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Review Article

Science of Advanced Materials

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Submitted: 07 September 2013

Accepted: 16 October 2013

Published: 18 October 2013

Keywords

- Nanomaterials
- Smart materials
- Superconductors
- Multifunctional materials
- Biomaterials

Abstract

In this article an overview of the developments, importance and applications of some advanced materials have been discussed. The materials which have been discussed are: nanomaterials, smart materials, self cleaning materials, superconductors, multifunctional materials, semiconductors, biological materials and environment friendly materials. It is emphasized that these materials have lot of impact on the society.

INTRODUCTION

The materials used by different cultures in most cases were the only records left for anthropologists to define the civilization. The progressive use of more sophisticated materials showed an innovative divide between peoples. This is partially due to the major material of use in that culture and its associated benefits and drawbacks. Indeed we have come a long way from our sylvan beginnings where the only concern of our ancestors was survival. After the stage of survival came the era of consolidation when man learnt to process some of the naturally occurring materials and change these into more useful forms. Since the dawn of human civilization, man tried to understand, initially through empirical experience, and later through systematic scientific studies, the properties of materials and simultaneously attempted to transform the naturally occurring materials to their usable forms. Historically development and advancement of societies have been intimately related to materials and its development. There were stone Age, bronze age, etc. With time, techniques were discovered for producing materials that had properties superior to naturally occurring materials.

Potteries and metals were some of the examples. With the advancement of science, structure-property correlation of materials could be understood and a new discipline of science known as Materials Science emerged. The development of many technologies that make our life comfortable is closely related to materials [1]. The basic strategy for the synthesis, characterization and processing of materials is given in (Figure 1).

The field of Materials Science and Engineering began to be considered its own discipline around the mid 1960's. The materials are substances having properties which make them useful in machinery, structures, devices and products. Materials are classified into broad categories, based on both their chemical constitution and their typical physical properties. Solid materials are generally grouped into three basic categories: metals, ceramics and polymers. In addition, there are two other groups of important engineering materials: composites and semiconductors. Composite consists of combinations of two or more different materials, whereas semiconductors

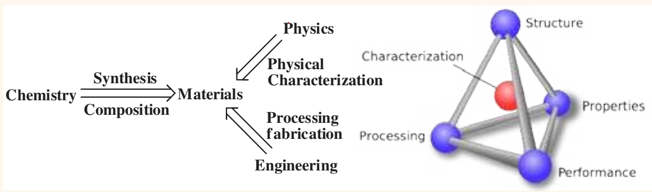


Figure 1 Strategies for Materials synthesis, characterization and processing.

are distinguished by their unusual electrical characteristics. In addition to this classification based on their structure, bonding, and properties, materials have increasingly come to be classified by their function [e.g. electronic, biomedical, structural and optical materials]. Materials technology will produce products, components, and system that are smaller, smarter, multifunctional, environmentally compatible, more survivable and customizable. These products will not only contribute to the growing revolutions of information and biology but will have additional effects on manufacturing logistics and personal lifestyles. Variety of materials known as advanced materials has been developed for different applications. A brief description of some of the important materials is given below.

NANOMATERIALS

Nanoscience and technology has emerged recently as a promising area in the knowledge bank with lots of scope for innovation to address the challenging problems faced by science, society and humanity. It is basically the study and manipulation of matter properties at sub-micron scale for technological applications in general and challenging applications in particular. It deals with fundamentals and applications of material systems/ structures having at least one dimension in the size ranging from 1 nm – 100 nm (nanoscale) [2]. It is an interdisciplinary branch of knowledge representing confluence of conventional disciplines like Physics, Chemistry, Material Science, Biology, Medicine, etc. at the nanoscale. This in turn has tremendously impacted our approach towards science and technology in a fundamental way.

Properties of Materials change at nanoscale. For example various properties of bulk gold change as it goes to nano regime (Figure 2).

