such imperfections in the final product.

Step 7: Glazing – Referring back to traditional ceramics, this step is added to the process prior to firing. Typically, the glaze consists of oxides that give the product the desired finish look. The raw materials are ground in a ball mill or attrition mill. The glaze can be applied using spraying or dipping methods.

Step 8: Firing – Also known as sintering ,the ceramics pass through a controlled heat process where the oxides are consolidated into a dense, cohesive body made up of uniform grain.

<u>Solve the following problems:</u>

1.What are the characteristics of ceramics?

2.What are clays and feldsper?

3.State different steps of manufacturing process of ceramics.