

Module-10

Applications and Processing of Ceramics

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- 1) Types and applications of ceramics
- 2) Fabrication and processing of ceramics

Introduction – Ceramics

- The word ‘ceramic’ is originated from greek word keromikos, which means ‘burnt stuff’.
- Ceramics are compounds of metallic and non-metallic elements.
- Characteristics of ceramics are:
 - high temperature stability
 - high hardness
 - brittleness
 - high mechanical strength
 - low elongation under application of stress
 - low thermal and electrical conductivities

Classification – Ceramics

- Ceramics are classified in many ways. It is due to divergence in composition, properties and applications.

- Based on their composition, ceramics are:
 - Oxides
 - Carbides
 - Nitrides
 - Sulfides
 - Fluorides
 - etc.

Classification – Ceramics

- Based on their specific applications, ceramics are classified as:
 - Glasses
 - Clay products
 - Refractories
 - Abrasives
 - Cements
 - Advanced ceramics for special applications

Classification – Ceramics

- Based on their engineering applications, ceramics are classified into two groups as: traditional and engineering ceramics.
- Traditional ceramics – most made-up of clay, silica and feldspar
- Engineering ceramics – these consist of highly purified aluminium oxide (Al_2O_3), silicon carbide (SiC) and silicon nitride (Si_3N_4)

Introduction – Processing ceramics

- The very specific character of ceramics – high temperature stability – makes conventional fabrication routes unsuitable for ceramic processing.
- Inorganic glasses, though, make use of lower melting temperatures. Most other ceramic products are manufactured through powder processing.
- Typical ceramic processing route: powder synthesis – green component (casting, extrusion, compaction) – sintering / firing.

Processing ceramics – Glasses

- Most of them are silica-soda-lime variety.
- Raw materials are heated to an elevated temperature where melting occurs.
- Glass melt is processed by different route to form different products:
 - Pressing – to form shapes like plates and dishes
 - Blowing – used to produce objects like jars, bottles, light bulbs.
 - Drawing – to form lengthier objects like tubes, rods, whiskers, etc.

Ceramic powder processing

- Ceramic powder processing route: synthesis of powder, followed by fabrication of green product which is then consolidated to obtain the final product.
- Synthesis of powder involves crushing, grinding, separating impurities, blending different powders.
- Green component can be manufactured in different ways: tape casting, slip casting, extrusion, injection molding and cold-/hot- compaction.
- Green component is then fired/sintered to get final product.

Ceramic powder processing - Casting

- Slurry of ceramic powder is processed via casting routes – tape casting, and slip casting.
- Tape casting – also known as doctor blade process – used for making thin ceramic tapes. In this slurry of ceramic powder + binders + plasticizers is spread over plastic substrate. Tape is then dried using hot air. Later tape is subjected to binder burnout and sintering.
- Slip casting – here aqueous slurry of ceramic powder is poured into plaster of Paris mold. As water begins to move out due to capillary action, thick mass builds along mold wall. It is possible to form solid piece by pouring more slurry.

Ceramic powder processing – Extrusion & Injection molding

- Extrusion – viscous mixture of ceramic particles, binder and other additives is fed through an extruder where continuous shape of green ceramic is produced. Then the product is dried and sintered.
- Injection molding – it is similar to the process used for polymer processing. Mixture of ceramic powder, plasticizer, thermoplastic polymer, and additives is injected into die with use of a extruder. Then polymer is burnt off, before sintering rest of the ceramic shape. It is suitable for producing complex shapes.
- Extrusion and Injection molding are used to make ceramic tubes, bricks, and tiles.

Ceramic powder processing – Compaction

- Ceramic powder is compacted to form green shapes of sufficient strength to handle and to machine.
- Basis for compaction – application of external pressure from all directions.
- In cold iso-static pressing (CIP), pressure is applied using oil/fluid, then green product is subjected to sintering.
- In hot iso-static pressing (HIP), pressure is applied at high temperatures thus compaction and sintering occurs simultaneously. It is expensive, but has certain advantages.

Ceramic powder processing – Compaction, HIP

- HIP is used
 - when during CIP not enough strength is gained
 - almost nil porosity is the requirement
 - for Refractories and covalently bonded ceramics.
- Sintering – process of subjecting the green ceramic to elevated temperatures with the purpose of gaining mechanical integrity.
- Driving force for sintering – reduction in total surface area and thus energy.
- Diffusion (atomic- and bluk-) is responsible for growth of bonds at contact points of particles (necks). This lead to coalescence of particles, and eventual mechanical integrity.