PUBLIC LECTURE SERIES

THE FOUNDATION AND THE FUNDAMENTAL PILLAR OF WORLD TECHNOLOGICAL CIVILIZATION AND ECONOMIC DEVELOPMENT

Cleopas. A. Loto
Professor of Mechanical Engineering
Covenant University

Corporate & Public Affairs
Covenant University
Canaanland, Km. 10, Idiroko Road, Ota, Ogun State, Nigeria
Tel: +234-1-7900724, 7901081, 7913282, 7913283

Covenant University Press
Canaanland, Km. 10, Idiroko Road, Ota, Ogun State, Nigeria

ISSN 2006---0327
Vol. 1, No. 17, October, 2007

Public Lecture Series Volume 17. 25th October, 2007

CLEOPAS. A. LOTO
Professor of Mechanical Engineering
Covenant University

INTRODUCTION

With this lecture of this afternoon, I welcome all of us to the wonderful world of materials and their impact on the evolution of mankind. Materials have been the milestones of progress. All civilizations have been categorized by the materials they used; *The Stone Age, The Gold Age, The Silver Age, The Bronze Age, The Iron Age,* etc. Some of these periods in history lasted centuries but in recent times both the rate of major materials breakthroughs and their improvements are increasing ever faster.

Materials are constituents of the earth and the earth is materials. In Genesis 2:1, it reads: “In the beginning, God created the heaven and the earth”. So the earth was either created simultaneously with the heaven or it was created second, sequentially. And in Psalm 24:1, it reads: “The earth is the Lord's and the fullness thereof”---. The fullness of the earth, are the materials, (plus water and air) that God had put therein from the beginning for mankind to process and use for their needs. It is not, therefore, by accident, that materials have constituted the greatest physical gifts of God, in addition to air and water that the Lord God has given to man kind to cope with life and sustain their existence (on earth) in the world.

In the Book of Exodus, Chapters 31-39, the Lord Himself commanded Moses to use gold, brass, silver, stones and wood all materials, for the wares and part of construction and decoration for the Great Tabernacles. God also commissioned Be-zal eel, the son of Uri, the son of Hur, of the tribe of Judah and filled him with His Spirit in wisdom, and in understanding, and in knowledge, and in all manner of workmanship to devise cunning works, to work in gold, and in silver, and in brass, and in casting of stones, to set them, and in carving of timber, to work in all manner of workmanship (Exodus 31:1-5). Lastly in Rev. 21:18-23, the beauty and the construction of New Jerusalem was described in various assorted materials. It is therefore correct to say that materials have both spiritual and physical connotations, dimensions and/or perspectives. Hence any nation that can study materials scientifically, process them technologically and apply them to use, are blessed with technological and economic prosperity. All things in life that one can see, handle/touch and use are all made of materials derived/extracted from the earth*: cars, air planes, computers, refrigerators, televisions, microwave ovens, dishes, silverwares, athletic equipment of all types, medical and biomedical devices such as replacement joints and limbs, all machines and machineries, industrial plants and all manners of very highly sophisticated analytical instrumentations and equipment* just to mention a few, are all made of materials as we shall see subsequently in this lecture. Without materials and their uses, the world will not know any civilization and one can imagine how things would have been by now.

With regard to the above, one can now ask, `what are materials'?(MSE). The answer is simple. Just look around. What do you see? Materials are everywhere! Nearly all that you see are either materials or made of materials. The clothes we wear are made from a variety of materials. Our home is made of materials and so also where we are now. Everything inside this building is made of materials.

By definition material is something that consists of matter. It is the substance of which a thing is made or composed. It is the constituent element of a thing. It is anything that serves as crude or original matter to be used or developed.

Materials comprise a wide range of metals and non metals which must be operated upon to form the end product. Whether this end product is a bridge, a computer, a space vehicle or an automobile, an engineer must have an intimate knowledge of the properties and behavioral characteristics of the materials he intends to use. In the modern complex society of today, which is producing more technically qualified people, complex products and more information than ever before, a constant challenge is being posed by the ever increasing demands for materials. These are materials of greater strength, lightness, safety, reliability, electrical conductivity, electromagnetism, hardness, hardenability, cutting power, softness, cheapness, resistance to corrosion and radiation, and resistance to heat. The understanding of the properties of materials is, therefore, highly essential. Without this information and knowledge, the manufacturing process may be an expensive and complex task which negates the profit and utility of the end product.

The tremendous increase in available materials, coupled with demands from new application and more severe service requirement, had brought about many changes in attitudes and view points. In effect, many and diverse factors have forced a renaissance in materials. Coupled with advances in fundamental science, they have led to the development of a new technical area which is known as Science of Materials or Materials Science. The scope of the materials science is confined to the study of that part of materials which are useful to the engineer or technologist in the practice of his profession to serve the needs of modern civilization. So materials mean engineering materials and these are limited to only solid materials. There is no gainsaying that without the advancement and technological development in the use of materials, life will not be worth living as it is today. This is the essence of this lecture presentation.

. However, before going into details, further preamble into man's early use of materials is of vital importance.

HISTORY OF MATERIALS DEVELOPMENT

Materials: The Milestones of Progress(MSE)

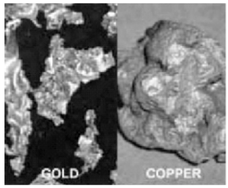
300,000 BC

Flint, the magic stone, easily shaped for tools - beginning of ceramics.

Flint: The Magic Stone

5500 BC

Native gold and copper used for tools and weapons - introduction of metals.



Native gold and copper

5000 BC

Introduction of fire and hammering of copper to change properties - introduction of materials processing.

4000 BC

Melting and casting of metals introduced - materials processing and shaping.

The earliest known metal object cast in a mold - a copper mace head.

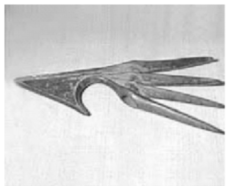
3500 BC

Reduction of copper from its ore - dawn of metallurgy.

This Egyptian tomb painting is one of the earliest records of metal working.

3000 BC

Bronze in use - combination of elements to make alloys.



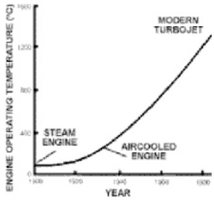
Bronze: the first alloy

1955

Polymerization catalysts discovered for polymers opened way for new range of plastics and dramatic growth in engineering utilization.

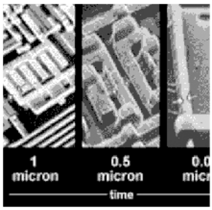
1950's

High temperature alloy development, nickel based alloy developments impact jet engine development.



1960's

Ability to grow smaller and smaller silicon wafers.



Silicon wafers get smaller

1970's

Mini-mills - emergence of new industry based upon materials processing of recycled scrap iron.

1980's

High temperature ceramic superconductors, rapid evolution coupled with ability to make the ceramic material.


High Temperature Ceramic Superconductor

The earth was created with a bountiful supply and range of raw materials to serve the needs of the human race that was to inhabit it so late in history. Until about a hundred years plus ago, man use the earth's materials as he found them; either rock or clay dug from the earth crust, or wood products from the earth's forested regions, or simply the water or air around him. The word, **materials** here do not refer to all matters that are found in the universe.

In acknowledging the importance of materials in human culture (and conceding the earlier times must have been better than the present) the Greeks posited four ages of man Gold, Silver, Bronze and Heroic before their own Iron age. For all that, materials have been pretty much taken for granted, and their diversity and adaptability has rarely been consciously considered. In a way, it was the merging of two opposing schools of Greek philosophy of matter that gave rise to the modern science of materials.

One of the great stages in man's development was the discovery that he could change the very nature of materials. It must have given early man an almost god - like feeling of control over nature as he turned clay to stone by heating it.

Ceramics is the earliest inorganic materials to be structurally modified by man. The earliest glazing technique is in many ways the most interesting. This was a Sumerian invention made famous after 4000 BC as Egyptian blue faience. The earliest use of metal followed not long after the first wide use of fire hardened clay. Metals began, as did ceramics and many other technological innovations somewhere in the region that today comprises eastern Turkey, northern Iraq and North Western Iran. Hammered copper objects in the form of dress ornaments, necklace- beads and the like are known from the eighth millennium BC. The artisans of the Old Copper Culture in the Great Lakes Region of North America (3000 1000 B.C) hammered sizable pieces of native metal into knives, spears and agricultural implements.

In the Middle East, cold hammered native metal was largely displaced around 4000 B.C by copper smelted from ores. About 3000 B.C came the bronze. For two millenniums thereafter the alloys of copper and tin dominated metallurgy in spite of the scarcity of the ores of tin. They combined ease of shaping, beauty and general serviceability better than any other metallic material. By the time bronze was discovered, elaborate methods of shaping and joining the precious metals gold and silver had appeared. Jewelry from the royal graves at Ur in

Mesopotamia (around 2600 B.C) exhibits higher standards, both aesthetic and technical, than most objects made today, and shows that their makers could reproducibly exploit most of the properties of metals that only now are being scientifically explained. It was economics rather than the inherent qualities of the metal that gave rise to the Iron Age.

The early metallurgy of iron was quite different from that of copper. Pure iron could not be melted in any furnace available prior to the 19^{th} century. Before A. D. 1400, the cast product of iron was little appreciated except in China where it was early used for making agricultural tools, stoves and minor work of art. Steel was easy to discover, but the recognition that it was an alloy was long delayed. The all important presence of carbon in steel and cast iron was not discovered until 1774, the same year the chemical role of atmospheric oxygen was discovered.

Despite the lack of knowledge of adequate heat treatment techniques, the early eastern empirical discoverers of materials did their work well. They found nearly all alloy composition that could have been made by charcoal reduction from recognizable natural minerals and that were fit for general services. The tools, guns, gadgets and cathedrals of the Middle Age, the instruments for the rise of Modern Science, the machine and structures of the 19th century engineers all were made of materials that had been known centuries before the rise of Greece. Metallurgists had been busy in the interim, increasing the scale and the economy of production and the reliability of the products, but neither they nor the user smiths felt the need for new compositions. Development much beyond the old, required new attitudes, new knowledge and new needs, all of which came together not much before the beginning of the 20th century.

The first three significant printed books on materials summarized a substantial accumulation of empirical knowledge. Vannoccio Biringuccio's **Pirotechnia** (1540) presents a comprehensive account of the operations of the foundry man and the smith in alloying and shaping materials for diverse end uses. Georguis Agricola's **De Metallica** (1556), gives superb detail on the mining of ore and smelting of ores with disproportionate emphasis on the nonferrous metals and near neglect of iron. Lazarus Ercker's book of 1574 (with the resounding title Beschreibung Allenfurnemisten Mineralischen Ertzt unnd Berkwercksarten) presents the quantitive laboratory approach of the assayer.

These three approaches to metals production, utilization and analysis have moved forward but have remained some what distinct ever since. The production of materials other than metals contributed rather little to the growth of their science. The desire of European potters to duplicate Oriental ceramics early in the 18^{th} Century, gave drive to the beginning of analytical chemistry, but thereafter the science of ceramics lagged. There has, however been substantial scientific and technological development of materials of engineering in general ever since then. For example, in September 1864, (Sorby, U.K.) exhibited a number of microscopical photographs of various kinds of steels. Further work by Marten in Germany (1878) revived Sir Sorby's interest in metallurgical problems and he summarized all his work in the field in a paper in 1887. About 1922, more knowledge of the structure and properties of metals and ceramics were added by the application of X ray diffraction and wave mechanics.

Classes of Engineering Materials

Materials may be classified in three broad groups according to their mode of occurrence. (1) Metals and Alloys, (2) Ceramics and (3) Organic Polymers. Additional generic descriptions to this classification are

(4) Composites and (5) Semiconductors.

Metals and Alloys

A **metal** is an elemental substance whilst an alloy is formed when two or more relatively pure metals are melted together to form a new metal having in many instances, properties quite different from those of the two metals used in its manufacture. Among the solid materials, metals and alloys predominate because of their useful characteristics of hardness, strength, rigidity, formability, machinabilty, weldability, conductivity and dimensional stability. They are malleable and tend to have a lustrous look when polished.

Ceramics

Ceramics are materials consisting of phases. A phase is a physically separable and chemically homogenous constituent of a material. These are themselves compounds of metallic and non metallic elements, and thus there is a multitude of materials which fall into this group. For instance, all metallic compounds such as oxides, nitrides and carbides, rocks, minerals, glass, glass fibre, abrasives and all fired clays are ceramics. Typically, they are insulating and resistant to high temperature and harsh environments.

Organic Materials or Polymers: are those materials derived from carbon. They usually consist of carbon chemically combined with hydrogen, oxygen or other non metallic substances, and their structures are in many instances fairly complex. Plastics and synthetic rubbers are common organic engineering materials. They are termed "polymers" because they are formed by polymerization reaction in which relatively single molecules are chemically combined into massive long chain molecules or "three dimensional" structures.

Composites - consist of more than one material type. Fibre-glass, a combination of glass and a polymer, is an example. Concrete and plywood are other familiar composites. Many new combinations include ceramic fibres in metal or polymer matrix.

The broad spectrums of engineering materials are listed in table I.

Semiconductors have electrical properties intermediate between metallic conductors and ceramic insulators. Also, the electrical properties are strongly dependent upon small amounts of impurities.

Table 1. Some important Grouping of Materials

S/N	Group of Materials	Common Examples
1	Metals and Alloys	Steels, aluminium, copper, brasses bronze, invar, conductors, super alloys etc.
2	Ceramics	MgO, CdS, ZnO, SiC, $BaTiO_2$, silica, soda lime –glass, concrete, cement, ferrites and garnets.
3	Organic Polymers	Plastics: PVC, PTFE, polyethylene. Fibres: terylene, nylon, cotton. Natural and Synthetic rubbers, leather, etc.
4	Composites	
(i)	Metals and alloys and ceramics:	Steel – reinforced concrete, dispersion – hardened alloys.
(ii)	Metals and alloys and organic polymers	Vinyl – coated steel, whisker – reinforced plastics.
(iii)	Ceramics and Organic polymers	Fibre – reinforced plastics, carbon – reinforced rubber.

