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Nanotechnology in High Performance Paint Coatings

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Abstract : There is hardly any technology that has attracted an immense interest in a shortest spell of a few years. Whether it is materials development, chemistry, physics or engineering sciences, there are ample examples where nano-science or technology has created sign of positive developments. Chemical Industry has played a very important role in developing not only nano-materials but also make use of them in various applications. One field where nanotechnology has created a ripple is the paint coatings. Whether it is the improvement of chemical resistance, erosion and abrasion resistance, resistance to U.V. light, anti-fouling properties, nano-modified paints have shown great potential in several industrial applications.

Key words : Nano-modified paints, Anti-fouling properties, High performance paint coatings

Introduction :

"*Small is beautiful*" is very famous statement of past but now it has to be modified by '*small is not only beautiful but powerful too*'. It is an age of nanotechnology where every thing is going smaller and smaller to create big impression. Nanotechnology is one of hottest field which is able to draw attention from all over the world, and it has potential to outdate most of the technology existing today. Because of its great application in future, chemists, physicists, biologist and all other scientist from renowned fields are putting their heads together, and targeting what promises to be a new Industrial Revolution. Nanotechnology will leave virtually no business untouched. The potential of creation of materials from building blocks the size comparable to virus will have tremendous potential. Whether Autos or airplanes, computers or chips, medicines or cosmetics, chemicals or coatings, construction and energy – all of these industrial sectors, and many more, are facing the heat of nanotechnology and going to benefit immensely from its application.

What is Nanotechnology?

"Nanotechnology" refers a wide range of scientific or technological phenomena that focus on the properties of the nanometer scale (around 0.1-100 nm). It is the science of developing materials by controlling individual atoms and molecules to create devices that are thousands of times smaller than current technologies permit in order to impart them with special electrical and chemical properties. The basis of this technology is to change the inherent properties of material like color, abrasion, conductivity etc by reducing its size without changing its chemical composition. Nanotechnology is expected to make a significant contribution to the fields of computer storage, semiconductors, biotechnology, manufacturing , energy, chemical and coating industry.

In coming future, this highly potent technology will allow us to arrange atoms

and molecules in most of the ways permitted by physical law. It exploits characteristic effect, which occurs in the transition zone between the atomic and microscopic level. It will give us a ability to completely control the structure of materials and developing complex objects with molecular accuracy. The best part of nanotechnology is that it makes it possible to manipulate individual atoms on surfaces using a variant of the atomic force microscope along with influencing wave like properties of electron inside matter by varying nanometer scale. All products are made from atoms and their properties depend on the arrangement of atoms. In future, it will be possible to manufacture products which are ultimate in precision; the finest features will be made from individual atoms and molecules. The diversity of products will be mind blowing and it will be possible to make almost any arrangement of atoms consistent with basic principles and laws.

Unique Properties of Nanoparticles

- Size of nano particles are smaller to wave length of visible light.
- Forces like Vander wall, electron resistance and magnetic force play more dominant role than gravitational force or inertia.
- One of the most critical characteristics of nanoparticles is their very high surface-to-volume ratio, i.e. large fractions of surface atoms and thus surface properties dominate bulk properties.
- Nanoparticles improves many of desired properties like chemical and heat resistance, reduction in weight and opacity.

Nanotechnology in Coating Industry

Coating industry is growing day by day in India and around the globe. Today, coating not only serves the purpose of beautification but also a means to protect valuable metals and buildings from corrosion, which almost accounts for 4% of worlds GNP. All major paint and coating companies are investing huge amounts on their research and development sector to formulate paints, which is compatible and suitable for today's aggressive environment. Although, many new formulations of paints and coating have come to light in recent years, but none is able to fullfull all the requirements in a single formulation. For example, a coating system having good chemical properties may be handicapped by poor weathering properties or flexibility, or one with good flexibility may not have good thermal stability and mar resistance property. Hence, it would be a great achievement to develop a paint formulation satisfying many of such conditions. Nanotechnology in paint coatings promises to fulfill this desire.