Description of nanotechnology is incomplete without touching upon Carbon nanotubes, nature's finest gift to mankind, the most amazing and wonderful nanostructure that the human being has discovered so far [3]. Carbon nanotube (CNT) has emerged as an important material in the nano-scale science. CNTs made from graphene are simply matchless to any other nanomaterials due to their unique properties. Recent exploration of electrical, magnetic, and optical properties of graphene nanostructures with different morphologies (nanosheets, nanoribbons, and nanodots) has attracted tremendous attention, by the scientific and the technological communities. Based on the diverse properties, these materials could have a wealth of applications in various fields, including spintronics, optoelectronics, and the design multimodal imaging probing biomedical applications. Carbon nanotubes are reported to be thermally stable in vacuum upto 2800 °C, to have a capacity to carry an electric current a thousand times better than copper wires, and to have twice the thermal conductivity of diamond (which is also a form of carbon). Carbon nanotubes are used as reinforcing particles in nanocomposites, but also have many other potential applications. These could be the basis for a new era of electronic devices smaller and more powerful than any previously envisioned. Nanocomputers based on carbon nanotubes have already been demonstrated. Basically there are two types of carbon nanotubes: single walled carbon nanotube (SWNT) and multiwalled carbon nanotube (MWNT) (Figure 3).

NANOCOMPOSITES

A nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometers, or structures having nano-scale repeat distances between the different phases that make up the material [4]. In the broadest sense this definition can include porous media, colloids, gels and copolymers, but is more usually taken to mean the solid combination of a bulk matrix and nano-dimensional phase(s) differing in properties due to dissimilarities in structure and chemistry. Nanocomposites have lot of applications particularly in purifications of water and as a sensor. Recently we prepared nanosize zinc ferrate by coprecipitating mixed hydroxides followed by calcination at 500°C. This was embedded in Polyvinyl alcohol to form a nanocomposite. The nanocomposite film was found to be a very efficient material for removal of chromium from water.

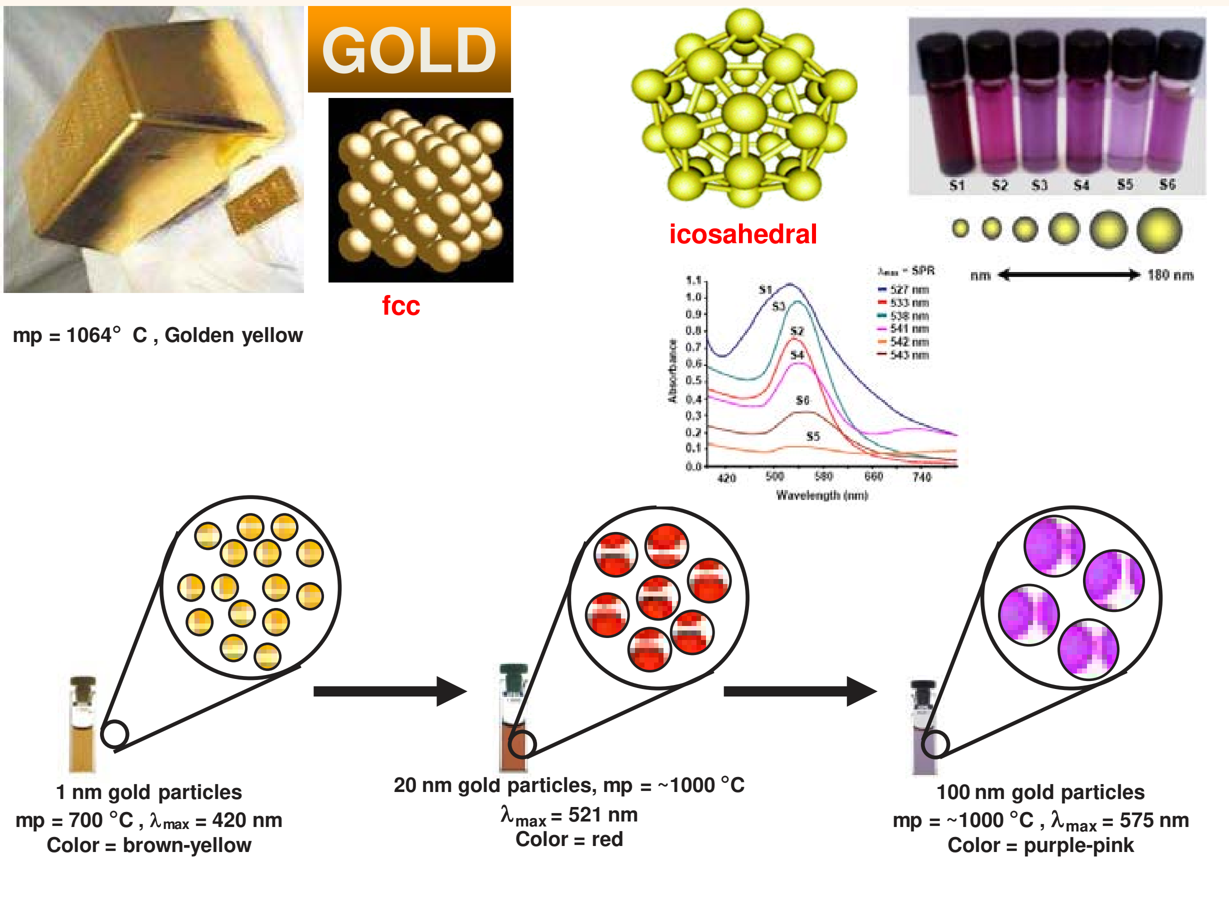


Figure 2 Properties of gold at nanoregime.