PROPERTIES OF ENGINEEERING MATERIALS

A thorough knowledge of the particular properties of engineering materials under a wide range of conditions is very importantly needed for their practical applications. A very large range of materials are found in different classes of materials; and some of their most important properties are hereby highlighted:

Electrical: Electrical properties include: conductivity, dielectric strength, dielectric permittivity, and resistivity.

Magnetic: These include mainly permeability, coercive force and hysteresis

Mechanical: The properties here include- strength, ductility, softness, toughness, brittleness, plasticity, elasticity, castability, malleability and hardness

Chemical: The chemical properties of interest are acidity and alkalinity, corrosion resistance and composition.

Physical: These are structure, dimensions, density and porosity

Thermal: They are conductivity, thermal expansion and specific heat.

Optical: The optical properties are colour, light transmission and light reflection.

Acoustical: The acoustical properties include sound transmission and sound reflection

SRUCTURE OF MATERIALS

The structure of a material is closely related to its properties and it can be studied at different levels of observation.

The structure of material, based on the level of study observation can be classified as: (1) Macrostructure (2) Microstructure, (3) Substructure, (4) Crystal Structure, (5) Electronic Structure, and (6) Nuclear Structure.

Macrostructure: This is the structure of material as ordinarily seen or observed with our eyes or with low power magnification such as optical microscope.

Microstructure: Microstructure differs from macrostructure only in the degree of magnification needed to study them; otherwise both are two words which relate to the same general type of phenomena.

Crystal Structure: The atomic arrangement within a crystal, which indeed resembles a molecule, is indicated by the crystal structure.

Electronic Structure: The electronic structure is usually concerned with the electrons in the outer-most shells of individual atoms that make the solid.

An engineer must have sufficient knowledge to select the optimum materials for each application since he must specify the materials, for example, for TV sets, computers, suspension bridges, oil refineries, rockets motors, nuclear reactors, or supersonic transports among others- all which made of materials: metallic and non-metallic. Although experience provides the engineer with a starting point for selection of materials, the skill of the engineer will be limited unless he understands the factors which contribute to the properties of materials.

THE MATERIALS

A large variety of materials, ranging from platinum to rocks, are used by the engineer to construct bridges, automobiles, process plant equipment, pipelines, power plants, etc. An engineer must have knowledge of chemical, mechanical, physical, and other properties to assure desired performance. The properties of engineering materials depend upon their physical structure and basic chemical composition. The chemical properties (corrosion resistance) are of utmost importance for consideration.

Mechanical properties are related to behaviour under load or stress in tension, compression, or shear. Properties are determined by engineering tests under appropriate conditions. Commonly determined mechanical properties are tensile strength, yield point, elastic limit, creep strength, stress-rupture, fatigue, elongation (ductility), impact strength (toughness and brittleness) hardness, and modulus of elasticity (ratio of stress to elastic strain rigidity). These properties are helpful in determining whether or not a part can be produced in the desired shape and also assist the mechanical forces anticipated.

The other properties an engineer must consider when selecting a material include density or specific gravity, fluidity or castability; formability; thermal, electrical, optical, acoustical, magnetic properties; and resistance to atomic radiation. For example, a particular part must be castable into intricate shape, possess good heat-transfer characteristics, and not be degraded by atomic radiation. In another case, the equipment must be good insulator, reflect heat, and have low unit weight.

Incidentally, radiation sometimes enhances properties of a material; e.g. the strength of polyethylene can be increased by controlled radiation.

METALS AND ALLOYS

These are numerous and they constitute more than 85% of the materials used for engineering purposes.(Fontana;Greene) Some of these will be mentioned in turns.

Cast Iron- Cast iron is a generic term that applies to high carbon-iron alloys containing silicon. The common ones are designated as grey cast iron, white cast iron, malleable cast iron, and ductile or modular cast iron. Ordinary grey irons contain about 2 to 4% carbon and 1 to 3% silicon. These are the least expensive of the engineering metals; white cast irons have practically all of the carbon in the form of iron carbide. These irons are extremely hard and brittle. Malleable irons are produced by high-temperature heat treatment of white irons of proper composition. Ductile irons exhibit ductility in the as-cast form, other types of cast irons include high-silicon cast irons and alloy. In the former, when the silicon content is increased to over 14%, it becomes extremely corrosion resistant to many-environments.

These high-silicon irons are the most universally resistant of the commercial/non-precious) metals and alloys. These alloys are available only in cast forms for drain lines, pumps, valve and other process equipment.

Carbon Steel and Irons: In hardness and strength these steels depend largely upon their carbon content. They are used in construction, work and many other applications such as machineries, structural parts, clamps, cable bushards, nuts, safety wires, threaded nuts etc.

Low- alloy steels: Carbon steel is alloyed, singly or in combination, with chromium, nickel, copper, molybdenum, phosphorus, and vanadium in the range of a few percent or less to produce low alloy steels. The higher alloy additions are usually for better mechanical properties and hardenability. Steels with very high strengths are of particular interest for aerospace applications.

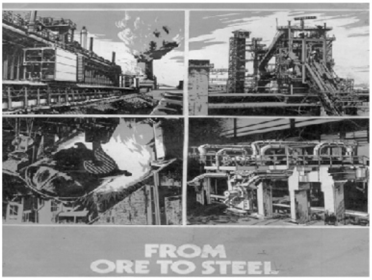
Medium Carbon Steel: is used for large parts, forging and automotive components.

High Carbon Steel is used for springs and high strength wires.

Stainless Steels: The main reason for the existence of the stainless steels is their resistance to corrosion.(IJsselling;1989) Chromium is the main alloying element, and the steel should contain at least 11%. A large number of stainless steels are available. Their corrosion resistance, mechanical properties, and cost vary over a broad range. For this reason, it is important to specify the exact stainless steel desired for a given application. There are four groups or classes of these materials: Group I materials are termed ***martensitic*** stainless steels because they can be hardened by heat treatment similar to ordinary carbon steel; Group II ***ferritic non-hardenable*** steels are so designated because they cannot be hardened by heat treatment: Group III consists of ***austenitic*** stainless steels; they are essentially nonmagnetic and cannot be hardened by heat treating equipment. They are the most widely utilized with II, I, and IV following in order.

The austenitic steels possess better corrosion resistance than the straight chromium (groups I and II) steels and generally the best resistance of any of the four groups. For this reason, austenitic steels are widely specified for the more severe corrosion conditions such as those encountered in the process industries. They are rust resistant in the atmosphere and find wide use for architectural purposes, in the kitchen, in food manufacture and dispensing, and for applications where contamination (rust) is undesirable

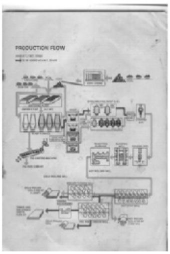
INTEGRATED IRON & STEEL PLANT



Mining: The Origin of Materials

Greenbushes mine near Perth, Western Australia, mined by Sons of Gwalia. Picture
rtesy of SOG annual report.

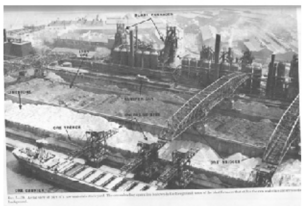
FLOW SHEET – ORE TO STEEL



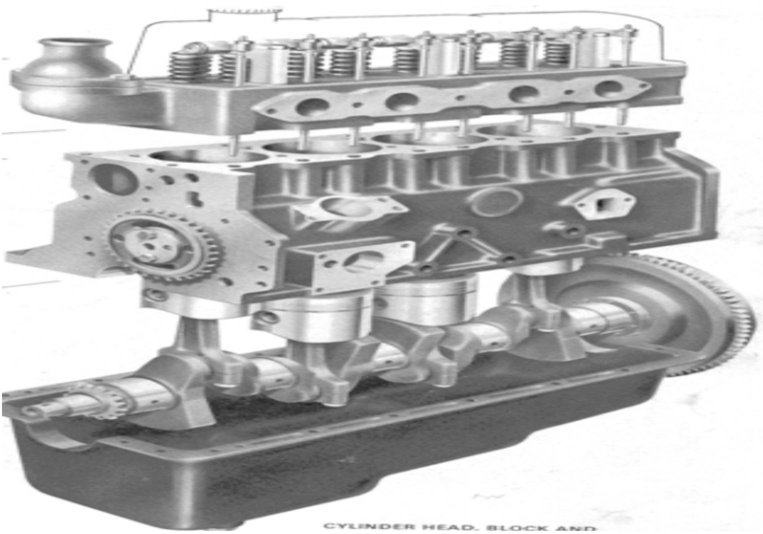
Blast Furnace & Auxilliaries

Lower Part of A Blast Furnace

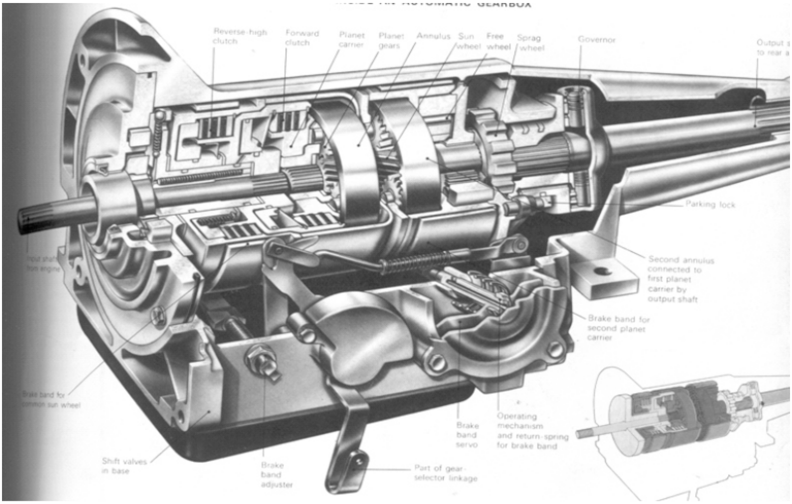
Iron & Steel Making Plant



Commercial Value of Stainless Steel: Stainless Steel's resistance to corrosion and staining, low maintenance, relative inexpensive and familiar lustre make it an ideal base material for a host of commercial applications. There are over 150 grades of stainless steel, of which fifteen are most common. The alloy is milled into sheets, plates, bars, wire, and tubing to be used in cookware, cutlery, hardware, surgical instruments, major appliances, industrial equipment, a structural alloy in automotive and aerospace assembly and building material in skyscrapers and other large buildings.



An Engine Block



Gear Component

Stainless steel is also used for jewellery and watches. The most common stainless steel alloy used for jewellery is 316L. It can be re-finished by any jeweller and unlike silver will not oxidize and turn black.

Stainless steel is 100% recyclable. In fact, an average stainless steel object is composed of about 60% recycled material, 25% originating from end-of-life products and 35% coming from manufacturing processes (a)

Aluminium and its Alloys: Aluminium is a reactive metal, but it develops an aluminium oxide coating or film that protects it from corrosion in many environments. In addition to corrosion resistance, other properties contributing to its widespread application are colourless and non toxic corrosion products, appearance, electrical and thermal conductivity, reflectivity, and lightness or good strength weight ratio. The high-copper alloys are utilized mainly for structural purposes. The copper-free or low copper alloys are used in the process industries or where better corrosion resistance is required. Pure aluminium is soft and weak, but it can be alloyed and heat-treated to a broad range of mechanical properties. A list of typical uses for the wrought Al Cu alloys is:

2011: Wire, rod and bar for screw machine products. It used in applications where good machinability and good strength are required.

2014: Heavy duty forgings, plate, and extrusions for aircraft fittings, wheels, and major structural components, space booster tankage and structure, truck frame and suspension components. It used in applications requiring high strength and hardness including service at elevated temperatures.

2024: Aircraft structures, rivet, hardware, truck wheels, screw machine products, and other miscellaneous structural applications. The first age-hardened alloy ever discovered.

2036: Sheet for auto body panels.

2048: Sheet and plate in structural components for aerospace application and military equipment.

2141: Plate in thickness of 40 to 150 mm (1.5 to 6.0 in.) for aircraft structures.

2218: Forgings; aircraft and diesel engine pistons; aircraft engine cylinder heads; jet engine impellers and compressor rings.

2219: Welded space booster oxidizer and fuel tanks, supersonic aircraft skin and structure components. Readily weldable and useful for applications over temperature range of - 270 to 300°C. Have high fracture toughness, and the T8 temper is highly resistant to stress-corrosion cracking.

2618: Die and hand forgings. Pistons and rotating aircraft engine parts for operation at elevated temperatures. Tyre moulds.

Al Cu alloy number 7075 (Al- 1.6% Cu 0.5 Si-0.30Mn-2.5Mg 0.3cr-5.6Zn-0.7Fe 0.20Ti is a high-strength alloy that is used in ship construction. Number 7178-Al with 2%

Cu and 6.8%Zn among others, is one of the highest strength heat-treatable alloys utilized in aircraft and aerospace applications. Aluminium alloys loose strength rapidly when exposed to temperatures of about 250°C and higher. Aluminium shows excellent mechanical properties at cryogenic temperatures because it is a face-centered cubic material.

Copper and its Alloys: Copper is different from most metals in that it combines corrosion resistance with high electrical and heat conductivity, formability, machinability, and strength when alloyed, except for high temperatures. Copper exhibits good resistance to urban, marine, and industrial atmospheres and waters.

In strongly reducing conditions at high temperatures (300 to 400°C), copper alloys are often superior to stainless steels and stainless alloys. Hundreds of compositions with a wide variety of mechanical properties are commercially available. The most common alloys are brasses (Cu-Zn), bronzes (Sn, Al, or Si additions to Cu) and cupronickels (Cu-Ni). Copper and copper alloys are available as duplex tubing (inside one metal, outside another) in combinations with steel, aluminium, and stainless steels. This construction solves much heat - exchanger materials problems. Copper and its alloys find extensive application as water piping, valves, heat exchanger tubes and tube sheets, hardware, wire, screens, shafts, roofing, bearings, stills, tanks, and other vessels.

