Potential of Nano Technology in Transportation

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Abstract: Nanotechnology is one of the leading scientific fields today since it combines knowledge from the fields of Physics, Chemistry, Biology, Medicine, Informatics, and Engineering. It is an emerging technological field with great potential to lead in great breakthroughs that can be applied in transportation. The application and use of nanomaterials in electronic and mechanical devices, in optical and magnetic components, quantum computing, and other technologies, with smallest features, are the economically most important parts of the nanotechnology nowadays and presumably in the near future. The number of nanoproducts is rapidly growing since more and more nanoengineered materials.

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1. Introduction

The term nanotechnology comes from the combination of two words: the Greek numerical prefix nano referring to a billionth and the word technology. As an outcome, Nanotechnology or Nanoscaled Technology is generally considered to be at a size below 0:1 m or 100 nm (a nanometer is one billionth of a meter, 109 m). Nanoscale science (or nanoscience) studies the phenomena, properties, and responses of materials at atomic, molecular, and macromolecular scales, and in general at sizes between 1 and 100 nm. In this scale, and especially below 5 nm, the properties of matter differ significantly (i.e., quantum-scale effects play an important role) from that at a larger particulate scale. Nanotechnology is then the design, the manipulation, the building, the production and application, by controlling the shape and size, the properties-responses and functionality of structures, and devices and systems of the order or less than 100 nm [1, 2]. Nanotechnology is considered an emerging technology due to the possibility to advance well-established products and to create new products with totally new characteristics and functions.

2. Main Text

Nanomaterials exhibit different chemical and physical properties, such as nano range size, size distribution, surface area to volume ratio, various surface properties, shape, chemical composition and agglomeration state. These are not always apparent in bulk materials. Hence, it is not shocking that implementation of nanotechnology techniques in several industrial areas, such as cosmetics, medicine, food, transportation, construction materials, etc., have significantly grown in the last decade.

From the clothes and sun glasses we wear to computer hard drives and even cleaning products, nanotechnology plays a big part in the manufacture of many familiar products.

Nanotechnology promises numerous modified materials which can give phenomenal strength advantage by nanostructuring the materials. This is practically achieved with the help of composites. The various potential applications of nanotechnology in composites for naval applications could be:

Nano Aluminium Composite.

It has been found by researchers in United states that by usage of advanced nanoscience in the processing of aluminium results in superior material for tough and lightweight structural applications. This process is known as cryomilling and it involves introducing nano aluminium in the standard aluminium. This process leads to the formation of nanoscale aluminium oxide and nitride particles, which makes the material stronger and stabilizes the microscopic orientation and structure. The tests conducted on the yield and tensile strength have shown improvements of 150 percent in strength over untreated aluminium. This nano-treated aluminium can be an extremely efficient substitute for making aluminium hulls, aluminium superstructures and various other ship structures where light weight and high strength are highly desirable.

Clay Nanoparticles.

These are composed of several aluminosilicates and are called as nanoflakes. These, when incorporated in composites, can incorporate flame retardance, anti-ultraviolet and anti-corrosive behaviour. As a quantitative measure, an addition of 5% of the mass fraction of these nanoparticles in composite fibres shows an increase by 40% in tensile strength and 60% higher flexural strength as against their conventional counterparts. These composites can be used for making sturdier sails, composite structures, boat hulls and even as additives for paints.

Metal Oxide Nanoparticles.

These are nanosize particles of $TiO2$, $Al2O3$, ZnO and MgO. These nanosized metal oxides when added to fibres and paint coatings have shown to increase the antimicrobial, ultraviolet blocking function and self-decontaminating function as against their conventional counterparts. These metal oxide additives can be used for making better fibres and coatings. sturdier sails, composite structures, boat hulls and even as additives for paints.

Carbon Nanotubes.

This is one of the most talked about material with nanostructured base. It is one sixth the weight of steel with 100 times the strength and excellent thermal conductivity comparable to purest diamond and thermal conductivity similar to copper. These can be impregnated into polymers for explosion proof structures, safety harness and electromagnetic shielding. These can be used for various riggings and load bearing applications.

