International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

The Importance of Engineering Materials in Present World

Satya Prakash Pandey[1], Vishwajeet Singh[2]

[1]Mechanical Engineering Department, Rajarshi Rananjay Sinh Institute of Management and Technology, Amethi (U.P), 227405, India

[2]Student of Mechanical Engineering, Rajarshi Rananjay Sinh Institute of Management and Technology, Amethi (U.P), 227405, India

Abstract: ***Materials had been in use of humanity since time immemorial. Our world is all about materials that are why Materials Science and Engineering has taken centre-stage position in many developed and developing nations. There have been changes in man's choice of materials for his engineering activities. Materials went through ages of man's activities on earth like the Stone Age, the Iron Age and the current Silicon age, etc. But the challenges of current worlds needs are constantly fuelling the need discovery and development of new kinds of materials with the desired properties and the relevant cost to meet the challenges of the world. This informative article is, therefore, aimed at reviewing the advances made in engineering materials, their classification and the importance of engineering materials in current day world, their properties and various areas of application.***

Keywords: Material, Advancement, Engineering, Importance

1. Introduction

Materials are probably more significant in our culture than we realize. Transportation, housing, clothing communication, reaction and food production and virtually every segment of our daily lives is influenced by materials. Materials have contributed to the advancement of a number of technologies, including medicine & health, information & communication, national security & space, transportation, structural materials, arts & literature, textiles, personal hygiene, agriculture & food science & the environment. These inter-disciplinary interactions between the Material sciences and other fields in the development of new materials and their applications is to be understood well.

As the contribution of materials science and engineering to other disciplines increases, it will become necessary for scientists of all backgrounds to better understand it. Although it is not feasible for scientists to master a vast body of scientific knowledge over many disciplines, scientists must gain the skills that will allow them to master some specific topics. Our presentation attempts to present a relatively brief overview of Materials Science and Materials Engineering and their importance in the present day world. It will also attempt to examine the four components that make up the whole gamut of the discipline of materials science and engineering and their inter-relationship.

2. Materials Science and Engineering

Materials Science and Engineering – (a) materials science, (b) materials engineering

Materials science involves investigating the relationships that exist between the structures and properties of materials

Materials engineering is based on the application of this structure-property correlations, in designing or engineering the structure of a material to produce a pre-determined set of properties

From a functional perspective, the role of a materials scientist is to develop or synthesize new materials, whereas a materials engineer is called upon to create new products or systems using existing materials and/or to develop techniques for processing materials.

2.1 Elements of Materials Science and Engineering

There are four essential elements in materials science and engineering

1) Processing/synthesis
2) Structure/composition
3) Properties
4) Performance/application

These four elements of Materials Science and Engineering is primarily concerned with the study of the basic knowledge of materials: the relationships between the composition/structure, properties and processing of materials. Materials engineering is mainly concerned with the use of this fundamental knowledge to design and to produce materials with properties that will meet the requirements of society. As subjects of study, materials science and materials engineering are very often closely related. The subject ―materials science and engineering" combines both a basic knowledge and application and forms a bridge between the basic sciences (physics, chemistry and mathematics) and the various engineering disciplines, including electrical, mechanical, chemical, and civil and aerospace engineering.

The structure of a material usually relates to the arrangement of its internal components. Subatomic structure involves electrons within the individual atoms and interactions with their nuclei. On an atomic level, structure encompasses the organization of atoms or molecules relative to one another. The next larger structural realm, which contains large groups of atoms that are normally agglomerated together, is termed ―microscopic, meaning that which is subject to direct observation using some type of microscope. Finally, structural elements that may be viewed with the naked eye are termed —macroscopic.

Material structure can be classified as: macrostructure, microstructure, substructure, crystal structure, electronic structure and nuclear structure.

(a) Macro structure - The macrostructure of a material is examined by low-power magnification or naked eye. It deals with the shape, size and atomic arrangement in a crystalline material. In case of some crystals, e.g., quartz, external form of the crystal may reflect the internal symmetry of atoms. Macrostructure may be observed directly on a fracture surface or on a forging specimen. The individual crystals of a crystalline material can be visible, e.g. in a brass doorknob by the constant polishing and etching action of a human hand and sweat. Macrostructure can reveal flaws, segregations; cracks etc. by using proper techniques and one can save much expenses by rejecting defective materials at an early stage.

(b) Micro structure - This generally refers to the structure of the material observed under optical microscope. Optical microscopes can magnify a structure about 1500 to 3000 times linear, without loss of resolution of details of the material structure. We may note that optical microscopes can resolve two lines separately when their difference of separation is 10–7 m (= 0.1 _m). Cracks, porosity, non-metallic inclusions within materials can be revealed by examining them under powerful optical microscope.

(c) Sub structure - When crystal imperfections such as dislocation in a structure are to be examined, a special microscope having higher magnification and resolution than the optical microscope is used. Electron microscope with magnifications 105 are used for this purpose. Another important modern microscope is field ion microscope, which can produce images of individual atoms as well as defects in atomic arrangements.

