Ceramic matrix composites

- **Ceramic matrix composites (CMCs)** are a subgroup of composite material as well as a subgroup of technical ceramic.
- They consist of ceramic fibers embedded in a ceramic matrix, thus forming a **ceramic fiber reinforced ceramic (CFRC)** material.

Introduction

- Ceramic materials often exhibit a combination of useful physical and mechanical properties, including high refractoriness, but their applications are restricted due to their brittle behavior.
- In an attempt to improve the strength, and particularly the toughness, of brittle ceramics particle-strengthening and fiber-reinforcement have been utilized, with limited success.

Short-fiber composites

- Ceramic Matrix Composites are reinforced by either continuous(long) fiber or discontinuous(short) fiber.
- Short-fiber (discontinuous) composites are produced by conventional ceramic processes from an oxide (alumina) or non-oxide (silicon carbide) ceramic matrix reinforced by whiskers of silicon carbide (SiC), titanium boride (TiB_2), aluminum nitride(AlN),zirconium oxide(ZrO_2) and other ceramic fibers.
- Most of CMC are reinforced by silicon carbide fibers due to their high strength and stiffness.
- However a character of failure of short-fiber reinforced materials is catastrophic (causing a lot of damage).

Long-fiber composites

- The best strengthening effect is provided by dispersed phase in form of continuous monofilament fibers, which are fabricated by chemical vapor deposition (CVD) of silicon carbide on a substrate made of tungsten (W) or carbon (C) fibers.
- Monofilament fibers produce stronger interfacial bonding with the matrix material improving its toughness.
- Failure of long-fiber Ceramic Matrix Composites is not catastrophic.

Typical properties of long-fiber Ceramic Matrix Composites

- High mechanical strength even at high temperatures
- High thermal shock resistance
- High stiffness
- High toughness
- High thermal stability
- Low density
- High corrosion resistance even at high temperatures.

Production

- Ceramic composites may be produced by traditional ceramic fabrication methods including mixing the powdered matrix material with the reinforcing phase followed by processing at elevated temperature: hot pressing ,sintering.
- Such fabrication routs are successfully employed for preparing composites reinforced with a discontinuous phase.

Infiltration methods

- Ceramic matrix composites reinforced with long fibers are commonly fabricated by infiltration methods.
- In this group of fabrication techniques the ceramic matrix is formed from a fluid (gaseous or liquid) infiltrated into the fiber structure (either woven or non-woven).

Continuous fiber

- Matrix material for long-fiber (continuous fiber) composite may be;

  - Silicon carbide ceramic,
  - Alumina and alumina-silica matrix
  - Carbon-carbon composite

Silicon carbide matrix composites

- **Silicon carbide matrix composites** are fabricated by chemical vapor infiltration or liquid phase Infiltration methods of a matrix material into a preform prepared from silicon carbide fibers.

Used

- manufacturing combustion liners of gas turbine engines
- hot gas re-circulating fans
- gas-fired burner parts
- filters for hot liquids

Mullite

- **Alumina and alumina-silica (mullite) matri composites** are produced by sol-gel method, direct metal oxidation or chemical bonding.

Used

- manufacturing heat exchangers
- burner stabilizers
- thermo-photovoltaic burners
- filters for hot liquids

over the unreinforced ceramic matrix.

The main types:

① Continuous - Fiber Reinforced CMCs :

Two types of fiber used : ⓐ Silicon Carbide ⓑ Aluminum oxide

Sic ® : woven into a mat and then chemical vapor diposition is used to impregnate Sic into fibrous mat.

® Sic fibers are encapsulated by a glass ceramic material.

Applications : heat exchanger tubes, thermal protection System, and mat. for corrosion-erosion environments.

② Dis Cont. (whiskers) and particulate Reinforced CMCs.

whiskers ⟶ increased fracture toughness of monolithic ceramics

20% V_f Sic whiskers ⟶ Al_2O_3 increass fractur toughness of Al_2O_3 ceramic 4.5 → 8.5 MPa $\sqrt{m}$

above fabricated by Common ceramic process (HIPing)

CMCs are believed to be toughness by ③ Main Mechanics:

ⓐ Crack deflection : need higher stresses to propagate the crack.

(crack deflected → making its propagating path.

ⓑ Crack bridging : Fiber, whiskers can bridge the crack, halp the material together → increasing stress level needed to cause further cracking

Fiber pull-out : Friction cause by Fiber and whisker ⟶ pulled out of cracking matrix absorbs energy

higher stresses → further cracking.