Magnesium and its Alloys: Magnesium is one of the lightest commercial metals, S.G. 1.74. It is utilized in trucks, automobile engines, ladders, portable saws, luggage, aircraft, and missiles because of its light weight and also good strength when alloyed. However, it is one of the least corrosion resistant and is accordingly used as sacrificial anodes for cathodic protection and dry-cell batteries. It is generally anodic to most other metals and alloys and must be insulated from them.

Titanium alloys: are metallic materials which contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and toughness (even at extreme temperatures), light weight, extraordinary corrosion resistance, and ability to withstand extreme temperatures. However, the high cost of both raw materials and processing limit their ***use to military applications, aircraft, spacecraft, medical devices, chemicals and petrochemicals, automotive, agri-food, desalination plants, and some premium sports***

equipment and consumer electronics.

Although "commercially pure" titanium has acceptable mechanical properties and has been used for orthopaedic and dental implants, for most applications titanium is alloyed with small amounts of aluminium and vanadium, typically 3% and 2.5% respectively, by weight.

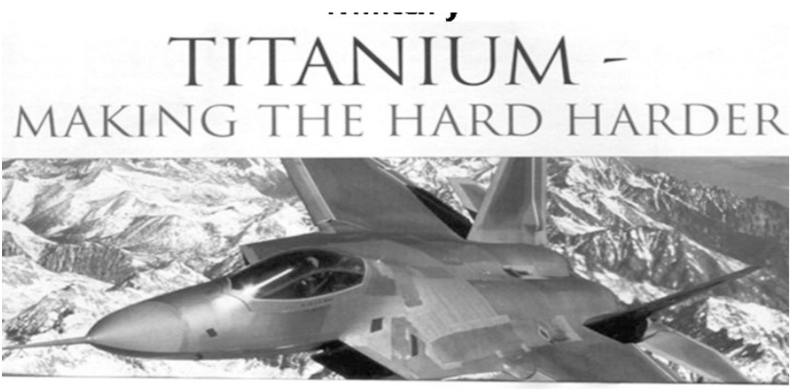
Titanium dioxide dissolves in the metal at high temperatures, and its formation is very energetic. These two factors mean that all titanium except the most carefully purified has a significant amount of dissolved oxygen, and so may be considered a Ti-O alloy.

Nitinol, a shape memory alloy, is a mixture of titanium and nickel, while niobium titanium alloys are used as wires for superconducting magnets.

Applications

Titanium is used in steel as an alloying element (ferro-titanium) to reduce grain size and as a deoxidizer, and in stainless steel to reduce carbon content.(Titanium)Titanium is often alloyed with aluminium (to refine grain size), vanadium, copper (to harden), iron, manganese, molybdenum, and with other metals. Applications for titanium mill products (sheet, plate, bar, wire, forgings, castings) can be found in industrial, aerospace, recreational and emerging markets. ***Powdered titanium is used in pyrotechnics as a source of bright burning particles.***

An Aeroplane



Military Aircraft (with titanium Component)

Pigments, Additives and Coatings

About 95% of titanium ore extracted from the Earth is destined for refinement into titanium dioxide (TiO_2), an intensely ***white permanent pigment used in paints, paper, toothpaste, and plastics. It is also used in cement, in gemstones, as an optical opacifier in paper, and a strengthening agent in graphite composite fishing rods and golf clubs.***

TiO_2 powder is chemically inert, resists fading in sunlight, and is very opaque: this allows it to impart a pure and brilliant white colour to the brown or gray chemicals that form the majority of household plastics. In nature, this compound is found in the minerals anatase, brookite, and rutile. Paint made with titanium dioxide does well in severe temperatures, is somewhat self-cleaning, and stands up to marine environments. Pure titanium dioxide has a very high index of refraction and an optical dispersion.

Recently, it has been put to use ***in air purifiers (as a filter coating) or in film used to coat windows on buildings which when exposed to UV (either solar or man-made) and*** moisture in the air produces reactive redox species like hydroxyl radicals that can purify the air or keep window surfaces clean.

Aerospace and Marine

Because of their high tensile strength to density ratio, high corrosion resistance and ability to withstand moderately high temperatures without creeping, titanium alloys are used in ***aircraft, armour plating, naval ships, spacecraft and missiles***. For these applications titanium alloyed with aluminium, vanadium and other elements is used for a variety of components including critical structural parts, fire walls, landing gear, exhaust ducts (helicopters) and hydraulic systems. In fact, about two thirds of all titanium metal produced is used in ***aircraft engines and frames***. The SR-71 "Blackbird" was the first aircraft to make extensive use of titanium within its structure, paving the way for its use in modern fighter and commercial aircraft. An estimated 58 tons are used in the Boeing 777, 43 in the 747, 18 in the 737; 24 in the Airbus A340, 17 in the A330 and 12 in the A320. The A380 may use 77 tons, including about 11 tons in the engines. ***In engine applications, titanium is used for rotors, compressor blades, hydraulic system components and nacelles. The titanium 6AL-4V alloy accounts for almost 50% of all alloys used in aircraft applications.***

Due to its high corrosion resistance to sea water, titanium is used to make ***propeller shafts and rigging and in the heat exchangers of desalination plants, in heater-chillers for salt water aquariums, fishing line and leader and for divers' knives.***

Titanium is used to manufacture the housings and other components of ocean-deployed surveillance and monitoring devices for scientific and military use.

Industrial

Welded titanium pipe and process equipment (heat exchangers, tanks, process vessels, valves) are used in the chemical and petrochemical industries primarily for corrosion resistance or combination of both. The pulp and paper industry uses titanium in process equipment exposed to corrosive media such as sodium hypochlorite or wet chlorine gas (in the bleachery). Other applications include: ultrasonic welding, wave soldering, and sputtering targets.

Consumer and Architectural

Titanium metal: is used in automotive applications, particularly in automobile or motorcycle racing, where weight reduction is critical while maintaining high strength and rigidity. The metal is generally too expensive to make it marketable to the general consumer market, other than high end products. Late model corvettes have been available with titanium exhausts, and racing bikes are frequently outfitted with titanium mufflers. Other automotive uses include piston rods and hardware (bolts, nuts, etc.).

The Parker Pen Company used titanium to form the T-1 fountain pen later expanded to T-1 ball pens and roller balls before it was discontinued in 1972 due to high cost of manufacturing. The T-I fountain pen was introduced in 1970 and the T-I roller ball and ball pen in 1971 before it was discontinued in 1972 due to high cost of manufacturing

Titanium is used in many sporting goods; tennis rackets, golf clubs, lacrosse stick shafts; cricket, hockey, lacrosse, and football helmet grills, and bicycle frames and components. Titanium alloys are also used in spectacle frames. This results in a rather expensive, but highly durable and long lasting frame which is light in weight and causes no skin allergies. Many backpackers use titanium equipment, including cookware, eating utensils, lanterns and tent stakes. Though slightly more expensive than traditional steel or aluminium alternatives, these titanium products can be significantly lighter without compromising strength.

Titanium is also favoured for use by farriers, since it is lighter and more durable than steel when formed into horseshoes. ***Titanium horseshoes can be found in horse racing, and are used by many Amish horse owners, who rely entirely on horse-drawn carriages for transportation. Titanium has even become somewhat popular for use in jewellery, such as rings.***

Titanium has occasionally been used in ***architectural applications***: the 120 foot (50m) memorial to Yuri Gagarin, the first man to travel in space, in Moscow, is made of titanium for the metal's attractive color and association with rocketry. The Guggenheim Museum Bilbao and the Cerritos Millennium Library were the first buildings in Europe and North America, respectively, to be sheathed in titanium panels. Other construction uses of titanium sheathing include the Frederic C.Hamilton Building in Denver, Colorado.

Due to its superior strength and light weight when compared to other metals traditionally used in firearms (steel, stainless steel, and aluminium), and advances in metal-working techniques, the use of titanium has become more widespread in the manufacture of firearms.

Primary uses include pistol frames and revolver cylinders.

Medical

Because it is biocompatible (non-toxic and is not rejected by the body), titanium is used in a gamut of medical applications including surgical implements and implants, such as hip balls and sockets (joint replacement) that can stay in place for up to 20 years. Titanium has the inherent property to osseointegrate, enabling use in dental implants that can remain in place for over 30 years. This property is also useful for orthopaedic implant applications.

Since titanium is non-ferromagnetic, patients with titanium implants can be safely examined with magnetic resonance imaging (convenient for long-term implants). Preparing titanium for implantation in the body involves subjecting it to a high-temperature plasma arc which removes the surface atoms, exposing fresh titanium that is instantly oxidized. ***Titanium is also used for the surgical instruments used in image-guided surgery, as well as wheelchairs, crutches, and other product where high strength and low weight are important***.

Its inertness and ability to be attractively coloured makes it a popular metal for use in body piercing. Titanium may be anodized to produce various colours. A number of artists work with titanium to produce artworks such as sculptures, decorative objects and furniture.

Jewellery

Because of its durability, titanium has become more popular for designer jewellery in recent years, whereas until recently the metal was too difficult to work into the intricate shapes with the precision necessary for fine jewellery. Today, titanium rings- including engagement rings and wedding bandsare one of the fastest growing segments of the titanium jewellery market, in part due to the ability of the metal to be grooved, inlaid, and carved without losing strength. Some titanium jewellery also incorporates diamonds or other gemstones, typically in close settings such as bezels, flush, or tension designs.

Compounds: The + 4 oxidation state dominates in titanium chemistry, but compounds in the + 3 oxidation state are also common. Because of this high oxidation state, many titanium compounds have a high degree of covalent bonding.

Star sapphires and rubies get their asterism form the titanium dioxide impurities present in them. Titanates are compounds made with tinanium dioxide.Barium titanate have piezoelectric properties, thus making it possible to use it as a transducer in the reaction of alcohols and titanium tetrachloride and are used to waterproof fabrics.

Titanium nitride (TiN) is often used to coat cutting tools, such as drill bits. It also finds use as a gold-coloured decorative finish and as a barrier metal in semiconductor fabrication.

Titanium tetrachloride (titanium (IV) chloride, TiCI, sometimes called “Tickle”) is used as an intermediate in the manufacture of titanium dioxide for paint. It is widely used in organic chemistry as a Lewis acid, for example in the Mukaiyama aldol condensation. Titanium also forms a lower chloride, titanium (III) chloride (TiCI3), which is used as a reducing agent.

Titanocene dichloride is an important catalyst for carbon carbon bond formation. Titanium isopropoxide is used for Sharpless epoxidation. Other compounds include; titanium bromide (used in metallurgy, super alloys, and high-temperature electrical wiring and coatings) and titanium carbide (found in high-temperature cutting tools and coatings).

Nickel and its Alloys: These alloys include Hastelloy B, C, D &F: Monel 400, Inconel 600, Nickel 200 Cast Nickel 210 and Duranickel 301, Chlorimet 2, Ni-o-nel 825, Nichrome, k Monel and "S" Monel. The nickel (base metal) is alloy with carbon raging from 0.03 to 0.15 and with various percent of Cr (15 22.5%) Mo (3-28%), Cu (0.5-30), Fe and others. Nickel content ranges form 72-99.5%. Nickel forms a good base for alloys requiring strength at high temperatures. The alloys are an important group of materials for corrosion applications. Nickels generally show good resistance to neutral and slightly acid solutions. It is widely used in the food industry. Most corrosion problems involving caustic solutions are handled with nickel.

Tin and Tin Plate: Tin cans are used for food products, beverages, petroleum products, and paints. Alloys of tin with zinc, nickel, cadmium, or copper can be deposited as electroplates. Tin shows excellent resistance to relatively pure water. Solid tin pipe and sheet and also tinned copper are utilized for producing and handling distilled water. Collapsible tubes are used for dentifrices and medicants. Tin foil is well known for wrapping material but has lost most of this market due to cheaper plastic films. Solders are another important outlet for thin. Tin and lead contents vary from 30 to 70%. Tin babbits are used for bearings. Pewter, an important tin alloy, is used for pitchers, flowers vases, and other containers. Tin bronzes are widely used in engineering applications. Zinc and its alloys and Lead and its alloy are equally significantly important in engineering

Noble Metals: These materials are characterized by highly positive potentials relative to the hydrogen electrode, excellent corrosion resistance, unstable oxides (do not oxidize), and high cost. The latter accounts for the term precious metals. In most cases formation of protective films (passivity) is not required. The noble metals are gold, silver, platinum, and the other five "platinum" metals, iridium, osmium, palladium, rhodium, and ruthenium. Gold, silver, platinum, and palladium are available in most commercial forms; the first three are used extensively in industry. The other noble metals are utilized chiefly as alloying elements, for example, Pt-Rh thermocouple wire. The use of noble metals for jewelry is well known. In spite of their high cost, the noble metals are the most economical for numerous corrosion applications. Their high scrap value is an advantageous characteristic. Cladding (veneer), linings, and coatings with inexpensive substrates providing strength are common combinations.

GOLD: Gold is one of the oldest metals utilized by man because it is found in nature in the pure state. Jewelry and coinage represent its first applications with jewelry accounting for most of its consumption today. In these cases, gold is alloyed with copper because of the extreme softness of pure gold. Gold coins are rare. A karat is 1/24 part, so fine or pure gold is 24 karats. Twelve karat would be 50% gold. In addition, gold and its alloys are used for dental inlays, electrical contacts, plating, tableware, process equipment (e.g, condensers and stills), printed circuits, gold leaf in surgery and body implants, and decorative purposes. A thin gold underplate (topped with cadmium) prevents hydrogen embrittlement of high-strength steels. Gold leaf and foil are readily produced because of the softness and excellent malleability of pure gold.

Gold is very good in dilute nitric acid and hot strong sulphuric acid. It is attacked by aqua regia, concentrated nitric acid, chlorine and bromine, mercury, and alkaline cyanides.