(d) Crystal structure - This reveals the atomic arrangement within a crystal. X-ray diffraction techniques and electron diffraction method are commonly used for studying crystal structure. It is usually sufficient to study the arrangement of atoms within a unit cell. The crystal is formed by a very large number of unit cells forming regularly repeating patterns in space.

(e) Electronic structure - This refers to the electrons in the outermost shells of individual atoms that form the solid. Spectroscopic techniques are commonly used for determining the electronic structure.

(f) Nuclear structure - This is studied by nuclear spectroscopic techniques, e.g., nuclear magnetic resonance (NMR)

2.2 Properties of Materials

A property is a material trait in terms of the kind and magnitude of response to a specific imposed stimulus. Generally, definitions of properties are made independent of material shape and size. The properties of engineering materials can be classified into two main groups

(a) physical

(b) Chemical.

Virtually all important properties of solid materials may be grouped into six different categories:

1) **Mechanical properties** relate deformation to an applied load or force; examples include: elastic modulus or Young's modulus and strength; tensile and shear strengths, hardness, toughness, ductility, deformation and fracture behaviours, fatigue and creep strengths, wear resistance, etc. The important mechanical properties affecting the selection of a material are:

a) **Tensile Strength**: This enables the material to resist the application of a tensile force. To withstand the tensile force, the internal structure of the material provides the internal resistance.

b) **Hardness**: It is the degree of resistance to indentation or scratching, abrasion and wear. Alloying techniques and heat treatment help to achieve the same.

c) **Ductility**: This is the property of a metal by virtue of which it can be drawn into wires or elongated before rupture takes place. It depends upon the grain size of the metal crystals.

d) **Impact Strength**: It is the energy required per unit cross-sectional area to fracture a specimen, i.e., it is a measure of the response of a material to shock loading.

e) **Wear Resistance**: The ability of a material to resist friction wear under particular conditions, i.e. to maintain its physical dimensions when in sliding or rolling contact with a second member.

f) **Corrosion Resistance**: Those metals and alloys which can withstand the corrosive action of a medium, i.e. corrosion processes proceed in them at a relatively low rate are termed corrosion-resistant.

g) **Density**: This is an important factor of a material where weight and thus, the mass is critical, i.e. aircraft components.

2) **Thermal properties** of solids can be represented in terms of heat capacity and thermal conductivity; the characteristics of a material, which are functions of the temperature, are termed its thermal properties. One can predict the performance of machine components during normal operation, if he has the knowledge of thermal properties. Specific heat, latent heat, thermal conductivity, thermal expansion, thermal stresses, thermal fatigue, etc., are few important thermal properties of materials. These properties play a vital role in selection of material for engineering applications, e.g. when materials are considered for high temperature service. Now, we briefly discuss few of these properties:

a) **Specific Heat**: It is the heat capacity of a unit mass of a homogeneous substance. For a homogeneous body, c = C/M, where C is the heat capacity and M is the mass of the body. One can also define it as the quantity of heat required to raise the temperature of a unit mass of the substance through 1°C. Its units are cal/g/°C.

b) **Thermal Conductivity (K)**: This represents the amount of heat conducted per unit time through a unit area perpendicular to the direction of heat conduction when the temperature gradient across the heat conducting element is one unit. Truly speaking the capability of the material to transmit heat through it is termed as the thermal conductivity. The higher the value of thermal conductivity, the greater is the rate at which heat will be transferred through a piece of given size. Copper and aluminum are good conductors of heat and therefore, extensively used whenever transfer of heat is desired. Bakelite is a poor conductor of heat and hence used as heat insulator. The heat flow through an area A which is perpendicular to the direction of flow is directly proportional to the area (A) and thermal gradient (dt/dx).

c) **Thermal Expansion**: All solids expand on heating and contract on cooling. Thermal expansion may take place as linear, circumferential or cubical. A solid which expands equally in three mutually orthogonal directions is termed as thermally isotropic. The increase in any linear dimension of a solid, e.g. length, width, height on heating is termed as linear expansion. The coefficient of linear expansion is the increase in length per unit length per degree rise in temperature. The increase in volume of a solid on heating is called cubical expansion. The thermal expansion of solids has its origin in the lattice vibration and lattice vibrations increases with the rise in temperature. Obviously, the thermal conductivity (K) and electrical conductivity (σ) vary in the same fashion from one material to another.

d) **Thermal Resistance (RT)**: It is the resistance offered by the conductor when heat flow due to temperature difference between two points of a conductor. It is given by: where H _ rate of heat flow and θ1 and θ2 are temperatures at two points (°C).

e) **Thermal Diffusivity (h)**: It is given by: A material having high heat requirement per unit volume possesses a low thermal diffusivity because, more heat must be added to or removed from the material for effecting a temperature change.

f) **Thermal Fatigue**: This is the mechanical effect of repeated thermal stresses caused by repeated heating and cooling. The thermal stresses can be very large, involving considerable plastic flow. We can see that fatigue failures can occur after relatively few cycles. The effect of the high part of the temperature cycle on the strength of material plays an important factor in reducing its life under thermal fatigue.

