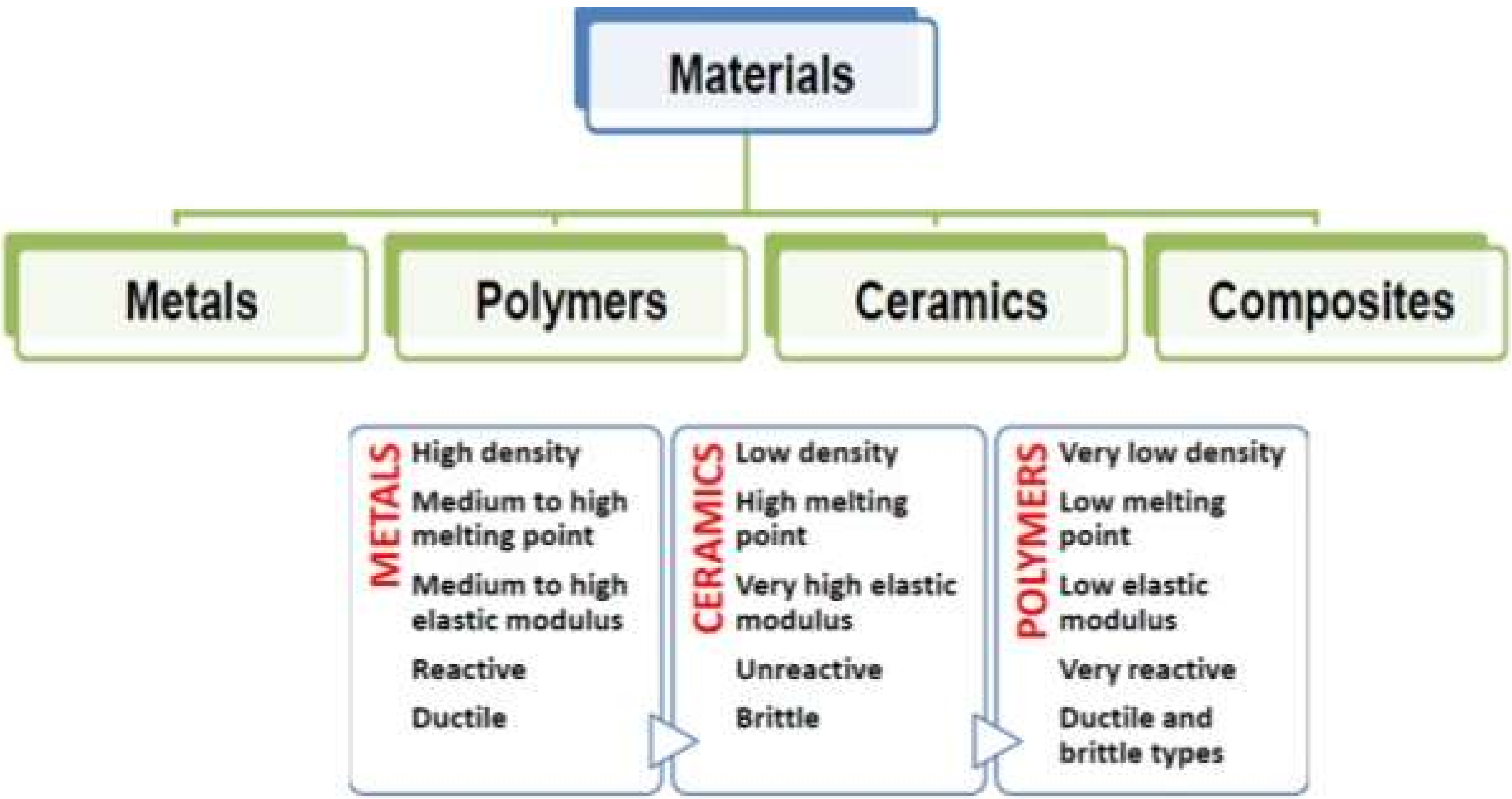
# CERAMICS



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

## What is “Ceramic”?

- **Ceramic materials** are **inorganic, non-metallic materials and things made from them.**
- They may be crystalline or partly crystalline.
- They are formed by the action of heat and subsequent cooling.
- Most ceramics are compounds between **metallic** and **nonmetallic elements** for which the interatomic bonds are either totally ionic bond or predominantly ionic but having same covalent character.
- **Clay** was one of the earliest materials used to produce ceramics, but many different ceramic materials are now used in domestic, industrial and building products.
- A wide-ranging group of materials whose ingredients are **clays, sand and felspar**.
  - The term “ *Ceramics*” comes from the Greek word ***keramikos***, which means “***Burnt stuff*** or ***drinking vessel***”, indicating that desirable properties of these materials are normally achieve through a high-

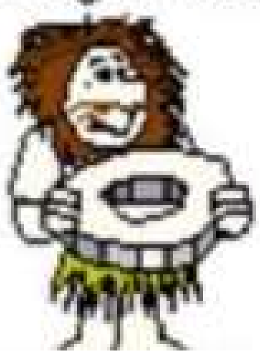
# What are Ceramic Materials?

- Inorganic, nonmetallic materials that consist of metallic and nonmetallic elements bonded together primarily by ionic and/ or covalent bonds
- Its chemical compositions vary considerably, from simple compounds to mixtures of many complex phases bonded together.
