CERAMIC MATERIALS I

Asst. Prof. Dr. Ayşe KALEMTAŞ

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Anticipated Learning Outcomes

Can explain classification of ceramic materials, their sub-groups, application areas and general properties.

An understanding on the traditional and advanced ceramic shaping methods.

An understanding on the traditional and advanced ceramic sintering methods.

Can comment on the traditional and advanced ceramic raw material production processes.

SYLLABUS

Course Content:	
1. Week	Introduction to ceramic materials. Classification of ceramics and general properties.
2. Week	Traditional ceramics. Classification and applications of traditional ceramics.
3. Week	Natural ceramic raw materials and their properties. Characterization of ceramic powders.
4. Week	Natural ceramic raw materials and their properties.
5. Week	Advanced ceramics. Classification and applications of advanced ceramics.
6. Week	1. Midterm Exam
7. Week	Advanced ceramic powder synthesis. Characterization of ceramic powders.
8. Week	Advanced ceramic powder synthesis.
9. Week	Rheology. Stability of ceramic suspensions.
10. Week	Rheology. Ceramic shaping techniques.
11. Week	Ceramic shaping techniques.
12. Week	2. Midterm Exam.
13. Week	Sintering of ceramic materials.
14. Week	Sintering of ceramic materials. Finishing of ceramic materials.

Reading List

1) Reed, J. S., ”Principles of Ceramic Processing” John Wiley&Sons, New York (1995).

2) Ring, T. A., "Fundamentals of Ceramic Powder Processing and Synthesis", Academic Press, San Diego (1996).

3) Hunter, R., “Introduction to Modern Colloid Science”, Oxford University Press (1993).

4) Rahaman, M. N., "Ceramic Processing and Sintering", Marcel Dekker Inc. (1995).

5) Hiemenz, P. C. and Rajagopalan, R., "Principles of Colloid and Surface Chemistry", Marcel Dekker Inc. (1997).

6) W.D. Kingery, H.K. Bowen, and D.R. Uhlmann, “Introduction To Ceramics”, John Wiley and Sons, 1976.

7) D. W. Richerson, "Modern Ceramic Engineering," Second Edition, Marcel Dekker Inc., (1992).

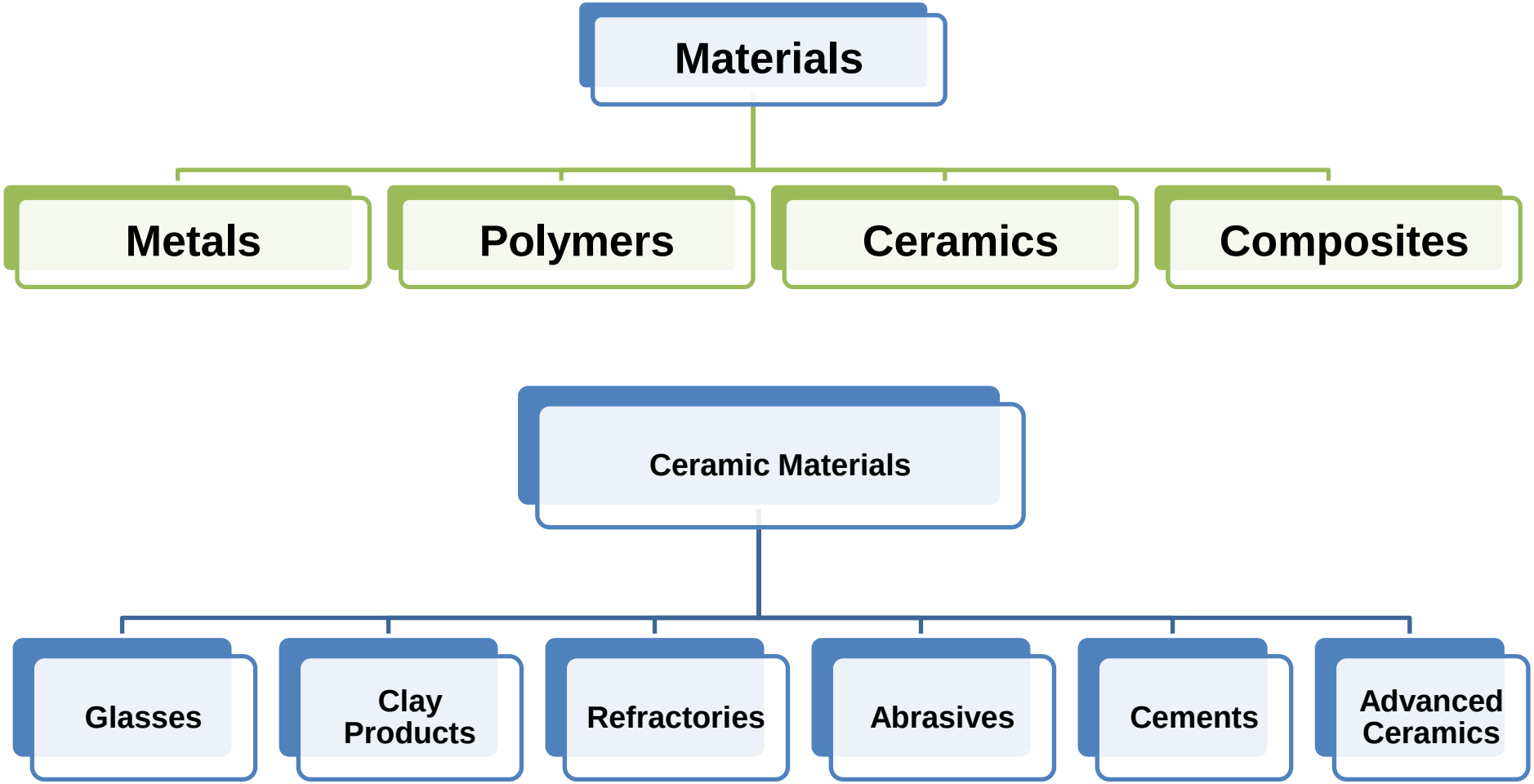
GRADING

1 Mid Term Exam: 20 %

Lab. Report: 30 %

FINAL EXAM : 50 %

CLASSIFICATION OF MATERIALS



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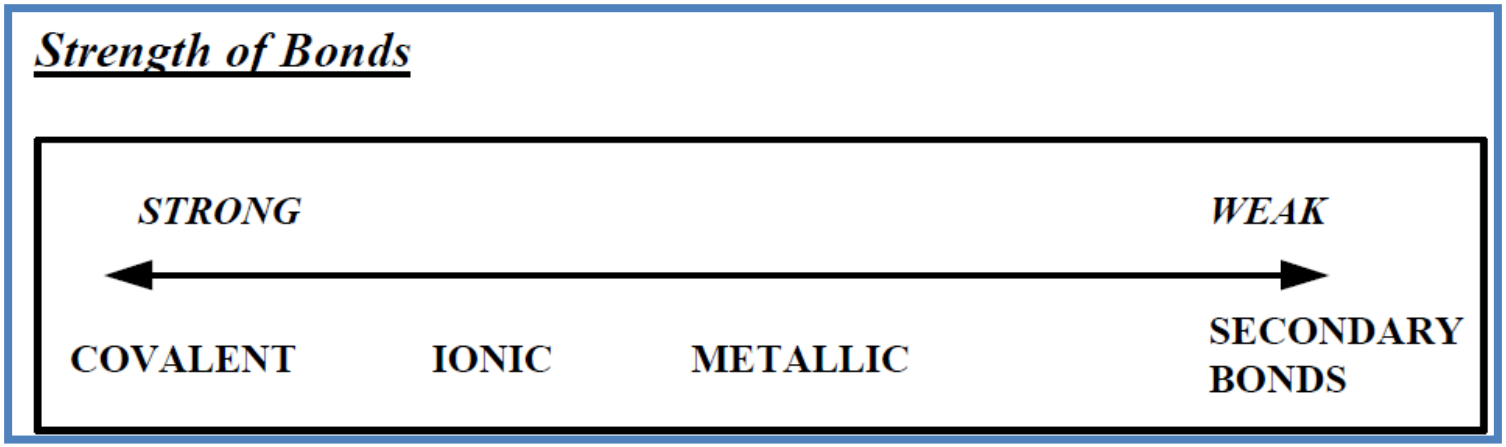
Historical Perspective

- Stone Age: 2.5 million years ago
- Pottery Age: 4000 B.C.E
- Copper Age: 4000 B.C.E – 3000 B.C.E.
- Bronze Age: 2000 B.C.E – 1000 B.C.E.
  - Foundation of metallurgy- Alloys of copper and tin
- Iron Age: 1000 B.C.E – 1B.C.E.
- Plastics Age: late 20th Century to current time
- Semiconductor Age: late 20th Century to current time

What is "ceramic"?