Nano coating

Nano-coatings are materials that are produced by shrinking the material at the molecular level to form a denser product. The appearance and usefulness of nanoparticles brings many advantages and opportunities to paint and coating industry. Coating industry is among the first to tap the potential of nanotechnology. Addition of nanoparticles to coatings can upgrade many properties of coating system and can produce multipurpose coatings with a little cost difference. Such coatings, sometimes made of self-assembling monolayers are applicable in many ways : from scratch resistant

coatings on glass to self-cleaning surfaces to moisture absorbing to anti-graffiti and corrosion resistance coatings. Further, unique composition, better strength and flexibility along with excellent gloss and transparency makes nano-coatings even more effective. Many of the nanoparticles like nano- ZnO are non-toxic in nature and thus add another advantage to coating industry.

Nano-coating can be applied in many ways including chemical vapor phase deposition, physical vapor phase deposition. Electrochemical deposition. Sol-gel methods, electro-spark deposition, and laser beam surface treatment.

Main Advantage of Nano-coating

Some of the main advantages of nano-coating are:

- Better surface appearance.
- Good chemical resistance.
- Decrease in permeability to corrosive environment and hence better corrosion properties.
- Optical clarity.
- Increase in modulus and thermal stability.
- Easy to clean surface.
- Anti-skid, anti-fogging, anti-fouling and anti-graffiti properties.
- Better thermal and electrical conductivity.
- Better retention of gloss and other mechanical properties like scratch resistance.
- Anti-reflective in nature
- Chromate and lead free
- Good adherence on different type of materials

Scratch Resistance

Many coating surfaces possess low scratch and abrasion resistance and have to be modified with scratch resistant additives to maintain an attractive appearance over long periods of time. As a result, interest in creating protective organic coatings is growing.

Scratch resistance of coating can be improved by using micron sized inorganic fillers, but they cause matt or semi-matt appearance to coating by scattering visible light. However, by using nanoparticles, scattering of light can be reduced significantly. Nano powders of particle size around 40 to 60 nm are effective fillers. Nanoparticles such as ZrO_2, AlOOH, SiO_2 have been embedded in UV-curable lacquers, resulting in improved abrasion resistance Nanoparticles have been shown to improve the mechanical properties even at low loadings and due to their small particle size, they do not affect the transparency of clear coats. Scratch resistance also improved further due to homogeneous distribution of nano particles in polymers. Even a small amount can retain the appearance of surface without any negative impact on coating and its gloss.

To evaluate the performance of alumina nanoparticles as scratch-resistant fillers in a transparent coating, a nanocomposite was prepared with Nano-alumina dispersed in a UV-curable coating formulation at 30 wt%, with variable levels of alumina particles between 0.2 and 2.0 wt%. These composites were subjected to a scratch test by measuring the increase in haze due to the scratches. The performance of the alumina-containing composite coatings was compared

with the neat coating without alumina particles. The results of this scratch study are shown in Figure 1.

The performance of the alumina nanoparticles in Figure 1 is expressed as X times improvement in scratch resistance compared with the neat coating. It is evident the alumina nanoparticles significantly improve the performance of the UV-curable coating, up to a nine-fold improvement, even with very low levels of alumina incorporated in the composite.

UV Resistance

Photochemical degradation caused by UV rays are common mode of failures of most of the coating systems. It causes the oxidation and decomposition of polymer films along with inorganic or organic pigments. Organic UV stabilizers also undergo deterioration after certain periods. Using nanoparticles like titania or zinc oxide improve UV resistance property by not only absorbing but also reflecting those harmful rays. Also, they are not easily destroyed by UV rays and hence can increase the life span and weather resistance of paints

Hydrophobic and Oil Repellent Nature

At present, water and oil repellent surfaces are being explored due to their self-cleaning properties as they can have wide range of applications like automobile and green house glass, bathroom mirrors and building materials too. These kinds of surfaces can be prepared by a combination of optimum surface roughening and lowering of surface energy. Addition of nanoparticles to coating systems increases its surface area and pore volume, which in turn increases the surface roughness of a surface.

Increase in roughness increases the contact angle of water and other solvents significantly and hence decreasing the surface tensions of a surface. Fig. 2 shows, the excellent water and oil repellency of a surface, coated with nanoparticles in combination with fluoromethyl group.