Zinc oxide/polyaniline (ZnO/PANI) nanocomposite film prepared by a chemical method (Figure 4) is found to be a good sensor for ammonia gas sensing [5]. (Figure 4) shows the variation of resistance with the concentration of ammonia. As the concentration is increased, the resistance of ZnO/PANI film continuously increased up to 10% ammonia and after that a small increase in the resistance occurred. It appears that ammonia is adsorbed by the film which increases the resistance. After certain concentration, adsorption of ammonia becomes small and the increase in resistance also becomes low. In the case of PANI alone the change in resistance is low due to lower adsorption because of lower surface area. When the ZnO/PANI nanocomposite film adsorbed with ammonia was exposed to dry air, the resistance of the film reverted back to the original value within few seconds. This showed that ZnO/PANI is a good candidate for ammonia sensing. There are many other nanocomposites which act as a sensor for different gases [6].

NANOSCIENCE OF CEMENTITIOUS MATERIALS

Concrete science is a multidisciplinary area of research where nanotechnology potentially offers the opportunity to enhance the understanding of concrete behavior, to engineer its properties and to lower production and ecological cost of construction materials. The construction industry will have to find new ways of building to accomplish radical reductions of pollution and waste.

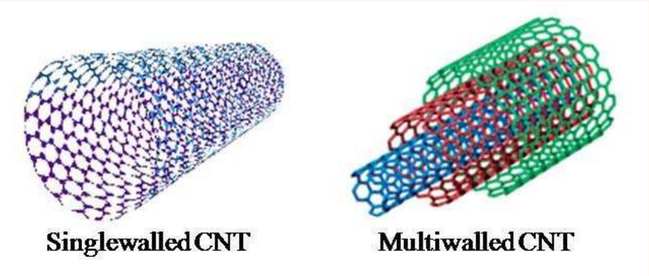


Figure 3 Single and Multiwalled carbon nanotubes.

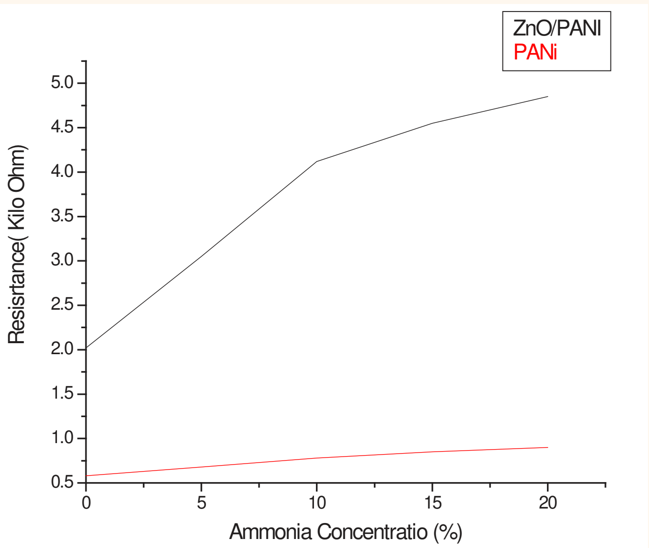


Figure 4 Change in resistance with increasing concentration of ammonia.

Nano and biotechnology along with information technology have the potential to constitute a new building paradigm. Portland cement is the most important constituent of the concrete, therefore understanding the nanoscience and technology of this material is essential. The major aspects are: uunderstanding basic phenomena of hydration at nanoscale, new production techniques (e.g. more energy-efficient and environmental friendly production of cements), role of mineral admixtures, new high performance structural materials (e.g., CNT, new fiber reinforcements, biomimetic materials, etc.), role of nanoparticles, high performance new coatings, paints and thin films (e.g.,wear-resistant coating, durable paints, self-cleaning/anti-bacteria coatings), new multi-functional materials and components (e.g., aerogel based insulating materials). Das and Singh [7] recently reviewed the nanoscience of cementitious materials.