3) **Magnetic properties** demonstrate the response of a material to the application of a magnetic field. Materials in which a state of magnetism can be induced are termed magnetic materials. There are five classes into which magnetic materials may be grouped:
   (i) diamagnetic
   (ii) paramagnetic
   (iii) ferromagnetic
   (iv) antiferromagnetic
   (v) ferrimagnetic.

Iron, Cobalt, Nickel and some of their alloys and compounds possess spontaneous magnetisation. Magnetic oxides like ferrites and garnets could be used at high frequencies. Due to their excellent magnetic properties alongwith their high electrical resistivity these materials today, find use in a variety of applications like magnetic recording tapes, inductors and transformers, memory elements, microwave devices, bubble domain devices, recording hard cores, etc. Hysteresis, permeability and coercive forces are some of the magnetic properties of magnetic substances which are to be considered for the manufacture of transformers and other electronic components.

4) **Electrical Properties-** Electrical conductivity, resistivity, dielectric strength, the stimulus is an electric field are few important electrical properties of a material. A material which offers little resistance to the passage of an electric current is said to be a good conductor of electricity. The electrical resistance of a material depends on its dimensions and is given by: Usually resistivity of a material is quoted in the literature. Unit of resistivity is Ohm-metre. On the basis of electrical resistivity materials are divided as:
   a) Conductors
   b) Semiconductors
   c) Insulators.

In general metals are good conductors. Insulators have very high resistivity. Ceramic insulators are most common examples and are used on automobile spark plugs, Bakelite handles for electric iron, plastic coverings on cables in domestic wiring.

5) **Optical properties -** The optical properties of materials, e.g. refractive index, reflectivity and absorption coefficient etc. affect the light reflection and transmission the stimulus is electromagnetic or light radiation.

6) **Chemical Properties** -These properties includes atomic weight, molecular weight, atomic number, valency, chemical composition, acidity, alkalinity, etc. These properties govern the selection of materials particularly in Chemical plant. Deteriorative characteristics relate to the chemical reactivity of materials. In addition to structure and properties, two other important components are involved in the science and engineering of materials— namely, ―processing‖ ―performance.With regard to the relationships of these four components, the structure of a material will depend on how it is processed. Furthermore, a material_s performance will be a function of its properties.

3. Classification of Materials in Engineering

The traditional method is to classify them according to their nature into metals, ceramics, polymers and composites. The factors which form the basis of various systems of classifications of materials in material science and engineering are:

1. The chemical composition of the material,
2. The mode of the occurrence of the material in the nature,
3. The refining and the manufacturing process to which the material is subjected to prior to acquiring the required properties,
4. The atomic and crystalline structure of material and
5. The industrial and technical use of the material.

Common engineering materials that fall within the scope of material science and engineering may be classified into one of the following six groups:
1. Metals (ferrous and non-ferrous) and alloys
2. Ceramics
3. Organic Polymers
4. Composites including Wood materials
5. Semi-conductors
6. Biomaterials
7. Advanced Materials

3.1 Metals and alloys are inorganic materials composed of one or more metallic elements. They may also contain a small number of non-metallic elements. All the elements are broadly divided into metals and non-metals according to their properties. Metals are element substances which readily give up electrons to form metallic bonds and conduct electricity. Some of the important basic properties of metals are:

a) Metals are usually good electrical and thermal conductors,
b) At ordinary temperature metals are usually solid,
c) To some extent metals are malleable and ductile,
d) The freshly cut surfaces of metals are lustrous,
e) When struck metal produce typical sound, and
f) Most of the metals form alloys - When two or more pure metals are melted together to form a new metal whose properties are quite different from those of original metals, it is called an alloy.

Metals usually have a crystalline structure and are good thermal and electrical conductors. Many metals are strong and ductile at room temperature and maintain good strength at high and low temperatures. Metallic materials possess specific properties like plasticity and strength. Few favourable characteristics of metallic materials are high lustre, hardness, resistance to corrosion, good thermal and electrical conductivity, malleability, stiffness, the property of magnetism, etc. Metals may be magnetic, non-magnetic in nature.

These properties of metallic materials are due to:
1) The atoms of which these metallic materials are composed
2) The way in which these atoms are arranged in the space lattice.

Metallic materials are typically classified according to their use in engineering as under:

