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Nanotechnology in Paint Industry

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ABSTRACT : Nano coatings are materials that are produced by shrinking the material at the molecular level to form a denser product. Nano coatings have several advantages such as better surface appearance, good chemical resistance, better thermal and electrical conductivity and better corrosion resistance. Incorporation of nanoparticles enhance the corrosion resistance of zeolite coatings, epoxy coatings and antimicrobial coatings. The nanopaint technology improves the system's entire ecobalance. The difference between nano paint and conventional paints lies in its structure. As with conventional paints, its basic components are binding agents, solvents and additives. But the nano paint binding agent is not an organic but an inorganic-organic hybrid polymer, in which the positive characteristics of organic and inorganic binding agents are combined. There are water and oil based paints, which can have additional functionalities depending on the necessities of the consumer. Nanomaterials are thought to improve these functionalities, i.e. water/dirt repellent "easy to clean". With reference to the improvement of erosion and corrosion resistance, weathering and ultraviolet (UV-rays) resistance, water repellence and chemical resistance, dispersion stabilityand aging resistance, surface covering and adhesion property,film smoothness and gloss retention alongwith other mechanicalproperties; nano materials adapted paints have shown greatpotential in several industrial applications.
Key words : nanotechnology, nanomaterials, nanopaints,

1.Introduction

It is well known fact that corrosion is a natural oxidation process by which a material degrades drastically due to chemical or electrochemical reaction with its environment, and it is also scientific fact that corrosion cannot be completely stopped but it can be reduced by applying proper technology and management. In this perspective, it has also been acknowledged that among all the methods of corrosion protection, protective coatings have become the most commonly used methods for corrosion-control[1, 2]. In this evolution, it is to state that paints have been fabricated at micron level for a long but in recent years nano technology has been introduced in the field of surface coatings to improve overall quality of industrial paints and coatings. Proper addition and optimum dispersion of required nanoparticles in. high quality of resin media can upgrade several properties of surface coatings by producing multipurpose reinforced composite coating with a little cost difference[3,4]. Nano coatings are polymer-nano composite materials made of resin, solvents, pigments and additives, produced by dispersing nano pigments in resin media at the nano scale (approx 1-100 nm) to form a denser product, which give a solid film on substrate surface after application alongwith curing for the purpose a better surface protection and aesthetic looks as well[2]. The applications of suitable nanoparticles within compatible ratio in paint formulations carry many advantages and opportunities to paint and coating industries. Coating industry is one of the first among all to utilize the potential of nanotechnology[5]. Nano coatings, sometimes made of self-assembling mono layers, are applicable in many ways e.g., from scratch resistant coating to super hydrophobic self-cleaning surfaces and also to weathering and corrosion resistant coatings[6-8]. Further, due to unique composition of nano materials, pigment, binder, solvents and additives in paint formulation; better adhesion, flexibility, durability along with excellent gloss as well as transparency make nano-coatings even more effective. Many of the nanoparticles like nano $TiO_2$and ZnO are non-toxic in nature and thus add an extra advantage to coating industries[9-12].The present paper gives a brief review of various nanomaterials that are used paints industry.

2. Nanopaints Initiative

Interestingly, the products that proudly use the "nano" brand are only a small percentage of the number of consumer products that actually contain nanotechnologies, for instance in the microelectronics, cosmetics, pharmaceutical and food industries. The field of nanotechnology is vast and interdisciplinary, ranging from medicine and healthcare to construction and consumer electronics. For this reason the definition of "nano" may vary and even among experts no consensus can be found today. The weakest definition of nanotechnology claims the ability to control matter at a level below 100 nm. A more demanding definition requires that new effects or functions have to play a critical role. Structures at the atomic and molecular scale obey rules that strongly differ from those in our macroscopic world(Fig.1), such as quantum effects which give rise to new applications.

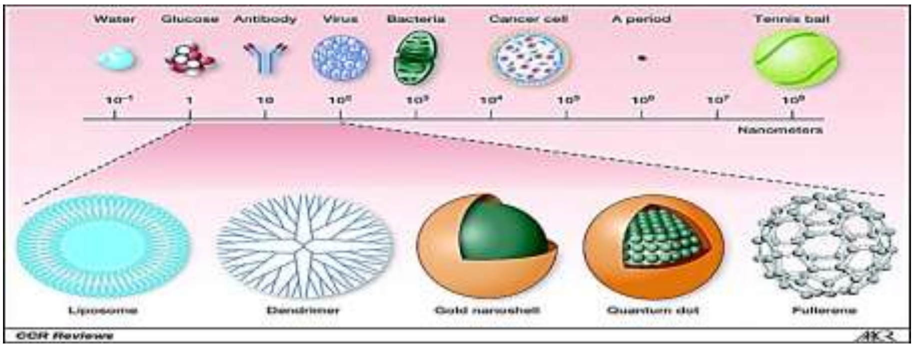

Figure 1. Shows various structures available in nanoscale.