Portland cement in the industry is still manufactured in the conventional way. However beta dicalcium silicate (β-C_2S) one of the important constituents of Portland cement, is prepared in the laboratory at a much lower temperature by using hydrothermal (Scheme 1) and sol-gel methods (Scheme 2). Highly reactive β-dicalcium silicate with high specific surface area (nanosize) has been prepared (Scheme 1) [7].

SMART MATERIALS

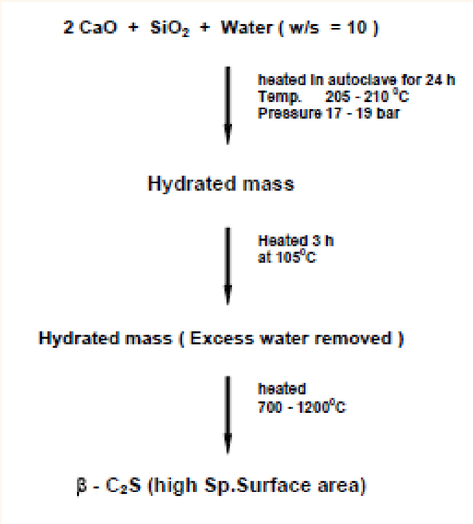
Smart or intelligent materials are materials that have the intrinsic and extrinsic capabilities, first, to respond to stimuli and environmental changes and, second, to activate their functions according to these changes [8]. The stimuli could originate internally or externally. Since its beginnings, materials science has undergone a distinct evolution: from the use of inert structural materials to materials built for a particular function, to active or adaptive materials, and finally to smart materials with more acute recognition, discrimination and reaction capabilities. To encompass this last transformation, new materials and alloys have to satisfy a number of fundamental specifications. Smart materials are the next frontier in engineering and manufacturing. Depending on changes in some external conditions, "smart" materials change their properties (mechanical, electrical, appearance), their structure or composition, or their functions such as-windows that automatically darken when the sun shines and detector that sense when an aircraft wing is about to ice up, and apply some heat.

A smart material has smart structure and incorporates particular functions of sensing and actuation to perform smart actions in an ingenious way. The basic five components of a smart structure are summarized in (Figure 5) [8]:

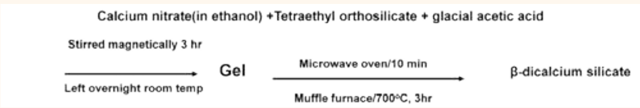
I. **Data Acquisition (tactile sensing)**: the aim of this component is to collect the required raw data needed for an appropriate sensing and monitoring of the structure.

II. **Data Transmission (sensory nerves)**: the purpose of this part is to forward the raw data to the local and/or central command and control units.

III. **Command and Control Unit (brain)**: the role of this unit is to manage and control the whole system by analyzing the data, reaching the appropriate conclusion, and determining the actions required.



Scheme 1 Hydrothermal method for the preparation of highly reactive β-dicalcium silicate.



Scheme 2 Sol-gel method for the preparation of highly reactive β-dicalcium silicate.

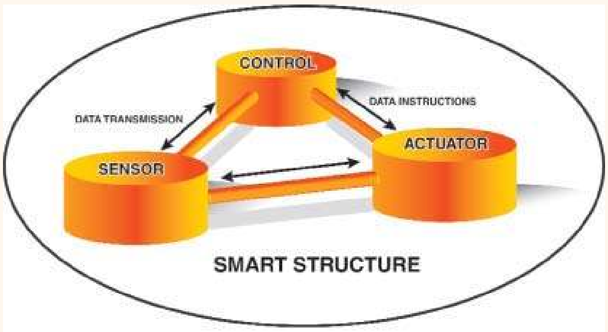


Figure 5 The Basic Five Components of a Smart Structure.

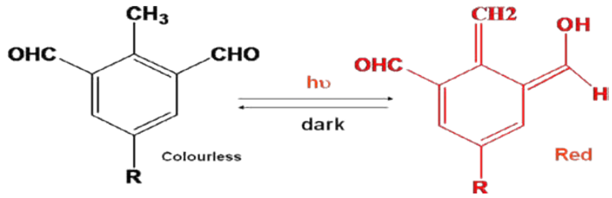
IV. **Data Instructions (motor nerves)**: the function of this part is to transmit the decisions and the associated instructions back to the members of the structure.

V. **Action Devices (muscles)**: the purpose of this part is to take action by triggering the controlling devices/ units.

There is variety of smart materials and some of them are given below.