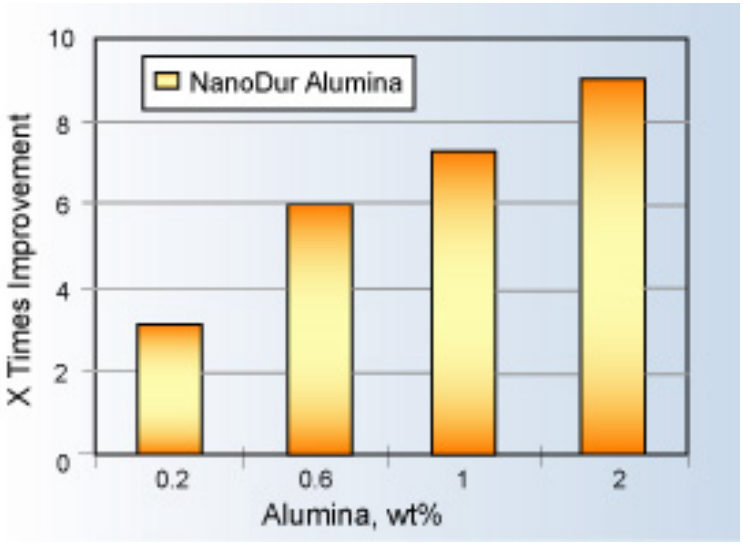


Fig. 1 : Scratch-resistance performance of NanoDur alumina particles in a UV-curable transparent coating.

Fire Resistant Property

Most of the flame retardant coating like ammonium polyphosphate and melamine loose their effectiveness as fire resistant because of their reduced mechanical properties and reduced char formation in fire and hence get easily detached from the substrate. Mechanical and chemical properties of flame retardant coating can be improved by incorporating nano-concentrates like nano sized magnesium aluminum –layered double hydroxides (LDH) to different flame retardant coating system. Also, specific amount of nano LDH improve the fire resistant and char formation properties of flame retardant coating. Nano –LDH absorbs the heat and send out water and carbon dioxide when burns and hence lowers the temperature of substrate along with enhancement in char formation.

Time period in which back temprature of the test plate got to 300^{o} C is known as fire resistant time. It is apparent from Figure

showing negative results as shown in figure because large amount of nano particles can make strong cross linking network and result in "lamp wick influence". Coating with 3% nano particle has shown this "lamp wick" effect as shown below.

Anti-corrosive Property

Corrosion resistance of a coating get influenced by P/B (pigment-binder) ratio. It is one important factor by which properties of coating can be determined and is related to transportation of harmful corrosive species in electrolyte through the coating system.

Plotting the low frequency R_f with respect to P/B ratio for different coating systems can gives clear picture of relative corrosion properties at different P/B loadings.

According to Figure 4 anticorrosive properties of coating with optimum level of nanoparticles show far better results than conventional coating. Highest value of R_f for nano-coating was at P/B ratio of 0.3 and for conventional coating, corresponding value is 1.0, which is much lower from the former.

Fig. 2 : Photographs of water and oil droplets on nanoparticle coated panel

Fig. 3 : Heat insulation graphs of film retardant coating with different content of nano- LDHs

Because of greater surface activity of nano particles they can absorb more resins compared to conventional pigments and thus reduce the free space between the pigment and the resin. Thus, incorporation of nanoparticles increase the density of coating, reduces the transport path of corrosive species and enhance the protective performance. Only optimum amount of nanoparticles should be added to the coating system to get maximum benefits. Excess of nanoparticles should not be used as pigments as the amount of resin may not be enough to wet all the nano-pigments, which may result in the formation of discontinuous film and in turn give rise to defects in the coating systems.