Nanotechnology is said to be present in anything from stained glass in Medieval European churches to blades of eighteenth century Indian warriors(as shown in Fig.2).The drinking cup, depicting King Lycurgus of Trace, has a green color when lit from the front. But when held against the light, the glass suddenly changes color and turns red. This feature has long puzzled researchers but is now explained by the presence of golden and silver nanoparticles that alter the color of the glass depending on the position of the observer in relation to the light The vast majority of nanotech consumer products on the market today make use of interface effects.

Figure.2.Ancient church Paints using nanotechnology(http://www.ancient-origins.net/news-science-space-ancient-technology/roman-nanotechnology-inspires-holograms 102783#sthash.LOZtKY0J.dpuf)

The interface is a two dimensional surface that marks the boundary between two materials. When an interface is made rougher, for instance, this surface area increases. Likewise, when particles are made smaller the surface area to volume ratio increases. A material consisting of nanoscopic building blocks exhibits an extremely large surface area to volume ratio. This effect influences for example the catalytic activity of nanoparticles. The inverse, a nanoporous structure, can be used as membrane in filtration processes or as an insulation material (e.g. zeolithes). This effect can also be exploited when a property of a given material is applied to a surface (e.g. scratch resistance). In many cases, a tiny, almost invisible coating of the material will still provide the desired physical property.

Finally, although it is not a typical physical effect as in the case of interface and quantum effects, complexity is another important factor leading to added value in nanotech consumer products. The consumer benefits from the integration of smaller and smaller devices have been most clearly illustrated by the microelectronics industry. There appears to be no end in sight to the steady improvement of processor speed and memory density by using miniaturization to create more complex circuitry. Several product innovations rely either on the use of nanoparticles or so called nanotubes (fullerenes). Many other products deal with improved water repellency. For this reason these three issues are briefly introduced below. This is followed by a comprehensive list of effects and innovations.

Fullerenes

Fullerenes are an allotrope of carbon, similar to the better known allotropes graphite and diamond, but with nanoscopic shapes ranging from spherical to cylindrical. The first fullerene to be discovered was C60, consisting of 60 carbon atoms arranged in 12 pentagons and 20 hexagons (identical in shape to that of a soccer football). This molecule was named Buckminsterfullerene, after the architect Richard Buckminster Fuller (1895-1983), as the molecules share the architecture of his geodesic domes. Soon after the discovery of this molecule other variations on the structure were discovered and these are collectively referred to as fullerenes. Fullerenes can also be shaped as cylindrical nanotubes. The most common form of nanotube is the carbon nanotube (CNT), although nanotubes can be formed from other elements as well. Nanotubes may occur individually as single-walled carbon nanotubes (SWNT) or stacked concentrically one into another, as multiwalled carbon nanotubes (MWNT). Nanotubes have attracted increasing attention due to their unique physical properties. They are capable of carrying an extremely high electrical current and are very good thermal conductors. Another unique property is their unusually high tensile strength which could be as large as 300 GPa in theory1 (steel is ~ 1-2 GPa). For this reason CNT have the potential to improve mechanical properties e.g. of polymers. In this sense, the following parameters play a critical role in order to enhance the material strength:[13]

- The connection of the nanotubes to the polymer matrix. This parameter can be influenced by adding functional groups to the CNT surface to establish covalent bonds to the matrix. CNTs with different chemical functional groups are available.
- The length of the individual tubes (aspect ratio). Stronger material can be obtained with longer tubes.
- Exfoliation. Nanotubes tend to occur in bundles after production. These bundles have to be fully exfoliated to obtain individual tubes.
- Dispersion. The nanotubes have to be fully dispersed within the polymer matrix to obtain a homogenous material with optimum strength.

However, a broad use of such nanotubes is limited today by their comparatively high price. There is also a problem in uniformity, regarding the diameter, length and electrical conductivity. Although progress has been made in this direction, producing large quantities of pure metallic or pure semiconducting carbon nanotubes with a specific diameter and length is still too prohibitively expensive.

Nanoparticles

When particles of a material are made smaller their surface area to volume ratio increases. The most obvious advantage of this is in cases where a large surface of a valuable material is necessary, for instance in the use of platinum nanoparticles in catalytic converters. However, another benefit is that cheaper materials can become valuable just because they are in nanoparticlulate form. This can occur because when the particle is small enough (e.g. below ~100nm), the properties of this interface can become more important than the properties of the material itself. As a result, only a tiny amount of this nanomaterial is needed to add new properties to a product. For example the hardness of silicon dioxide (SiO2, glass) can be used to lower the wear and tear of scratch sensitive surfaces by incorporating SiO2 nanoparticles. This even works on flexible surfaces such as textiles, since the nanoparticles do not exhibit the undesired brittleness of the macroscopic glassy solid.