Colour changing materials

Photochromic materials: Photochromic materials - change colour reversibly with changes in light intensity. Usually, they are colourless in a dark place, and when sunlight or ultraviolet radiation is applied molecular structure of the material changes and it exhibits colour. When the relevant light source is removed the colour disappears. Photochromic molecules can belong to various classes: triarylmethanes, stilbenes, azastilbenes, nitrones, fulgides, spiropyrans, naphthopyrans, spiro-oxazines, quinones and others. 2,5-Dimethylisophalaldehyde changes colour as given below.



Temperature changing materials

Thermochromic materials: Thermochromic materials change colour reversibly with changes in temperature. They can be made from semi-conductor compounds, liquid crystals or using metal compounds. The change in colour happens at a determined temperature, which can be varied doping the material. They are used to make paints, inks etc.T-shirt uses thermochromic inks for decoration purposes. An increase in temperature produces a reversible change in colour. The heat from direct sunlight is enough to produce the change.

Light emitting materials

(a) Electroluminescent materials: Electroluminescent materials produce a brilliant light of different colours when stimulated electronically (e.g. by AC current). While emitting light no heat is produced. Like a capacitor the material is made from an insulating substance with electrodes on each side. One of the electrodes is transparent and allows the light to pass. The insulating substance that emits the light can be made of zinc sulphide or any other material. They can be used for making light stripes for decorating buildings, or for industrial and public vehicles as safety precautions.

(b) Fluoroscent materials: Fluorescent materials produce visible or invisible light as a result of incident light of a shorter wavelength (i.e. X-rays, UV-rays, etc.). The effect ceases as soon as the source of excitement is removed. Fluorescent pigments in day light have a white or light colour, whereas under excitation by UV radiation, they irradiate an intensive fluorescent colour.

Luminiscent aerogels emit red light when excited with ultraviolet light. This effect is due to a coat of silicon nanoparticles deposited within the structure of a silica aerogel, through chemical vapour infiltration.

MOVING MATERIALS

(a)Conducting Polymers: Conducting polymers are conjugated polymers, namely organic compounds that have an extended p-orbital system, through which electrons can move from one end of the polymer to the other. The most common are polyaniline and polypyrrole. Polypyrrole has been used for the development of micro muscles. Polyaniline films sandwiched around a ion-conducting film are considered as material for artificial muscles for robots. A current flow reduces one side and oxidises the other. Ions are transferred. One side expands and the other contracts, resulting in a bending of the sandwich. Electrical and chemical energies are so transformed in mechanical energy.

(b)Polymer gels: Polymer gels consist of a cross-linked polymer network inflated with a solvent such as water. They have the ability to reversibly swell or shrink (up to 1000 times in volume) due to small changes in their environment (pH, temperature, electric field). Micro sized gel fibres contract in milliseconds, while thick polymer layers require minutes to react (up to 2 hours or even days). They have high strength and can deliver sizeable stress (approximately equal to that of human muscles). The most common are polyvinylalcohol (PVA), polyacrylic acid (PAA) and polyacrylonitrile (PAN). Many potential applications (e.g. artificial muscles, robot actuators, adsorbers of toxic chamicals), but presently, few of them have a commercial value.

(c))Shape-Memory Alloys (SMA): When subjected to a thermal field, this material will undergo phase transformations which will produce shape changes. It deforms to its 'martensitic' condition with low temperature, and regains its original shape in its 'austenite' condition when heated (high temperature) (Example: Nitinol TiNi.)

(d)Superelastic glasses: These glasses are made from a superelastic metal alloy. Therefore, they can be bended quite drastically without permanent damage. The glasses utilizes the superelastic property of Ni-Ti alloys. A Nickel-Titanium spring in coffeepots marketed in Japan is trained to open a valve and release hot water at the proper temperature to brew a perfect pot of coffee. It is a Shape-Memory Alloy that, after being strained, at a certain temperature revert back to its original shape. Nickel-Titanium (NiTi) alloy is the most used Shape Memory Alloy. It is an equiatomic compound of NiTi, whose transformation temperature can range between -100 and +110 ^{o}C.