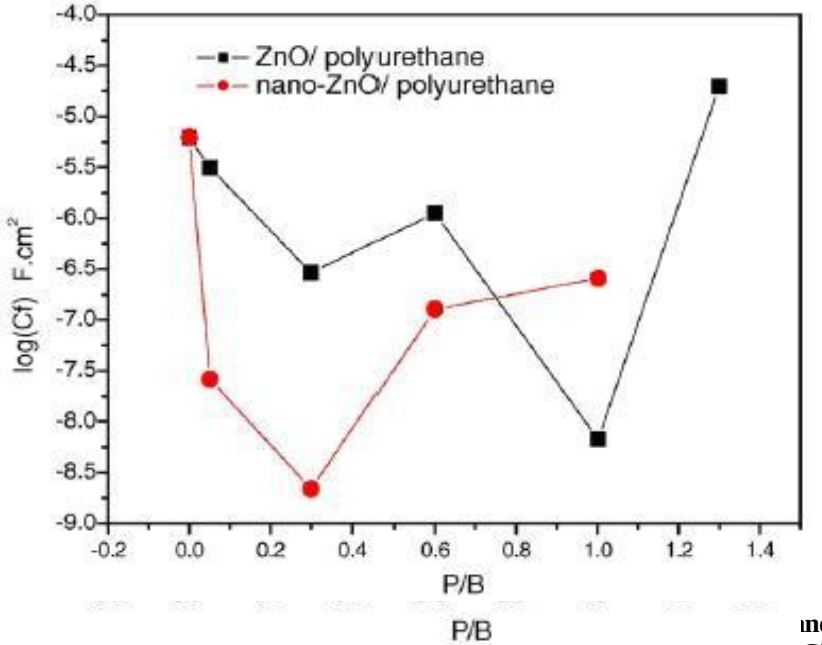
High Performance Coating

Using nanotechnolgy, it is possible to create better pigments and coating systems that can give UV alternation, transparency to visible light according to need, along with different colors. Nano-coating can be in great demand for automobile industry. Arrangement of nano pigments can be changed in paints by altering electrical field. Thus, paints can change its color as a function of voltage. This concept can be highly applicable for automobile sector. Nano-sized pigments particle having narrow particle size distribution packed well at the surface of the film resulting in a uniform surface finish. This uniform surface complemented by high scattering power of nanoparticles gives excellent gloss properties to coating systems.

Self-Cleaning

Otus effect (self cleaning surface)is popular in nano-coating. They check even very fine dirt or droplets from being accumulated on surface. If nano-coating is applied to glass surface, nanoparticles will interact with ultra violet rays, loose down the dirt particles and than using water, dirt will be distributed across the surface. So, in such glasses dirt can easily be washed off.

Fig. 4 : Coating resistance of coatings vs. P/B after exposure to 3.5%of NaCl for 1000 hours



ınd nano sized) based coatings vs. P/B after exposure to 3.5%oI NaCl for 1000 hours

Anti-fouling

Nano-coating inhibits the adhesion of microbes and marine fouling organisms. Establishment of nano-structure results in appreciable reduction in interaction between germs and surface. Nano-coating helps in reduction of germs, virus, algae by oligodynamic effect of metal component.

Anti fingerprints Coating

It involves establishment of surface with low surface free energy followed by establishing extremely flat surface using nanoparticles. This kind of surface significantly reduces fingerprints and other contaminants. As adhesion of fingerprints is reduced, oxidation will not take place and hence increases durability. Also, time to clean the surface will reduce significantly.

Hydrophilic Surface

Nano particles may increase surface free energy and thus improve the wetting behavior of water and other solvents. They results in antifog effect due to maximum spreading of water droplets. They also affect capillary flow in microstructure

Main Issues in Nano-Coating

- Main problem in using nano particles for coating purpose is dispersion and stability of nanoparticles. Agglomeration may take place because of high surface energy possessed by nanoparticles due to their large surface area.
- Pigments may lose their color on reducing their size to nano level and hence will loose their opacity.
- Stable binder is required to inhibit photocatalytic activities of nano TiO_2.
- Hardening problems of ultrafine powder.
- Extensive use of nanoparticles may give birth to new type of environmental problems, such as newer type of toxic materials and other environmental hazards. Ultrafine particles can catalyze chemical reactions inside body which might be dangerous.

Future of Nano-coating.

Future of nano-coating is looking very bright. Advancement in nano-technology will improve the properties of nano-coating even further. Automobile sector is going to get lot of benefits from nano coating. Goal for future nano-coating would be to formulate such a system in which center will have one set of properties and exterior will have other set of properties.

We have to make coating systems where nanoparticles are soluble even at very high concentration without increasing the viscosity of system. Making hybrid coating using nanoparticles may have most of the properties required for effective coating system to sustain various environmental impacts and others too.

Conclusion

Application of nanotechnology in the field of coating can facelift the coating industry. Properties like corrosion resistance, flame resistant, UV stability, gloss retention, chemical and mechanical properties are improved significantly using nanoparticles. Hybrid coating has many properties in single coating system and hence can give corrosion protection without affecting its gloss and appearance. However, nano-coating also have some limitations, like agglomeration of nanoparticles, hardening of ultra fine particles *etc*. However, benefits of nano-coating out-weigh its drawbacks. Our aim, therefore, should be to overcome these drawbacks and make even more effective coating systems.