In addition to changes in mechanical properties, a variety of other properties of materials can change when the material is in nanoparticle form – including mechanical, solubility, magnetic, electrical and more. Of particular interest is the incorporation of zinc oxide (ZnO) or titanium dioxide (TiO_2) nanoparticles into sunscreen[14]. These are effective UV absorbers and have been used for decades in sunscreens. However as large (microscopic) particles these materials appear as white pastes which limits their aesthetic appeal. By making the particles smaller they no longer absorb visible light, and therefore the sunscreen appears transparent, while still absorbing dangerous UV light from the sun. As particles become even smaller (e.g. below 10nm), energy levels become quantized which means that the particles behave more like atoms or molecules than classical particles. Such nanoparticles are typically referred to as quantum dots.

3. Different Effects and Their Nanopaint Applications

The different effects described above can be used to overcome several drawbacks in consumer products that are currently available on the market. Many different terminologies have been defined to address the various drawbacks or to describe innovations. The following list provides an outline of existing terms complete with a short description of the technology:

Lotus-Effect

The leaves of the Lotus plant exhibit an extremely high water and oil repellency which is based on hydrophobic wax crystals in combination with a micro- and nanosized surface roughness. It is a combination of structure and chemistry that defines the lotus surface unique properties.

Even very sticky and highly viscous liquids such as honey or glue roll off when the surface of the leaf is slightly tilted. However, the tiny structures on the surface can be easily disturbed which is disadvantageous for most technological applications. For this reason a synthetic lotus effect is hard to achieve on technical surfaces, especially when mechanical stress is involved. Furthermore, the natural structures of a lotus leaf are bigger than the 100 nm. Since nature has evolved its “products” very well, one could argue that nanotechnology is not needed to mimic this effect.

Nevertheless, in order to distinguish between a surface with a lotus effect and other hydrophobic surfaces the following requirements have to be met3:

1. The static contact angle against water has to be at least 140° measured for a 20 µl droplet after 1 min time of relaxation.
2. The hysteresis between the advancing and receding contact angle is not larger than 10°.
3. The minimum tilt angle of the surface, where a 20 µl droplet applied from a height of 1 cm height rolls off, is 10°.
4. A sample tilted by 10° shows no wetting water film after 30 min of continuous standardized showering. Wetting phenomena are playing a dominant role in different surface treatment strategies, as described below. The wetting of a surface is determined by the interfacial tensions of the wetting liquid, the wetted solid and the surrounding gas phase. Besides these three parameters, which are caused by molecular interactions, the surface roughness or specific structures play a key role in wetting phenomena. Surfaces can be divided into hydrophobic (water hating) and hydrophilic (water loving) surfaces. Well known hydrophobic surfaces are all kinds of plastics, especially those with a large proportion of fluorinated carbons, such as Teflon. Prominent hydrophilic surfaces are all untreated metals and glass surfaces. From a chemical point of view, surfaces can be classified as reactive or inert, where a hydrophilic surface typically has a much stronger affinity to bind adsorbates and a hydrophobic surface has not. Unfortunately, many technically relevant materials fall within the reactive species, such as metals and glass. Such surfaces tend to stain easily due to their high surface.[16-17]. energy. A clean metal can easily reach several 1000 mN/m (iron is ~ 2500 mN/m), depending on its cleanliness. In contrast Teflon has a surface energy of just 18 mN/m. For this reason several attempts have been made to reduce the interfacial tension of technical relevant surfaces. The wetting condition of a surface is defined by the contact angle, which is the slope of the tangent at the intersection of solid and liquid. A contact angle of 0° corresponds to complete wetting. In the case of water, this phenomenon is often termed super-hydrophilicity or complete wetting. At the other extreme is a contact angle of 180°. Surfaces with very large contact angles are called super-hydrophobic. A

surface with a contact angle of 180°, for example, has been achieved by a vertically grown Teflon coated nanotube forest[15, 18-19].

Figure 3: A hydrophobic wooden surface. BASF AG

Self Cleaning

Ultra hydrophobic surfaces or Lotus-effect surfaces are contaminated to a far lesser degree than surfaces with a higher interfacial tension. In addition, loosely bonded dirt particles are removed easily by wetting e. g. during a rain fall. Besides this strategy to increase the intrinsic stain repellency of a surface by reducing its free energy, one can directly attack adsorbants by decomposing them through photocatalysis. Thus even a highly sticky surface, such as glass, could be equipped with a self-cleaning finish which is activated with UV light. However, this approach is only suitable for outdoor applications (e.g. facades)[20].