- Ceramics used for engineering applications, can be divided into two groups: 1) Traditional ceramic materials
  2) Advanced ceramic materials
- Typically hard and brittle with low toughness and ductility
- Usually good electrical and thermal insulators
- Normally have relatively high melting temperatures and high chemical stability in many hostile environments

# History of Ceramics

**26,000 B.C.**

Early man discovers that clay, consisting of mammoth fat and bone mixed with bone ash and local loess, can be molded and dried in the sun to form a brittle, heat-resistant material. Thus begins **ceramic** art.



**6,000 B.C.**

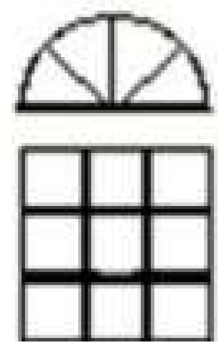
Ceramic **firing** is first used in Ancient Greece. The Greek pottery *Pithoi* is developed and used for storage, burial, and art.

**4,000 B.C.**

**Glass** is discovered in ancient Egypt. This primitive glass consisted of a silicate glaze over a sintered quartz body and was primarily used for jewelry. The use of ceramic coating continues today in many things from bathtubs to tailpipes of jet aircraft.

**50 B.C. - 50 A.D.**

Optical **glass** (lenses and mirrors), window **glass** and **glass** blowing production begins in Rome and spreads around the world with the Roman empire.