- from Greek meaning: "burnt earth"
- non-metal, inorganic

- Ceramic materials are inorganic compounds consisting of *metallic and nonmetallic* elements which are held together with *ionic and/or covalent bonds.*

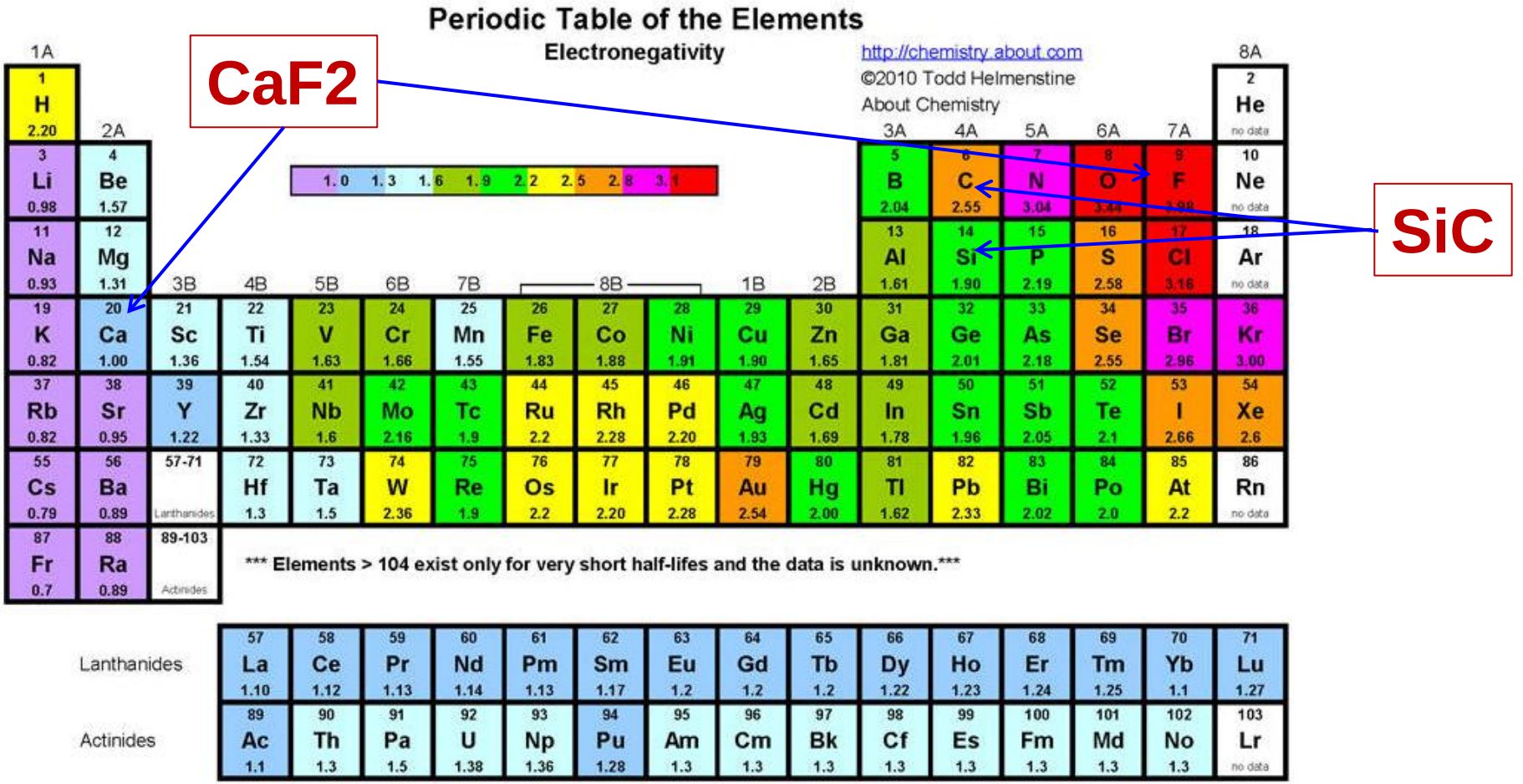


What is "ceramic"?

- Ceramics are
  - *inorganic, nonmetallic, solids, crystalline, amorphous (e.g. glass),* ***hard, brittle, stable to high temperatures, less dense than metals, more elastic than metals, and very high melting.***
- Ceramics can be covalent network and/or ionic bonded.

What is "ceramic"?

- Bonding:
  - Mostly ionic, some covalent.
  - % ionic character increases with difference electronegativity.



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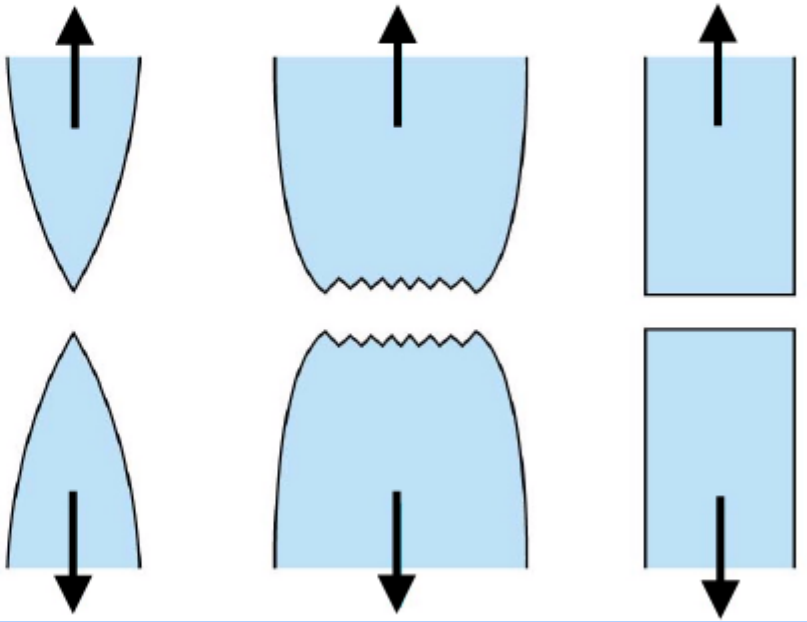
What is "ceramic"?

Ductile vs. Brittle Fracture

Fracture behavior:	Very Ductile	Modulate Ductile	Brittle
%RA or %EL:	Large	Moderate	Small



Ductile fracture is desirable!

Ductile:
warning before fracture

Brittle:
No warning

Ceramic materials → brittle fracture !!!

Introduction to Ceramic Materials

METALS	CERAMICS	POLYMERS
High density	Low density	Very low density
Medium to high melting point	High melting point	Low melting point
Medium to high elastic modulus	Very high elastic modulus	Low elastic modulus
Reactive	Unreactive	Very reactive
Ductile	Brittle	Ductile and brittle types

Examples of ceramic materials ranging from household to high performance combustion engines which utilize both metals and ceramics.

Introduction to Ceramic Materials

TABLE 12.4 Properties of Some Ceramic and Selected Nonceramic Materials

Material	Melting Point (°C)	Density (g/cm^3)	Hardness (Mohs)[a]	Modulus of Elasticity[b]	Coefficient of Thermal Expansion[c]
Alumina, Al_2O_3	2050	3.8	9	34	8.1
Silicon carbide, SiC	2800	3.2	9	65	4.3
Zirconia, ZrO_2	2660	5.6	8	24	6.6
Beryllia, BeO	2550	3.0	9	40	10.4
Mild steel	1370	7.9	5	17	15
Aluminum	660	2.7	3	7	24

[a] The Mohs scale is a logarithmic scale based on the relative ability of a material to scratch another softer material. Diamond, the hardest material, is assigned a value of 10.

[b] A measure of the stiffness of a material when subjected to a load (MPa $\times 10^4$). The larger the number, the stiffer the material.

[c] In units of ($K^{-1} \times 10^{-6}$). The larger the number, the greater the size change upon heating or cooling.

Introduction to Ceramic Materials

A comparison of the properties of ceramics, metals, and polymers

	Ceramic	Metal	Polymer
Hardness	↑	↓	↓
Elastic modulus	↑	↑	↓
High temperature strength	↑	↓	↓
Thermal expansion	↓	↑	↑
Ductility	↓	↑	↑
Corrosion resistance	↑	↓	↓
Resistance to wear	↑	↓	↓
Electrical conductivity	↕	↑	↓
Density	↓	↑	↓
Thermal conductivity	↕	↑	↓