Nanocellular Foam Structure.

This structure is made by introducing certain amount of nanoporosity in material which results in lightweight, good thermal insulation and high cracking resistance with no compromise in the mechanical strength. This aspect can be utilised in providing superior insulation materials which are extensively used in the outfitting of the ship structures

Nanotechnology promises increased strength for lower weight which is an ideal situation for weight sensitive marine applications. Any weight saved can be translated into usable payload or cargo carrying capacity depending on the end use of the ship/vessel. It is therefore inferred that the structural nanocomposites have potential application in maritime applications.

(a) The quantum of tangible benefits achieved using nanotechnology based structural composites cannot be achieved by existing micro based structural composites.

(b) The composites are achievable and have been manufactured as part of research/ in situ testing.

(c) The cost benefit analysis is not very clear at this stage. However, with the success of research/tests and the results like 100 times increase in strength as in case of carbon nanotubes, it is a realistic estimate that in future these applications will become cost effective.

Marine environment is one of the harshest any structure could be subjected to in the lifecycle. Corrosion therefore becomes a necessary evil for all marine structures and poses a daunting challenge. It is therefore imperative that extensive research and development goes into ever improved protective coatings for marine structures.

Nanotechnology promises a new era in protective coating that is named nanocoating. These are coatings that are produced by usage of at least one component at nanoscale to obtain desired properties. The most recently reported potential application of nanotechnology for improved protective coatings for marine structures.

Scratch Resistance.

The paint coatings are added with scratch resistant additives to improve scratch and abrasion resistance and maintain an attractive appearance over long periods of time. Nano-sized (< 50 nm) inorganic particles have been observed to provide much better wear and scratch resistance when compared to same material at microscale. Further, nanoparticles due to their small particle size, do not affect the transparency of clear coats.

Ultra Violet Resistant Coatings.

The photochemical degradation caused by ultra violet(UV) rays is common mode of failure of most of the coating systems. This causes the oxidation and decomposition of polymer films along with inorganic or organic pigments which leads to discoloration and cracking of paint films. Using nano particles like titania or zinc oxide (ZnO) have shown improved UV resistance in the coatings. It is observed that the nano ZnO addition leads to significantly less yellowing.

Water and Oil Repellent Coatings.

The addition of nano particles to coating systems increases the surface area and pore volume, which in turn increases the surface roughness of a surface. This has been observed to make the surface as water and oil repellant. Water and oil repellent surfaces can be exploited for self cleaning mirrors, building exteriors, domes and ships. It has been reported that addition of titanium oxide nanoparticles in the polymer coatings results in water and oil repellent coatings.

Lotus Effect.

Another interesting application of the nanoparticle addition in paint coatings is the self cleaning of surface using 'Lotus Effect'. In the lotus effect, oxidation and chalking of the paint film is limited to the very near surface layers such that over time, rain water will wash the top layer leaving an underlying clean fresh surface. This development of self cleaning paint surfaces can be a boon for exteriors of tall buildings, structures and ships, which will clean on their own and will require minimum maintenance.

Fire Retardant Coatings.

Recent research into the application of nano-size particulate on flame-retardant coating has demonstrated that nano-fillers can improve fire retardancy of the paint films. It has been observed that the flame spread rate reduces with increase in weight percentage of nanocomposites as shown in the table below. This leads to fire redundancy for the coating with increased reaction time for fire fighting. These coatings can be a major development in the fire safety for the coatings applied inside the ship compartments.

Improved Anti Corrosive Coatings.

The nanoparticles because of their greater surface area can absorb more resins compare to conventional pigments. This reduces the free space between the pigment and the resin. Thus, nanoparticles increase the density of coating, reduce the transport path of corrosive species and enhance the protective performance.

Anti-Bacterial Effect.

Avoiding infection from surface contact is vital in specific environments like onboard ships in the galleys and sickbays. Experimental results show that the ability of the nanoparticles to destroy bacteria is better than the conventional microparticles. This aspect is being researched to provide a coating that is hygienic and destroys any contaminants like bacteria on the surface.