PIEZOELECTRIC MATERIALS

When subjected to an electric charge or a variation in voltage, piezoelectric material will undergo some mechanical change, and vice versa. These events are called the direct and converse effects. Many polymers, ceramics, and molecules such as water are permanently polarized: some parts of the molecule are positively charged, while other parts of the molecule are negatively charged. When an electric field is applied to these materials, these polarized molecules will align themselves with the electric field, resulting in induced dipoles within the molecular or crystal structure of the material. Furthermore, a permanently-polarized material such as quartz (SiO_2) or barium titanate ($BaTiO_3$) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. These materials are piezoelectric, and this phenomenon is known as the piezoelectric effect. Conversely, an applied electric field can cause a piezoelectric material to change dimensions. This phenomenon is known as electrostriction, or the reverse piezoelectric effect. Piezoelectric materials are used in acoustic transducers, which convert acoustic (sound) waves into electric fields, and electric fields into acoustic waves. Transducers are found in telephones, stereo music systems, and musical instruments such as guitars and drums.

Quartz, a peizoelctric material, is often found in clocks and watches. An oscillating electric field makes the quartz crystal resonate at its natural frequency. The vibrations of this frequency are counted and are used to keep the clock or watch on time.

PIEZOELECTRIC POLYMERS

The materials discussed so far are hard, brittle crystalline materials and often difficult to fabricate into large devices. There is a large potential market for relatively cheap, large area, flexible materials. One such material is poly(vinylidine fluoride) PVDF. It is a semi crystalline polymer with a planar zig-zag conformation. The C-F bond has a high dipole moment (charge separation) so that if all can be made to point the same way the material becomes piezoelectric. This can be done by heating the polymer up, stretching it, turning it into a thin film and applying a high voltage ("Poling") so that the material has permanent electric polarisation on cooling.There are many applications such as- (i) under water sound receivers (hydrophones),

(ii) Medical diagnostics- ultrasonic imaging, etc.

FERROELECTRIC MATERIALS

A ferroelectric solid is a material that has a permanent polarization on account of a cooperative shift of some of its atoms in a given direction. For example, above 120^{o}C, barium titanate, $BaTiO_3$, is electrically a normal solid, and the titanium ion is symmetrically placed inside an octahedron of O atoms. However below 120^{o}C, Ti ion moves from the centre of the octahedron by about 10pm and every unit cell over a large domain acquires an electric dipolemoment that persists even in the absence of an applied field.

BENEFITS OF SMART MATERIALS

Smart materials are used in number of areas. The potential future benefits of smart materials, structures and systems are amazing in their scope. This technology gives promise of optimum responses to highly complex problem areas by, for example, providing early warning of the problems or adapting the response to cope with unforeseen conditions, thus enhancing the survivability of the system and improving its life cycle. Moreover, enhancements to many products could provide better control by minimizing distortion and increasing precision. Another possible benefit is enhanced preventative maintenance of systems and thus better performance of their functions.

SELF CLEANING MATERIALS

Scientists may have found an answer to the prayers of every lazy person - clothes that clean themselves. A chemical coating has been developed which destroys any dirt that gathers on clothing. The clothes simply need to be exposed to sunlight for the cleaning process to begin. The breakthrough came when scientists coated clothing with nano sized particles of titanium dioxide (20 nm) [9]. This helps to break down carbon-based molecules. In a similar way buildings can be made clean and durable. The initial aesthetic qualities of new buildings often deteriorate due to attack from environmental aggressors (atmospheric or biological pollution).

There are certain materials which prevent the buildings from deterioration and in addition, are self-cleaning. These materials are covered with an invisible coating of catalyzer which destroys the organic dirt as it is deposited. When exposed to daylight, this coating generates free radicals at the surface of the materials. These radicals destroy the soots and microorganisms that come into contact with them. Titanium oxide is the preferred catalyst for this application. This chemical phenomenon, called photocatalysis, is similar to photosynthesis. It ensures these “intelligent” construction materials stay durably clean, and even purifies the air that comes into contact with them. TiO_2-loaded cementitious materials are used for self-cleaning purposes as well as for pollution control. Examples of pollutants that can be eliminated by the photocatalytic TiO_2/cement system are NO*x*, SO*x*, NH_3, CO, volatile organic carbons such as benzene and toluene, organic chlorides, aldehydes, and polycondensated aromatics.

SUPERCONDUCTORS

The phenomenon of superconductivity, in which the electrical resistance of certain materials completely vanishes at low temperatures, is one of the most interesting and sophisticated in condensed matter physics [10]. It was first discovered by the Dutch physicist Heike Kamerlingh Onnes, who was the first to liquefy helium (which boils at 4.2 Kelvin at standard pressure). In 1911 Kamerlingh Onnes and one of his assistants discovered the phenomenon of superconductivity while studying the resistance of metals at low temperatures. They studied mercury because very pure samples could easily be prepared by distillation.

