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Engineering Material and Their Properties

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Abstract – Nanotechnology is not only a simple continuation of miniaturization from micron meter scale down to nanometer scale. Because of their small size which gives large surface areas, they can lead to unexpected or dramatically differing properties than the bulk. Different sized nano materials exhibit different properties. For example bulk gold has golden color but the gold nano particle having diameters of >1nm and 3-30 nm has orange and red colors. They are useful candidates for many applications like solar cells, batteries, computer chips, cosmetics, drug delivery, optoelectronic devices, catalysis, display devices, photo and electroluminescent devices, spintronics, sensors etc. leading them to enter the world market in a big way. Although many countries are majorly investing in this field of nanotechnology.

Natural inorganic nanomaterials occur through crystal growth in the diverse chemical conditions of the earth's crust. Fullerenes, carbon nanotubes are some of the examples of synthetic organic nanomaterials. Inorganic nanomaterials are based on other elements, such as silicon. Solids and molecules have been studied and understood quite well, however nanomaterials exhibits properties that are entirely different from either of the two. If the physical size of the material is reduced below the nanometer length scale, it's all properties like mechanical strength, thermal, optical, magnetic, conducting etc. change and become sensitive to its size and shape.

Keywords: Synthesis, Polymer, Nano-Composites, Organic, Polymers

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INTRODUCTION

The number of surface atom increases with decreasing particle size. In other words nanomaterials have large number of atoms on their surface as compared to those in the interior. For example, in a cube of edge size 1 cm, the % of the surface atoms would be 10-5 % of the bulk atoms whereas for a cube of edge size 1 nm, the percentage surface atoms would be 10 % of the bulk atoms.

The surface atoms in nanomaterials play a dominant role in governing the electronic, optical and thermodynamic properties of nanomaterials. The variation in material properties with size i.e. from bulk to nano includes depression in melting point, increase in the pressure required to produce transformation, reduction in Young's modulus, increase in specific heat, increase in resistivity, enhancement in luminescence etc. For example, bulk gold has melting point ~1064 ºC, whereas on reducing the size of gold from bulk to particle size of 2 nm, the reduction in melting point is observed and it melts at ~ 500 ºC.

Nanomaterials can be synthesized by growing and shaping the materials by variety of physical, chemical, biological or hybrid methods. All the nanomaterial synthesis method are often divided into two categories: top down and bottom up approach.[9] In top down approach materials are brought down from a larger size to nanometer dimensions. This approach involves milling, machining and lithographic techniques. On the other hand, it is also possible to start with atoms or molecules, bring them together to make the required particles or assemblies of nanometer size. This is known as bottom up approach. The bottom up approach consists of physical as well as chemical methods.

A polymer is like a thread joining many coins punched through the center, in the end we get a string of coins, the coins would be the monomers, and the chain with the coins would be the polymer. The basic part of a polymer are the monomers, the monomers are the chemical units that are repeated throughout the chain of a polymer, eg In polyethylene, monomer is ethylene, which is repeated 'n' times along throughout the chain. Number of polymers, such as starch and proteins are natural materials and have been used by human being. In reality, the body of man itself is partly composed of polymer substance, such as the keratin in hair and nails and the deoxyribonucleic acid (DNA) found in the every nucleus of the body cells. Now a days, the material made of polymers finds multifarious uses starting from common household utensils, automobiles, furniture, etc to space, the aircraft, biomedical and surgical appliances.

Natural resins and gums were with us and had unique properties. Natural polymers have attracted the interest of researchers about a century ago and they were classed as 'colloids' to distinguish from crystalline material. The concept gradually changed with the improvement by researchers in synthetic polymer.

The polymers obtained from nature (plants and animals) are called natural polymers. These polymers are very essential for life. Natural polymers contain starch, cellulose, polysaccharides, proteins, nucleic acid and natural rubber. Starches are polymers of glucose i.e. starch molecule consist of several hundreds of glucose molecules connected together. Cellulose is also a polymer of glucose. It's made by using the plant from glucose produced through photosynthesis. Similarly, protein is a result of polymerization of amino-acids. Protein is composed of 20-1000 amino acid in a highly organized arrangement. Another very significant natural polymer is rubber. It is a polymer consisting of repeat unit of the hydrocarbons isoprene (2-methyl 1,3- butaidiane).