↑ Tendency to high values ↓ Tendency to low values

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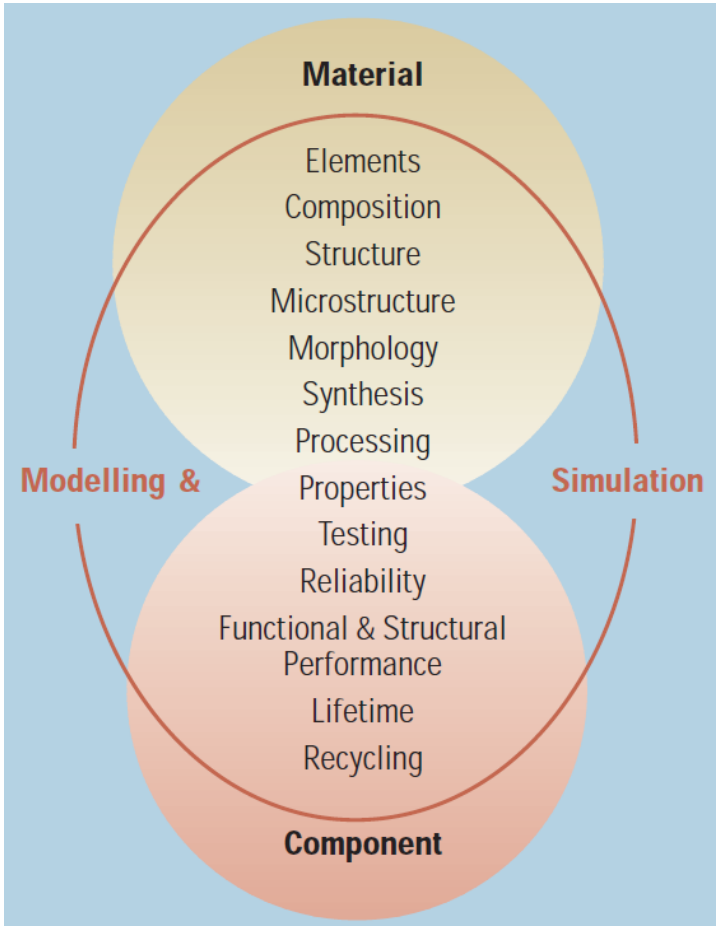
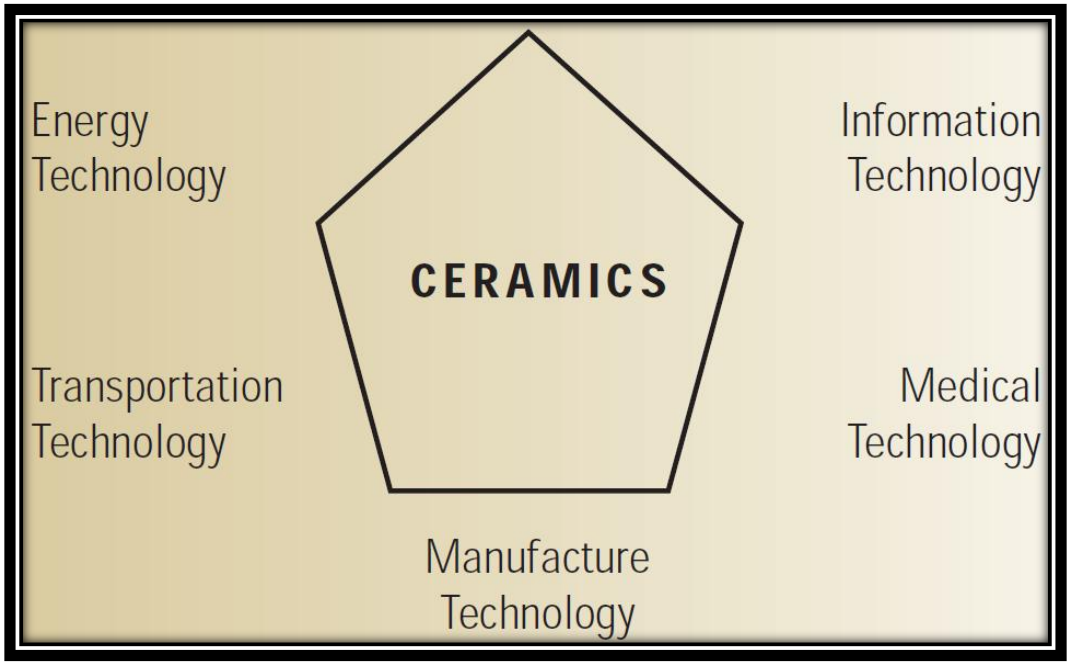
Ceramic Materials





Ceramic materials have now become the cornerstone of such advanced technologies as energy transformation, storage and supply, information technology, transportation systems, medical technology, and manufacturing technology

Future of Materials Science

Design of materials having specific desired characteristics directly from our knowledge of atomic structure.

• **Miniaturization: "Nanostructured" materials, with** microstructure that has length scales between 1 and 100 nanometers with unusual properties. Electronic components, materials for quantum computing.

• **Smart materials: airplane wings that deice themselves,** buildings that stabilize themselves in earthquakes…

• **Environment-friendly materials: biodegradable or** photodegradable plastics, advances in nuclear waste processing, etc.

• **Learning from Nature: shells and biological hard tissue** can be as strong as the most advanced laboratory-produced ceramics, mollusces produce biocompatible adhesives that we do not know how to reproduce…

• Materials for lightweight batteries with high storage densities, for turbine blades that can operate at 2500 C, room-temperature superconductors? chemical sensors (artificial nose) of extremely high sensitivity, cotton shirts that never require ironing…

Application Base Classification

Ceramic Materials		
Advanced Ceramics		**Traditional Ceramics**
Structural Ceramics	**Functional Ceramics**	Whitewares
Bioceramics	Electronic substrate, package ceramics	Cement
Ceramics used in automotive industry	Capasitor dielectric, piezoelectric ceramics	Abrasives
Nuclear ceramics	Magnetic ceramics	Refractories
Wear resistant ceramics (tribological)	Optical ceramics	Brick and tile
	Conductive ceramics	Structural clay products

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Traditional Ceramics: Applications

Earthenware, Stoneware, China, Porcelain, are all distinguished by their firing temperature and glass forming temperature

Tiles are made from similar composition material

Structural bricks are made from cheaper mixtures -often a single clay (“Fletton Brick”)

Refractory bricks have special compositions to withstand high temperatures or corrosive environments

Traditional Ceramic Products

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Traditional Ceramic Products

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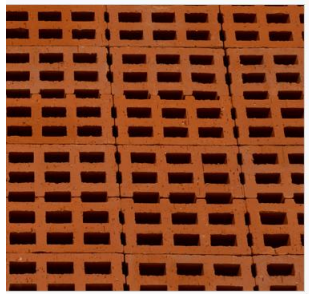
Traditional Ceramic Products

Clay pipes are sustainable products and last longer than other materials



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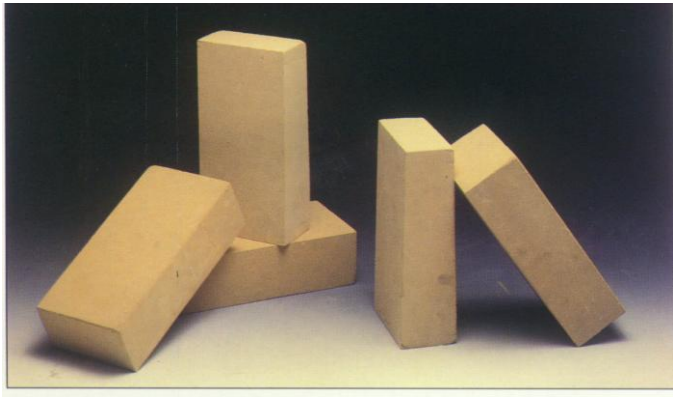
Traditional Ceramic Products

Insulating brick



Refractory Brick

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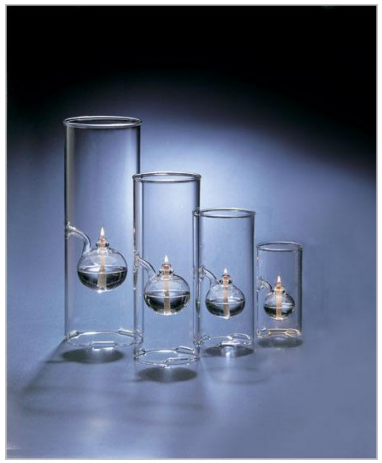
Well Known Glass Products



http://www.wolfard.com

Classic Wolfard Oil Lamp

Heat resistant glassware (microwave safe)

Heat resistant glass lid

Tempered Glass Cutting Board

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Well Known Glass Products

Tempered glass table

http://www.ifjk.org

http://freshome.com

www.tripadvisor.com
Glass sink cabinets in the bathroom

www.aarticommercial.com/products.php
Laminated Windscreen Glass

Heat resistant glass door

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Well Known Glass Products

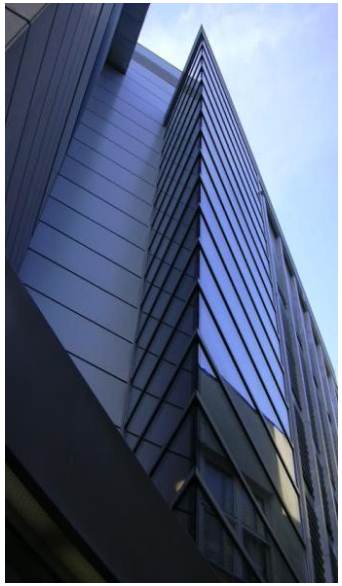
www.toxel.com
Glass Bathtub

http://freshome.com
Superdurable tempered glass

www.whitersstreetglass.com.au
Glass splashbacks

http://worlds-interior-design.blogspot.com
Wall-to-wall glass windows

http://www.wickedreport.com
Hirom Glass Violin is a product of Hario Glass Co. Ltd., Japan. And also, The world's first hand made glass violin.



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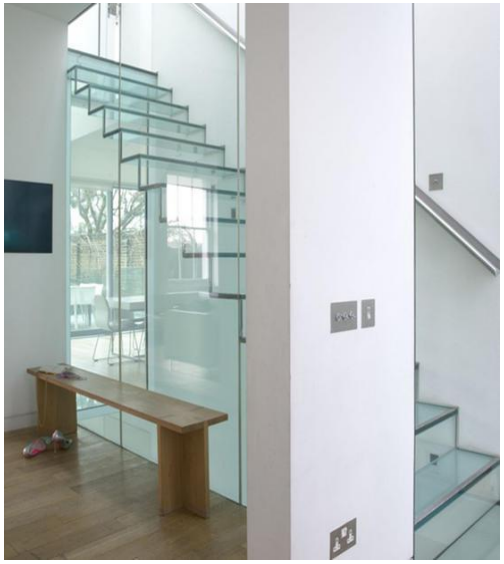
Special Glass Products

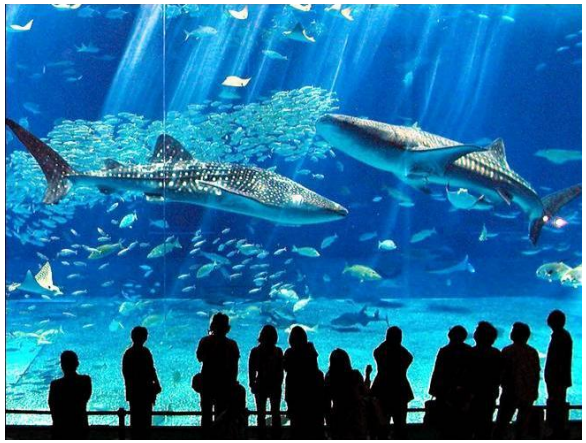
Laminated Glass

Laminated glass is widely used for

- bullet proof
- burglar-proof
- showcase
- counter
- aquarium
- skylight
- long corridor
- sidelite, etc.



http://www.livingetc.com
Glass staircase



www.aarticommercial.com
Laminated Windscreen Glass

If the laminated glass is made from "ordinary" float glass, it is still workable (cutting and drilling is possible) and the PVB helps the fractured glass to stay put inside the construction.