It has long been a dream of scientists working in the field of superconductivity to find a material that becomes a superconductor at room temperature. A discovery of this type will revolutionize every aspect of modern day technology such as power transmission and storage, communication, transport and even the type of computers we make. All of these advances will be faster, cheaper and more energy efficient. This has not been achieved to date. However, in 1986 a class of materials was discovered by Bednorz and Müller that led to superconductors that we use today on a bench-top with liquid nitrogen to cool them. Not surprisingly, Bednorz and Müller received the Nobel Prize in 1987 (the fastest-ever recognition by the Nobel committee). The material we mostly use on bench-tops is Yttrium – Barium – Copper Oxide, or $YBa_2Cu_3O_7$, otherwise known as the 1-2-3 superconductor, and are classified as high temperature (Tc) superconductors.

The discovery of high-temperature superconductivity in both Bi-Ca-Sr-Cu-O and Tl-Ca-Ba-Cu-O systems has provided a further stimulus to the studies in the field of high T_c oxides. The T_c's of some of the superconductors are

$Tl_2Ca_2Ba_2Cu_3O_{10}$	-	125 K
$Bi_2Ca_2Sr_2Cu_3O_{10}$	-	110 K
$Tl_2CaBa_2Cu_2O_8$ -	below 106 K	
$YBa_2Cu_3O_{7-x}$	-	90 K

Meissner and Ochsenfeld found that when a superconducting material is cooled below its critical temperature, T_C, it expels all magnetic flux from within its interior the magnetic flux is thus zero inside a superconductor. Researchers are interested in having room temperature superconductors but they could not succeed so far.

The most recent discovery in the area of superconductivity is the discovery of magnesium diboride. Magnesium diboride (MgB_2) is inexpensive and simple superconductor. Its superconductivity was announced in March 2001. Its critical temperature (T_c) is 39 K.

Applications of superconductors

Superconductors have two unique properties that could be very important for technology if methods can be found for exploring them. First they have zero electrical resistance and so carry current with no energy loss; this could revolutionize the national grid for instance, and is already exploited in the windings of superconducting magnets as used in NMR experiments. Second, they expel all magnetic flux from their interior and so are forced out of a magnetic field. The Superconductors can float or ‘levitate’ above a magnetic filed: the Japanese have an experimental frictionless train that floats above magnetic rails and has achieved speeds of over 500 km h^{-1}.

A super magnetic energy storage unit (SMES) has been designed that could store a massive amount of direct current with no energy loss. The design currently uses Nb Ti alloy and a liquid He cooling system. It would be used to store electricity generated at tunes of low demand at night for instance. A liquid nitrogen cooling system would be cheaper to build and to run.

Superconductors are of great interest to electronic industry because they can be used for switching voltages very quickly. As they do so they consume very little power and thus do not heat up.

One of the biggest difficulties in further miniaturization of computer chips is how to get rid of unwanted heat. If Superconductors were used, the heat problems would be dramatically reduced. The greater speed of chips is hindered by the time it takes to charge a capacitor, due to the resistance of inter connecting metal film. Superconductors could lead to faster chips.

Making useful products in the form of wire or tape has proved to be difficult. They are made from a powdered mixture of Superconductor and polymer which is formed into the appropriate shape, sintered and then annealed; unfortunately the product tends to be brittle. Another problem is that the 1-2-3 Superconductors tend to loose oxygen, and therefore the Superconductivity at the same time. However the development of superconductors of magnesium boride type may minimize these problems.

MULTIFUNCTIONAL MATERIALS

Nature offers numerous examples of materials that serve multiple functions. Biological materials routinely contain sensing, healing, actuation, and other functions built into the primary structures of an organism. The human skin, for instance consists of many layers of cells, each of which contains oil and perspiration glands, sensory receptors, hair follicles, blood vessels, and other components with functions other than providing the basic structure and protection for the internal organs. Scientists now seek to mimic these material systems in designing synthetic multifunctional materials using physics, chemistry, and mathematics to their advantage in competing with the unlimited time frame of nature's evolutionary design process.

The term 'Multifunctional Material' is defined to be any material or material-based system which integrally combines two [or possibly more] properties, one of which is normally structural and the other functional, e.g. optical, electrical, magnetic, thermal etc [11]. Likely candidate systems will include aspects of 'smart materials/ systems' and biologically-inspired materials [biomimetics] and cover all materials types [e.g. polymers, ceramics, metals, composites] and forms[e.g. bulk, coatings, fibres, fabrics]. Both active and passive functionality is included and the concept of 'designed-in' functionality is a further useful descriptor. Materials are central to every energy technology, and future energy technologies will place increasing demands on materials performance with respect to extremes in stress, strain, temperature, pressure, chemical reactivity, photon or radiation flux, and electric or magnetic fields.