1) **Pure Metals**: They are obtained by refining the ore. Mostly, pure metals are not of any use to the engineers. However, by specialised and very expensive techniques, one can obtain pure metals (purity ~ 99.99 %), e.g. aluminum, copper, etc.
2) **Alloyed Metals**: Alloys can be formed by blending two or more metals or at least one being metal. The properties of an alloy can be totally different from its constituent substances, e.g. 18-8 stainless steel, which contains 18 %, chromium and 8 % nickel, in low carbon steel, carbon is less than 0.15 % and this is extremely tough, exceedingly ductile and highly resistant to corrosion.
3) **Ferrous Metals**: Iron is the principal constituent of these ferrous metals. Ferrous alloys contain significant amount of non-ferrous metals. Ferrous alloys are extremely important for engineering purposes. On the basis of the percentage of carbon and their alloying elements present, these can be classified into following groups:
   (a) Mild Steels: The percentage of carbon in these materials range from 0.15 % to 0.25 %. These are moderately strong and have good weldability. The production cost of these materials is also low.
   (b) Medium Carbon Steels: These contains carbon between 0.3 % to 0.6 %. The strength of these materials is high but their weldability is comparatively less.
   (c) High Carbon Steels: These contains carbon varying from 0.65 % to 1.5 %. These materials get hard and tough by heat treatment and their weldability is poor. The steel formed in which carbon content is up to 1.5 %, silica up to 0.5%, and manganese up to 1.5 % along with traces of other elements is called plain carbon steel.
   (d) Cast Irons: The carbon content in these substances vary between 2 % to 4%. The cost of production of these substances is quite low and these are used as ferrous casting alloys.
4) **Non-Ferrous Metals**: Out of several non-ferrous metals only seven are available in sufficient quantity reasonably at low cost and used as common engineering metals. These are aluminum, tin, copper, nickel, zinc and magnesium. Some other non-ferrous metals, about fourteen in number, are produced in relatively small quantities but these are of vital importance in modern industry. These include chromium, mercury, cobalt, tungsten, vanadium, molybdenum, antimony, cadmium, zirconium, beryllium, niobium, titanium, tantalum and manganese.
5) **Sintered Metals**: These materials possess very different properties and structures as compared to the metals from which these substances have been cast. Powder metallurgy technique is used to produce sintered metals. The metals to be sintered are first obtained in powered form and then mixed in right calculated proportions. After mixing properly, they are put in the die of desired shape and then processed with certain pressure. Finally, one gets them sintered in the furnace.
6) **Clad Metals**: A sandwich _of two materials is prepared in order to avail the advantage of the properties of both the materials. This technique is termed as cladding. Using this technique stainless steel is mostly embedded with a thick layer of mild steel, by rolling the two metals together while they are red hot. This technique will not allow corrosion of one surface. Another example of the use of this technique is cladding of duralumin with thin sheets of pure aluminum. The surface layers, i.e. outside layers of aluminum resist corrosion, whereas inner layer of duralumin imparts high strength. This technique is relatively cheap to manufacture.

3.2 Ceramics are inorganic materials consisting of both metallic and non-metallic elements bonded together chemically. Ceramics can be crystalline, non-crystalline or a mixture of both. Generally, they have high melting points and high chemical stabilities. They also have high hardness and high temperature strength but tend to be brittle. Ceramics are usually poor electrical conductors.

3.3Polymers are organic materials which consist of long molecular chains or networks containing carbon. Most polymers are non-crystalline, but some consist of mixtures of both crystalline and non-crystalline regions. They typically have low densities and are mechanically flexible. Their mechanical properties may vary considerably. Most polymers are poor electric conductors due to the nature of the atomic bonding.

3.4 Composites are mixtures of two or more types of materials. The constituent elements in a composite retain their identities (they do not dissolve or merge completely into each other) while acting in concert to provide a host of benefits such as light weight, high strength, corrosion resistant, high strength-to-weight ratio, directional strength - tailor mechanical properties, high impact strength, high electric strength (insulator), radar transparent, non-magnetic, low maintenance, long-term durability, parts consolidation, dimensional stability, small to large part geometry – styling/design – sculptural form, customized surface finish, rapid installation. Usually, they consist of a matrix phase and a reinforcing phase. They are designed to ensure a combination of the best properties of each of the component materials. There is also an increasing trend to classify engineering materials into two further categories: structural materials and functional materials. Structural materials, as the name indicates, are materials used to build structures, bodies and components. For instance, in a car the body, frame, wheels, seats, inside lining, engine and various mechanical transmission parts are all constructed from structural materials.

3.5 Semi-Conductors These are the materials which have electrical properties that are intermediate between the electrical conductors and insulators. The electrical characteristics of semi-conductors are extremely sensitive to the presence of minute concentrations of impurity atoms; these concentrations may be controlled over very small spatial regions. Semi-conductors form the backbone of electronic industry. The semi-conductors have made possible the advent of integrated circuitrythat has totally revolutionized the electronics and computer industries. They affect all walks of life whether it is communications, computers, biomedical, power, aviation, defence, entertainment, etc. The field of semi-conductors is rapidly changing and expected to continue in the next decade. Organic semi-conductors are expected to play prominent role during this decade. Diamond as semiconductor will also be important. Optoelectronic devices will provide three dimensional integration of circuits, and optical computing.

4. The Importance of Engineering Materials in Our Present World

Development of new materials has followed a number of different pathways, depending on both the nature of the problem being pursued and the means of investigation. Breakthroughs in the discovery of new materials have ranged from pure serendipity, to trial-and-error approaches, to design by analogy to existing systems. These methodologies will remain important in the development of materials but as the challenges and requirements for new materials become more complex, the need to design and develop new materials from the molecular scale through the macroscopic final product will become increasingly important. The use of molecular modeling and the engineering of new materials into useable forms or devices are of particular importance.