Special Glass Products

Laminated Glass

BULLETPROOF GLASS

Bulletproof glass is made of laminated glasses and films which have special shielding capability towards bullets.

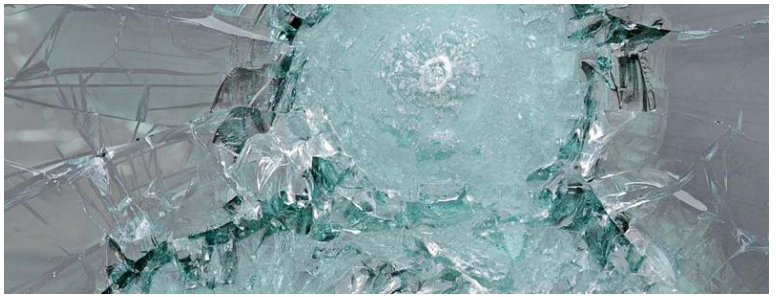
The different levels of bullet proof glasses are able to shield the bullets from penetration and prevent the broken parts from injuring people. They are widely applied in

bank,

counters of jewelry and gold shops,

cash trucks and

other regions requiring special safety prevention.



www.bmw-security-vehicles.com

22-millimetre glass/plastic laminate with a polycarbonate coating on the inside to prevent flying splinters. The 22-millimetre glass protects against:

- Blunt instruments
- .44 Magnum with full-jacket flat-nose bullets
- .357 Magnum with coned bullets
- 9-millimetre Luger with round-nose bullets

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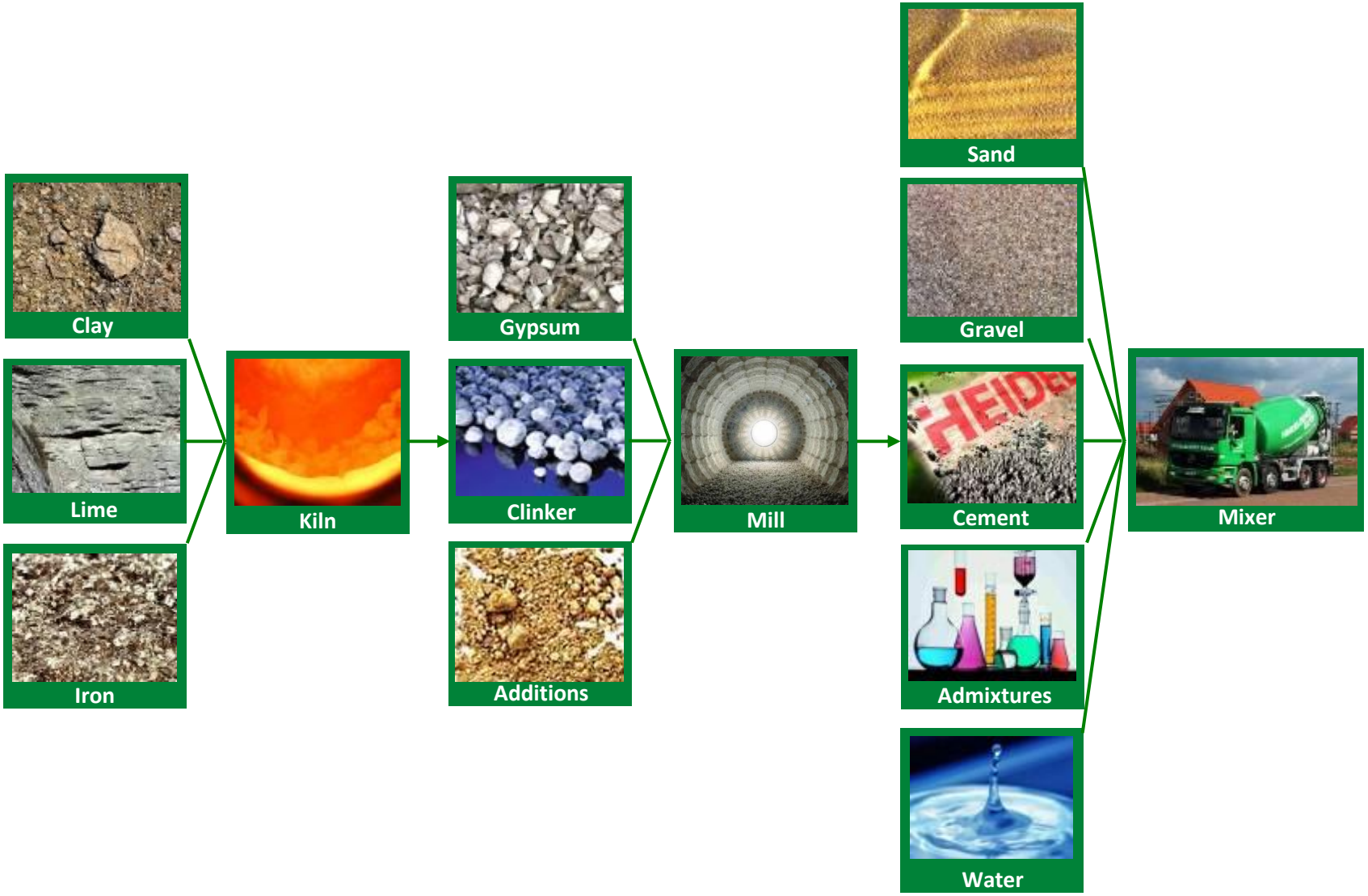
CEMENT AND CONCRETE MANUFACTURING



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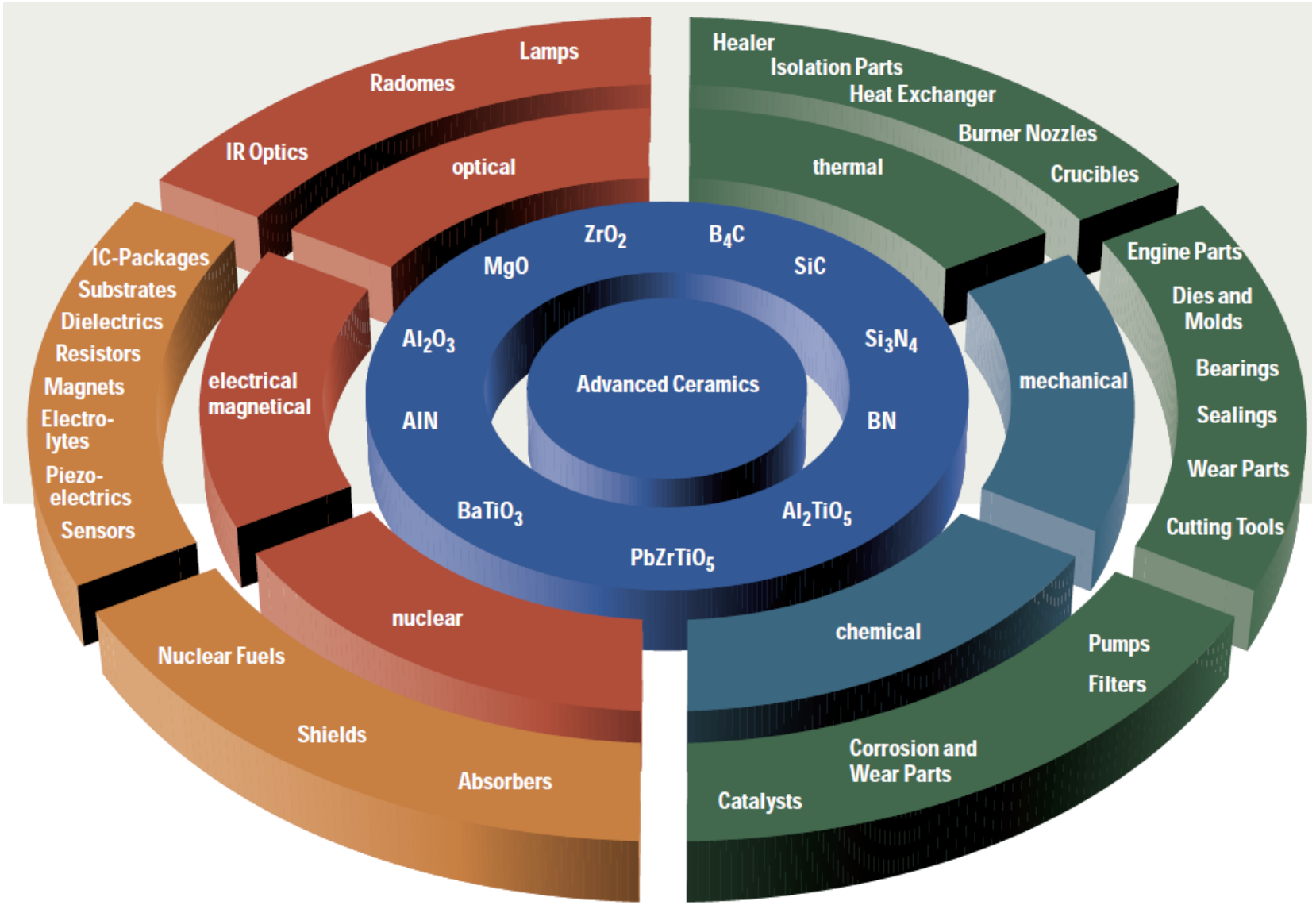
Advanced Ceramics



