Innovative Nanotechnology Applications In Automobiles

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Abstract - ***Need of mobility all across the world is increasing exponentially. This is also an important prerequisite for the progress of modern society. In the past, automobile has played a crucial role and shall continue to play a dominant role in the progress of society. The demand of automobiles is increasing rapidly especially in the countries like China, India, Brazil and Korea. The rising economies of these countries will further increase the demand of automobiles. In order to achieve safety, comfort and environment friendliness, automobile companies are investing heavily in research and development. In this context, nanotechnologies are likely to play an important role. Nanotechnology is opening new doors for innovative products and imaginative applications in automobile sector. This paper focuses on the recent trends and future innovative nanotechnology applications in automobile industry.***

Keywords–Nanotechnology, Nanomaterials, Automobile

Introduction

Nanotechnology is one of the most significant research areas to emerge in the past two decades or so. It is based on the concept of creating applications based on components built at the very small scale. Nanotechnology is the understanding and control of matter at dimensions of roughly 1-100 nm, where unique phenomena enables novel applications. A nanometer is 10^{-9} of a meter; a sheet of paper is about 100,000 nm thick. Encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modelling, and manipulating matter at this length scale. At this level, the physical, chemical and biological properties of materials differ in fundamental and valuable ways from both the properties of individual atoms and molecules or bulk matter. Nanotechnology R&D is directed towards understanding and creating improved materials, devices and systems that exploit these new properties. The unique properties of nanotechnology originate from small dimensions, enabling high speed and high functional density (nanoelectronics, lab-on-chip), small and lightweight devices and sensors, high sensitivity (sensors, nanowires) and special surface effects (such as lotus effect). Nanotechnology gives rise to new molecular structures, with new material properties - high strength nanotubes, nanofibers and nanocomposites.

Nanotechnology offers many benefits to various aspects of entire spectrum of industry. The automotive industry is also not untouched by the brewing nanotechnology revolution. Nanotechnology enhanced materials have already started beginning to improve the performance and cost-effectiveness of automobiles, and in coming years it will further become more and more viable as stronger, lighter and harder nonmaterial are commercially available. Although, a large number of nano-structures have been investigated till now, however, the most significant among them are synthesized from single atomistic layers of carbon. These structures include hollow ball shaped "Buckyballs" (Fullerene-C60), Carbon nano tubes (CNTs) and graphene sheets which have a very interesting range of mechanical, thermal and electrical properties [1]. A large number of nano-materials such as metal nanoparticles, nano-powder, nano-adhesives, nano coatings, are being increasingly used in automotive applications.

Functional Advantages of Nanotechnology

Nanotechnologies can be utilized in a wide range of industries owing to unique effects and functional properties. Functional advantages which are direct fallout of unique properties of nano materials are described hereunder.

Mechanical Properties

The demonstrated improved mechanical properties of nanostructure material are higher hardness, increased breaking strength at low temperatures or super elasticity at higher temperatures. The mechanical properties exhibited are due to decrease in grain size resulting in dimensions below which deformation mechanism does

not occur in grain itself. These benefits can be translated in terms of lightweight materials, increased durability of components and effective lubricating system.

Geometric Effects

At contact surfaces, a crucial reaction between gaseous or liquid and solid substances takes place at nanoscale. Interaction in different medias therefore require special physical and chemical properties of the surface of the particles, fibres, pores and the products. With regard to protection function, these demands include resistance against oxidation, corrosion, mechanical abrasions and high temperature [2]. Because of the small size of nanostructures, the extreme surface-to-volume ratio of these materials becomes more important. Therefore, large specific surface and the surface properties of nanostructured materials influence chemical activity [2]. Due to pores at nanometer range, materials can exhibit properties which can be used in nanofilters.

Optical Properties

Since nanoparticles are very small as compared to the wavelength of the visible light, no reflection occurs from these particles. Dispersion effect is also demonstrated by nanoparticles which can cause colour effect. By altering the size of the nanoparticles, desired wavelength region can be achieved for intended application. Therefore, the optical property such as light absorption and emission behaviour gets altered. The fact nanoscale features are smaller than the wavelength of visible photons, also impacts light scattering, enabling the design of nanocrystalline ceramics that are as transparent as glass [1].

Electronic Functionalities

In the nanometer range, quantum effects take place that cannot be observed in larger objects. Charge carriers that can move freely in volume of solid material are strongly influenced in their mobility by nano objects given their small dimensions. The behaviour can also be observed in a material with macroscopic dimensions consisting of nanocrystalline crystallites separated by grain boundaries. Scattering of charge carriers on boundary surfaces affects several electrical properties. Therefore, an increase in the specific electrical resistance in comparison to a material with crystals in the micrometer range can often be observed. The manipulation of the grain size of such a material allows turning of the electronic properties [2].