PLATINUM: Because it is resistant to many oxidizing environments and particularly air at high temperatures, platinum is utilized for thermocouples (Pt-PtRh), tanks and spinnerets for molten glass, crucibles for chemical analytical work, windings for electrical resistance furnaces (alloys up to 1882^{0}C) and combustion or reaction chambers for extremely corrosive environments at temperatures over 1059^{o}C. Sheet linings on a "base" alloy substrate are used for the latter. An applied oxide layer (e.g., $A1_2O_3$) prevents alloying or reaction with the substrate material. It has replaced fused quartz in several chemical applications of this type. Incidentally contact with silica at very high temperatures embrittles the platinum. The inertness of platinum is attested by its extensive service as catalyst. Other uses for platinum and its alloys are spinnerets (70 Au, 30 Pt) for rayon, safety or frangible disks up to 530^{o}C (Silver is good only up to 176^{o}C gold to 95^{o}C). Sulfuric acid absorbers, electroplating anodes, impressed-current anodes for cathodic protection, other chemical equipment, and high-quality jewelry. It is not attacked by mercury.

Platinum exhibits good mechanical properties at high temperatures. Gold and silver are poor in this respect. Platinum is attacked by aqua regia, hydriodic and hydrobromic acids, ferric chloride, and chlorine and bromine. Aqua regia is 1:3 mixtures of hydrochloric acid and nitric acid that can dissolve gold or platinum.

SILVER: Silver is best known for its use as coinage and tableware, in solid and plated form. Sterling silver contains not more than 7.5% copper for hardness. Silver loses its

Metal	Melting Point
Columbium (Niobium)	2468
Molybdenum	2610
Tantalum	2996
Tungsten	3410
Zirconium	1852
Iron (for comparison)	1536

Molybdenum: Molybdenum shows good resistance to hydrofluoric, hydrochloric, hydrochloric, and sulfuric acids, but oxidizing agents such as nitric acid cause rapid attack. It is good in aqueous alkaline solutions. This metal forms a volatile oxide (MoO_3) in air at temperatures above about 722°C. One great advantage of molybdenum from the mechanical standpoint is its high modulus of elasticity. This means it is stiffer and will deflect much less than steel under a given load and cross section.

Tantalum: Because of its superior resistance to most environments tantalum has been used for many years. A few exceptions include alkalies, hydrofluoric acid, and hot concentrated sulfuric acid. It is used in handling chemically pure solutions such as hydrochloric acid. Because of tantalum's wide spectrum of corrosion resistance it is utilized in repair of glass-lined equipment. Tantalum sheet is strong, so cost is reduced through the use of sections. Tantalum is used for surgical implants.

Tungsten: Tungsten has the highest melting point of any metal. Its chief use involves strength at high temperatures. A common example is filaments in light bulbs.

Zirconium: With the advent of the Atomic Age zirconium has found increased use primarily because it has a very low thermal neutron cross section and resists high-temperature water and steam. Its excellent corrosion resistance is due to a protective oxide film. Zirconium has found some application in hydrochloric acid service. Zirconium alloyed with small amounts of tin, iron, chromium, and nickel (zircalloys) shows improved resistance to high-temperature water.

METALLIC ALLOYS: SUMMARY

Alloys have many applications. Alloys based on tin, cadmium, copper, or silver are used to make bearings which reduce friction between two sliding surfaces. Dental fillings can be made from alloys of silver and mercury or alloys of gold, silver, and copper. Stainless steels, iron alloys with more than 12% chromium, are examples of corrosion resistant alloys. Other alloys, such as Nichrome, a nickel based alloy with 12-15% chromium and 25% iron, are very strong at high temperatures. They are used in power-generating plants, jet engines, and gas turbines***. Light weight alloys, like the aluminum, zinc, and magnesium system, are used in aircraft***. Some alloys, like soldier, which is usually 60% tin and 40% lead, are used to make electrical circuits***. Prosthetic devices, like artificial knees and hips, are made from high-strength, corrosion-resistant alloys that are usually based on iron, cobalt, or titanium.*** Alloys can also be superconductors, which are materials that have zero resistance to the flow of electrical current at low temperatures. One alloy of Niobium and Titanium becomes superconducting at 263°C. Alloys of precious metals, like gold, silver, and platinum, are used as coins, catalysts for chemical reactions, electrical devices, temperature sensing devices, and jewelry. Yellow gold contains gold, silver, and copper in a 2:1:1: ratio. Some iron-based alloys like Alnico-4, which is 55% iron, 28% nickel, 12% aluminum, and 5% cobalt, are used as magnets. Many other applications exist for the over 10 thousand different types of alloys that have been developed.

POLYMERS

A polymer is a substance composed of molecules with large molecular mass composed of repeating structural units, or molecules, connected by covalent chemical bonds.Well known examples of polymers include plastics and DNA.

While the term polymer in popular usage suggests “plastic”, polymers comprise a large class of natural and synthetic materials with a variety of properties and purposes. Natural polymer materials such as shellac and amber have been in use for centuries. Paper is manufactured from cellulose, a naturally occurring polysaccharide found in plants. Biopolymers such as proteins and nucleic acids play important roles in biological processes.

Historical Development

Historically, the term polymer was coined in 1833 by Jons Jacob Berzelius. Around the same time Bracconnot did pioneering work in derivative cellulose compounds, perhaps the earliest important work in polymer science. The development of vulcanization later, in the nineteenth century improved the durability of natural polymer rubber, signifying the first popularized semi-synthetic polymer. The first wholly synthetic polymer, Bakelite, was introduced in 1909. Despite significant advances in synthesis and characterization of polymers, a proper understanding of polymer molecular structure did not come until the 1920's. Further work by Herman in 1922 that polymers consisted of long chains of atoms held together by covalent bonds earned him the Nobel Prize. In 1963, the Italian chemist Giulio Natta and Karl Ziegler won the Nobel Prize in chemistry for the development of the Ziegler- Natta catalyst. In the intervening century, synthetic polymer materials such as Nylon, polyethylene, Teflon, and silicone formed the basis for a burgeoning polymer industry.

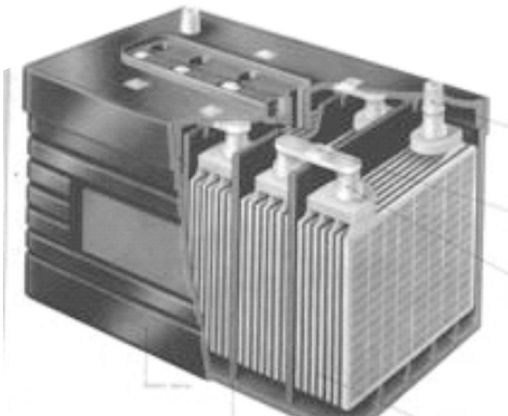
Application.

Synthetic polymers today find application in nearly every industry and area of life. Polymers are widely ***used as adhesives and lubricants, as well as structural components for products ranging from children's toys to aircraft***. Polymers such as poly (methyl methacrylate) find ***application as photo-resist materials used in semiconductor manufacturing and low-k dielectrics for use in high-performance microprocessors.*** The areas of use of polymers are far too numerous to list here. ***The structural components where polymers are used also include briefly computers and accessories, cars, telecommunications, buildings, petrochemical plants, electrical wires insulation, pipes, tyres, etc. Future applications include flexible polymer- based substrates for electronic displays and improved time-released and targeted drug delivery. Other products include pumps, billiard balls, valves, hosiery, fans, nosecones, telephones, radio cabinet, bushings, insulators, drawer rollers, waxes, pot handles, heart valves, and other body implants. They are available as solid parts, linings, coatings, foams, fibers and films.***

Industry

Today there are primarily six commodity polymers in use,

A Tyre



A Battery

Thermoplastics

Fluorocarbons. These are the `noble metals' of the plastics in that they are corrosion resistant to practically all environments. They consist of carbon and fluorine. Polytetra fluroethylene was the first one produced by and designated Teflon. Ordinary greases are attacked by many environments. They are used as gasket.

Acrylics: Methyl methacrylate (Lucite and Plexiglas) is the best known of this group. It is used for brush and purse handles, transparent displays, working models, airplane canopies, and taillights. It is pretty, and transmits and conducts light. The acrylics are soft, easily scratched, and not very temperature resistant.

Nylon: This material is best known as hosiery, but also finds much use for strictly corrosion-resistant applications. Its main applications depend on strength, low coefficient of friction, and wear resistance***. These are gears, drawer and shelf rollers, fishline, sutures, tennis-racker strings, dentures, automobile door catches, and brush bristles. It is also utilized for electrical insulation which permits higher temperature operation than rubber. It is used in the manufacture of nylon.***

Chlorinated Polyether: Penton, a chlorinated polyether, is one of the newer plastics; it is widely used for handling corrosives, including aggressive environments. Solid parts such as valve and pipe and also linings and coatings are available. Coatings can be applied by the fluidized-bed process up to 40 mils thick.

Polyethylene: Alathon, Aeroflex, Polythene and other polyethylene materials represent the largest production of the plastics and are marketed by many producers. ***They are used for packaging film, sheet, squeeze bottles, pans tumblers, ice trays, and many other household items. Piping for water and other chemicals is common.*** Certain solvents produce stress-corrosion cracking of polyethylene.

Polypropylene: Polystyrene (Styron, Lustrex) ***is used for wall tile, battery cases, flow meters, radio cabinets, bottle closures, and refrigeration equipment***. It possesses good chemical resistance but is too brittle for many structural applications. Polystyrene shows good resistance to hydrofluoric acid.

Rigid Polyvinyl Chloride (PVC): This material is basically rigid but can be softened by additions of polyvinyl acetate and plasticizers to vary mechanical properties.

PVC is used for pipe and fittings, ducts, fans, sheet, containers, and linings.

Vinyls: Tygon, Vinylite, Plioflex, Saran, and other vinyl's are well known and versatile group materials. Most of them are copolymers of vinyl chloride and vinyl acetate. ***Some uses are pipe and rubbing, packaging film, floor tile, fibers, phonograph records, raincoats, garden hose, and insulation. Laboratory tubing is a common example.*** They can be joined by heat-sealing, fusion-welding, and adhesives.

Thermosetters

Epoxies: Epon, Durcon, Araldite, and other epoxies represent perhaps the best combination of corrosion resistance and mechanical properties. ***Epoxies are available as castings, extrusions, sheet, adhesives, and coatings. They are used as sinks, bench tops, pipe, valves, pumps, small tanks, potting compounds, adhesives, linings, protective coatings, dies for forming metal, printed circuits insulation, and containers.***

Phenolics: Phenolic materials (Bakelite, Durez, Resinox) are among the earliest and best known plastics. They are mostly based on phenol formaldehyde. Bakelite was developed by Leo Backeland shortly after the turn of the century. ***Applications include radio cabinets, telephones, electrical sockets and plugs, pumps, valves, trays, auto distributors, rollers, and coatings.***

Polyesters: Polyester plastics (Mylar, Dacron, Dypol, and Vibrin) are best known to the general public for their use in the "space mirror" satellite (Echo). The satellite was made of thin, reflective Mylar film. Corrosion resistance of the polyesters compares unfavorably with many other plastics. One of the main uses of polyesters involves reinforced material. A popular application is luggage. The body of the Corvette automobile is made of fiber-glass-reinforced polyester.

Silicones: Silicones offer outstanding heat resistance. Mechanical properties change little with variations in temperature. These plastics differ from most plastics in that an important ingredient is inorganic silicon. ***Silicones are used for molding compounds, laminating resins, and insulation for electric motors and electronic equipment***. Resistance to attack by chemicals is not outstanding.

Ureas: Ureas (Lauxite, Beetle, and Avisco) were the second important class, after the phenolics, of the thermosetting resins to be developed. They are based on urea and formaldehyde. Corrosion resistance is not good. ***Uses include kitchen dishware and utensils, electrical fixtures, radio cabinets, closures, and adhesives (e.g. bonding plywood).***

Laminates and Reinforced Plastic: These materials usually consist of thermosetting resins "filled" or laminated with cloth, mats, paper, chopped fabrics or fibers such as fiber glass, which is commonly used, has high tensile strength. This results in a high strength weight ratio for these light materials. ***Availability and uses include tanks, pipe, ducts, sheets, and rod, car bodies (Corvette), boats, and missile and satellite parts***.

Polymer Synthesis

Polymers are synthesized by three primary methods: organic synthesis in a laboratory or factory, biological synthesis in living cells and organisms, or by chemical modification of naturally occurring polymers.

Organic Synthesis: In 1907, Leo Baekeland created the first completely synthetic polymer, *Bakelite*, by reacting phenol and formaldehyde at precise controlled temperature and pressure. Subsequent work by Wallace

Carothers in the 1920's demonstrated that polymers could be synthesized rationally from their constituents' monomers. Most commercially important polymers today are entirely synthetic and produced in high volume, on appropriately sealed organic synthetic techniques. Laboratory synthetic methods are done by condensation polymerization and addition polymerization. A newer method which can also be used is plasma polymerization. Synthetic polymerization reactions may be carried out with or without a catalyst. An area of intense research is the efforts towards rational synthesis of biopolymers via laboratory synthetic methods, especially artificial synthesis of protein.

Biological Synthesis: Natural polymers and biopolymers formed in living cells may be synthesized by enzyme-mediated processes such as the formation of DNA catalyzed by DNA polymerase.

Modification of Natural Polymers: Many commercially important polymers are synthesized by chemical modification of naturally occurring polymers. Prominent examples include the reaction formation of vulcanized rubber by heating natural rubber in the presence of sulphur.

Polymer Structure / Property relationships: Polymer bulk properties (tensile strength and Young's Modulus of elasticity) are strongly dependent upon their structure and mesoscopic behaviour. A number of qualitative relationships between structure and properties are known. Some of these are:

Chain Length: Increasing chain length tends to decrease chain mobility, increase strength and toughness, and increase the glass transition temperature (Tg). This is a result of the increase in chain interactions such as Van der Waals attractions and entanglements that come with increased chain length.

Branching: Branching of polymer chains also affect the bulk properties of polymers. Long chain branches may increase polymer strength, toughness, and TG due to an increase in the number of entanglements per chain

Chemical Cross- linking. Cross linking tends to increase Tg and increase strength and toughness. Cross linking consists of the formation of chemical bonds between chains. Among other applications, this process is used to strengthen rubbers in a process known as Vulcanization which is based on cross linking by sulphur. Car tyres, for example, are highly cross linked in order to reduce the leaking of air out of the tyre and to toughen the tyres durability. Eraser rubber, on the other hand, is not cross-linked to allow flaking of the rubber and prevent damage to the paper.