SEMICONDUCTORS

The semiconductors are very important class of materials [12]. They are used in variety of industries. Most people interact with about 300 semiconductors. Semiconductors are all around us. They are in cars, radios, stereos, cell phones, pagers, microwave ovens, kitchen appliances, and medical equipment, to name just a few applications. They are everywhere. The silicon IC is the engine that drives the information age [13]. Fiber optics, for example, is another key base technology. If silicon is the engine that drives the information age, then optical fiber is the highway of the information age. There are other types of semiconductors that are important today. Compound semiconductors, for instance, provide the photons that are the vehicles that carry the information along optical-fiber highways. Compound semiconductors also make possible the very-high-frequency devices - cell phones and pagers - used in today's wireless communications.

Photovoltaic solar cells are being used for conversion of solar energy into electrical energy and the cells use semiconductor devices [14]. The first solid-state solar cell was made by depositing a thin layer of Au on Se semiconductor. The two fundamental processes, namely light absorption and charge separation, are still the basis in all inorganic solar cells today. The current solar cell industry is dominated by Si with nearly 90% of the market. The lack of a "perfect" semiconductor or semiconductors for terrestrial solar cells has been a fundamental limit to an exponential expansion of the solar cell industry. These cells need to be deployed on a scale of $\sim 10^{12}$ W to make a meaningful impact on our energy infrastructure. They need to go on rooftops, windows, highways, and large-scale solar farms. The widespread deployment of solar cells requires many desirable properties for the semiconductor(s) in the cells. However the most important bottleneck for solar electricity to become a household energy source is cost.

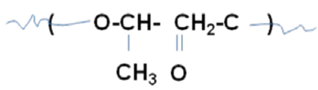
BIOLOGICAL MATERIALS

Biomaterial can be defined as any material used to make devices to replace a part or a function of the body in a safe, reliable, economic, and physiologically acceptable manner. Biological material is a material produced by a biological system. Most biological materials can be considered as composites [15]. The biomedical materials span a wide range and include materials, ceramics, polymers and composites. The functions they fulfill have been growing over the years. From the well known use of ceramics in dentistry and orthopaedic implants, now specialized materials have been developed for making valves, pacemakers and vascular grafts for the heart and blood circulating systems of the body, eye lens replacements, artificial hearts, devices for hearing and invivo pumps for the release of drugs like insulin.

During the last 40 years a revolution has occurred in the use of ceramics. The revolution is the development of specially designed and fabricated ceramics for the repair and reconstruction of diseased, damaged and 'worn out' parts of the human body. The ceramic materials must be biocompatible. Most clinical applications of bioceramics related to the repair of the skeletal system, composed of bones, joints and teeth, and to augment both hard and soft tissues. Ceramics are also used to replace parts of the cardiovascular system, especially heart valves, and also in the treatment of tumors. Now polymers are used as biomaterials.

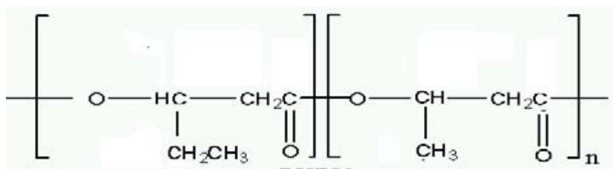
ENVIRONMENT FRIENDLY MATERIALS

Plastic waste is a serious concern for the environment because of its resistance to microbial attack. There have been significant advances in the manufacture of materials that completely degrade by microbial attack-under appropriate environmental conditions. Generally these materials are more expensive but they are much friendlier to the environment. These polymers are being used for making shopping bags, food packaging and medical disposables. Poly (β-hydroxybutyrate) PHB is an example of biodegradable polymer.



PHB

One problem with PHB is its slow rate of degradation. This can be overcome by making copolymers of PHB with hydroxyl valeric acid.



PHBV

The copolymer is called PHBV.

CONCLUSIONS

It has been emphasized that materials especially the advanced materials are scientifically and technologically very important for the development of a country. Most of the comforts to the society are the outcome of advanced materials. Still lot of research is needed to develop specific material for a specific job.

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Cite this article

Singh NB, Agrawal S (2013) Science of Advanced Materials. JSM Chem 1(1): 1003.