4.1 Current Trends and Advances in Materials

Timber, steel and cement are the materials which are widely used for engineering applications in huge quantities. The consumption of steel in any country is considered as an indicator of its economic well being. For high temperature applications. Newer materials for combined resistance to high temperature and corrosion are increasing rapidly and material scientists and engineers are busy in developing such materials. Different kinds of ceramics, though difficult to shape and machine, are finding demand for their use at high temperatures. Recently prepared new metallic materials in conjunction with new processing techniques as isostatic pressing and isothermal forging are capable of imparting better fatigue properties to aircraft components. Powder metallurgy technique while producing finished surfaces and cutting down metal cutting cost is much capable of imparting improved mechanical properties under different loading conditions. Surprisingly, rapid cooling technology achieving cooling rates in the vicinity of one million degree Celsius per second and this is being used to produce metal powders which can be used in such product producing techniques as powder metallurgy and hot isostatic pressing to obtain temperature resistant parts. Nowadays, metallurgists have produced several molybdenum and aluminium alloys as well as alloys of titanium and nickel to meet anticorrosion properties at elevated temperatures. Polymeric materials are growing at annual rate of 9% and have grown in volume more than any other material. In several applications plastics have replaced metals, wood, glass and paper. A new trend in plastic technology is the production of synergistic plastic alloys which have better properties than individual members producing the alloy. Recent discovery of plastic conductors may have wider impact in near future. The major drawback of ceramics is the brittleness and difficulty in cutting and shaping. When mixed with metal powder like molybdenum, ceramic produce cements, which are expected to be useful cutting materials. Tool bits of cements are expected to find various applications in attaining high cutting speeds and producing better surface finish. Alumina, a well-known ceramic is expected to be successfully reinforced with fibres of molybdenum. Due to micro cracking of molybdenum fibres, the attempts to achieve better strength in such composite ceramics have not been successful yet. However, such composites have been found to exhibit better impact and thermal shock resistance.

4.2 Further Advances in Materials Development from View Point of New and Advanced Materials

Recent development especially from the point of view of new and advanced materials could be classified into:

4.3 Advanced Materials

The materials that are utilised in high-technology (or high-tech) applications are sometimes called advanced materials. By high technology we mean a device or product that operates or functions using relatively intricate and sophisticated principles; for example, electronic equipment (VCRs, CD players, etc.), computers, fiber optic systems, spacecraft, aircraft and military rocketry. These advanced materials are typically either traditional materials whose properties have been enhanced or newly developed high performance materials. Furthermore, advanced materials may be of all material types (e.g., metals, ceramics, and polymers) and are normally relatively expensive. In subsequent chapters are discussed the properties and applications of a good number of advanced materials—for example, materials that are used for lasers, ICs, magnetic information storage, liquid crystal displays (LCDs), fiber optics, and the thermal projection system for the space shuttle orbiter.

4.4 Smart Materials (Materials of the Future)

Smart or intelligent materials form a group of new materials now being developed that will have a significant influence on many of our technologies. In addition, the concept of smart materials is being extended to rather sophisticated systems that consist of both smart and traditional materials. The field of smart materials attempts to combine the sensor, actuator and the control circuit on as one integrated unit. Actuators may be called upon to change shape, position, natural frequency, or mechanical characteristics in response to changes in temperature, electric fields, and magnetic fields. The combined system of sensor, actuator and control circuit on as one IC unit, emulates a biological system. These are known as smart sensors, microsystem technology (MST) or microelectromechanical systems (MEMS). Materials/devices employed as sensors include optical fibers, piezoelectric materials, and MEMS. MEMS devices are small in size, light weight, low cost, reliable with large batch fabrication technology. They generally consist of sensors that gather environmental information such as pressure, temperature, acceleration etc., integrated electronics to process the data collected and actuators to influence and control the environment in the desired manner. The MEMS technology involves a large number of materials. Silicon forms the backbone of these systems also due to its excellent mechanical properties as well as mature micro-fabrication technology including lithography, etching, and bonding. Other materials having piezoelectric, piezoresistive, ferroelectric and other properties are widely used for sensing and actuating functions in conjunction with silicon. The field of MEMS is expected to touch all aspects of our lives during this decade with revolution in aviation, pollution control, and industrial processes.

4.5 Nano-Structured Materials and Nanotechnology

Nanotechnology is a field that deals with control of structures and devices at atomic, molecular and super-molecular levels as well as the efficient use and manufacture of these devices. Key areas in Nanotechnology are:
1) Nano-medicine for disease detection and treatment
2) Nano-engineered materials for improved agriculture
3) Nanotechnology for energy
4) Nano porous materials for water filtration

Nanostructured materials are those materials whose structural elements clusters, crystallites or molecules have dimensions in the range of 1-100 nm. These small groups of atoms, in general, go by different names such as nanoparticles, nanocrystals, quantum dots and quantum boxes. One finds a remarkable variations in fundamental electrical, optical and magnetic properties that occur as one progresses from an infinitely extended solid to a particle of material consisting of a countable number of atoms. The various types of nanostructured materials which has been considered for applications in opto-electronic devices and quantum- optic devices are nano-sized powders of silicon, silicon-nitride (SiN), silicon-carbide (SiC) and their thin films. Some of these are also used as advanced ceramics with controlled micro structures because, their strength and toughness increase when the grain size diminishes. Carbon-based nanomaterials and nanostructures including fullerenes and nanotube plays an increasingly significant role in nanoscale science and technology.