Polymers are traditionally regarded as electrical insulators, hence any conduction of electricity is regarded as an undesirable property. However, a new class of polymers known as intrinsically conducting polymers or electroactive conjugated polymers has emerged during the past two decades. These novel materials with interesting and unanticipated properties have attracted the whole scientific community including polymer and synthetic chemists, material scientists, organic chemists as well as theoretical and experimental physicists. The conduction of electricity in conducting polymers is due to the occurrence of delocalized molecular orbital.

Intrinsically conducting polymers are also known as synthetic metals, because these organic polymers have electrical, electronic, and optical properties, which are the unique properties of metal. The behaviour of metallic nature of conducting polymer can be obtained during mechanical properties, processability, etc.

It is a flexible polymer with similar characteristics to semiconductors. Advantages include its fairly low cost, simple production process and it's stable conductive form. Disadvantages include little electrochemical strain, insolubility in the majority solvents and infusibility, which makes it inappropriate for melting processes.[54] However, solubility has been enhanced with the use of new solvents, such as dimethyl urea and N-methyl-2-pyrrolidone (NMP). Since, polyaniline undergoes decomposition upon heating above its critical temperature, synthesis was preferred in its solution form. In general, polyaniline characteristically has relatively low strain (1−2 %), actuation stress in the range of 2−4 megapascals (MPa) and a conductivity for approximately 103 S/cm.

ENGINEERING MATERIAL AND THEIR PROPERTIES

In the field of nanotechnology, polymeric nanocomposites are a new class of materials that combine the properties of inorganic particles with the processability and flexibility of an organic polymer matrix. The polymer with incorporation of nanoscopic materials is called as polymer nanocomposites.

Polymers are flexible, lightweight materials and can be produced at a low cost. Inorganic nanoparticles (NPs) possess specific optical, catalytic, electronic and magnetic properties, which are significantly different from their bulk states. The integration of inorganic nanoparticles into a polymer matrix allows both properties from the inorganic nanoparticles and the polymer to be combined/enhanced and novel functionalities can be generated in the polymer nanocomposites. In particular, the fabrication of optically transparent nanocomposites via the incorporation of inorganic NPs into a polymer matrix is of immense industrial interest because of their promising potential applications in the fields of light-emitting diodes, optoelectronic packages, transistors, solar cells, and coatings.

A number of metal and metal oxide particles have been encapsulated into the conductive polymer to form nanocomposites (NCs). The NCs exhibit combination of properties like conductivity, electrochemical, catalytic and optical properties. The NCs are used in applications like electrochromic devices, light-emitting diodes, electromagnetic interference shielding, secondary batteries, electrostatic discharge systems, chemical and biochemical sensors.

Silver nanomaterials have unique thermal, electrical and optical properties. Because of their stability, low sintering temperatures and high electrical conductivity they are incorporated into many products. When these silver nanomaterials are incorporated with other nanomaterials their photocatalytic activity is improved because of its high electron affinity. The antibacterial effect also improves for silver based compounds as they are highly toxic to microorganisms which include 16 major species of bacteria.

As several pathogenic bacteria have developed resistance against various antibiotics the usage of silver nanomaterials as antibacterial is very important. This antibacterial behaviour of silver nanomaterials has led to many diverse medical applications such as silver based dressings, silver coated medicinal devices. Silver nanomaterials are widely used for several applications including consumer products mainly due to their antibacterial and optical properties.

Silver nanomaterials can be used in the diagnostic applications i.e. they can be used as biosensors and as biological tags for quantitative detection. They can be incorporated into footwear, cosmetics, and clothes because of their marvellous antibacterial properties. They can be used as conductive pastes in the integrated chips. They can be used as composites to improve thermal and electrical conductivity.