Anti Fouling.

A team of researchers at the Hanover School of Veterinary Medicine in Germany have discovered that whale's skin has a specialized nano-structure that stops the build-up of microscopic organisms such as barnacle larvae. They plan to mimic the idea in anti-fouling paints with provision of Nano ridges in polymer matrix to give effect similar to whale's skin. This can potentially remove the requirement of anti fouling paints.

Nano Ceramic Coating for Underwater Valves in Submarines.

The ball valves that regulate water flow in submarines during diving and surfacing, suffer from metal-on-metal friction and resultant corrosion. Repair by replacement results in costly and time intensive procedures such as pressure hull cutting. This leads to submarine being out of operational availability for extended durations. The solution of the problem has been attempted using aluminum-enhanced nano ceramic coating. The results are encouraging and the preliminary results show that the ball valves may last the life of the submarine.

With the advent of nano-technology in smart coatings , it is possible to have coatings which can predict onset of corrosion, can release healing agents to cure coating cracks and allow protective coatings to release corrosion inhibitors on demand to name a few applications. Future development of protective coatings will take advantage of this aspect of coating technology and are likely to be the coatings of 21st century.

Stealth.

The application of stealth technology in warship construction to reduce radar cross section, magnetic signature and infrared signature has been the ongoing endeavor of the ship designers. The advent of nanotechnology has given new concepts in the field of stealth technology.

Adaptive Camouflage.

Adaptive camouflage is a concept where the material surface changes external appearance in response to a preprogrammed stimulus in the environment in which it works. In order to achieve adaptive camouflage the material surface is cover with thin plastic sheets. These sheets have numerous embedded light-emitting diodes (LEDs). The colours and patterns displayed on the sheet are controlled by the LEDs with inputs from a camera which scans the surroundings. This adaptive change of colour and pattern can be used as a effective deception tool in tactical situations. Several nanotechnology enabled techniques are in research and development stage and can be applied for adaptive camouflage.

Propeller Coating for Minesweepers.

The minesweepers have to avoid magnetic materials to make them immune to magnetic underwater mines. The propeller shafts are purposely made from bronze to suppress the magnetic signature; Bronze is softer than steel and susceptible to frictional wearing in the operating environment. Replacing these shafts requires dry-docking which adversely affects the operational availability of the ships. The nano enhanced ceramics have been used on experimental basis on these bronze shafts. The preliminary results indicate that the coating is unaffected by highly erosive shaft operating conditions. This can be a highly effective solution of the erosion corrosion in the shafts of minesweepers without compromising the magnetic signature of the ship.

Biological human thinking is limited to 1016 calculations per second (cps) per human brain (based on neuromorphic modeling of brain regions) and about 10 26 cps for all human brains. It is expected that the application of nanorobots could help enhance the 100 trillion very slow interneuronal connections with highspeed virtual connections. With the advent of nanotechnology the processing capability of non-biological intelligence or strong artificial intelligence is likely to exceed biological intelligence by the mid-2040s.This will open up vast applications like nanorobots manning unmanned vehicles, paradigm shift in decision making of automated controls and may be the use of virtual crew to man automated ships.

In case the primary generator fails, this nano battery system is envisaged to provide UPS till secondary generator comes online. This will enable ships to run only one primary generator. The fuel cost savings are expected to be nearly $1 million per vessel for a six month cruise.

The use of asynchronous architectures in IC design removes the problem of timing closure, eliminate global clocks and tolerate parametric variation. However these circuits are two to six times the area of synchronous circuits. However, at nanoscale, these asynchronous circuits can be produced at significantly reduced areas. This application of nanotechnology will make asynchronous circuits a viable option at 65 nm and below. These circuits will be a more reliable solution for critical applications such as fire control systems.

The ability to develop nano based micro-sensors that could be scattered on the ocean floor to detect enemy submarines could lead to a paradigm shift in the Navy's undersea warfare systems and capabilities. The same concept can be tailored for detecting enemy mines in the littorals. These futuristic nano based sensors will be networked and can be laid/controlled from distant locations.