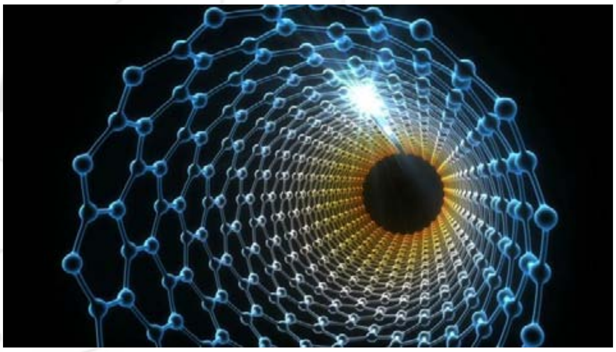

Figure 1: nano materials structure

4.6 Quantum Dots (QDS)

Rapid progress in the fabrication of semiconductor structures has resulted into the reduction of 3D bulk systems to 2D & 1D, and ultimately to 0D systems. Quantum dots represent the ultimate reduction in the dimensionality of semiconductor devices. These are 3D semiconductor structures only nanometer in size confining electrons and holes. QDs operate at the level of single electron which is certainly the ultimate limit for an electronic device and are used as the gain material in lasers. QDs are used in quantum dot lasers, QD memory devices, QD photo detectors and even quantum cryptography. The emission wavelength of a quantum dot is a function of its size. So by making dots of different sizes, one can create light of different colors.

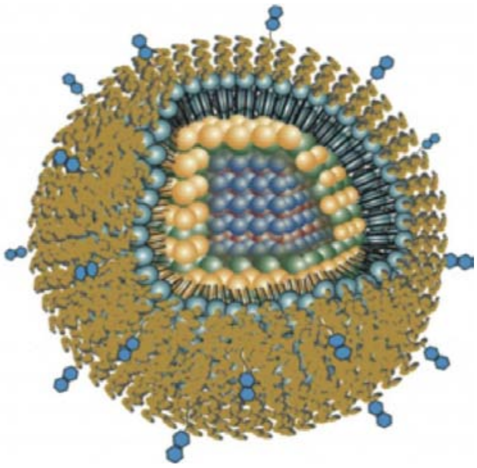

Figure 2: Quantum dots representation

4.7 Spintronics

A revolutionary new class of semiconductor electronics based on the spin degree of freedom could be created. The study of electron spin in materials is called spintronics. Spintronics is based on the direction of spin- and spin-coupling. Every appliance ranging from electric bulb to laptop computer works on the principle of transport of electric charge carriers-electrons. The electrons have both charge and spin. The spin of the electrons could greatly enhance the particles ‗usefulness. Presently, the semiconductor technology is based on the number of charges and their energy. The electron can be assumed as tiny rotating bar magnet with two possible orientations: spin-up or spin-down. An applied magnetic field can flip electrons from one state to another. Obviously, spin can be measured and manipulated to represent the 0‗s and 1‗s of digital programming analogous to the ―current on and current off states in a conventional silicon chip. The performance of conventional devices is limited in speed and dissipation, whereas, spintronic devices are capable of much higher speed at very low power. Spintronic transistors may work at a faster speed, are also smaller in size and will consume less power. The electron spin may exist not only in the up or down state but also in infinitely many intermediate states because of its quantum nature depending on the energy of the system. This property may lead to highly parallel computation which could make a quantum computer work much faster for certain types of calculations. The mixed state could form the base of a computer, built around not only on binary bits but the quantum bits or cubit. It is any combination of a 1 or a 0. Scientists are now trying to use the property of the electron-like spin rather than charge to develop new generation of microelectronic devices which may be more versatile and robust than silicon chips and circuit elements. Spins appear to be remarkably robust and move effectively easily between semi-conductors.

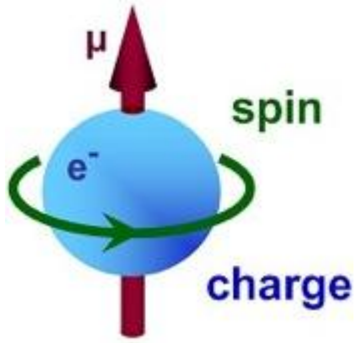

Figure 3: Spintroniccs

4.8 Fermionic Condensate Matter

Very recently scientists had created a new form of matter called a fermionic condensate matter and predicted it could lead to the next generation of superconductors . Solids, liquids, gases, plasma and Bose-Einstein condensate, fermionic condensate matter is a scientific breakthrough in providing a new type of quantum mechanical behaviour. It is related to Bose-Einstein condensate. However, new state is not a superconductor but it is really something in between these two states.