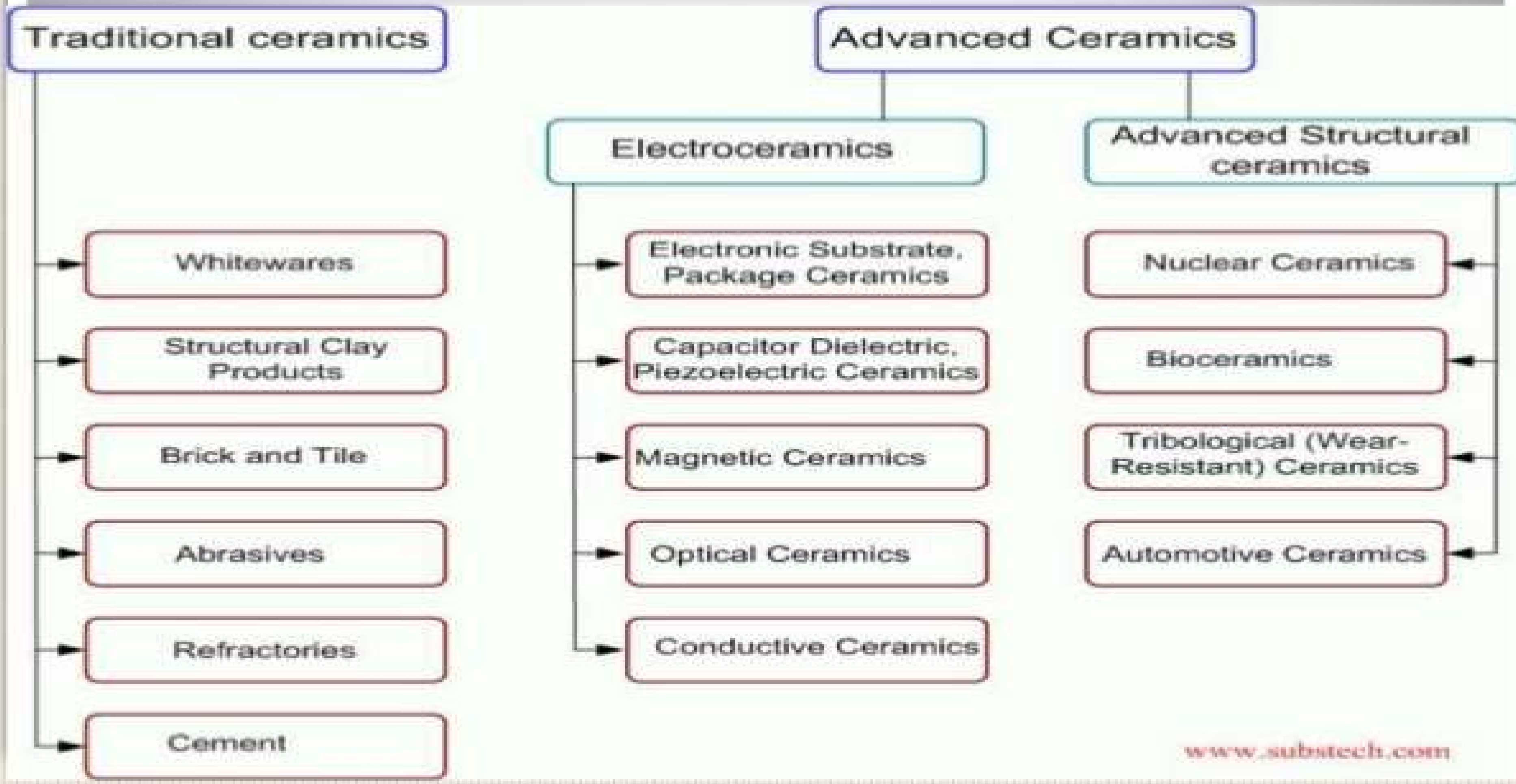
# Ceramic Crystal Structure

- Broader range on chemical composition than metals with more complicated structures
- contains at least 2 and often 3 or more atoms
- usually compounds between metallic ions (e.g. Fe, NI, Al) -called cations - and non-metallic ions (e.g. O, N, Cl) -called anions
- Bonding will usually have some covalent character but is usually mostly ionic

# PROPERTIES OF CERAMICS

- Extreme hardness:
  - High wear resistance
  - Extreme hardness can ***reduce wear caused by friction***
- Corrosion resistance
- Heat resistance:
  - Low electrical conductivity
  - Low thermal conductivity
  - Low thermal expansion
  - Poor thermal shock resistance
- Low ductility:
  - Very brittle
  - High elastic modulus
- Low toughness:
  - Low fracture toughness
  - Indicates the ability of a crack or flaw to produce a catastrophic failure
- Low density:
  - Porosity affects properties
- High strength at elevated temperatures

# *Classification of Ceramics based on APPLICATION



## Whitewares

- Made from components of clay, silica, and feldspar for which the composition is controlled.

*Example:*

- Electrical porcelain
- Dinner china
- Sanitary ware

## Whitewares

Electrical porcelain

Dinner China

Sanitary ware

## Structural Clay Products

- Made of natural clay, which contains all three basic components.