Treatment with nanoAg destabilized the outer membrane of bacteria. This indicates that nanoAg can disrupt the outer membrane barrier components such as lipopolysaccharide orporins, culminating in the perturbation of the cytoplasmic membrane. Although the detailed mechanism by which nanoparticles with a diameter of 10 nm can penetrate and disrupt the membranes remains to be determined. Electron microscopy and optical imaging results suggest that nanoAg penetrate the outer and inner membranes of the treated Gram negative bacteria, with some nanoparticles being found intracellularly. NanoAg elicited a rapid collapse of proton motive force. This was also indicated by the observation that nanoAg induced a massive loss of intracellular potassium. As expected, nanoAg also decreased the cellular ATP levels, apparently resulting from the collapse of membrane potential. The rapid and complete depletion of ATP may be also indicative of a stimulation of hydrolysis of residual ATP. It is conceivable that this dissipation of bacterial membrane potential and reduction of ATP levels by nanoAg may culminate in loss of the cell viability

Antibiotics act by inhibiting the growth (microbiostatic) or killing microorganisms (microbiocidal) by arresting the bacterial functions that are essential for the growth. However, the action of antibiotics imposes a selective pressure that fosters the growth of antibiotic-resistant strains, and thus the treatment of antibioticresistant strains of a post-antibiotic era is looming as a challenge of 21st century.

Biofilm protect their constituent cells in various ways, which makes it difficult to treat both the clinical and industrial contaminations. Over past few years, some inorganic materials exhibit improved physical and chemical properties at the nanoscale level, and have gained attention because of their potential in impeding microbial growth on surfaces and solutions.

Several classes of antimicrobial nanomaterials and nanocomposites have successfully being used to eradicate the growth of organisms causing infectious disease including the antibiotic-resistant ones. The CPs are emerging as an exciting class of materials with an ability to design and synthesis novel nanomaterials for various applications.

This may be possible due to their freely conducting electrons along with any intrinsic charges associated with the polymer backbone, thus, allowing the formation of complexes with metal ions in solution and subsequently reduction to zero-valent metals in the absence of any externally applied electric field.

Polyaniline is a highly functional unique synthetic polymer among the family of π-conjugated polymers because of its ease of synthesis, relatively good environmental stability and simple acid/base doping/dedoping chemistry.

As polyaniline has been shown to be non-toxic and biocompatible, conducting polymers of polyaniline have been used in the development of cardiac muscles, controlled drug release and as an antimicrobial agents.

These features of CNTs make them attractive candidates in nanoscale device applications. However, due to strong inter-tube van der Waals interactions, CNTs lack solubility and are difficult to manipulate in any solvent. Hence applications using these CNTs materials have been limited. Therefore, strategic approaches toward the solubilization/suspension of CNTs for their integration into inorganic, organic, and biological systems are important.

DISCUSSION

The sp2 hybridization, composed of one's orbital and two p orbitals, is a strong bond within a plane but weak between planes. When more bonds come together, they form sixfold structures, like honeycomb pattern, which is a plane structure, the same structure as graphite. Graphite is stacked layer by layer so it is only stable for one single sheet. Wrapping these layers into cylinders and joining the edges, a tube of graphite is formed, called nanotube. Multiwalled carbon nanotubes (MWCNTs) are of pure carbon and can be reacted and manipulated using the rich chemistry of carbon. This provides opportunity to modify the structure and to optimise solubility and dispersion, allowing innovative applications in materials, electronics, chemical processing and energy management, to name just a few.

Owing to the uncommon combination of a relatively small energy barrier for rotation and a large mass of macroscopically long nanotubes, individual tubes are unlikely to move as rigid objects in the rope, but rather to bend and twist locally, displacing orientational dislocations that were frozen in during the tube synthesis.

The storage of electrical energy through a double layer charging and faradic processes or combination of both the device is known as supercapacitor. The stored quantity of energy is usually less and will be provided very quickly when supercapacitor is ready to supply power rather than energy. Supercapacitor is known by different terms viz. ‘double-layer capacitor’, “ultra-capacitor”, ‘power capacitor’, ‘gold capacitor’, ‘power cache’ or ‘electrochemical double-layer capacitor’.