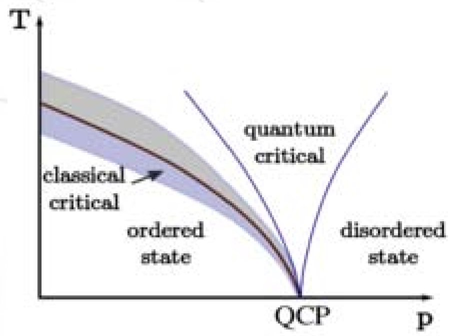

Figure 4: Fermionic matter

5. Breakthroughs in Materials Development

The Material Science has made great strides over the past several decades in the development of novel materials. Although the following is not meant to be an exhaustive list of such breakthroughs, these examples point to the range of materials and their applications.

Examples such as Teflon serve to show how the chemical sciences have contributed indispensable materials to everyday use. More recently, the development of thermoplastics and structural polymers has had an increasing influence on applications ranging from construction to national defense. New paints and coatings, clothing fibers, and photographic films have all benefited from the development of new materials. There are newer polymeric materials whose commercial impact has yet to be realized. Work on semi-conductive and conductive polymers have made great strides, but further work is necessary. Synthesis of amphiphilic dendritic block copolymers that are designed to form ultrathin organic films have also had major advances, other promising materials, from polymers for drug delivery to tissue engineering, have the potential to benefit the biomedical field but are still in a relatively early stage of development.

Catalysis Advances in new materials cover a wide range of applications. Zeolites and pillared clays have had a huge impact on the petroleum industry. New zeolites with specified properties continue to be developed with various utilities. Ziegler-Natta catalysts allow the preparation of billions of pounds per year of organic polymers with controlled molecular structures and useful material properties. This method is also useful because it allows the synthesis of polymers that cannot be produced in a practical manner by any other method. In the energy and transportation sector, catalysis has been an especially fruitful area of research. As a result, supported gold catalysts have been developed. In addition, selective oxidation of carbon monoxide has been achieved and a gold transition- metal oxide has been developed that provides very active NOx reduction as well as hydrocarbon oxidation. The platinum particles serves to complete the oxidation of hydrocarbons and carbon monoxide to carbon dioxide, while rhodium converts nitrogen oxides to nitrogen and oxygen. The use of supramolecular organic templates containing appropriate surface functionalities to regulate the nucleation and growth of inorganic magnets, semiconductors, and catalysts is significant as well.

Electronics This broad category has benefited from many breakthroughs in the development of new materials. Perhaps no recent advance has had a greater impact in this area than the creation of chemically amplified photo resist. Photo resist, resins containing photo chemically active polymers, can be coated on a wafer and irradiated using photons (photolithography), electrons (electron beam lithography), or X-rays (X-ray lithography). These developments have had considerable impact on computer chip production. In the field of telecommunications, high-temperature superconductors and ceramic materials containing copper-oxide planes have potential uses in communications shielding. The development of new instrumentation is essential both in characterizing materials and in exploring their potential applications. Matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF), a mass spectrometry technique that uses laser light to ablate unfragmented polymer molecules mixed with an organic acid matrix into a time of- flight mass spectrometer, is finding increasing application in the polymer community.

Composites – Composites have recently found wide application in various area of life such as Aircraft, Commercial, pleasure and military aircrafts, including components for aerospace and related applications; Appliance, Business. Composite applications for the household and office including appliances, power tools, business equipment, etc; Automotive/Transportation :The largest of the markets, products include parts for automobiles, trucks, rail and farm applications; Civil Infrastructure: A relatively new market for composites, these applications include the repair and replacement of civil infrastructure including buildings, roads, bridges, piling, etc. Construction: Includes materials for the building of homes, offices, and architectural components. Products include swimming pools, bathroom fixtures, wall panels, roofing, architectural cladding; Consumer products : sports and recreational equipment such as golf clubs, tennis rackets, snowmobiles, mobile campers, furniture, microwave cookware; Corrosion-Resistant and Chemical-Resistant Equipment : tanks, ducts and hoods, pumps, fans, grating, chemical processing, pulp and paper, oil and gas and water / wastewater treatment markets; Electrical: Components for both electrical and electronic applications such as pole line hardware, substation equipment, microwave antennas, printed wiring boards, etc; Marine: Products for commercial, pleasure and naval boats and ships.

6. Modern Materials Needs & Challenges

In spite of the tremendous progress made in the field of material science within the past few years, there still remains technological challenges, including the development of more sophisticated and specialized materials, as well as the impact of materials production on ecosystem. Nuclear (fission as well as fusion) energy holds some promise, but the solutions to the many key problems that remain will, necessarily, involve materials from fuels to containment structures to facilities for the disposal of radioactive waste. Progress in fusion research has been incredibly rapid in recent years. There has been major progress in fusion materials and technology, with prototypes of the key components of a fusion power plant built and successfully tested. Obviously, new high strength, low density structural materials remain to be developed, as well as materials that have higher temperature capabilities, for use in engine components. Furthermore, there is an urgent need to find new, economical sources of energy and to make use of present energy resources more economically. Hydrogen seems to be the fuel of the future. Hydrogen offers the greatest potential environment and energy supply benefits. Like electricity, hydrogen is a versatile energy carrier that can be made from a variety of widely available primary energy sources including natural gas, coal, biomass, wastes, sunlight, wind, and nuclear power. Although hydrogen production techniques do exist, further optimization is desirable for use in energy systems with zero carbon emissions. Materials will undoubtedly play a significant role in these developments, We know that environment quality depends on our ability to control air and water pollution. Pollution control techniques employ various materials. There is a need to improve material processing and refinement methods so that they produce less environmental degradation. Toxic substances are produced during manufacturing processes of some materials and therefore we have to consider the ecological impact of their disposal. There are many materials which we use are derived from resources that are non renewable, These include polymers for which the prime raw material is oil, and some metals. These non renewable resources are gradually becoming depleted, which necessitates:

1) The search of additional reserves
2) The development of new materials having comparable properties with less adverse environmental impact
3) Increased recycling efforts and the development of new recycling technologies.