Applications of Nanotechnologies in Automobiles

Nanotechnology offers great promises of innovative products and sustainable solutions to entire cross section of industry. Automotive industry is set to get benefited with research and development taking place in nanotechnology. The nanotechnology enabled products have already started showing its presence across automotive industry by way of enhanced performance and cost effectiveness. The industry requirements of increased fuel efficiency, safety and comfort, environmental safety etc are set to be revolutionarised by nanotechnology. As on date, a large number of nanotechnology applications are in use in automobile industry. The areas which are likely to have impact in future are discussed below.

Nanotechnology for Car Body

Keeping in mind the safety of the automobile occupant, it is important to develop nano structured materials which can offer high strength to take care of the high intensity impact during crash. Light weight would also lead to reduced fuel consumption and thus economy in operation.

Nano Steel

Crash safety and lightweight are the two major issues which are required to be addressed. A high strength yet light weight material for car body can be produced by using nanotechnologies. It has been reported that embedded nano particles of metallic carbon nitride can effectively increase the strength of steel. In long term loading tiers of up to 10,000 hours, it was observed that a share of 0.002 percent of finely dispersed carbon can increase the stability of the steel significantly. The small size of only five to ten nanometer of carbon nitride is responsible for the outstanding properties [2].

Corrosion Protection

Another desired characteristic of automotive parts is corrosion protection. Widely used Chrome III (Cr^{3+}) does not offer long term protection. By the use of nanotechnologies it has been made possible to enhance protection by the use of SiO_2 nano particles in the electrolyte. The passivation achieved through galvanization processes consists of a Cr^{3+} enriched layer and a layer containing SiO_2 nano particles in a Cr^{3+} matrix. In case the Zinc layer gets exposed due to damage, a positive surface charge builds up. The SiO_2 particles have negative charge and migrate to the

damaged area as shown in figure 1. [2].

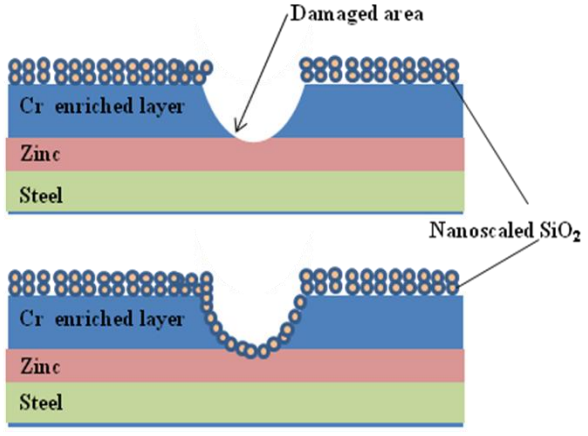

Fig. 1. Corrosion protection ans self healing by migration of SiO_2 particles to the damaged location.

Nanotechnology for Chassis and Tyres

Reduction of the automobile weight is the primary concern of the automobile manufacturer. The reduced weight of the automobile leads to reduced fuel consumption and emission of exhaust fumes. Nanotechnologies can give rise to lighter and more resistant materials by incorporation of nano particles or by the control of structure at nano scale. It is possible to achieve same mechanical strength with less and lighter material with enhanced performance. Carbon black was the first nano material to be used by the automotive industry in tyres as a pigment and reinforcing agent. Almost one-third of the cover consists of reinforcing filler which ensures desired properties such as abrasion resistance, grip, resistance to tear and low rolling resistance. Some of these requirements are contradictory in nature. The mechanism behind these tyre properties that partly contradict each other are mainly lightly complex chemical and physical interactions between the rubber and the filler material [2]. The Soot, Silica and organosilane are found to improve the properties of natural rubber significantly. Soot and Silica are the most important chemical ingredients used for reinforcing in tyres. By using nano structured soot as filler in tyres, prolonged durability and higher fuel efficiency can be achieved. These nano structured soot particles have a coarser surface than those that have been used till date. Nano particles result in increased surface energy thereby increasing the interaction with the natural rubber molecules. This further leads to reduction of inner friction and better rolling resistance. At the same time, the strain vibrations that occur within the material at high speeds are reduced. The consequence is a superior traction, especially on wet roads. Figure 2 gives the layout of running surface of the tyre along with comparison of size between individual particles.

