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THE ROLE/IMPORTANCE OF ENGINEERING AND MATERIALS UTILIZATION IN PRESENT DAY WORLD

Chaitanya Halmare[1], Mayur Mandavkar[2], Aarish Mohammad[3]

[1]*UG Student, Mechanical Department, Jawaharlal Darda Institute of Engineering & Technology, Maharashtra, India,* ***c_halmare@rediffmail.com***

[2] *UG Student, Mechanical Department, Jawaharlal Darda Institute of Engineering & Technology, Maharashtra, India,* ***mayur2mandavkar@gmail.com***

[3] *UG Student, Mechanical Department, Jawaharlal Darda Institute of Engineering & Technology, Maharashtra, India,* ***aarishmohammmad533@gmail.com***

Abstract

Materials had been in use since time immemorial. Our world is all about materials, which is why Materials Science and Engineering are taking prominence and centre-stage position in many developed and developing countries. Over the years there have been changes in man's choice of materials for his engineering activities. The ages and times/period of man's activities on earth are sometimes usually referred to by age and period when such materials were in vogue like the Stone Age, the Iron Age and the current Silicon age, etc. But the challenges of current world are constantly fuelling the discovery and development of new kinds of materials with the desired properties and the right cost to meet the challenges of the current day world. This article is, therefore, aimed at reviewing the advances made in engineering materials, their classification and the role/importance engineering materials in current day world vis-a-vis their properties and areas of application. The Importance of material in modern world can be realized from the fact that much of the research is being done to apply new material to different components. However it is natural for a design engineer to rely on trusted and tested materials, but now the world is changing. Today composite materials has given an opportunity to various designers to use an better materials resulting in cost reduction, increase in efficiency and better utilization of available resources. Composite materials in mechanical engineering, terminology used in composite materials, various definition, classification and the latest developments in composite materials in different parts of the world.

Key Words: *Semi-conductors , Polymers , Catalysis , Electronics.*

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1. INTRODUCTION

Materials are probably more deep-seated in our culture than most of us realize. Transportation, housing, clothing communication, reaction and food production and virtually every segment of our daily lives is influenced to one degree or another by materials. Materials have contributed to the advancement of a number of technologies, including medicine and health, information and communication, national security and space, transportation, structural materials, arts and literature, textiles, personal hygiene, agriculture and food science and the environment. The excitement of Materials Science and Engineering is amplified by its intimate connections with other disciplines and its impact on daily life. These inter-disciplinary interactions between the Material sciences and other fields in the development of new materials and their applications also require close interaction and clear communication between scientists working in diverse areas.

As the contribution of materials science and engineering to other disciplines increases, it will become necessary for scientists of all backgrounds to better understand how to undertake collaborative activities with other disciplines. 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 specific topics.

This presentation represents an attempt to present a relatively brief overview of Materials Science and Materials Engineering and their roles in the present day world. Emphasis is thus, placed on the relationship between structure and properties of materials, starting with the concept of ‗structure' at three levels – crystal structure, microstructure, and molecular structure. 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. Furthermore, the presentation will try to decipher why the need to study Materials Science and Engineering as well as take a look at classification of Engineering Materials and their importance in various live endeavors.

2. HISTORICAL PERSPECTIVE

Historically, the development and advancement of societies have been intimately tied to the members 'ability to produce and manipulate materials to fill their need. In fact, early civilizations have been designated by the level of their materials development (e.g Stone Age, Bronze Age, Iron Age, New and Advanced Materials Age, etc.).

The earliest humans had access to only a very limited number of materials, those that occur naturally: stone, wood, clay, hides and skins, etc. With time they discovered techniques for producing materials that had properties superior to those of the natural the natural ones; these new materials included pottery and various metals. Furthermore, it was discovered that the properties of a material could be altered by heat treatments and by the addition of other substances. At this point, materials utilization was totally a selection process that involves deciding from a given, rather limited set of materials the one best suited for an application by virtue of its characteristics. It was not until recent times that scientists came to understand the relationships between the structural elements of materials and their properties. This knowledge acquired over approximately, the past 100years, has empowered them to fashion, to a large extent, the characteristics of materials. Thus, tens of thousands of different materials have evolved with rather specialized characteristics that meet the needs of our modern and complex society; these include metals, plastics, ceramics, glasses, fibers. The development of many technologies such as biotechnology, nanotechnology, advanced electronics etc; that make our existence so comfortable has been intricately associated with the accessibility of suitable materials. Advancement in the understanding of a material type is often the fore-runner to the stepwise progression of a technology. For example automobiles would not have been possible without the availability of inexpensive steel or some other comparable substitutes. contemporary era, sophisticated _high tech' electronics or gadgets/devices rely on components that are made from what are called semi-conduction materials.

3. MATERIALS SCIENCE AND ENGINEERING

Sometimes the discipline of Materials Science and Engineering can be sub-divided into materials science and materials engineering sub disciplines. Strictly speaking, ―materials science‖ involves investigating the relationships that exist between the structures and properties of materials. Conversely, ―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 synthesis 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. Most graduates in materials programmers are trained to be both materials scientists and materials engineers.