CERAMICS

The word ceramic is derived form the Greek word (keramikos). The term covers inorganic non-metallic materials whose formation is due to the action of heat. Ceramic materials consist of compounds of metallic and nonmetallic elements.(Ceramics).A simple example is MgO or magnesia. Other ceramics include brick, stone, fused silica, stoneware, glass, clay tile, porcelain, concrete, abrasives, mortars, and high-temperature refractories. In general, compared with metals, ceramics resist higher temperatures, have better corrosion and abrasion resistance, including erosion-corrosion resistance, and are better insulators; but the ceramics are brittle, weaker in tension, and subject to thermal shock. Most ceramic materials exhibit good resistance to chemicals, with the main exceptions of hydrofluoric acid and caustic. Parts are formed by pressing, extrusion, or slip-casting.

Types of Ceramic Materials

For convenience ceramic products are usually divided into four sectors, and these are shown below with some examples:

Structural, including bricks, pipes, floor and roof tiles.

Refractories, such as kiln linings, gas fire radiant, steel and glass making crucibles.

White wares, including tableware, wall tiles, decorative art objects and sanitary ware.

Technical, is also known as Engineering, Advanced, Special, and in Japan, Fine Ceramics. Such items include tiles used in the Space Shuttle program, gas burner nozzles, ballistic protection, nuclear fuel uranium oxide pellets, biomedical implants, jet engine turbine blades, and missile nose cones. Frequently the raw materials do not include clays.

Examples of structural ceramics products

? Construction bricks

? Floor and roof tiles, Wall tiles

? Sewage pipes, Paving bricks, Terra-cottas

Examples of white ware ceramics

? Bone china

? Earthenware, which is often made from clay, quartz and feldspar

? Porcelain, which are often made from kaolin

? Stoneware.

Technical ceramics can also be classified into three distinct material categories:

? ***Oxides***: Alumina, Zirconia

? ***Non-Oxides***: Carbides, borides, nitrides, silicides

? ***Composites***: Particulate reinforced combinations of oxides and non-oxides.

Each one of these classes can develop unique material properties.

Examples of technical ceramics

? Barium titanate (often mixed with strontium titanate) displays Ferro-electricity, meaning that it's mechanical, electrical, and thermal responses are coupled to one another and also history-dependent. It is widely used in electromechanical transducers, ceramic capacitors, and data storage elementsBismuth strontium calcium copper oxide, a high-temperature superconductor

? Boron carbide (B_4C) which is used in ceramic plates in some personnel, helicopter and tank armor.

? Boron nitride is structurally isoelectronic to carbon and takes on similar physical forms: a graphite-like one used as a lubricant, and a diamond-like one used as an abrasive.

? Ferrite (Fe_3O_4), which is ferromagnetic and is used in the magnetic cores of electrical transformers and magnetic core memory.

? Lead zirconate titanate is another ferroelectric material

? Magnesium diboride (MgB_2), which is an unconventional superconductor.

? Sialons/Silicon Aluminium Oxynitrides, high strength, high thermal shock/chemical/wear resistance, low density ceramics used in non-ferrous molten metal handling, weld pin and the chemical industry.

? Silicon carbide (SiC), which is used as a susceptor in microwave furnaces, a commonly used abrasive, and as a refractory material.

? Silicon nitride (Si_3N_4), which is used as an abrasive powder.

? Steatite is used as an electrical insulator

? Uranium oxide (UO_2), used as fuel in nuclear reactors.

? Yttrium barium copper oxide ($YBa_2Cu_3O_7$), another high temperature superconductor.

? Zinc oxide (ZnO), which is a semiconductor, and used in the construction of varistors.

? Zirconnium dioxide (zirconia), which in pure form undergoes many phase changes between room temperature and practical sintering temperatures, can be chemically "stabilized" in several different forms. Its high oxygen ion conductivity recommends it for use in fuel cells. In another variant, metastable structures can impact transformation toughening for mechanical applications; most ceramic knife blades are made of this material.

Some Specific Uses

ACIDBRICK: This material is made from fireclay with a silica content about 10% greater than ordinary firebrick. A common application is lining of tanks and other vessels to resist corrosion by hot acids or erosion corrosion by hot acids or erosion corrosion. A brick-lined steel tank usually contains an intermediate lining of lead, rubber, or a plastic.

Acid-resistant cements and mortars join the brick.

STONEWARE AND PORCELAIN**:** Porcelain parts are usually smaller in size than stoneware, and the porcelain is less porous. Both can be glazed for easy cleaning. They show good tensile strengths***. Stoneware sinks, crocks, and other vessels, absorption towers, pipes, valves, and pumps are available. Porcelain can be made into similar equipment (e.g., acid nozzles) and is widely used as insulators and spark plugs***

STRUCTURAL CLAY: These clay products include building, fire, sewer, and paving brick, terra-cottas, pipe, and roofing and wall tile.

GLASS: Glass is an amorphous inorganic oxide, mostly silica, cooled to a rigid condition without crystallization. ***Glass laboratory ware, such as Pyrex, and containers are well known. Piping and pumps are available. Transparency is utilized for equipment such as flow meters. Glass fibers are widely used for air filters, insulation, and reinforced plastics.***

VITREOUS SILICA: This material, also called fused quartz (almost pure silica) has better thermal properties than most ceramics and excellent corrosion resistance at high temperatures***. It is used for furnace muffles,***

burners, reaction chambers, absorbers, piping, etc, particularly where contamination of product is undesirable.

CONCRETE: Tanks and pipes made of concrete are well-known for handling mid corrosives. If aggressive environments are involved, the concrete is protected by coatings or linings.

Properties of Ceramics

Mechanical properties: Ceramic materials are usually ionic or covalently-bonded materials, and can be crystalline or amorphous. A material held together by either type of bond will tend to fracture before any plastic deformation takes place, which results in poor toughness in these materials. Additionally, because these materials tend to be porous, the pores and other microscopic imperfections act as stress concentrators, decreasing the toughness further, and reducing the tensile strength. These combine to give catastrophic failures, as opposed to the normally much more gentle failure modes of metals.

Electrical Properties

Semiconductors: There are a number of ceramics that are semiconductors. Most of these are transition metal oxides that are II-VI semiconductors, such as zinc oxide.

The grain boundary effects make ***them ideal for surge-protection applications***. As there is control over the threshold voltage and energy tolerance, they find use in all sorts of applications. The best demonstration of their ability can be found in electrical substations, where ***they are employed to protect the infrastructure from lightning strikes***. They have rapid response, are low maintenance, and do not appreciably degrade from use, making them virtually ideal devices for this application.

Semi-conducting 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.

Superconductivity

Ferro-electricity and supersets: Piezoelectricity, a link between electrical and mechanical response, is exhibited by a large number of ceramic materials, including the quartz used to measure time in watches and other electronics. Such devices use both properties of piezoelectric, using electricity to produce a mechanical motion (powering the device) and then using this mechanical motion to produce electricity (generating a signal). The unit of time measured is the natural interval required for electricity to be ***converted into mechanical energy and back again.***

Pyroelectric materials can be used to store information in ferroelectric capacitors elements of ferroelectric RAM.

The most common such materials are lead zirconate titanate and barium titanate. Aside from the uses mentioned above, their strong piezoelectric response is exploited in the design of high-frequency loudspeakers, transducers for sonar, and actuators for atomic force and scanning tunneling microscopes.

Other Applications of Ceramics

? Ceramics are used in the manufacture of knives. The blade of the ceramic knife will stay sharp for much longer than that of a steel knife, although it is more brittle and can be snapped by dropping it on a hard surface.

? Ceramics such as alumina and boron carbide have been used in ballistic armored vests to repel large-caliber rifle fire. Such plates are known commonly as small-arms protective inserts (SAPI). Similar material is used to protect cockpits of some military airplanes, because of the low weight of the material.

? Under some conditions such as extremely low temperature some ceramics exhibit superconductivity. The exact reason for this is not known, but there are two major families of super conducting ceramics.

? Ceramic balls can be used to replace steel in ball bearings. Their higher hardness means that they are much less susceptible to wear and can often more than triple lifetimes. They also deform less under load meaning they have less contact with the bearing retainer walls and can roll faster. In very high speed applications, heat from friction during rolling can cause problems for metal bearings; problems which are reduced by the use of ceramics.

? Ceramics are also more chemically resistant and can be used in wet environments where steel bearings would rust. The major drawback to using ceramics is a significantly higher cost. In many cases their electrically insulating properties may also be valuable in bearings.

? In the early 1980s, Toyota researched production of an adiabatic ceramic engine which can run at a temperature of over (330°C). Ceramic engines do not require a cooling system and hence allow a major weight reduction and therefore greater fuel efficiency. Fuel efficiency of the engine is also higher at high temperature, as shown by Carnot's theorem. In a conventional metallic engine, much of the energy released from the fuel must be dissipated as waste heat in order to prevent a meltdown of the metallic parts. Despite all of these desirable properties, such engines are not in production because the manufacturing of ceramic parts in the requisite precision and durability is difficult. Imperfection in the ceramic leads to cracks, which can lead to potentially dangerous equipment failure. Such engines are possible in laboratory settings, but mass-production is unfeasible with current technology.

? Work is being done in developing ceramic parts for gas turbine engines. Currently, even blades made of advanced metal alloys used in the engines' hot section require cooling and careful limiting of operating temperatures. Turbine engines made with ceramics could operate more efficiently, giving aircraft greater range and payload for a set amount of fuel.

? Recently, there have been advances in ceramics which include bio-ceramics, such as dental implants and synthetic bones. Hydroxyl apatite, the natural mineral component of bone, has been made synthetically from a number of biological and chemical sources and bone can be formed into ceramic materials. Orthopedic implants made from these materials bond readily to bone and other tissues in the body without rejection or inflammatory reactions. Because of this, they are of great interest for gene delivery and tissue engineering scaffolds. Most hydroxyl apatite ceramics are very porous and lack mechanical strength and are used to coat metal orthopedic devices to aid in forming a bond to bone or as bone fillers. They are also used as fillers for orthopedic plastic screws to aid in reducing the inflammation and increase absorption of these plastic materials. Work is being done to make strong-fully dense nano crystalline hydroxapatite ceramic materials for orthopedic weight bearing devices, replacing foreign metal and plastic orthopedic materials with a synthetic natural bone mineral. Ultimately these ceramic materials may be used as bone replacements or with the incorporation of protein collagens, synthetic bones.

Composite MaterialS

Composite materials (or composites for short) are engineered materials made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure.(Composites)

Background

The most primitive composite materials comprised straw and mud in the form of bricks for building construction; the Biblical book of Exodus speaks of the Israelites being oppressed by Pharaoh, by being forced to make bricks without straw. The ancient brick-making process can still be seen on Egyptian tomb paintings in the Metropolitan Museum of Art.

The most advanced examples perform routinely on spacecraft in demanding environments. The most visible applications pave our roadways in the form of either steel and aggregate reinforced Portland cement or asphalt concrete. Those composites closest to our personal hygiene form our shower stalls and bath tubs made of fiberglass. Solid surface, imitation granite and cultured marble sinks and counter tops are widely used to enhance our living experiences.

There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination. Engineered composite materials must be formed to shape.

Most commercially produced composites use a polymer matrix material often called a resin solution. The reinforcement materials are often fibers but also commonly ground minerals.

Moulding Methods:

The moulding methods are:

Open moulding: is a process that uses a rigid, one sided mold which shapes only one surface of the panel. This process is generally done at ambient temperature and atmospheric pressure.

Vacuum bag moulding. A process using a two-sided mold set that shapes both surfaces of the panel. On the lower side is a rigid mold and on the upper side is a flexible membrane. This process can be performed at either ambient or elevated temperature with ambient atmospheric pressure acting upon the vacuum bag.

Autoclave moulding. A process using a two-sided mold set that forms both surfaces of the panel. One of the lower sides is a rigid mold and on the upper side is a flexible membrane made from silicone or an extruded polymer film such as nylon. Reinforcement materials can be placed manually or robotically. This process is generally performed at both elevated pressure and elevated temperature. The use of elevated pressure facilitates a high fiber volume fraction and low void content for maximum structural efficiency.

Resin transfer moulding. A process using a two-sided mold set that forms both surfaces of the panel. The lower side is a rigid mold. The upper side can be a rigid or flexible mold. Flexible molds can be made from composite materials, silicone or extruded polymer films such as nylon. The two sides fit together to produce a mold cavity. The distinguishing feature of resin transfer moulding is that the reinforcement materials are placed into this cavity and the mold set is closed prior to the introduction of matrix material. This process can be performed at either ambient or elevated temperature.

Others types of moulding

Other types of mouding include press moulding, transfer moulding, pultrusion moulding, filament winding, casting, centrifugal casting and continuous casting.

Examples of composite materials

Fiber Reinforced Polymers or FRPs include Wood comprising (cellulose fibers in a lignin and hemicellulose matrix), Carbonfiber reinforced plastic or CFRP, Glass-fiber reinforced plastic or GFRP (also GRP). If classified by matrix then there are ***Thermoplastic Composites, short fiber thermoplastics, long fiber thermoplastics or long fiber reinforced thermoplastics***. There are numerous thermoset composites, but advanced systems usually incorporate aramid fibre and carbon fibre in an epoxy resin matrix.

Composites can also utilize metal fibres reinforcing other metals, as in Metal matrix composites or MMC. Ceramic matrix composites include Bone (hydroxyl apatite reinforced with collagen fibers), Cermet (ceramic and metal) and Concrete. Organic matrix/ceramic aggregate composites include Asphalt concrete, Mastic asphalt, Mastic roller hybrid, Dental composite, Syntactic foam and Mother of Pearl. Chobham armour is a special composite used in military applications.