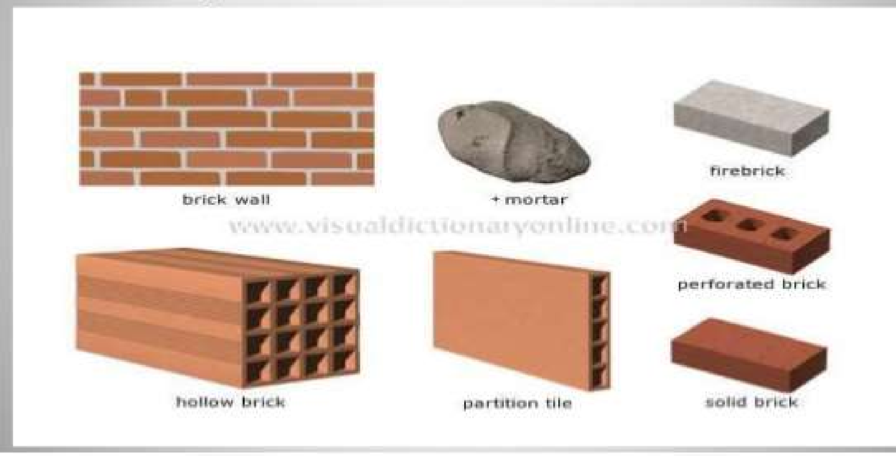
*Example:*

- Building brick
- Sewer pipe
- Drain tile
- Roofing tile
- Floor tile

Sewer pipe

## Structural Clay Products

Building brick




Roofing tile

## Abrasives

- is a material, often a mineral, that is used to shape or finish a workpiece through rubbing which leads to part of the workpiece being worn away
- a material often means polishing it to gain a smooth, reflective surface which can also involve roughening as in satin, matte or beaded finishes

## Abrasives

# Refractories

- is one that retains its strength at high temperature

*Example:*

- kiln linings
- gas fire radiants
- steel
- glass making crucibles

# Refractories

KILN LININGS

Gas fire radiants


STEEL

# Cements

- is a binder, a substance that sets and hardens independently, and can bind other materials together
- used in construction can be characterized as being either hydraulic or non-hydraulic
- The most important uses of cement are as an ingredient in the production of mortar in masonry, and of concrete, a combination of cement and an aggregate to form a strong building material

# Cements

# Advanced Ceramics

- Advanced ceramics are ideally suited for industrial applications that provide a physical interface between different components due to their ability to withstand high temperatures, vibration and mechanical shock.
- A type of ceramic exhibiting a high degree of industrial efficiency.
- A type of ceramic used in specialized, recently developed applications.
- Advanced ceramics often have simple chemical compositions, but they are difficult to manufacture.

# Electroceramics

- is a class of ceramic materials used primarily for their electrical properties.

*Further classified to:*

- Dielectric ceramics
- Fast ion conductor ceramics
- Piezoelectric and ferroelectric ceramics

## Dielectric Ceramics

- are capable of storing large amounts of electrical charge in relatively small volumes.
- Is an electrical insulator that can be polarized by an applied electric field.
- Dielectric materials can be solids, liquids, or gases.
- Solid dielectrics are perhaps the most commonly used dielectrics in electrical engineering, and many solids are very good insulators.

Solid Dielectric


Liquid Dielectric


sulfur hexafluoride ($SF_6$)

Gas Dielectric

# ➢ Fast Ion Conductor Ceramics

- are solids in which ions are highly mobile. These materials are important in the area of solid-state ionics, and are also known as **solid electrolytes** and **superionic conductors**.
- These materials are useful in batteries and various sensors. Fast ion conductors are used primarily in solid oxide fuel cells.

## ➢ Piezoelectric Ceramics

- Piezoelectric ceramic materials are categorized as functional ceramics.
- In sensors they make it possible to convert forces, pressures and accelerations into electrical signals, and in sonic and ultrasonic transducers and actuators they convert electric voltages into vibrations or deformations.
- Piezo-ceramics have a wide range of uses. Piezo-ceramics are used in the automotive industry in a number of applications such as in knock and oil level sensors or as actuators for precise control of injection processes in engines.
- In medical technology piezo-ceramic components can be found in lithotripters, devices for plaque removal and in inhalers. Common applications in mechanical engineering include ultrasonic cleaning, ultrasonic welding and active vibration damping.