Antimicrobial Coating

Fighting bacteria and other microbes is commonly achieved by certain chemical agents. Two inorganic approaches can be used for sanitizing surfaces. The first is based on the photocatalytic activity of titanium dioxide as described below. The second exploits the toxicity of certain metallic cations such as silver. Silver has long been known for its excellent antimicrobial effect due to the release of silver ions which are taken up by microbes and exert a toxic effect[21]. Modern approaches increase its activity by dispersing silver in ultra fine particles. The extreme increase in surface area enhances silvers natural sanitizing ability. Advantages of Antimicrobial coating is as follows:

- Bactria are targeted and destroyed.
- The use of disinfectants can be reduced.
- Supports hygiene methods – especially in health care environments.

Photocatalytic surfaces have an antibacterial side effect due to their ability to break down organic substances in dirt, with the help of silver nanoparticles[22].In addition, it is also advisable to equip surfaces with an anti-stick function to prevent the buildup of a bio-film of dead bacteria from which new bacteria could eventually grow. Fig. 4. Shows a-Contact surfaces such as light switches, door grips and handles are typical germ accumulators. An antibacterial material, such as that used for this light switch, can prevent germs spreading. b- Nanoscalar silver particles contained in the glaze applied to ceramic sanitary installations lend it antibacterial property[21].

Nano-scalar silver particles contained in the glaze applied to ceramic sanitary installations lend it antibacterial properties. Contact surfaces such as light switches, door grips and handles are typical germ accumulators. An antibacterial material, such as that used for this light switch, can prevent germs spreading[23].

Fig. 4. A-Contact surfaces such as light switches, door grips and handles are typical germ accumulators. An antibacterial material, such as that used for this light switch, can prevent germs spreading.
b- Nanoscalar silver particles contained in the glaze applied to ceramic sanitary installations lend it antibacterial properties[21].

Figure 5 Antimicrobial wall coating containing nano sized silver particles for use in clinics and hospitals

Then, to act as a biocide, Ag+ ions need to be released which requires water to actually dissolve the ions. Bioni CS GmbH4 produces Bioni Hygienic (Figure 5), a fungi- and bactericidal interior wall paint that is claimed to permanently destroy even the most resistant of hospital germs and bacteria without contaminating the air inside the building(http://www.bioni.de/index.php?lang=en).

Anti-fouling surface treatment

Incorporating nanoparticles in paints could improve their performance, for example by making them lighter and giving them different properties. Thinner paint coatings ('lightweighting'), used for example on aircraft, would reduce their weight, which could be beneficial to the environment. It may also be possible to substantially reduce solvent content of paints, with resulting environmental benefits. Anti-fouling surface treatment is also valuable in process applications such as heat exchange, where it could lead to energy savings. If they can be produced at sufficiently low cost, fouling-resistant coatings could be used in routine duties such as piping for domestic and industrial water systems. It remains speculation whether very effective anti-fouling coatings could reduce the use of biocides, including chlorine. Other novel, and more long-term, applications for nanoparticles might lie in paints that change colour in response to change in temperature or chemical environment, or paints that have reduced infra-red absorptivity and so reduce heat loss[24-25].Fig.6 shws Antifouling coating using nanomaterials. (http://nanotechmarine.com/new-nanotech-antifouling-40-c.asp) . When this coating is applied the surface becomes extremely slick and will not allow fouling to adhere, any fouling that does occur when the vessel is not being used will be removed when the vessel is underway, therefor this coating offers a self cleaning effect that will continue to work for a minimum of 3 years.

Figure 6 Antifouling coating using nanomaterials. http://nanotechmarine.com/new-nanotech-antifouling-40-c.asp

Antifog

Bringing a cold surface into a warmer surrounding will lead to fogging. This effect is inevitable unless the surface is heated. It results from the formation of tiny droplets on the mirrors surface scattering the light and nebulizing reflections. A superhydrophilic coating can prevent droplet formation to a certain extent. The droplets simply merge into a thin water layer on the mirror without changing the reflectivity too much. Photocatalytic TiO_2 coatings are super-hydrophilic when exposed to sufficient UV light[14].

Corrosion protection

Steel parts in automotive manufacture are commonly heat-treated to achieve the desired shape. During this heating process (of up to 1000 degrees centigrade) the steel will corrode. It can be protected against high temperature corrosion by applying a nanoparticulate coating[26-27].