3.1 Why Study Materials Science and Engineering?

Why do we study materials? Many an applied scientist or engineer, whether mechanical, civil, chemical, or electrical, will at one time or another be exposed to a design problem involving materials. Materials selection is one key problem that will always face engineers that must work with materials. Examples might include a transmission gear, the superstructure for a building, an oil refinery component, or an integrated circuit chip. Of course, materials scientists and engineers are specialists who are totally involved in the investigation and design of materials.

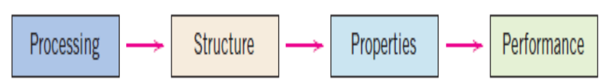
3.2 Elements of Materials Science and Engineering

There are four essential elements in materials science and engineering (Fig. 1).

(i) processing /synthesis;
(ii) structure/composition;
(iii) properties; and
(iv) performance/application.

There is a growing realization among scientists and engineers that in order to develop new materials and provide materials efficiently for society, all four elements need to be considered. This gives materials science and engineering its inter-disciplinary nature. Nowadays, it is common (and indeed preferred in many cases) for people with different backgrounds (materials, physics, chemistry, metallurgy, ceramics, electronics, etc.) to work together to solve materials problems and to make important contributions to this field. 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, civil and aerospace engineering.



The four components of the discipline of materials science and engineering and their interrelationship.

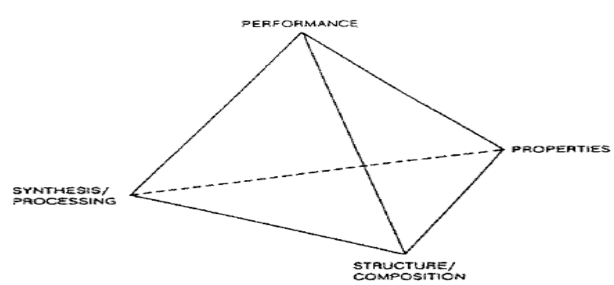


Fig-1: Four elements of materials science and engineering

4. THE ROLE/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 modelling 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, e.g. steam and gas turbines the design engineers keep creating the demand for various high steel alloy. However, alloys of chromium, nickel, molybdenum and tungsten along with iron are better suited for the said 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 aluminum 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.

Fig-2 : Gears made from advanced plastics : Source : High Performance polymer website

Ceramics are mainly used as high temperature low load carrying materials. The major drawback of ceramics is the brittleness and difficulty in cutting and shaping. When mixed with metal powder like molybdenum, ceramic produce cerements, which are expected to be useful cutting materials. Tool bits of cerements 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 fibers of molybdenum. Due to micro cracking of molybdenum fibers, 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.

The advent of solar cells, electronic digital circuits and computers in factory automation and use of robots in several industrial applications is adding to the enormous demand of silicon chips and of such material as silicon. Today, semi-conductors form the backbone of electronics and they affect all types of instruments/industries related to e.g. communications, computers, biomedical, power, aviation, defense, entertainment, etc.

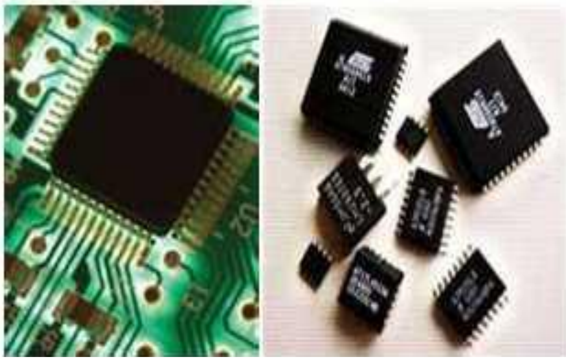


Fig-3 : Semi – Conductors

5. BREAKTHROUGHS IN MATERIALS DEVELOPMENT

The Material Sciences have made great strides over the past several decades in the development of novel and useful 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.

5.1 Polymers

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/or structural polymers has had an increasing influence on applications ranging from construction to national defence. New paints and coatings, clothing fibres, 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, but these materials also need further development. 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.

5.2 Catalysis

Advances in new materials for catalysis 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. Some examples of these are linear unbranched polyethylene and isostactic polypropylene.

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 goldtransition- metal oxide has been developed that provides very active NOx reduction as well as hydrocarbon oxidation. Perhaps no more ubiquitous an example of novel catalysis exists than the catalytic converter, which contains a porous ceramic coating embedded with palladium and rhodium. The platinum particles serve to complete the oxidation of hydrocarbons and carbon monoxide to carbon dioxide, while rhodium converts nitrogen oxides to nitrogen and oxygen.

Another important breakthrough in this field includes the development of metallocene catalysts, which are expected to revolutionize the polyethylene and polypropylene markets. The use of super molecular organic templates containing appropriate surface functionalities to regulate the nucleation and growth of inorganic magnets, semiconductors, and catalysts is significant as well.

5.3 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 photoresist. Photoresist, resins containing photochemically 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.

6. CONCLUSION

Engineering materials will continue to play even more significant role in the current and future world. The factors that will influence this are found in economic/cost, environmental requirements, development trends, depletion of traditional materials, advances in research and market drives, etc. The importance of engineering materials in every aspect of life endeavour can, therefore, not be over emphasised. 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 the economy and smart nations are quickly creating niche areas for themselves by developing materials of both comparative and competitive advantage.

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