# ➢ Magnetic Ceramics

- Magnetic ceramics are made of ferrites, which are crystalline minerals composed of iron oxide in combination with some other metal. They are given the general chemical formula M(Fe*x*O*y*), M representing other metallic elements than iron. The most familiar ferrite is magnetite, a naturally occurring ferrous ferrite ($Fe[Fe_2O_4]$, or $Fe_3O_4$) commonly known as lodestone. The magnetic properties of magnetite have been exploited in compasses since ancient times.

*Magnetic bracelet*

*Ceramic Magnets*

# Optical Ceramics

- are polycrystalline materials produced through controlled crystallization of base glass.
- Glass-ceramic materials share many properties with both glasses and ceramics.
- Glass-ceramics have an amorphous phase and one or more crystalline phases and are produced by a so-called "controlled crystallization" in contrast to a spontaneous crystallization, which is usually not wanted in glass manufacturing.
- Glass-ceramics have the fabrication advantage of glass as well as special properties of ceramics.
- Glass ceramics has a variety of properties such as, high strength, toughness, translucency or opacity, opalescence, low or even negative thermal expansion, high temperature stability.

# Optical Ceramics


*Watch Glasses*

*Optical Glass Lenses*

High-pressure sodium-vapour lamp bulb

## Advance Structural Ceramics

- ceramic materials that demonstrate enhanced mechanical properties under demanding conditions. Because they serve as structural members, often being subjected to mechanical loading, they are given the name structural ceramics. Ordinarily, for structural applications ceramics tend to be expensive replacements for other materials, such as metals, polymers, and composites.

## Advance Structural Ceramics

Classified to:

- Nuclear Ceramics
- Bioceramics
- Tribological Ceramics
- Automotive Ceramics

## Nuclear Ceramics

*The image above shows a vintification process or encapsulating nuclear waste in glass is a possible method of containing nuclear wastes*

## Bioceramics

- Ceramics are now commonly used in the medical fields as dental, and bone implants. Artificial teeth, and bones are relatively commonplace. Surgical cermets are used regularly. Joint replacements are commonly coated with bioceramic materials to reduce wear and inflammatory response. Other examples of medical uses for bioceramics are in pacemakers, kidney dialysis machines, and respirators.

*Femoral Head of a Hip Prosthesis*

*Hip Prosthesis*

## Tribological Ceramics

- **Tribological ceramics,** also called **wear-resistant ceramics**, ceramic materials that are resistant to friction and wear. They are employed in a variety of industrial and domestic applications, including mineral processing and metallurgy.
- Advanced structural ceramics offer unique capabilities as tribomaterials.
- They are being used today in diverse applications such as tips for ball-point pens, precision instrument bearings, and cutting tool inserts.
- Tribological applications of ceramics can be divided into several categories based on the properties of the ceramics. These include: resistance to abrasion and erosion; resistance to corrosive wear; wear resistance at elevated temperatures; low density; and electrical, thermal and magnetic properties.

## Tribological Ceramics

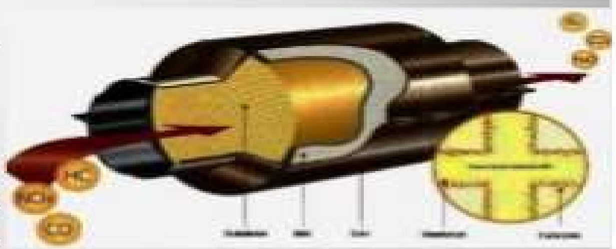
Tip of a ball Point Pen

Ceramic Instrumental Bearing

# ➢ Automotive Ceramics

- **Automotive ceramics,** advanced ceramic materials that are made into components for automobiles. Examples include spark plug insulators, catalysts and catalyst supports for emission control devices, and sensors of various kinds. Its powerful physical, thermal and electrical properties make it a reliable, highly durable and cost-effective alternative to metal. As the industry faces continued pressure to deliver innovative design, improved safety features and environment-friendly vehicles (while also reducing production costs), use of this material looks set to grow.

Spark Plug Insulators




Catalytic Converter


THANK
YOU