Scratch resistance

Until the recent advancements that led to the availability of a wide range of inorganic nanoparticles, silica has been the choice material for reinforcing clear coatings for applications such as automotive top-coats, floor wear layers, acrylic eye-glass lenses, and scratch resistant polycarbonate sheets for various applications. Colloidal silica has been available for decades from at least a dozen companies around the world in the particle sizes range from about 2 to 100 nm, in aqueous and non-aqueous media. The refractive index (RI) of silica which is 1.46 closely matches the refractive index of common organic binders in coatings, and therefore, high silica loading levels can be achieved without causing haziness problems in coatings. In 1976, Dow Chemical has claimed use of colloidal silica in abrasion resistant coatings for acrylic lenses The use of higher refractive index inorganic oxides such as alumina, zinc oxide, and titanium dioxide (RI = 1.76, 2.00, 2.50-2.70, respectively) in clear coatings has grown in recent years with the advancements of nanoparticle manufacturing processes. As the refractive index difference between the inorganic material and the resin matrix increases, particle size must be reduced to prevent scattering of light that leads to haze in the composite clear coating. Controlling the average size alone is not sufficient; small amounts of larger particles can cause significant haze problems.Hard nanoparticles, such as silicon dioxide, can be used to build up scratch resistant coatings. For example, they can be incorporated in an organic matrix to improve the scratch resistance of lacquers[28-31].

Tensile strength / Impact strength

Adding nanoscale components into composites will enhance their tensile and impact strength. Carbon nanotubes offer the highest tensile strength ever observed. In this sense, carbon nanotubes are expected to be of great importance in the future**15**.

UV protection

Coatings play a critical role in controlling the effects of electromagnetic radiation (UV, Visible, IR, other) on many surfaces. The specific electromagnetic frequency range of interest is a factor that determines the coating formulation ingredient selection. Controlling the interactions with the visible light to affect the color and appearance through the right choice of ingredients is the best example of this. Various organic and inorganic pigments are selected for this purpose. $Ti0_2$ (RI=2.5-2.7) is the most effective white pigment; its hiding power is highest at about 250 nm particle size . Prolonged exposure to UV radiation causes degradation of coating films, and special additives are needed to minimize coating damage. In the case of clear coatings, UV stabilizers that do not compromise the film clarity are needed. UV degradation is a critical issue for automobile and aircraft coatings.

Dispersed TiO_2 and ZnO particles are excellent UV filters, and are sometimes referred to as mineral or physical filters. In contrast, most sunscreen formulations contain classical chemical filters, based on the ability of complex molecules to absorb in the UV range. Both TiO_2 and ZnO are commonly used as white pigments (titanium white and zinc white). TiO_2 in the rutile form is the most common white pigment due to its extremely high refractive index (n=2.8). Ultrafine TiO_2 and ZnO particles lose their capability to scatter visible light, but retain the ability to absorb UV light. The bandgap of ZnO (3.2 eV) is similar to that of TiO_2 in the anatase modification and a little larger than the rutile type. When using TiO_2 for UV protection the rutile type is more suitable due to its lower photocatalytic activity, which could destroy the surrounding matrix. Mixed material containing both forms (anatase/rutile) is also in use. The undesired photocatalytic activity can be significantly reduced by doping TiO_2 crystals with manganese. One problem of ultra fine particles is their tendency to form agglomerates resulting in poor dispersion within the carrier matrix. This drawback can be overcome by coating the particle's surface, e.g. silica-coated ZnO particles[32-33].

Anti reflective coating / Moth-eye structure

In many applications a strong reflection from a smooth surface is undesirable, e.g. for displays or spectacles. The reflectivity of a surface can be reduced by two different concepts: the first introduces a micro- and nano-roughness, which reduces uniform reflection through light scattering. This concept is sometimes referred to as nano-moth eye structure because the same principle is found in the facet eyes of insects and acts as part of their camouflage. It can also be used to increase the sensitivity of solar cells due to the enhanced transmission. Nevertheless, the size of an efficient moth-eye structure has to be in the range of 200 nm. The easiest way to obtain such a structure is embossing, which is limited to comparatively small areas[29-30]. The second concept is based on a coating of alternating layers of silicon dioxide and titanium dioxide. These two materials provide a strong contrast in refractive index resulting in a significantly higher transmission and reduced reflection. Although being more expensive, the second concept offers a better control. Table1 Gives the information various nanomaterials and their applications[34-35].

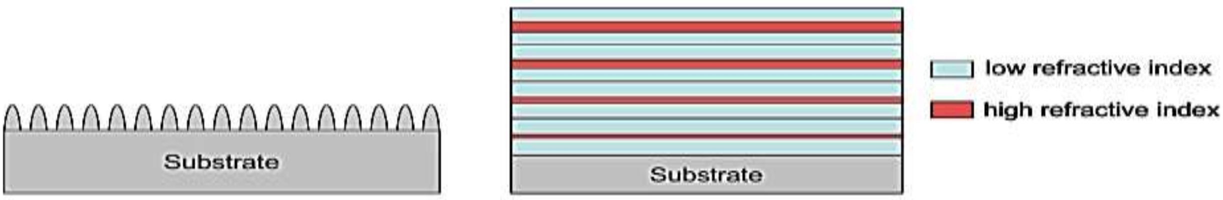

Figure 6: Comparison between a moth-eye structured surface (left) and an antireflective coating(right). Both methods reduce the reflection efficiently.