Additionally, thermoplastic composite materials can be formulated with specific metal powders resulting in materials with a density range from 2 g/cc to 11 g/cc (same density as lead). These materials can be used in place of traditional materials such as aluminum, stainless steel, brass, bronze, copper, lead, and even tungsten in weighting, balancing, vibration dampening, and radiation shielding applications. High density composites are an economically viable option when certain materials are deemed hazardous and are banned (such as lead) or when secondary operations' costs (such as machining, finishing, or coating) are a factor.

Engineered wood includes a wide variety of different products such as Plywood, Oriented strand board, Wood plastic composite (recycled wood fiber in polyethylene matrix), Pykrete (sawdust in ice matrix), Plastic-impregnated or laminated paper or textiles, Arborite, Formica (plastic) and Micarta. Other engineered laminate composites, such as Mallite, use a central core of end grain balsa wood, bonded to surface skins of light alloy or GRP. These generate low-weight, high rigidity materials.

Typical Products

Composite materials have gained popularity (despite their generally high cost) in high-performance products such ***as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, and racing car bodies. More mundane uses include fishing rods and storage tanks.***

SemiconductorS

A semiconductor is a solid whose electrical conductivity is in between that of a conductor and that of an insulator, and can be controlled over a wide range, either permanently or dynamically.(Semiconductors).Semiconductors are tremendously important in technology. Semiconductor devices, electronic components made of semiconductor materials, are essential in modern electrical devices. Examples range from computers to cellular phones to digital audio players. Silicon is used to create most semiconductors commercially, but dozens of other materials are used as well.

Overview

Semiconductors are very similar to insulators. The two categories of solids differ primarily in that insulators have larger band gaps energies that electrons must acquire to be free to move from atom to atom. In semiconductors at room temperature, just as insulators, very few electrons gain enough thermal energy to leap the band gap from the valence band to the conduction band, which is necessary for electrons to be available for electric current conduction. For this reason, pure semiconductors and insulators in the absence of applied electric fields, have roughly similar resistance. The smaller band gaps of semiconductors, however, allow for other means besides temperature to control their electrical properties.

Semiconductors' intrinsic electrical properties are often permanently modified by introducing impurities by a process known as doping. Usually, it is sufficient to approximate that each impurity atom adds one electron or one “hole” that may flow freely. Upon the addition of a sufficiently large proportion of impurity dopants, semiconductors will conduct electricity nearly as well as metals. Depending on the kind of impurity, a doped region of semiconductor can have more electrons or holes, and is named N-type or P type semiconductor material, respectively. Junctions between regions of N- and P-type semiconductors create electric fields, which cause electrons and holes to be available to move away from them, and this effect is critical to semiconductor device operation. Also, a density difference in the amount of impurities produces a small electric field in the region which is used to accelerate non-equilibrium electrons or holes.

In addition to permanent modification through doping, the resistance of semiconductors is normally modified dynamically by applying electric fields. The ability to control resistance/conductivity in regions of semiconductor material dynamically through the application of electric fields is the feature that makes semiconductors useful. It has led to the development of a broad range of semiconductor devices, like transistors and diodes. Semiconductor devices that have dynamically controllable conductivity, such as transistors, are the building blocks of integrated circuits devices like the microprocessor. These “active” semiconductor devices (transistors) are combined with passive components implemented from semiconductor material such as capacitors and resistors, to produce complete electronic circuits.

In most semiconductors, when electrons lose enough energy to fall from the conduction band to the valence band (the energy levels above and below the band gap), they often emit light, a quantum of energy in the visible electromagnetic spectrum. This photoemission process underlies the light-emitting diode (LED) and the semiconductor laser, both of which are very important commercially. Conversely, semiconductor absorption of light in photo detectors excites electrons to move from the valence band to the higher energy conduction band, thus facilitating detection of light and vary with its intensity. This is useful for fiber optic communications, and providing the basis for energy from solar cells.

Semiconductors may be elemental materials such as silicon and germanium, or compound semiconductors such as gallium arsenide and indium phosphide, or alloys such as silicon germanium or aluminium gallium arsenide.

WOOD AND PULP

Wood has been used as a structural material since the dawn of history. Today it is used because it is less costly and steel, concrete, brick, or stone. Products obtained from wood and pulp include: sawn timber, plywood, blackboards and decorative veneers, floor tiles, flush and panel doors, pulp and papers, furniture and components, saw dust and wood briquettes, and particles board etc.

SPECIFIC APPLICATIONS OF MATERIALS

Materials for the petrochemical (process) industry

Petrochemical industry is a very versatile and complex industry with very highly significant economic value. The complexity of the industry necessitates the meticulous attention paid to the selection use and behaviour of materials in petrochemical plant and particularly, with the selection of materials for those sections of the industry that operate on a large scale such as those producing fertilizers and ethylene and those used for its various major equipment and components.(Lancaster;1978). This complexity also accounts for selecting this industry here as the representative one for the process industry. The equipment in a typical petrochemical plant includes; furnaces, exchangers, reactors, towers, drums and tanks, steel structure, pumps and compressors, building, piping, electrical, instruments, insulation, utilities, transportation, catalysts, and fire and safety equipment. These are subject to different service conditions and effects of very high temperature, sub-zero temperatures in cryogenic processes, carburization corrosion, creep-rupture, nitriding, and catastrophic oxidation. For the effective running of the plant, different metals and alloys are used. These include the heat resistant alloys e.g.18Cr-8Ni steel, 25Cr-20Ni-0.4C,18Cr-35Ni, Incoloy 800; corrosion resistant alloys; metals for subzero temperature e.g. Al, impacted tested carbon steel, 3.5Ni steel, 9% Ni steel and austenitic Cr-Ni steel and other alloys to minimize the deleterious effect of oxidation, creep, carburization etc. The other specific metallic materials used in this industry for corrosion and heat resistance, include: carbon steels, carbon-manganese; austenitic stainless Cr-Ni steels e.g AISI types 304L (18-20Cr-8-12Ni-.03)316L(.08C16-18Cr-10-14Ni-2-3-Mo); ferritic stainless steel e.g 12%CrAISI type 410; copper alloys e.g.77Cu- Zinc-0.4As-2.0Al; aluminium alloys e.g Al-Mg; nickel alloys e.g monel alloy 400 (Ni-30Cu); incoloy825(42Ni-22Cr-30Mi) hastelloy B and C inconel alloy 600.

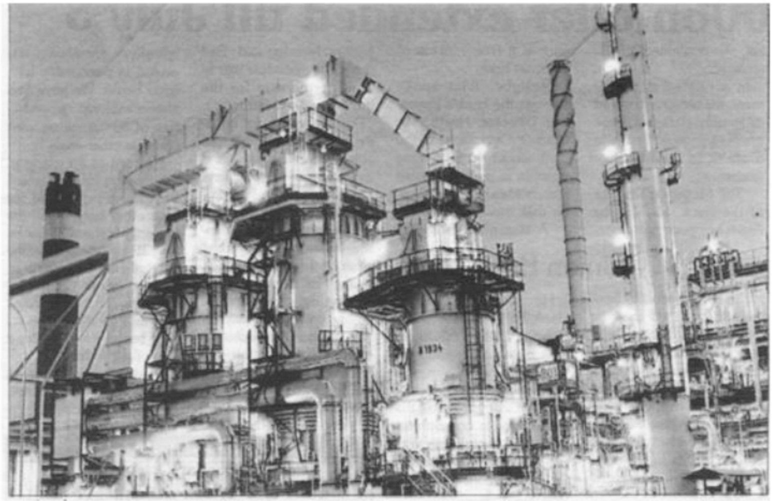
The organic linings and coatings include: poly-tetrafluoroethylene (PTFE) chemically cured or air dried epoxides, polyurethanes, glass reinforced polymer, modified phenolic, vinyl, neoprene, PVC, and thermally cured epoxides, fluorocarbon and ebonite. Their typical uses vary from corrosion protection to chemicals and powder storage. Refractory is also used for lining where fluid temperature is too high for pressure equipment to be fabricated economically from unlined metal. This refractory is normally monolithic but brick work is also used.

Just like any other process industry plant, the petrochemical plant and the refineries are 99% constructed of metallic alloys, the rest being polymers, ceramics and composites.

Without these, can you imagine what the world economics and human civilization will be like?

Oil Production Vessel

A Refinery



Metals and Non-metallic Materials in medicine and Surgery

For many centuries, isolated cases of the use of metallic implants in surgery have been recorded. Most of these cases represented the application of a noble metal to repair a localized structural defect. For example, in 1546, Ambrose Pare described the use of gold plates to repair traumatic defects in the skull and of gold wire for repair of abdominal hernias. Widespread application of metals in medicine and surgery was not feasible, however, until the evolution of aseptic surgical technique with general or regional anesthesia and adequate blood and fluid replacement. These provisions have enabled bioengineers and surgeons to design, test, and implant a wide variety of metallic devices for the repair and replacement of human organs, especially for the treatment of musculo-skeletal disease but also for the management of cardiovascular, otolaryngological, neurosurgical, and general surgical disorders.

About 1900, surgeons did not possess the metal of adequate strength and inertness for extensive implantation. Most noble metals such as gold were too soft, and the available ferrous alloys were of inadequate inertness. Others such as copper, zinc or aluminium were of inadequate inertness and frequently possessed toxic dissolution products. About 1936, two alloys, 18Cr-8Ni-3Mo austenitic stainless steel and 27Cr-5mo-Co, were shown to have adequate strength inertness.

The development of new materials for implantation and of novel designs of surgical implants imposes some unique demands in bioengineers. Laboratory corrosion tests are difficult to undertake in an environment that accurately simulates body fluids.

At present, metals have extensive application in medicine and surgery.(Mears:1977) They are widely used for the construction of artificial limbs and appliances (e.g orthoses) and for dental prostheses. Radioactive metals and metallic compounds are used for therapeutic treatment of malignant tumours. Also, they are used extensively for a variety of non-invasive diagnostic procedures. Metallic salts have been administered parenterally for the treatment of bacterial and protozoan infections such as syphilis, trypanosomiasis, and leishmaniasis as well as for infestations such as hook worms. Gold compounds are used systemically and by intra articular injections for the treatment of rheumatoid arthritis.

Metallic alloys: Implantable metals with structural applications that are wholly confined within the human body include: 316 stainless steel - annealed and also the cold worked type; wrought cobalt-chromium alloy, cold worked; cast cobalt-chromium alloy; titanium 160, annealed, and Ti -6Al 4V alloy**.**

Polymeric materials: A variety of polymeric materials have gained acceptance for use in conjunction with metallic implants. These include: methyl methacrylate cement; polypropylene, polyethylene, PTFE (polytetrafluoroethylene) and silicone rubber; nylon and dacron polyester.

These materials are used, among others, in the repair of femoral neck fracture, treatment of mid-shaft femoral or tibial fractures by insertion of intramedullary rods; surgical treatment of spinal deformity, making implantable cardiac pacemakers and in other bone surgery such as total joint replacement, total hip replacement, total knee placement and total shoulder replacement (total joint replacement arthroplasties).

The most widely studied composites for use in surgery have been fibre reinforced materials such as epoxy resins reinforced with carbon fibres. Whiskers composed of ceramics such as silicon carbide, boron carbide, and aluminium oxide could, provide great stiffness and wear resistance when embedded in an inert ductile matrix of titanium or niobium. It must be remembered that one of the outstanding natural composite materials is bone itself. It consists of the strong, ductile protein collagen and the hard, brittle mineral hydroxyl-apatite. Bone illustrates the behaviour of combined action wherein two components act together to equalize their different strains. Materials are of great extensive use in medicine and surgery. Their contributions in saving lives and in health care in general can not, therefore, be over-emphasized. All tools used in hospitals for healthcare, all equipment and instrumentations are all made of materials. These also include the buildings, and the operations theaters and their facilities. Without the development and processing of materials there will be no medicine and pharmaceuticals and life will be in jeopardy. The modern medical civilization would have been a mirage an absolute impossibility.

The manufacture/production of all medical, surgical and pharmaceutical instrumentations, equipment and their packaging and marketing, has on the other hand, generated very great industries that contribute tremendously to the world economic growth and development.

Metals and alloys in dentistry

Metals and alloys are of great application in dentistry. In fact without the use of these materials it would have been impossible even to get the dentist/dental surgeons trained.

Metallic materials used in dentistry cover a very wide spectrum, ranging from pure metals such as gold and platinum to simple solid solutions to complex multiphase alloys. (Bates:Knaptan,1977)

An essential requirement of any dental alloy is a high resistance to corrosion. The warm saline environment with a surplus of oxygen and a variety of different foods, liquids, medicines, etc being brought into contact with the alloys provides a severe testing ground. Not all alloys used are entirely free from corrosion, but many become passive, which enables them to serve usefully in the mouth over a long period of time.

The most common type of fixed restoration is the dental filling, which may be metallic, polymeric, or inorganic. The metals may be amalgam or pure gold packed into the cavity or a cast gold alloy restoration may be cemented into position. Extremely realistic and durable restorations are made by a porcelain enamelling technique, using gold or, less frequently, a base-metal alloy to support the porcelain veneer. Notable alloys used include: silver-tin amalgams Ag_3Sn with additions of 6% Cu and 0.2% Zn; gold and gold alloys. Because of its outstanding chemical stability, gold was among the first materials to be used in dentistry, and examples over 2,500 years old have been found. Dental casting gold alloys are of four types with varying percent composition of Au (60-96%), Ag (2.4-17.4%), Cu (1.6-15.4%), Pd (0-0.1%), Pt (0-8.2%), and Zn (0-2.7%). In these alloys, copper (Cu) is responsible for an increase in strength and hardness, silver tends to whiten the alloy and nullify the reddening effect of copper additions. Platinum (Pt) acts as a potent solid solution hardner in gold alloys and increases corrosion and tarnish resistance. It tends to whiten gold alloys but is not as effective in this respect as palladium, addition in small quantities. Zinc addition in small quantities, functions in the alloy system as a deoxidant and to improve the castability of the alloy. White gold is basically the alloy of gold with palladium or platinum. For partial and complete dentures and orthodontic plates, alloys of cobalt-chromium (plus some little quantities of nickel, molybdenum, manganese, silicon, aluminium, or beryllium - as deoxidizers) are used. For many instruments and fittings, stainless steel of the 18-8 variety is employed very widely in dentistry. Stainless steel wires are used for orthodontic purposes to form arch bars, springs, and bands to affect and control the movement of teeth. Gold alloys and copper-base alloys are also used (occasionally) for memorable appliances.