The need to reduce the weight of the engine is an ever growing requirement, with the aim of reducing the fuel consumption and the emission of harmful exhaust fumes. Nanotechnology offers the solution in terms of lighter and more resistant materials by incorporating nano particles or by the control of structure at nanoscale. Polymers reinforced with nanoclays play an important role. A small amount of nano particles, roughly 2-5%, is good enough to obtain significant improvement of the properties, like resistance, elasticity or dimensional stability, as well as specific properties like fire resistance for interior parts, or weather resistance for outer parts [3].

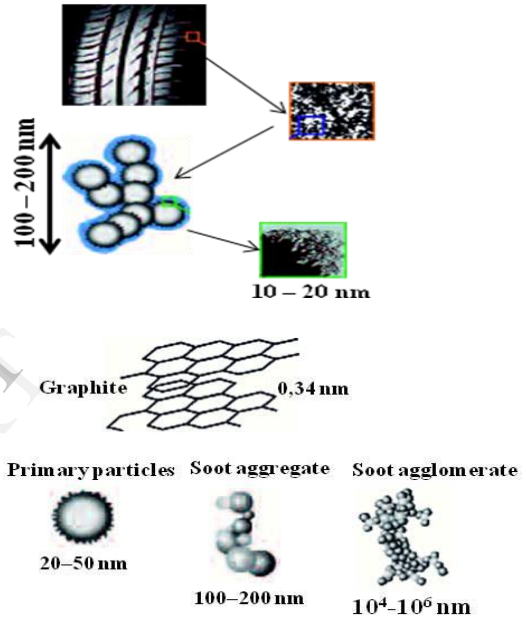

Fig. 2. Size comparison of individual particles of tyre running surface [2]

Another area where nanotechnology is playing important role is achieving driving comfort by the use of switchable materials. In adjustable damping systems, the optimal hardness can be adjusted depending on the situation. These adjustable damping systems use magneto or electro-rheological (MR/ER) fluid, which is classified as smart material. These fluids have the property of altering the viscosity instantly and also reversibly by applying a magnetic or electric field. The effect is based upon the fact that polarized particles in the substrate fluid arrange themselves along the field lined and form chains. The effective viscosity is thus increased, which means that the flow resistance of the fluid rises. If the electric or magnetic field is removed, the chains decompose and the fluid again becomes thin [2]. This change in viscosity is

very fast. In milliseconds a fluid can turn into a tenacious gel. The advantage accrued is that the hydraulic system can be built simpler and compact. Since lesser parts are needed this can result in lighter vehicle

Nanotechnology for Shell of the Car

Nanotechnology offers innovative solution for scratch resistance, dirt repellent and self healing car paints beside ultrathin coating for mirrors and reflectors applicable for car body shell. Following are some of the recent developments taken place for car body shell applications.

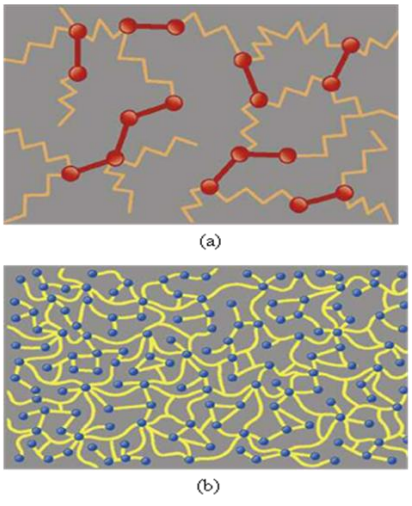

Fig. 3 (a) Conventional paints with binder and crosslinking agents.
Fig. 3 (b) Nano paints with organic binder with high elasticity and inorganic binder with high strength.

Scratch Resistance

Nano-varnishes are now offering scratch resistance and maintained paint brilliance for a long time. This property is possible due to embedded ceramic particles in the final varnish layer in the nanometer range. Conventional paints consist of binder and cross linking agents while the nano paints consist of organic binder with high elasticity and inorganic nano particles with high strength. The tightly packed nano particles make the paint scratch-resistant. Figure 3(a) and 3(b) shows the conventional and nano paint structure. Nowadays, large amount of glass is processed in a car with major chunk used for windscreen and window panes. Nanotechnology holds great promise in reducing the weight of the glass by the substitution of mineral glass by polymer glass. in order to make polymer glass scratch and impact resistant , it is coated with paints having extremely hard aluminum oxide nano particles placed in the substrate matrix during the hardening process resulting in high abrasive resistance with increased impact strength. Since the size of the filler particles is very small and their distribution is even, this results in highly transparent glass.