Depending on the desired function, nanotechnology-based functional coatings typically contain the following nanomaterials: Titanium dioxide, silicon dioxide, carbon black, iron oxide, zinc oxide and silver.

Table 1 Gives the information various nanomaterials and their application[34-35].

Function	Nanomaterial (Examples)	Advantage/Effect	Industrial Branch
Colour brilliance, shade, colour effects (flip-flop effect), reproducible paints, easily dispersible paints	Carbon black; Oxides (TiO_2, Fe_2O_3, Fe_3O_4, SiO_2,Cr_2O_3) (on mica flakes or SiO_2 spheres, with metal pigments), ZnO	Intensify effects of metal pigments; Stabilize pigments and fillers; Positive effects in dispersion paints; Prevent crack formation (Phyllosilicates/sheet silicates); Improve resistance to fading	Automotive, consumer goods (furniture), construction
Self-cleaning („easy-to-clean“)	Organic-inorganic hybrid polymers (organically modified ceramics), nanosilica/colloidal silica embedded in resin particles following polymerisation; Silanes (silicon-based mixtures with other chemicals, e.g. fluorine compounds); TiO_2	Dirt and water repellant, Protection against algae and fungi; Anti-graffiti protection: Easy removal of unwanted paint	Automotive, construction (facades), glass
Switchable (electrochromic, photochromic, thermochromic)	Tungsten oxide (WO_3) (electrochromic)	Colour effects	Automotive
„Self-Assembly“	Polymer gel, specific organic-inorganic hybrid polymers	Self-healing surfaces	Automotive, cosmetics
Monolayer adhesive films	Polymers	Ultra-thin layers	Automotive, consumer goods
Scratch resistance	Oxide (synthetic amorphous silica), SiO_2, Al_2O_3)	Improved scratch resistance	Automotive, information and communication, parquet flooring, consumer goods (furniture), optics (lenses)

Table 1 (Continued)

Function	Nanomaterial (Examples)	Advantage/Effect	Industrial Branch
Optimized flow characteristics	Oxide (synthetic amorphous silica)	Generate new rheological properties (elasticity, flow characteristics, thixotropy)	Various
Conductive coatings for electrostatic paint spraying	Carbon: Fullerenes, carbon nanotubes (CNT)	Enhanced spraying processes	Automotive
Photocatalytic effect, antimicrobial effect	TiO_2, ZnO^6, Ag	Removal of grease, dirt, algae, bacteria, fungi, odourants and pollutants, transformation of NOx and ozone from the atmosphere into harmless compounds.	Construction (facades, noise barriers, tiles), road surface, vehicles, wood preservation, glass
Fire retardant	SiO_2	When a certain temperature is exceeded, a heat-insulating carbon foam layer is created on the wood surface followed by a flame-resistant ceramic layer.	Construction, protection of wood against fire
Corrosion protection, wood preservation	Zinc or aluminium coated with nano-TiO_2, nanoclay (like hydrotalcite $Mg_4Al_2(OH)_{12}CO_3xH_2O$)	Nanoclay coatings delay the fading of wood (which is a result of the bleeding of complex chemicals like tannins).	Construction, automotive, wood preservation
UV protection, IR reflective or IR absorbing	(TiO_2; ZnO, CeO_2, iron oxide pigments (transparent iron oxide; needle-shaped particles with a length of 50-100 nm and width of 2 nm)	Enhanced UV resistance, blocking of IR and visible light, indoor climate control	Construction (facades), wood preservation, glass, plastics

4. Nanotechnology Risk and Challenges

There is no doubt that nanotechnology has great potential to bring benefits to society over a wide range of applications, but it is recognized that care has to be taken to ensure these advances come about in as a safe manner as possible[36]. Some engineered nanoparticles, including carbon nanotubes, although offering tremendous opportunities also may pose risks which have to be addressed sensibly in order that the full benefits can be realized. We have all learned how to handle electricity, gas, steam and even cars, airplanes and mobile phones in a safe manner because we need their benefits. The same goes for engineered nanoparticles. Mostly they will be perfectly safe, embedded within other materials, such as polymers[37].

There is some possibility that free nanoparticles of a specific length scales may pose health threats if inhaled, particularly at the manufacturing stage. So, industry and government must be very conscious of this, are funding research into identifying particles that may pose a hazard to health or the environment, and how these risks may be quantified, and minimized over the whole lifecycle of a given nanoparticles. While nanotechnology based construction products provide many advantages to the design and construction process, the production of these products, however, require a lot of energy. Also, the nanotubes might cause a lung problem to construction workers. In other words, it creates an environmental challenge to the construction industry as well. Sustainability and environmental issues caused by growing economic development has gained intensive statewide and worldwide attention. Since the construction industry is heavily involved in the economic development and consumes great amount of resources and energy, its impact on environment is significant. Therefore, it is necessary and urgent to regulate the construction and its related performance to sustainable manners. The nanotechnology becomes a double-edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to environment. It is necessary to establish a system to identify the environmentally friendly and sustainable of construction nanomaterials and to avoid the use of harmful materials in the future.