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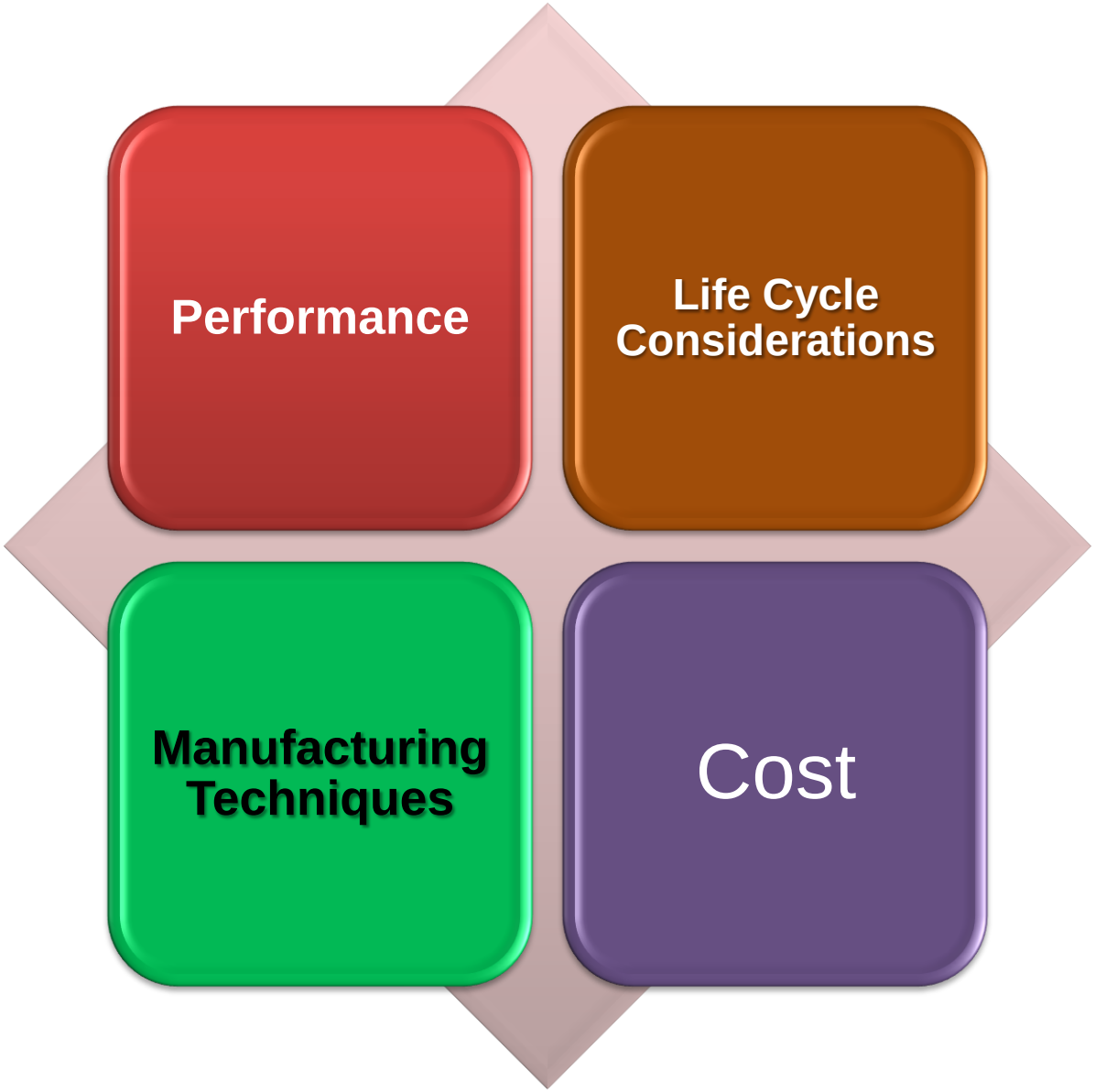
Design Objectives



Applications of Advanced Ceramics

Application	Property	Material
Cutting tools	Hardness, toughness	Alumina, SiAlON
Bearing, liners, seals	Wear resistance	Alumina, zirconia
Agricultural machinery	Wear resistance	Alumina, zirconia
Engine and turbine parts	Heat, wear resistance	SiC, Alumina, Si_3N_4
Shielding, armour	Hardness, toughness	Alumina, B_4C
Hig performance windows	Translucence, strenght	Alumina, Magnesia
Artificial bones, teeth	Wear resistance, strenght	Zirconia, Alumina

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Applications of Advanced Ceramics

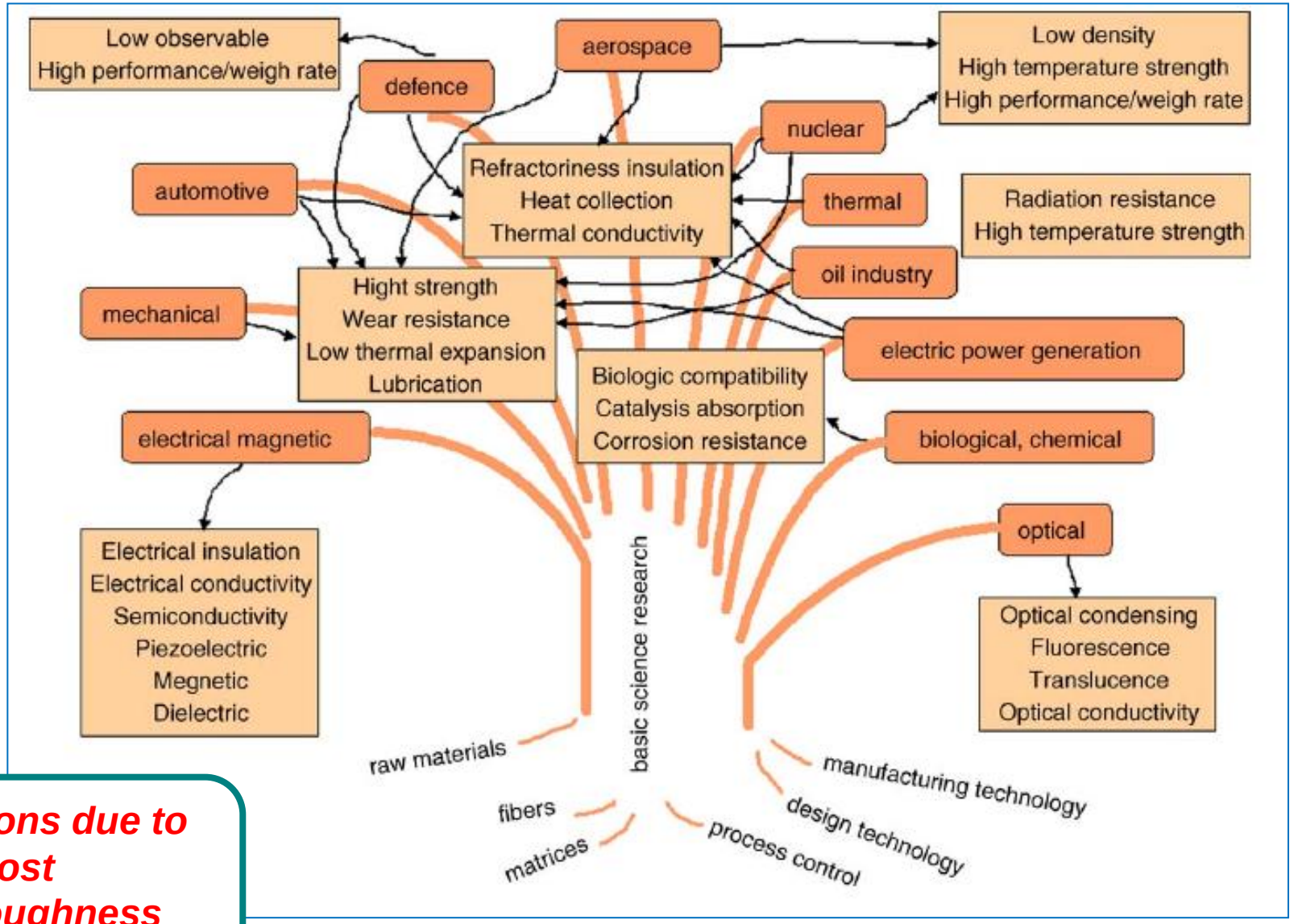
Current and future products for advanced ceramics [1]

Mechanical engineering	Aerospace	Automotive	Defense industry
Cutting tools and dies	Fuel system and valve	Heat engines	Tank power trains
Abrasives	Power units	Catalytic converters	Submarine shaft seals
Precise instruments parts	Low weight components	Dri vetrain components	Improved armors
Molten metal filter	Fuel cells	Turbines	Propulsion system
Turbine engine components	Thermal protection systems	Fixed boundary recuperators	Ground support vehicles
Low weight components for rolary equipment	Turbine engine components	Fuel injection components	Military weapon system
Wearing parts	Combustors	Turbocharger rotors	Military aircraft (airframe and engine)
Bearings	Bearings	Low heat rejection diesels	Wear-resistant precision bearings
Seals	Seals	Waterpump seals	–
Solid lubricants	Structures	–	–