Fabricated a nanotechnology-based catalyst which is less expensive and more carbon mono-oxide tolerant than the material used in conventional PEM fuel cells. The application of nanotechnology has the potential to decrease the weight of electrodes as well as to increase the conductivity and electrochemically active surface of catalysts. The mechanical properties, conductivity and corrosion resistance of interconnect and bipolar plates could also be improved with nanocoatings. These properties are predicted to ensure commercial availability of fuel cells in near future.

The biggest challenge in materials science is to design "smart" materials that can sense the presence of a defect and actively re-establish the continuity and integrity of the damaged area. Such materials would significantly extend the lifetime and reduce breakdowns of manufactured items. Nanotechnology has potential to design a system that could recognize the appearance of a nanoscopic crack or fissure and then could direct agents of repair specifically to that site. The ability of nanotechnology to tailor the surface chemistry of nanoparticles aids in designing self-healing materials. Nanoscopic polymer gel particles a coating has been designed that undergoes structural rearrangement in response to mechanical stress, and thereby prevents the catastrophic failure of the material.

Encapsulated solid nanoparticles that can deliver the encapsulated nanoparticles to specific cracks on the substrate. Once the healing nanoparticles are deposited on the desired sites, the fluid-driven capsules move further. This strategy is called "repair-and-go" and has negligible impact on the precision of the non-defective regions and involves minimal amounts of the repair materials.

We interact mostly with the interior parts of the automobile such as seats, door paddings, dashboard, airbags, seat belts, boot carpets, etc. These are the place where microbial and bacterial infections are most common. Since the interior is the place of an automobile where we interact mostly, it should be free from all bacterial and microbial infections. The most important nanostructured antibacterial and antimicrobial agents are silver, gold, titanium oxide, zinc oxide, titania nanotubes, gallium, liposomes loaded nanoparticles and copper nanoparticles. They are commonly used as incorporated nanoparticles in a matrix such as silica network. The action of these nanoparticles is initiated either by a photocatalytic reaction or by the biocidal process.

Ultra reflecting a thin layer of aluminum oxide having a thickness less than 100 nm is applied to the surface of mirrors and headlights. This makes the mirrors to equip surfaces with fat, dirty water and repellant features. Hydrophobic and oleophobic nanometer layers are applied over the surface of the mirrors by chemical vapor deposition (CVD) method. Mainly fluoro-organic material layers of thickness 5–10 nm are used as they have high resistance to friction and are applicable for longer times. To prevent the problems created by the light of other vehicles falling on our eyes at night, nanotechnology and electrochromic properties are applied together.

By coating the cylinder wall with nanocrystalline materials we can reduce abrasion and friction and in turn the fuel consumption. There are research projects going on, which aim to directly coat tracks of the aluminum crankcase with nanomaterials. Iron carbide and boride nanocrystals with size 50 nm to 120 nm are used to coat the engine parts which result in an extremely hard surface with very low friction.

New materials that will permit ultra-miniaturisation of space systems and equipment, including the development of ‘smart’ sensors and probes. Applications include economical supersonic aircraft; low-power, radiation-hardened computing systems for autonomous space vehicles; and advanced aircraft avionics

New photonic nanodevices could replace the heavy and costly radio frequency transmission equipment on board aircraft, ships, or satellites or be exploited for inexpensive remote control of vehicles.

With the development of technology, it has become very necessary that our equipments and systems should also be updated. Hence the use of nanotechnology is inevitable.

Conclusion

The continuous revolution in nanotechnology will result in the fabrication of nanomaterials with properties and functionalities which are going to have positive changes in the transportation. In the energy generation challenge where the conventional fuel resources cannot remain the dominant energy source, taking into account the increasing consumption demand and the CO2 emissions alternative renewable energy sources based on new technologies have to be promoted. Innovative solar cell technologies that utilize nanostructured materials and composite systems such as organic photovoltaics offer great technological potential due to their attractive properties such as the potential of large-scale and low-cost roll-to-roll manufacturing processes.

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References:

1. Material has been taken from a study conducted by the University of California.
2. Also from Azo Nano Technology