5. Conclusions

In conclusion, modification of the surface of nanoparticles is essential if the application demands particles in a nano-dispersed state. The particles need to be tailored to the application, principally to the paint composition, as nanoparticle systems are quite sensitive to changes in the formulation. The chemistry of nanoparticles is comparable to that of molecular substances and thus established chemical concepts can be applied. Using agglomerated nanoparticles as starting materials, the chemomechanical processing of nanoparticles in an agitator bead mill is a versatile means of producing tailored nanoparticles in a highly dispersed state. In addition, self-cleaning or "easy-to-clean" surfaces may minimize the need for cleaning, reduce the consumption of energy and cleaning agents and extend the life span of the coated objects. However, to ensure the safety of coatings that contain nanomaterials, studies should be performed at an early stage of their development already that look not only at the environmental benefits but also at the risks posed by nanomaterials and their applications.

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References

1. A. Mathiazhagan and Rani Joseph, Nanotechnology- A New Prospective in Organic Coating –Review, International Journal of Chemical Engineering and Applications, P. 225-26,Vol. 2 , No. 4 , (Aug 2011)
2. A.S. Khanna, Nanotechnology in High Performance Paint Coatings, Asian J. Exp. Sci., (Vol. 21, No. 2; page; 25-32 (2007)
3. ASTM International Standard (2010), chemical analysis of paints and paint materials, D 817-96.
4. ASTM Standard, “Standard practice for preparing, cleaning, and evaluating corrosion test specimens,” American Society for Testing and Materials G1-03, (2011),.
5. Raymond HF (2009) Nanocomposite and Nanostructured Coatings: Recent Advancements, in Nanotechnology Applications in Coatings. American Chemical Society pp. 2-21
6. van Ooij WJ, et al. (2005) Corrosion Protection Properties of Organofunctional Silanes—An Overview. Tsinghua Science & Technology 10: 639-664.
7. Pathak SS, Khanna AS (2009) Investigation of anti-corrosion behavior of waterborne organosilane–polyester coatings for AA6011 aluminum alloy. Progress in Organic Coatings 65: 288-294.
8. Chad EI, et al. (2009) Reactive Nanoparticles in Coatings, in Nanotechnology Applications in Coatings. American Chemical Society. pp. 188-209.
9. Fateh R, Ismail AA., Dillert R, Detlef W. J., Highly Active Crystalline Mesoporous TiO2 Films Coated onto Polycarbonate Substrates for Self-Cleaning Applications, *Phys. Chem*. C, 115, 2011,10405.
10. Dhoke SK, Bhandari R, Khanna AS (2009) Effect of nano-ZnO addition on the silicone-modified alkyd-based waterborne coatings on its mechanical and heat-resistance properties. Progress in Organic Coatings 64: 39-46.
11. Shukla RK, Sharma V, Pandey AK, Singh S, Sultana S, et al. (2011) ROS mediated genotoxicity induced by titanium dioxide nanoparticles in human epidermal cells. Toxicol In Vitro 25: 231-241.