Ultra Thin Layers for Mirrors and Reflectors

In recent years, superior coating process for mirrors and headlights have been developed for ultra reflecting layers with thickness lesser than 100 nanometers. Another field where nanotechnology applications are utilized is to equip surfaces with water, oil and dirt repellent features. Codec has developed a Fluor-organic material which exhibits both hydrophobic and oelophobic qualities when segregated on a work piece [2]. This layer with a thickness of 5 to 10 nanometers creates a super smooth surface and has ease of cleaning water drops, oil, dust, dirt etc. It offers good dynamic friction properties and thus longer durability of the layer. This layer consists of molecular chains that have an anchor group at one end with which the layer forms a chemical bond on the surface of substrate. The functional group at the other end is responsible for the water, oil and dirt repellent effect [5]. Figure 4shows the illustration of the effect of a perfluorinated coating for the adjustment of hydrophobic and oelophobic properties.

Nanotechnology for Engine and Transmission System

The improved fuel efficiency can be achieved by designing ultra precision fuel injection and variable value controls to optimize the consumption process. Moreover, reduction in engine friction by the use of nano layer can also result in fuel savings.

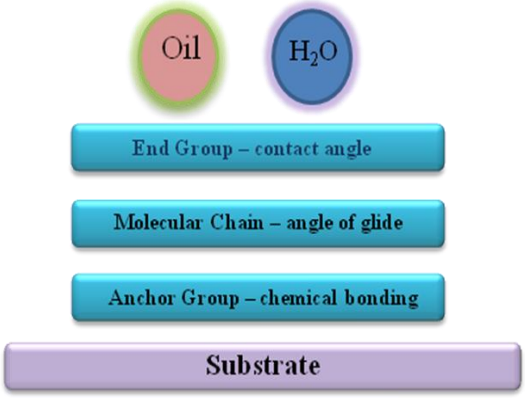

Fig.4. Illustration of the effect of perfluorinated coating for the adjustment of hydrophobic and oelophobic properties.

Reduction in Friction amongst Moving Parts

Almost one tenth of fuel consumption is impacted by various frictional losses in moving parts comprising piston aggregates, cylinder surface, came drive, came shaft and valves. Nano technology can be used in

reducing the friction thereby increased fuel efficiency. By applying nano crystalline coating on cylinder wall, friction and abrasion can be reduced thus fuel consumption. Coating materials with imbedded nano crystals with a size from 60 nm to 130 nm on the basis of iron carbide and boride result in extremely high surfaces with low friction properties [2]. Nano structure ceramics (Zircon, Alumina) or nano reinforced ceramics (Alumina + Silicon Nitride) are being extensively studied for engine jacketing [3]. Nano crystalline ceramics like Si_3N_4 or SiC are also being used in ball bearings and valve springs.

Improving Fuel Injection

In modern diesel automobiles, direct injection pumps are used to spray the fuel into combustion chamber. By controlling the pressure and precise time of injection, more efficient combustion can be achieved. Piezo ceramic materials are used these days to achieve higher fuel economy, reduced pollution and noise by the use of piezoelectric effect to enable the opening and closing mechanisms of the injection valve. Nanocrystalline piezoelectric materials are used (Lead-Zirkone Titanate) in injectors regulating the distance which is in nanometer range. Nanotechnology enabled piezo injectors can ensure several finely closed injections per combustion cycle in powerful diesel engines at 1600 bar injection pressure [2].

Reduction in Exhaust Emission

Modern automobiles are able to reduce exhaust emission by the use of catalytic converter which consist of high grade steel housing that include catalytically active materials used for conversion of pollutants to nitrogen , steam and carbon dioxide. Nanotechnology plays an important role during conversion of toxic to non-toxic gases. If the material used for the catalytic function is scaled to nanometer range, the specific surface increases drastically [2]. The composition is designed in such a way that the exhaust gases can optimally interact with catalytic coating thereby increasing the rate of chemical transformation into harmless substances.

Conclusion

Automobile industry is set to be influenced by the development taking place in the field of nanotechnology. Due to small size of particles in nano range, their chemical and physical properties can be altered to improve the overall properties of conventional material. Increased surface area of the metal nano particles results in significantly enhanced reactivity in a catalytic converter thereby resulting in reduction of emission. Other fields where nano technology is likely to be employed gainfully are cooling systems for efficient heat transfer and use of nano-magnetic fluids in shock absorbers to increase vibration control efficiency. High efficient nano layers of semi conductor materials provide electronic components and systems with a longer lifetime. Sensors based on nano-layer structures find applications in engine control, airbag, antilock brake and electronic stability program systems. Nanotechnology is therefore likely to influence the auto industry in a great deal and shall deliver features and products which are not scalable today.

5. References

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