Implants. Many of the corrosion resistant implant materials used in general surgery have been applied in dentistry. The chromium cobalt molybdenum type alloys as described for removable appliances are the most widely employed. More recently, nickel base alloys have been introduced for surgical use with a typical composition of 54.3Ni 24.6Cr 15Co. In surgical cases, the stainless steel AISI 316L is used to wire fractures. The high strength titanium alloy with 6% Al and 4% V has been proposed and may prove satisfactory for the intra-osseous types of implant. All tools, equipment, instrumentations and other facilities used in density are made of materials metallic and non-metallic.

Materials in Ophthalmology

Metallic and non-metallic materials are used in ophthalmology. All instrumentations and equipment used in testing/diagnosis, treatment and surgical operations are all made from metals and alloys, polymeric and ceramic materials. These include gold, and copper alloys, stainless steels, glass, and plastics. Ophthalmology has a long history of successful conventional biomaterial applications including viscoelastics, drug delivery vehicles, contact lenses, and a variety of implants. A myriad of further possibilities exists as the margins between conventional material concepts and natural tissues continue to blur, and biomaterials move closer to nature. Genetically engineered materials (for example, hyaluronic acid and fibrin tissue glues) harnessing the power and accuracy of biological systems in molecular synthesis are becoming commonplace. New synthetic surfaces capable of up regulating or down regulating biological responses at the tissue/material interface are starting to reach clinical application; and an emerging understanding of matrix/cell interactions may soon allow engineered replacement for a range of tissues in the eye. Modern ophthalmic implants are almost all fabricated from synthetic polymers.

Further sIgnificant/specific areas of materialS applications

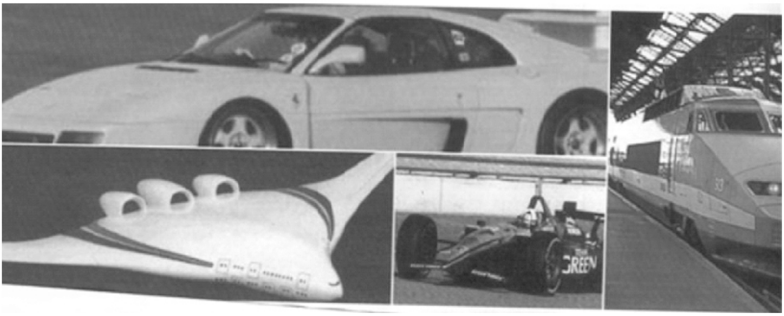
All physical activities in life involve the use and application of materials. Time will not all to be discussed here. However, significant areas of application are mentioned.

Materials in Households: Nearly every thing used in the house from the kitchen items of pots, plates, coolers, kettles refrigerators, knives, sponge microwave ovens to radios TVs, Computers, Chairs and tables, beds in the sitting and bed rooms are made of materials metallic and/or non-metallic. The house itself is built with materials concrete, cement, reinforcement bars, roofing, tiles, woods and the grainite/ marbles. The glass in the windows, the vinyl siding, the ceramic dinner ware, the metal silver ware and all decorative items are all made of materials. Without the use of materials, there will be no shelter to live in, food cannot be prepared and cooked and so nothing to eat. The clothes we wear are made from materials, and so also all the jewelries and shoes.

Machines/Machineries: These are used in all facets of production/manufacturing processes. In services, in transportations in cars, aeroplanes, locomotives, production, agriculture, health care, buildings, etc. All machines /machines and their components are made of material of which about 95% are metallic alloys. Medium and high strength carbon steels and cast iron are widely used in the production of machines and machineries which include agricultural tractors and road construction machineries. Without machines/machineries the world technological civilization will hardly exist lest we take of economic development.

Materials application in Agriculture: The tractors, cutlasses, nets, anchors, spears canoes and boats, and trucks, hoes, etc, used in agriculture whether farming or fishing are all made of various types of materials metals, polymers, ceramics, composites and woods. All associated facilities and infrastructure such as buildings and silos for food storage are all made of materials

Materials in Transportation



A helicopter

A Ship

A Car

Copper and aluminium wires are used as cables. Polymers and composites are now being increasingly used in aircraft manufacturing. Cast irons, copper and aluminum alloys and magnesium alloys among others are being extensively used in different parts of car manufacturing from the engines to other components of car production Polymer materials, composites and semi conductors are also being used extensively in car production. Ships are built with high strength aluminium alloys, carbon and stainless steels. Polymers, composites and semi-conductors are also used extensively. It is important also to mention here that woods also find extensive use in ships, trains etc.

Buildings/Constructions: All buildings/constructions are made on materials. These consist of steels mold, low alloy, medium alloy, and high strength carbon steels for reinforcement and stainless steels.

A Building

A Stadium – materials in sport

Extensive use is also made of aluminium and its alloys. Copper and its alloys are used mainly as wires. Other forms of non-ferous alloys are used mainly for decorative purpose. Titanium alloy is now being used for building sheaths. Aggregates for buildings and constructions consist of sand, gravels/granites and cement for concrete. Cement and sand are used for building blocks. Polymers are used as pipes and use of ceramics particularly the refractories in form of bricks are extensively used. Word is one of the major important materials of building and other constructions.

Industrial Plants: Without materials there will be no industrial plants and hence no manufacturing of any type of products. All industrial buildings are constructed of materials metallic, polymeric, ceramic and composites. All machines used in the industrial plants are made from materials particularly metallic materials of different alloys. Every other industrial machinery components are also made of materials. Industrial plants include petroleum industry (the backbone of our national economy), off shore structures, chemical/pharmaceutical plants, all production engineering plants, food processing, textile industry, car, aeroplane, electrical and electronics manufacturing plants, computers and accessories and all other industrial plants for the production of light and heavy equipment.

Energy and Power: All buildings and other infrastructures involved in energy and power generation/distribution are made of materials metallic and non-metallic. All machines/machineries including large turbings are made of materials particularly metallic materials. Copper (and its alloys) and aluminum (and its alloys) are the major /dominant metals used for electrical wiping and cables because of their excellent electrical conductivity. Electrical bulbs are made of glass a ceramic and plastic (polymer). Many other components are made form semiconductors and composites. Without the application of materials, it would have been impossible to produce any form of energy /power.

Materials in Marine application:

All structures in the marine environment are made of materials particularly metal alloys. Marine environment is very corrosive and hence very hostile to metal alloys. This necessitates that very careful selection of materials must be made for marine structures and other applications. Off-shore platforms for Petroleum and gas production are typical examples. Also sea vessels like ships of various kinds merchant, naval and tankers are all made of materials mostly metal alloys. Mild steel and alloy steels could be used, but must be protected with paints or cathodically. Corrosion resistant alloys for marine application include stainless steels, copper alloys, nickel alloys, aluminum alloys and titanium and its alloys. Sea water is corrosive due to its heavy ion contents particularly chloride ions. All the metal alloys mentioned above are still subject to various corrosion attacks in sea water but at varying magnitude. Titanium, though very expensive, is considered by many to be the most stable of the commercially available alloys in sea water. Without materials nothing could be done in the marine environment.

Computer and Information Technology: The use of computer and information technology has been made possible by the use of materials. All things that are involved in the manufacture/production of computer are all materials. These range for casing and other many components; and of course ceramics/semi conductor materials from when silicon chip is made. The economic gain and development these have brought to mankind can never be quantified. It brought the world into another era of civilization.

Materials in Sports: We all enjoy every form of sports today because of the use of materials. All stadium and other sports infrastructures and facilities are made of materials. All balls, form football, basket ball, volley ball, billiard/snooker balls, lawn tennis ball, etc are all made of materials particularly polymeric materials. The goal posts, javelin, shot put, hurdles, high jump and pole vault facilities are all made of materials. All trophies and medals are made of materials.

Music and Entertainment: Music world and entertainment have generated enormous economic activities and worldwide prosperity. All musical and entertainment instruments are made of materials metals, polymers ceramics and wood. Music has become a major feature in our worshipping in churches. Musical instruments such as trumpets, guitar, organs/pianos, etc are being used daily. These have made immense contribution to our daily spiritual life.

Fashion / Ornaments: All fashion/ornaments as we know them today would never have been possible or ever be in existence without the materials and their uses. All clothes we wear and use in whatever form; our shoes, wrist watches, rings, eye-glasses, chains and all jewelries are made of materials metals and that alloys, particularly gold, silver, platinum, palladium, titanium stainless steels and copper alloys bronzes and brasses; polymers from which we get terylene, teflon and nylon; and ceramics, for example, talc is a ceramic and this is used to make powders.

Materials Application in Telecommunication: Materials are the dominant things used in all facets of telecommunication a major aspect of world technological utilization today and its attendant economic advancement. All machineries, facilities and other infrastructures used in telecommunication are made of materials. All forms of cable used in telecommunication either wires (from metals and alloys-copper and aluminum) or optical fibres (from glasses) are materials. Without materials, there will be no telecommunication.

Materials in Territorial Defence: Military Services/National Security

Materials particularly metallic materials are used to manufacture and produce all weapons and ammunitions that are used for the country's territorial defence and also for internal security. Armored vehicles, tanks, guns, artilleries, missiles, bombs, fighter and bomber airplanes, transport airplanes, combat helicopters, naval ships equipment, logistics and weaponry submarines, etc, are all made of materials metals, particularly titanium, Lithium; aluminum alloys, polymer ceramics semi-conductors and composites. Without these, a nation remains defenseless. At the same time, there may be no need to defend anything since no one will have anything to attack one another with. The economic activities involved in the production of the above for world wide trade have

F-22 Raptor

Type: Stealth Air Superiority Fighter

Military Equipment

Military Equipment

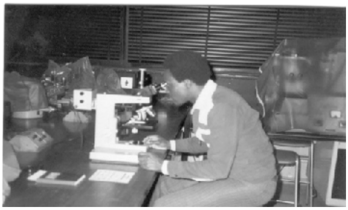
Nimitz - nuclear-powered aircraft carriers

A Russian Mil Mi-24 attack helicopter

Materials in the development of other Engineering and Scientific Fields

Application of materials has made it possible for all other engineering and scientific fields to develop and be useful. Physics and chemistry are the science subjects behind the

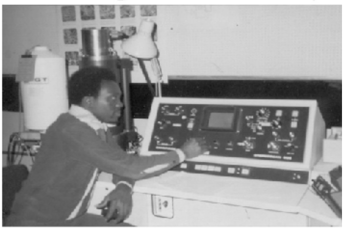
Metallurgical Microscope



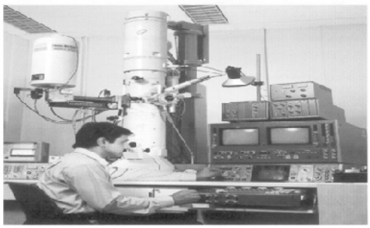
Auger Spectroscopy

Examining top atomic monolayers of a material by Auger spectroscopy

Scanning Electron Microscope



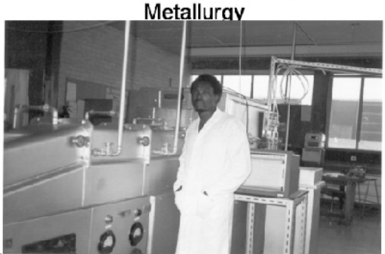
Transmission Electron Microscope



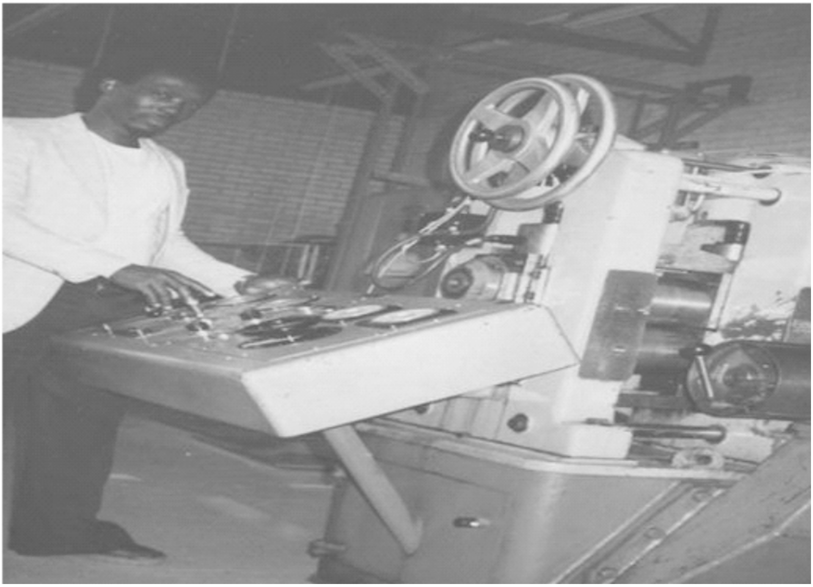
State-of-the-art materials characterization laboratory

Compacting Machine

Sintering Furnace, Powder Metallurgy



Mechanical Testing Equipment



Development of materials science. However, today the two subjects cannot move forward without the use of apparatus, instrumentations and equipment that are all made of materials. There will be no scientific research and development of any type without the use of materials.

All engineering fields mechanical, production/ manufacturing/ industrial engineering, and materials engineering itself; electrical, civil, chemical /petroleum, computer, and electronic engineering; information technology; agricultural and telecommunications engineering, among others, would have become absolutely impossible to practice without the use of materials in producing all their infrastructural needs buildings, facilities, instrumentations and equipment, machines (made of materials) and metallic alloys and other materials. There will be no building technology /engineering, and architecture would have become just an idea or a dream. There will be no wire copper or aluminium and so no electricity distribution. Neither can we generate electricity in whatever form without the use of materials just to mention a few.