12. Wang Z Y, Liu F C, Han E H, et al. Effect of ZnO nanoparticles on anti-aging properties of polyurethane coating. Springer; Chinese Science Bull, 54: 3464—3472, doi: 10.1007/s-11434-009-0024-7, (2009).
13. Min-Feng Yu, Oleg Lourie, Mark J. Dyer, Katerina Moloni, Thomas F. Kelly, Rodney S. Ruoff, Strength and Breaking Mechanism of Multiwalled Carbon Nanotubes Under Tensile Load,*Science*, 287 (2000) 637.
14. Shambhu Sharan Kumar*, N.D. Pandey, S.S. Narvi and A.S. Khanna, "Application of Nano TiO2 and Nano ZnO Particles in TSA-amino Stoving Top Coats to Study their Synergistic Effect" International Conference on Multifunctional Materials, Structures and Applications-ICMMSA-2014; M.N.N.I.T. Allahabad & University of Missouri, Columbia, USA, Springer- ISBN-13: 978-93-392-2019-8. ISBN-10: 93-392-2019-6, Page: 167-171, Mc Graw Hill Education (Dec. 2014).
15. Lau, K.S.K.; Bico, J; Teo, K.; Chhowalla, M.; Milne, W.; McKinley, G.H.; Gleason, K. K. Superhydrophobic Carbon Nanotube Forests, *Nano Lett.*, 3(12), (2003), 1701-1705. http://web.mit.edu/nnf/publications/GHM72.pdf
16. Dyett BP, Wu AH, Lamb RN (2014) Toward Superhydrophobic and Durable Coatings: Effect of Needle vs Crater Surface Architecture. ACS Applied Materials & Interfaces 6: 9503-9507.
17. Wankhede RG, et al. (2013) Development of Hydrophobic NonFluorine Sol-Gel Coatings on Aluminium Using Long Chain Alkyl Silane Precursor. Wankhede RG, et al. (2013) Development of water-repellent organic–inorganic hybrid sol–gel coatings on aluminum using short chain perfluoro polymer emulsion. Applied Surface Science 283:1051-1059.
18. Wankhede RG (2014) Development of hydrophobic inorganic hybrid sol-gel coatings on aluminium using nano-particles, in Metallurgical and Materials Science. IITB Monash Research Academy.)
19. Yan YY, Gao N., Barthlott W., Mimicking natural superhydrophobic surfaces and grasping the wetting process: A review on recent progress in preparing superhydrophobic surfaces, *Advan in Collo Interf Sci* 169 (2011) 80.
20. Dodiuk H., Rios P. F., Dotan A., Kenig S., Hydrophobic and self-cleaning coatings, *Polym. Adv. Technol.* 2007; 18: 746.
21. Leydecker, S. (2008).Nano Materials in architecture, Interior architecture and Design, Springer Science & Business Media, Birkhäuser, Berlin, Germany.
22. Inas, H. I.A. (2014).Nanomaterials and their applications in interior design, American International Journal of Research in Humanities, Arts and Social Sciences, 7(1), June-August, pp. 16-27. http://www.iasir.net
23. Morones JR, Elechiguerra JL, Camacho A, Holt K, Kouri JB, et al. (2005) The bactericidal effect of silver nanoparticles. Nanotechnology 16: 2346-2353.
24. Dhoke SK, Khanna AS (2009) Electrochemical behavior of nanoiron oxide modified alkyd based waterborne coatings. Materials Chemistry and Physics 117: 550-556.
25. Kasturi Janaki Varun ASK (2015) Development of low surface energy foul release coatings for ships, in Department of Metallurgical Engineering and Materials Science. Indian Institute of Technology: Mumbai, India
26. Pathak SS, Khanna AS, Sinha TJM (2007) HMMM cured corrosion resistance waterborne ormosil coating for aluminum alloy. Progress in Organic Coatings 60: 211-218.)
27. Dhoke S, Mangal Sinha TJ, Khanna AS (2009) Effect of nano-Al2O3 particles on the corrosion behavior of alkyd based waterborne coatings. Journal of Coatings Technology and Research 6: 353-368.
28. Barletta M., Bellisario D., Rubino G., Ucciardello N., Scratch and wear resistance of transparent topcoats on carbon laminates, *Prog. Org. Coat*. 67 (2010) 209.)
29. Bautista Y., Gómez M.P., Ribes C., Sanz V., Correlation between the wear resistance, and the scratch resistance, for nanocomposite coatings *Prog. Org. Coat*., 70 (4) (2011) 178-185.
30. Schulz U., Wachtendorf V., Klimmasch T., Alers P. The influence of weathering on scratches and on scratch and mar resistance of automotive coatings, *Prog. Org. Coat*, 42 (2001) 38.
31. Schwarzentruber, P., Scratch resistance and weather fastness of UV-curable clearcoats, Macromolecular Symposia, 187, 2002, 531.
32. Titanium-Oxide Photocatalyst, Three Bond Technical News, Jan 1 2004, http://www.threebond.co.jp/en/technical/technicalnews/pdf/tech62.pdf

33. Wakefield, G., Lipscomb, S., Holland, E.; Knowland, J. The effect of manganese doping on UVA absorbtionand free radical generation of micronised titanium dioxide and its consequences for the photostability ofUVA absorbing organic sunscreen components, *Photochem. Photobiol. Sci*., 3 (2004) 648-652.
34. Paschen H., Coenen C., Fleischer T., Grünwald R., Oertel D., Revermann C. (2003): *TA-Projekt Nanotechnologie Endbericht*. Büro für Technikfolgen Abschätzung beim Deutschen Bundestag (TAB)
35. BG BAU (2013): *Nano-Liste der BG BAU – Nanoteilchen in Bau- und Reinigungsprodukten*. Stand 28.03.2013. http://www.bgbau.de/praev/fachinformationen/gefahrstoffe/nano/pdffiles/nano-liste.pdf
36. http://www.nanowerk.com/spotlight/spotid=1007.php
37. What's nanotechnology. http://www.nano.org.uk/whatis.htm. Retrieved September, 2014.

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