7. Conclusion

Engineering materials always continue to play a significant role in the current and upcoming future world. The relevant factors that will influence this are economic/cost, environmental requirements, development trends, depletion of traditional materials, advances in research and market drives, etc. The importance of engineering materials is in every aspect of life, therefore, need to be over emphasized. We ourselves are materials and so also is everything around us; to stop talking of and working with materials is to foreclose the essence of life existence. So a bright future is that of even more sophisticated, better and cost effective materials. Materials Science, Technology and Engineering of Materials has the capability of solving problems in different sectors of life & the economy. Therefore smart nations are quickly creating areas for themselves by developing materials of both comparative and competitive advantage as required.

8. Acknowledgement

We are thankful to our Institute ―Rajarshi Rananjay Sinh Institute of Management & Technology, Amethi "for encouraging us to explore ourselves. The Incubation Centre of the Institute. Is a beehive of intellectual and innovative activities? Under the excellent & effective guidance of our faculty from Mechanical Engineering Department, Mr. Satya Prakash Pandey Sir, we have completed the informative concepts on materials which focuses on the complete/partial information of same.
Our Institute has always focused on providing us a framework for better future for mankind. Also in shaping us to become effective, skilled professionals in coming future. I am very thankful to the Institute's Management& our Director Sir for his influential leadership

References

[1] Ashby, M. F. and D. R. H. Jones(2005). Engineering Materials 1: An Introduction to Their Properties and Applications, 3rd edition, Butterworth-Heinemann,Woburn, UK.
[2] Ashby, M. F. and D. R. H. Jones, Engineering Materials 2: An Introduction to Microstructures, Processing and Design, 3rd edition, Butterworth- Heinemann,Woburn, UK, 2005.
[3] Flinn, R. A. and P. K. Trojan (1994). Engineering Materials and Their Applications, 4th edition, John Wiley & Sons, New York.
[4] Jacobs, J. A. and T. F. Kilduff (2005). Engineering Materials Technology, 5th edition, Prentice Hall PTR, Paramus, NJ.
[5] K. M. Ralls, T. H. Courtney, and J.Wulff, Introduction to Materials Science and Engineering, p. 22. Copyright 1976 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)
[6] Murray, G. T. (1993) Introduction to Engineering Materials— Behavior, Properties, and Selection, Marcel Dekker, Inc., New York.
[7] Ralls, K. M., T. H. Courtney, and J. Wulff (1976). Introduction to Materials Science and Engineering, John Wiley & Sons, New York.
[8] Organising Committee for the Workshop on Materials and Manufacturing, Committee on Challenges for the Chemical Sciences in the 21st Century, National Research Council. .Materials Science and Technology: Challenges for the Chemical Sciences in the 21st Century by ISBN: 0-309-51684-6, 98 pages, 6 x 9, (2003) Free PDF downloaded from: http://www.nap.edu/catalog/10694.html
[9] Schaffer, J. P., A. Saxena, S. D. Antolovich, T. H. Sanders, Jr., and S. B. Warner (1999). The Science and Design of Engineering Materials, 2nd edition, WCB/McGraw-Hill, New York.
[10] Sigma-Aldrich (2007). ―Advanced Metals and Alloys Material Matter, Vol. 2, No. 4.
[11] Smith, W. F. and J. Hashemi (2006). Principles of Materials Science and Engineering, 4th edition, McGraw-Hill Book Company, New York..
[12] Van Vlack, L. H. (1989). Elements of Materials Science and Engineering, 6th edition, Addison-Wesley Longman, Boston, MA.
[13] William D. Callister, Jr. (2007). Department of Metallurgical Engineering, The University of Utah with special contributions by David G. Rethwisch The University of Iowa - Materials Science and Engineering -An Introduction to Materials Science and Engineering.―7th ed.
[14] www.wiley.com/college/callister (Student Companion Site).

Author Profile

Satya Prakash Pandey received the B.Tech. degree in Mechanical Engineering from IIMT, Meerut in 2008.He is pursuing M. Tech from KNIT, Sultanpur. He is now with Rajarshi Rananjay Sinh Institute of Management & Technology, Amethi as a Assisstant Professor in Mechanical Engineering Department.

Vishwajeet Singh is persuing the B.Tech in Mechanical Engineering from Rajarshi Rananjay Sinh Institute of Management & Technology, Amethi. Currently, He is a student of Second Year.