MATERIALS PERFORMANCE IN SERVICE AND THE ECONOMIC IMPACT

All the materials that have been mentioned, when processed, are used to manufacture and produce different items most, which have been mentioned, for our needs in all areas of life. These finished products of these materials must be put to use in a particular environment and the other atmosphere, in water, under-ground and in different industrial environments such as in acids and alkalines. Their performance in service is of utmost importance, because these refined materials / products will and must fail in service. About 85% of materials failure in service is due to corrosion; others being mechanical failure (fatigue), creep, and tribological (wear) failures. Materials corrode in different ways or suffer degradation when in interaction with its environment. For metals and their alloys, this is because they want to go back to their original stable position e.g. as oxides, sulphides, carbonates, nitrites etc. from which they were extracted and refined. They become metastable when in interaction with their `new' environments. This corrosive degradation phenomenon has very great economic consequences negatively and positively. The cost of this phenomenal damage to facilities, equipment, industrial plants and industrial structures, etc, is very grave. The facilities must be protected and prevented from corrosion.

Cost of Corrosion: The annual cost of corrosion protection worldwide is enormous and in the United States, for example, it was estimated (in 1975) at 70 billion dollars. This tremendous cost is less surprising when we consider that corrosion occurs, with varying degrees of severity, wherever metals and other materials are used. For example, one plant spends 2 million dollars a year for painting steel to prevent rusting. One large Chemical Company spent more than $400,000 per year for corrosion maintenance as its sulphuric acid plants, though the corrosion conditions were not considered to be particularly severe. Corrosion in automobile fuel system alone costs $100 million per year. Auto radiators account for about $52 million. The estimated cost of corrosion of automobile exhaust systems is $500,000, etc.

In fact our economy and indeed, the world economy would be drastically changed if there were no corrosion. For example, automobiles, ships, underground pipelines, and household appliances would not require coatings.

The stainless industry would essentially disappear and copper could be used only for electrical purposes. Most metallic plants, as well as consumer products, would be made of steel or cast iron. Corrosion touches all inside and outside the home, on the road, on the sea, in the plant, and in aerospace vehicles. But while corrosion is inevitable, its cost can be considerably reduced through cathodic and anodic protection, proper selection of materials and good design; and a good maintenance painting program.

The positive side of the above is that the action and the activities to protect facilities and prevent materials, have contributed immensely to world economic development. Quite a lot of industries have been established worldwide for corrosion protection prevention and control. Stainless steel industries are massive. A lot of other non-ferrous alloys such as monel, inconel, hastelloy, bronzes, brasses, and titanium alloy have been produced in large industries for proper materials selection to mitigate against corrosion in different environments.(Fontana;Greene). Other corrosion protection methods/ industries such as electroplating, electroless plating, electrophoretic deposition, electrodeposited composites, hot dip coating, cementation, cladding, vacuum deposition, vapour deposition, sprayed metallic coating, pyrolysis, paints, lacquers, vitreous enamels, anodizing, phosphating, plastic coatings, etc.

These combined together have created hundreds of millions of employment all over the world. The corrosion protection industries have impacted world economic growth and development in a tremendous way.

Impact of Materials Application on the World Technological Civilization and Economic Development

From this lecture presentation, we can summarize that materials are used for the manufacture of all machines/machineries and which in turn, are used to produce all scientific, engineering and technological components and products. The application of materials in all facets of life; in all manufacturing and productions, and in all things we see, handle/touch, and use has impacted on-and provided the greatest contribution to the world economic development in terms of wealth creation, employment generation and comfort for mankind. The effect of all these on world civilization is immeasurable.

The broad areas of application of materials include, among others, the following: aviation airplanes, helicopters, etc, buildings/construction, transportation, medicine and dentistry, sports, stadia, bridges, agriculture, industrial plants chemical, metallurgical, etc; petrochemicals and refineries; oil/petroleum production, off-shore facilities and marine services e.g. oil tankers; energy and power, mining and extraction, electrical products and components, electronics, computers and information technology, ships, all metal and non metal fabrication products, in space technology, military hard wares of diverse kinds and logistics; jewelry, churches/cathedrals, ships, automobiles cars, buses, trucks, etc; all instrumentations and analytical/process equipment, telecommunications, music and entertainments, household utilities cookers, pots and plates, micro-wave oven, furniture, TVs and radios; containers, trains/railways, road, and all other multifarious engineering and technological facilities and products that are two numerous to mention here.

As mentioned earlier, all materials metallic and non-metallic, at one time or the other, in an interaction with environment air/atmosphere, water, under ground, etc, will suffer degradation and performance failure in service. The result of this degradation phenomenon, particularly in terms of corrosion may not only be catastrophic but of great adverse economic consequences. As a result of these effects, various means of protecting metallic materials, in particular, have been devised. These have resulted in massive diversified industries all over the world. Thousands of metallic alloying industries including stainless steels are part of this development. Protection methods include electro-deposition (electroplating) and diversified coating techniques such as paints, lacquers, plastic coatings, vitreous enamel, phosphatizing, chromating, sheradizing, anodizing, sprayed metal coatings, hot dip coating (galvanizing), cementation, vacuum deposition, etc. The manufacture of all these, has contributed immensely to the world economic development and civilization. The manufacture of corrosion monitoring equipment; instrumentations for metallurgical, polymeric, composite and semi-conductor materials' examination, characterization, and analysis is a very huge industry worldwide. All these contribute to the world economic development and civilization. All the industries mentioned above have generated and are generating millions of employment for mankind worldwide. Our comfort in all areas of life is dependent on the application of materials.

All commercial houses and banking industry now depend on the use of computer, information technology and effective telecommunication system for innovation and hence improved economic activities we are experiencing today in these sectors. All the devices mentioned are produced by the application of materials.

Utilisation of Available Materials of Engineering for National Technological and Economic Development

With regard to all the materials of engineering previously mentioned in this lecture presentation, Nigeria is a blessed country. The fact that most of these materials are locally available makes this nation a fortunate one among many others but they must not be plundered. Exporting them as raw materials and buying them back by importation as finished products and goods will not do this country any good. It will not allow any initiative in materials research and development, materials processing, and application. In this regard, the country becomes stagnant scientifically, technologically and economically.

To launch this country into technological age, to be an economic giant, at least, within our own region of the world, and to command the respect we deserve with regard to our resources among the comity of nations, we need to pursue aggressive industrialization of the country fundamentally. This could be done by making use of our available materials of engineering. Examples of this proposition could be taken from Brazil, India, South Korea and China - some of the developing countries who have gone far in this industrialization direction and have now become our alternative technological mentors. The initiatives of the 1970s in our country, Nigeria, in this direction have, unfortunately, been killed. Our metallurgical strategic industries established then had been sold out. The case of Ajaokuta Steel Co. Ltd., Delta Steel Co. Ltd, Aladja, Warri; the rolling mills in Oshogbo, Katsina and Jos, the Nigeria Machine tool in Oshogbo and the Aluminum Smelting Co. at Oku- Iboku, all sold out due to improper management, is a national tragedy. It is a case of a baby being thrown away with the bath water.

Time will not permit me for any further analysis on this.

Though, we now practice the liberal market economy driven by private initiatives, I still believe, that it is pertinent, to suggest that the National Government should make the initiative to encourage the industrialists/ entrepreneurs in all ways possible to invest massively in all types of metals and non-metallic industries. This will create employment for the citizenry and bring wealth to the nation. It will bring respect to our nation. Those nations that have this technological breakthrough are the advanced countries today. Failure to process, develop and apply our materials for technological use will make us stagnant economically and technologically. We will perpetually remain consumers and importers. The Government should fund, probably in collaboration with the private sectors, the needed infrastructures and the exploration of all the known available materials metallic and non-metallic, to determine their viability- quantity and qualities. Efforts should be made to explore for the very useful and strategic non-ferrous mineral deposits such as chromium, copper, nickel, molybdenum, magnesium, manganese, tungsten, titanium (occurs principally with rutile and ilmenite), niobium, vanadium, etc. They are important and compulsory for our technological needs.

The development of advanced materials in form of composites, super conductive alloys, polymers, ceramics, optic fibres, and semi-conductors must receive proper attention.

It is equally important that the Federal Government of Nigeria establish functional national laboratories in at least six different zones of this country for intensive research and development activities of all our locally available engineering materials. Such laboratories are to be well equipped to international standards and must be well manned. These will complement our universities' laboratories efforts to assist in technological innovation. In this regard, it is compulsory that materials scientist and engineers be massively trained preferably, externally, at the postgraduate studies level for better exposure as it was done in South Korea and Japan, for example. The establishment of National Scientific Research Council must be a necessity to coordinate the research activities. This is the practice in the developed world.

It is important also to conserve our materials of engineering from early exhaustion. Materials recycling industry must be encouraged. Metals, plastics, bricks, concretes, etc. could be recycled for use. Maintenance of facilities, in general, in form of corrosion protection (prevention and control) is essential. We can take examples from the Government of other nations like the United Kingdom, United State of America, Germany, India, etc. who set up National Commission to determine the economic effects of metallic corrosion in their countries. The cost is huge. In 1975, corrosion has cost the United States over $70 billion. By now, it may be hundreds of billions of dollars. If corrosion is not controlled and facilities well protected, there will be deterioration and hence premature replacement of capital goods, waste of materials, machineries, and increased maintenance cost, etc. The overall effect is the fast depletion of our materials resources. Their conservation is, therefore, an absolute necessity.

To be relevant, and to be certain that the 2020 target of becoming the 20th largest economy in the world is achieved; that our dreams and goals for technological lift will not be a mirage, Nigeria needs now:

? Hundreds at least, of different types of foundry complexes for both ferrous and non ferrous castings. (India has over 2,500 foundries; the USA over 6000).

? Numerous rolling mills for metallic alloys and their versatile rolled products including particularly the flat sheets;

- ? Extrusion factories for metals and polymeric materials;
- ? Hundreds of forging and wire drawing factories;
- ? Many machine tools factories:
- ? Numerous processing plants for plastics, rubber, semi-conductors, composites, and wood and pulp industry. Nokia started business with wood and pulp.

While the Federal and State Governments should take the initiative of providing every necessary infrastructure power/energy, roads, water, etc.; policies (technological and scientific), and any other blue prints, their participatory role in the real establishment and commercialization could be minimal.

CONCLUSION

? In this lecture, I have presented the wonderful world of materials to us.

? Materials are the fulness of the earth.

? Materials create wealth, comfort, and provide shelter.

? Metallic materials sustain life. These major elements Fe, Mg, K, Na, Cu, Zn, Mn, etc with which we have been formed from creation are retained in our bodies. Any deficiency of any of these in our bodies results into health trouble and chaos.

? Any part, components, tools, utilities and their applications in all areas of engineering and technology, that are manufactured / produced as we can see today, in all areas of life, are obtained from materials-metallic and/or non-metallic.

- ? The world civilization and the world economy, depend largely, on the application of materials to scientific and technological production of goods and services.
- ? Every scientific discipline which includes all engineering fields, medicine, astronomy, pharmaceuticals and their applications could only be made possible by the use/ application of materials either in machineries, equipment, instrumentation, transportation, buildings, logistics, etc
- ? Virtually all things of life, particularly, concerning every aspect of technology- the past, the present and the future scientific and technological civilization of mankind, is based on the knowledge , development, processing and utilization of materials.
- ? Materials touch all the areas of human existence
- ? These materials are metals and alloys, polymers, ceramics, composites and semiconductors.

ACKNOWLEDGMENTS

The Lord God has been wonderful to me at every moment of my life. I appreciate Him for His abundant mercies and grace. I give Him the glory, the honour and adoration in Jesus name.

Today's event has afforded me the unique opportunity of thanking the Chancellor of this great Citadel of learning, Dr David Oyedepo, for giving me the opportunity to be a part of this beautiful academic family. I appreciate you, Sir. My very sincere thanks go to the Vice-Chancellor of this University, Professor Aize Obayan, and to the Registrar, Deacon Yemi Nathaniel. They showed me kindness and love. The Lord God used both for me in a wonderful and miraculous way. May the Lord bless you in Jesus name.

Very importantly, my very deep and profound thanks and appreciation go to my very lovely and most beautiful wife for her unwavering love for me all the time; for her indescribable sacrifices- especially during my sojourns through the wilderness of life; for keeping the fort all the time, and for her uprightness. Dr Mrs. M. Abiola Loto, you are a wonderful woman; a beautiful gift of nature that one will always desire. I appreciate you. To my wonderful children- Oluwagbenga, Tolulope, Olatokunbo and

Olakunle, I appreciate the Lord God for your lives and for blessing me with you all. I thank you for yours support always.

I wish to appreciate all the academic and non-academic staff of this great institution and especially those from my department for their co-operation. I thank very much Professor T. Mosaku, Prof. C. Oluwafemi and Prof. E. Adeyemi for your guidance whenever necessary. The Kings and Queens of Hebron, you are all great: I appreciate you. I thank and appreciate all the Distinguished Guest and friends who are here present today for this magnificent event. May God bless you all in Jesus name.

Notes and References

1. *What is MSE? http://www.crc4mse.org/what /index.html*
2. *A Brief History* of *MSE. http://www.crc4mse.org/what/MSE_hstory.html*
3. Fontana M.G. And Greene N.D., *Corrosion Engineering*, 2nd Edition, McGraw-Hill Intl., pg. 160-180
4. Ijsselling F.P.(1989), *Corrosion Testing for Marine Applications*, Br. Corrros. J., Vol. 24 No. 1, pg 72-75
5. *Titanium http://en.wikipedia.org/wiki/Titanium*
6. *Polymer http://en.wikipedia.org/wiki/Polymer*
7. *Ceramics http://en.wikipedia.org/wiki/Ceramics*
8. *Composites http://en.wikipedia.org/wiki/Composites*
9. *Semiconductors http://en.wikipedia.org/wiki/Semiconductors*
10. Lancaster J. F. (1978), "Materials for the Petrochemical Industry," *Review 230, International Metals Review,* N0.3
11. Mears D.C.(June 1977), "Metals in medicine and surgery", *Review 218: International Metals*

Reviews,

12. Bates J.F. And Knapton A.G.(March 1977), "Metals and Alloys in Dentistry", *Review 215, International Metals Reviews,*

13. As in 3 above