According to the intrinsic principles of charge storage and discharge in super capacitors, there are two kinds of capacitance viz. double-layer and pseudo capacitance. The double layer capacitance involves non-faradic process, whereas pseudo capacitance involves a periodic process. The double layer obtained on separation of ionic charges (or electronic charges) arises at interfaces between solids and ionic solutions, especially in colloids, metal electrodes and semiconductors. An q), of contrasting sign takes place across boundaries to anΔamassing of charges (V) (related to the potentialΔextent that is dependent on the potential of electrode (alteration built up across an interface). This consequences in a capacitance (C) = V), which is referred to as the ‘double-layer’ capacitance. ChargeΔq)/d(ΔV or d(Δq/Δ storage in accurate double-layer capacitors is solely electrostatic in nature (separation of ion and electron charges) with no chemical reaction is involved. Consequently, charging and discharging is extremely reversible and takes place practically instantaneously. Sometimes double layer also known as Helmholtz layer.

Pseudo capacitance is related with electro sorption of ions or metal atoms and particularly some redox processes which is apart from the double-layer capacitance. Pseudo capacitance occur due to the thermodynamic reasons, the charge (q), required for progression of an electrode process, e.g. electro sorption or redox conversion of an oxidized species to a reduced species in liquid or solid solutions and is a function of potential (V). So, the derivative of charge with respect to change in V) corresponds to a faradic capacitance (or pseudo capacitance). ThusΔq/Δvoltage (pseudo capacitance can be related with either a redox reaction, for which potential is a logarithmic function of the ratio of activities of the oxidized species or with a process of progressive occupation of surface sites on an electrode by an under potential deposited species. Pseudo capacitance arises, when the conducting polymer (for example PANI) is being charged. It loses electrons and becomes polycations, causing the anions in the solution to intercalate into the conducting polymer in order to maintain electro neutrality

CONCLUSION

Polymers have been widely used since their early days, as electrical insulation materials. Traditionally dielectric materials are made from inorganic substances eg. mica and silicon dioxide. However, now a days polymers are gaining wider use as dielectric materials. This is due to the easier processing, flexibility, able to tailor made for specific uses and better resistance to chemical attack. As early as mid-60’s polymers e.g. polyvinyl fluoride and aromatic polymers were used as dielectric materials in capacitors. Further improvement in organic film fabrication was established in US. Polymers can be fabricated fairly easily into thin film by solution casting and spin coating, immersion in organic substrate, electron or UV radiation and glow discharge methods. This is mainly due to lower thermal properties such as glass transition and melting temperature which contribute to a lower temperature processing windows. Their solubility is controllable without offsetting their intrinsic properties.

REFERENCES

1. K. Bandyopadhyay (2014). Nano Materials, New Age International Publications, 1.

2. M. A. Rafiee, W. Lu, A. V. Thomas, A. Zandiatashbar, J. Rafiee, J. M. Tour, N. A. Koratkar (2010). ASC Nano, 12, pp. 7415.

3. X. Li, C. W. Magnuson, A. Venugopal, R. M. Tromp, J. B. Hannon, E. M. Vogel, L. Colombo, R. S. Ruoff (2011). J. Am. Chem. Soc., 133, pp. 2816.

4. C. Dale, Brownson, C. E. Banks (2015). RSCAdv., 2, pp. 5385.

5. L. Jiao. L. Zhang, X. Wang, G. Diankov, H. Dai (2013). Nature, 458, pp. 877.

6. Novel natural nanomaterial spins off from spider-mite genome sequencing., Phys.Org, May 23, 2013

7. S. Link, M. A. El-Sayed (2010). Int. Rev. Phys. Chem., 19, pp. 409.

8. R. W. Kelsall, I. W. Hamley, M. Geoghegan (2015). Nanoscale Science and Technology John Wiley and Sons Ltd,.

9. W. Caseri, H. S. Nawa (2014). Encyclopaedia of Nanoscience and Nanotechnology Ed, American Scientific Publisher, California, 6, pp. 235.

10. L. H. Baekeland (2015). Chemtech, 6, pp. 40.

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