Biological, Chemical processing engineering	Electrical, Magnetic Engineering	Nuclear industry	–
Artificial teeth, bones and joints	Memory elements	Nuclear fuel	–
Catalysts and igniters	Resistance heating elements	Nuclear fuel cladding	–
Hearts valves	Varistor sensor	Control materials	–
Heat exchanger	Integrated circuit substrate	Moderating materials	–
Reformers	Multilayer capacitors	Reactor mining	–
Recuperators	Advanced multilayer integrated packages	–	–
Refractories	–	–	–
Nozzles	–	–	–

Oil industry	Electric power generation	Optical Engineering	Thermal Engineering
Bearings	Bearings	Laser diode	Electrode materials
Flow control valves	Ceramic gas turbines	Optical communication cable	Heat sink for electronic parts
Pumps	High temperature components	Heat resistant translucent porcelain	High-temperature industrial furnace lining
Refinery heater	Fuel cells; (solid oxide)	Light emitting; diode	–
Blast sleeves	Filters	–	–

Advanced Ceramic Application Tree



Limitations due to
- High cost
- Low toughness
- Low reliability

M. Rosso, Ceramic and metal matrix composites: Routes and properties, Journal of Materials Processing Technology 175 (2006) 364–375

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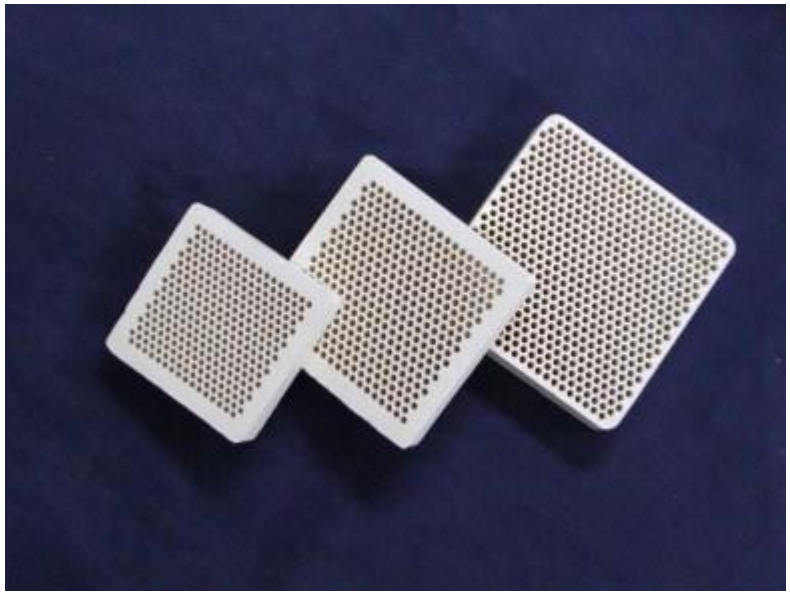
Applications of Advanced Ceramics



Ceramic filter

Foam ceramic molten metal filter

Ceramic Knife

Ceramic Fiber Boards As The Heat Insulation

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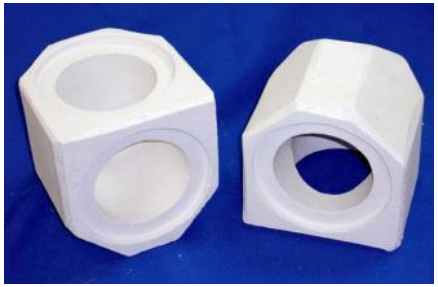
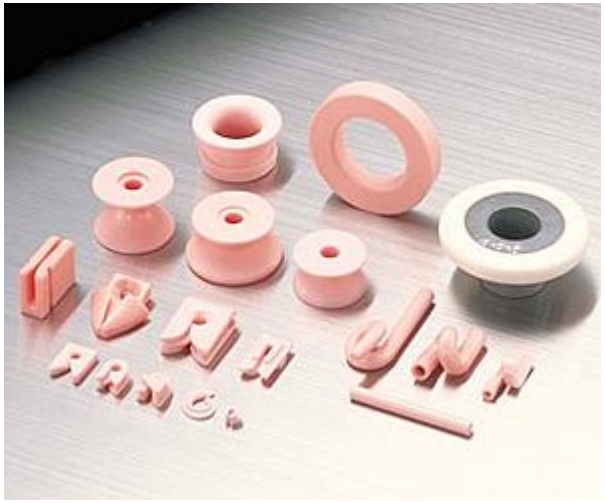
Applications of Advanced Ceramics



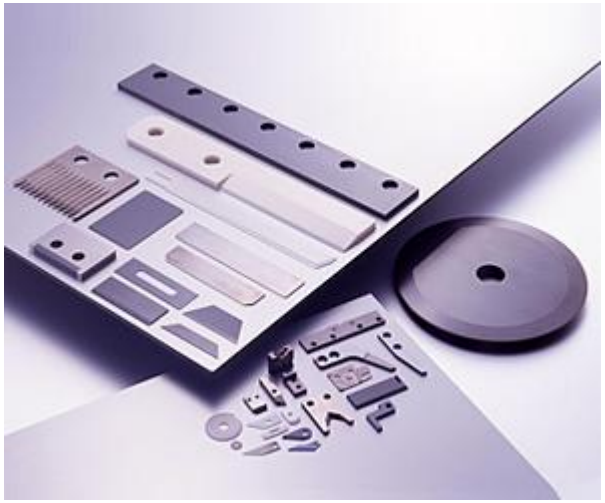
Ceramic fittings

Ceramic Fiber Products

Ceramic faucet valves with superior wear resistance and sealing performance.



Ceramics are used in various textile machines as guide parts, thread processing nozzles, oiling nozzles, rollers and twister parts.



Cutting and wear-resistant parts

Alumina Ceramic Pipe Lining

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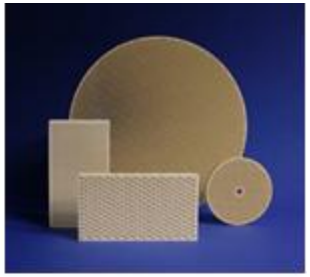
Applications of Advanced Ceramics


Alumina Ceramics


Large Alumina Ceramics


Alumina Ceramic Tubes


Alumina Ceramic balls

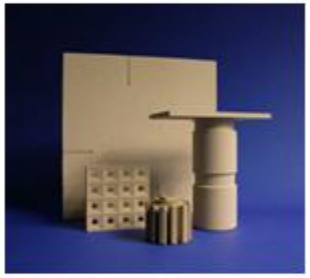

Honeycomb Ceramics


Zirconia Ceramics

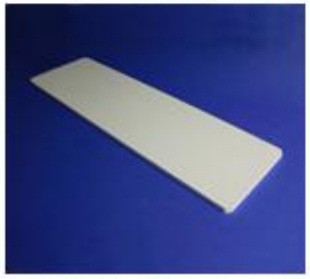

Zirconia Ceramic Beads

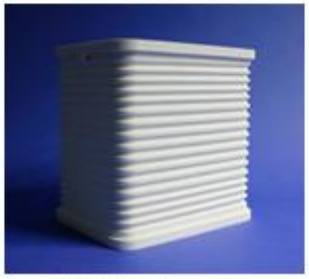

SiC Mechanical Seals

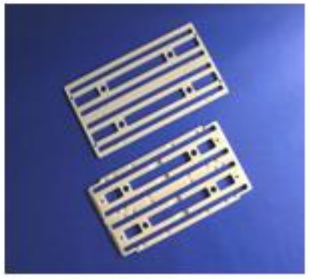

SiC Mechanical Seals


Cordierite Ceramics


Steatite Porcelain


Mullite Ceramics


Mullite Ceramics


Semiconductor Ceramics


Semiconductor Ceramics

http://aluminatechnologies.com/products.php

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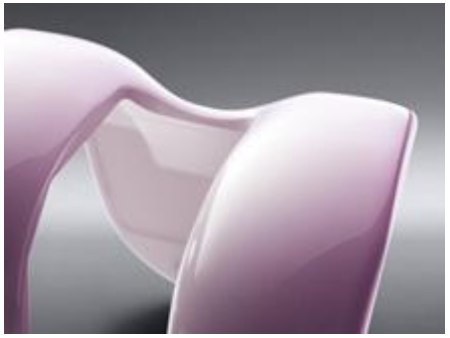
Applications of Advanced Ceramics

Ball Heads

Cup Inserts. For inserting into the acetabular cup



Knee Joint Components. Improved quality of life, reduce wear and minimize the risk of allergies.

Ceramic seal rings, axial bearings and radial bearings ensure highly reliable operation and long service life wherever fluids are pumped or gas is compressed.

High temperature wear resistance industrial zirconia advanced ceramic insulator products

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Applications of Advanced Ceramics

Sheer Veneers

ZrO_2-metal free restorations

Biocompatible ceramic parts for drug-delivery systems.

With its extensive material range and continuously growing production expertise in the field of ceramic components for textile processing,

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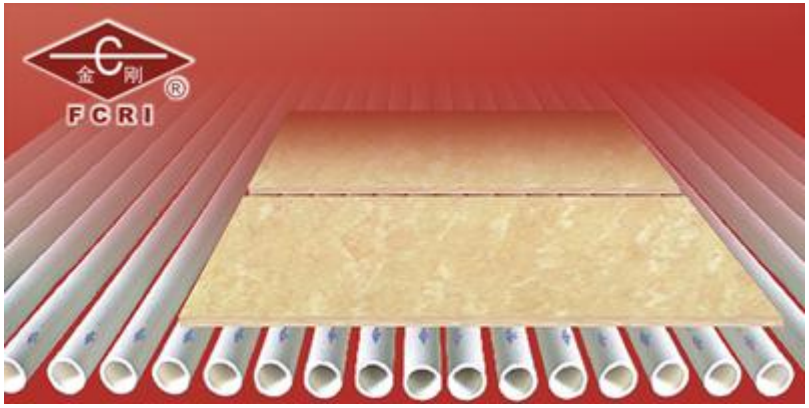
Applications of Advanced Ceramics

Bearing Rollers made from Silicon Nitride

In engine design or exhaust systems, in liquid or gas circuits – automotive industry demands on seal rings, bearings and sealing technology are especially high. Technical ceramics ensure wear resistance, temperature resistance and stability in these aggressive environments.

Ceramic gas nozzles made of silicon nitride



Ceramic rollers

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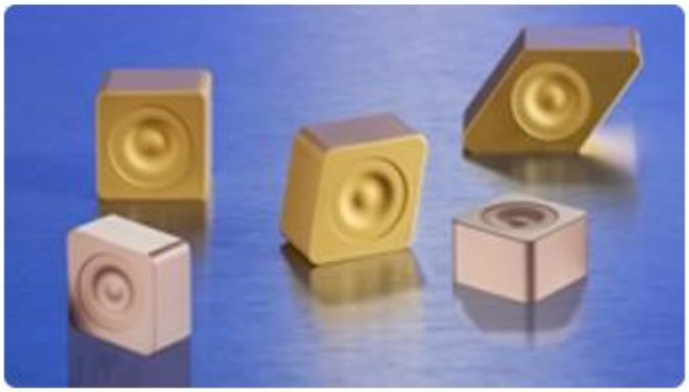
Applications of Advanced Ceramics

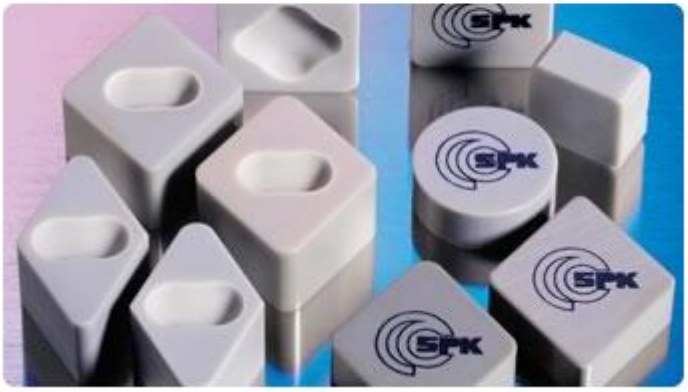
Cutting Material Grades and Applications in Machining

SiAlON Ceramics – Uncoated and Coated

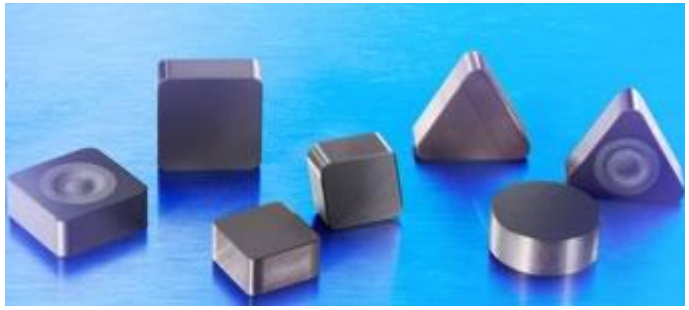


Inserts from CeramTec's latest generation of ceramic cutting materials. Designed specifically for high-perfor-mance machining of cast iron materials.

Silicon Nitride Ceramics – Uncoated and Coated



The proven performance standard for efficient machining with indexable inserts made of ceramic cutting materials.



CBN indexable inserts (polycrystalline cubic boron nitride) for efficient machining of cast iron materials and sintered steels for turning, milling, boring and grooving.

Whether filtration, galvanization, water heating or soil analysis; fields of application such as the chemicals industry, laboratories, electronics and electrical engineering, environmental technology or foundry technology

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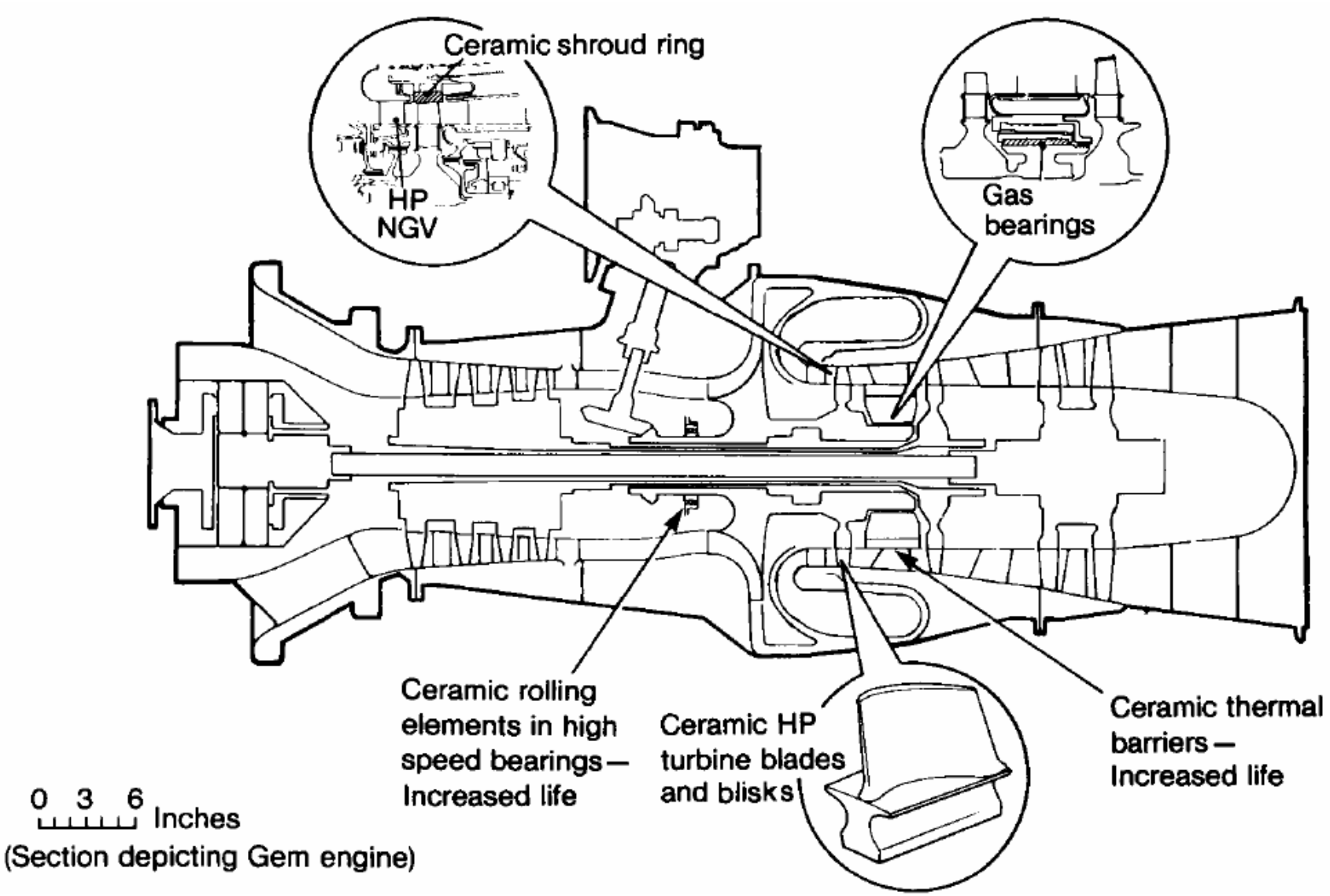
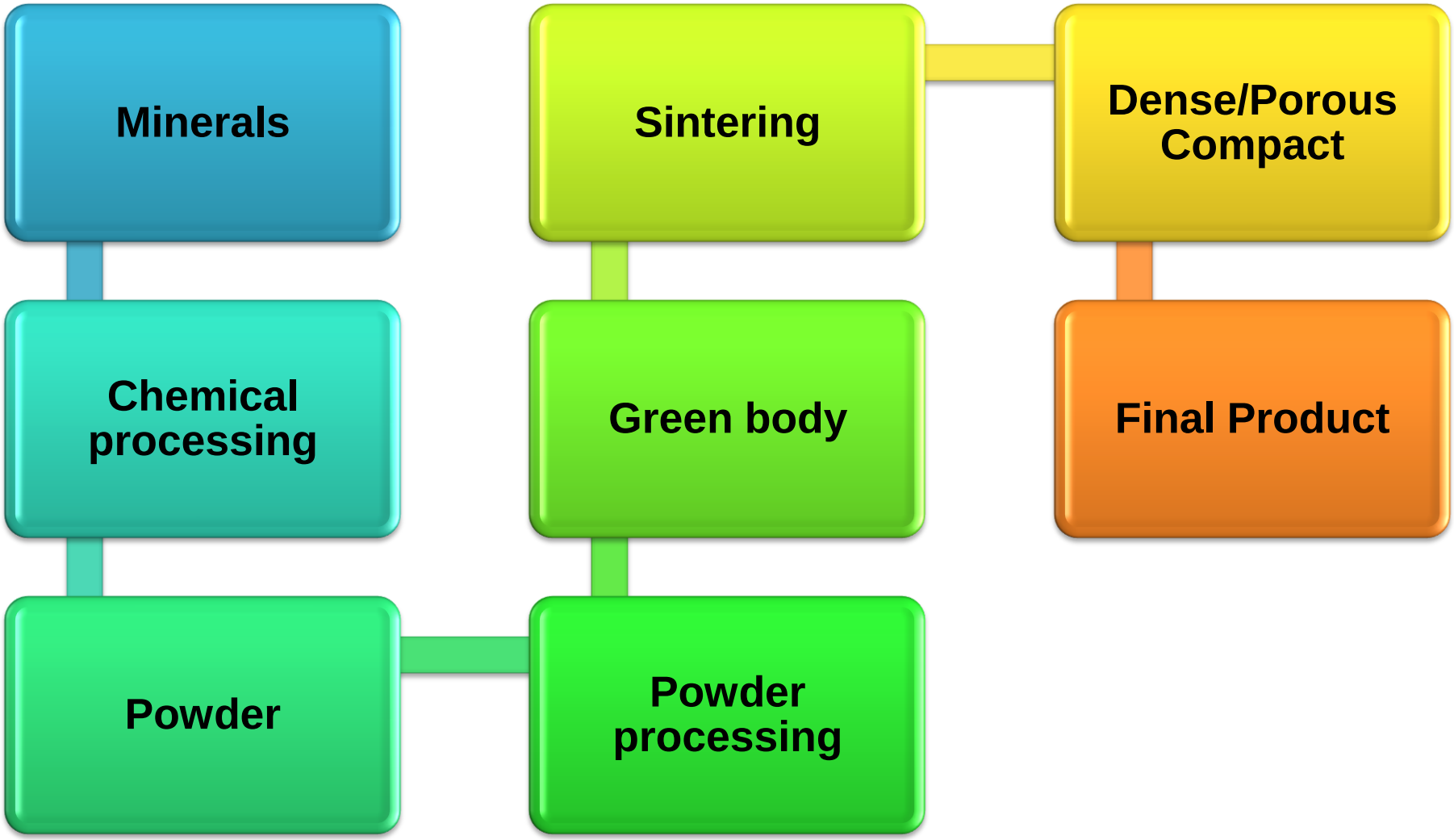
Ceramics in Aerospace



CERAMIC PROCESSING



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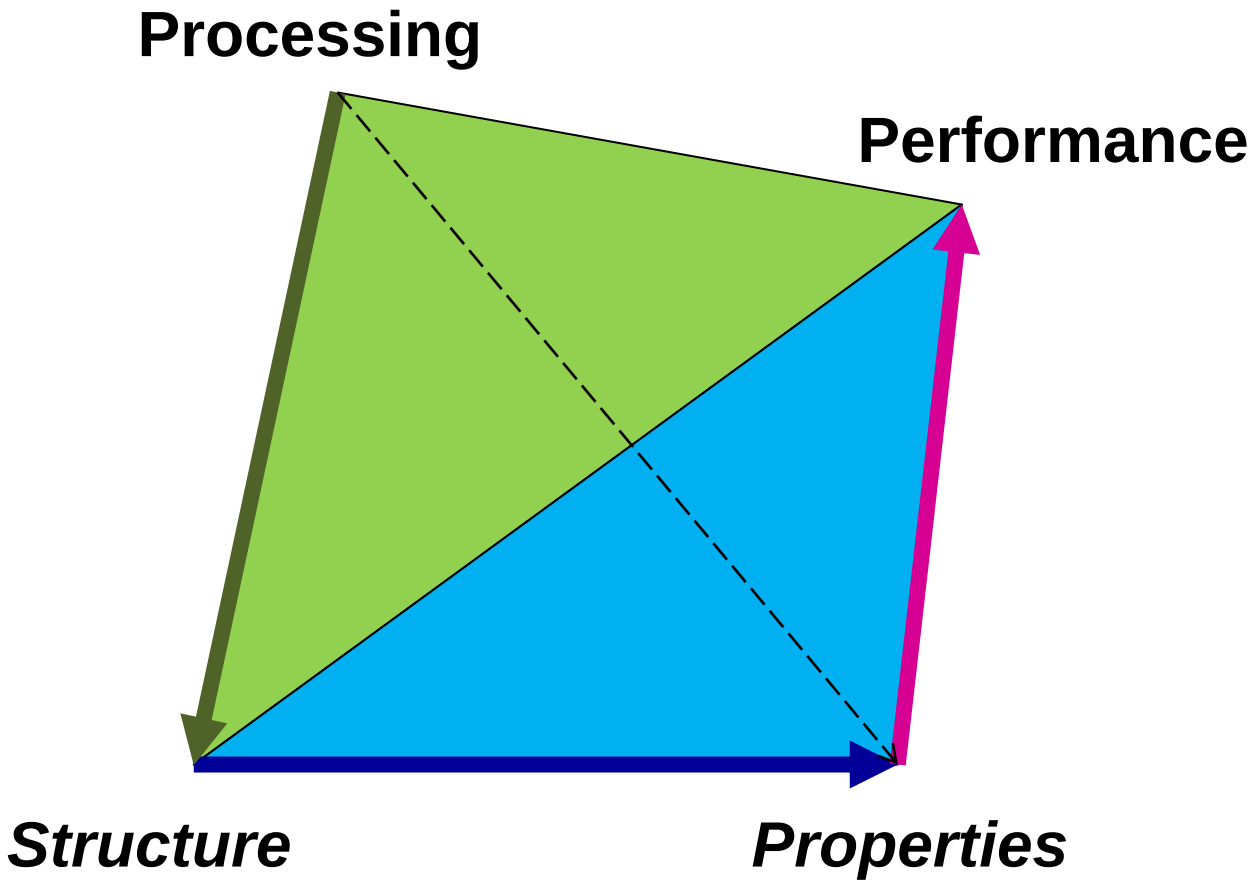
Materials Science and Engineering



Material science is the investigation of the relationship among processing, structure, properties and performance of materials.

Asst. Prof. Dr. Ayşe KALEMTAŞ

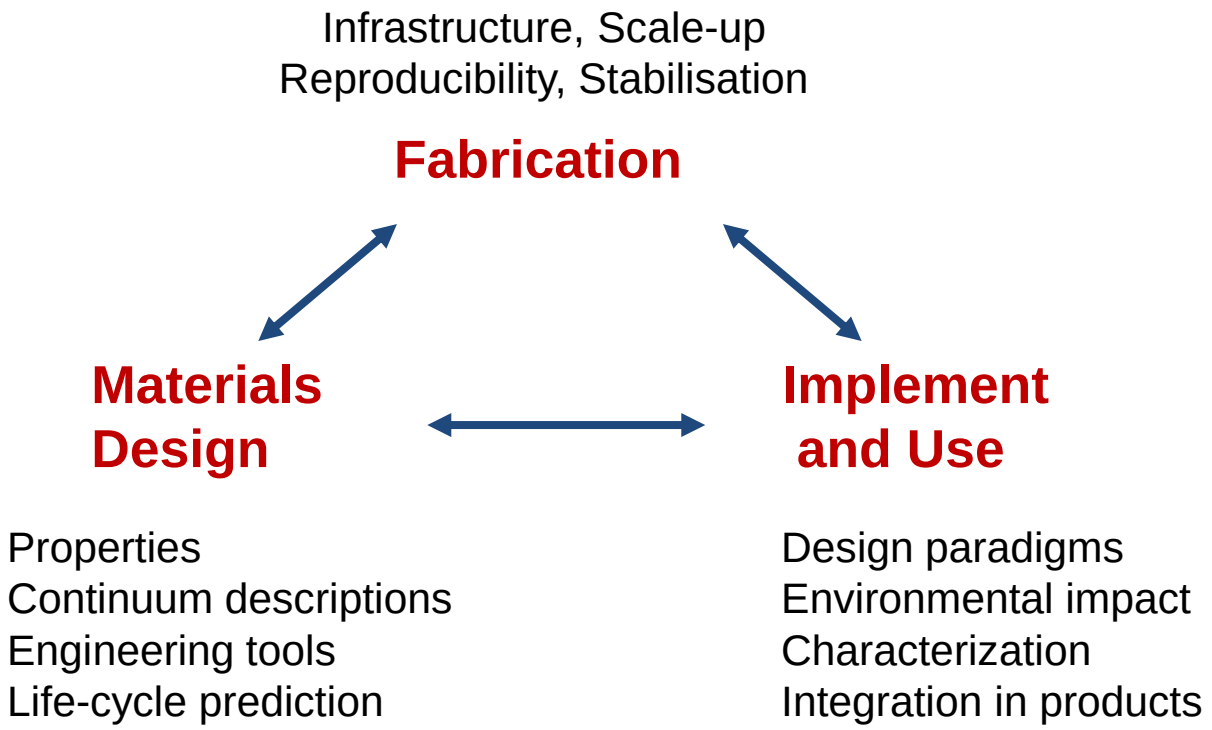
KEY STEPS

- Powder synthesis
- Powder handling
- Green body formation
- Sintering of green body
- Final machining and assembly

NanoTechnology: The Material Challenges

Fundamental Predicting process – structure – property relationships

Technological Taking laboratory materials into production



Other Ceramic Materials

- **Cements** - Ceramic raw materials are joined using a binder that does not require firing or sintering in a process called cementation.
- **Coatings** - Ceramics are often used to provide protective coatings to other materials.
- **Thin Films and Single Crystals** - Thin films of many complex and multi-component ceramics are produced using different techniques such as sputtering, sol-gel, and chemical-vapor deposition (CVD).
- **Fibers** - Fibers are produced from ceramic materials for several uses: as a reinforcement in composite materials, for weaving into fabrics, or for use in fiber-optic systems.
- **Joining and Assembly of Ceramic Components** - Ceramics are often made as monolithic components rather than assemblies of numerous components.

THE END

Thanks for your kind attention

Asst. Prof. Dr. Ayşe KALEMTAŞ

Any Questions