Review Paper

Nanomaterial applications for preventing metallic surfaces corrosion

Abstract

This review describes some nano-technological applications concerning the corrosion incidence and protection of steel pipelines mainly used in the petroleum sector. These application techniques play a major role in producing anti-corrosion coatings which enhances (and enhancing) metal durability with high abrasion and corrosion resistances towards adverse environmental conditions. In addition the review also (demonstrates) describes the (many) advantages for employing nano-materials in protecting metal and other materials' surfaces.

Keywords

nanotechnology, advantages, corrosion protection, coating, anti-corrosion, steel oil pipes, applications.

Introduction

Nano-compounds possess many advantages over their micrometer scale counterparts. The main aspect of many applications of nano-materials in industry is to highlight the desired advantages in the product and to avoid the negatives. Efforts are undertaken to promote their effective utilization in the sector of corrosion control and protection [1]. The enhancement of materials performances in different industrial areas can be done through employing these nano-materials especially in an advanced coating [2]. More advanced studies should be performed to confirm the use of nano-materials in the area of corrosion control and prevention and also to authenticate the corrosion/oxidation performance of the nano-structured compounds. Nowadays, the application of nano-compounds in corrosion control, protection and prevention is of increasing interest to avoid the deleterious problems in many industries [3]. The large economic

impact of corrosion of metallic structures is very important for all industrial societies. The cost of corrosion degradation estimates to about 270 billion dollars/year in the United States of America and 200 billion Euros/year in Europe. Both direct and indirect costs represent the annual cost of corrosion. Direct costs to provide corrosion protection are related to construction, manufacturing and design, and the indirect costs are dealing with maintenance, corrosion-related inspection and repairs.

Electrochemical incidence of steel corrosion

The electrochemical corrosion of steel occurs in nature and includes many forms such as galvanic, pitting, de-alloying, erosion, uniform, microbial influenced corrosion (MIC). The process of incidence of electrochemical corrosion is summarized in the following equations:-

$Fe \rightarrow Fe^{2+} + 2\,\bar{e}$ 1

$2\,H_2O + O_2 + 4\,\bar{e} \rightarrow 4\,OH^-$ 2

$2\,Fe + 2\,H_2O + O_2 \rightarrow 2\,Fe^{2+} + 4\,OH^-$ 3

$4\,Fe^{2+} + 8\,OH^- \rightarrow 4\,Fe(OH)_2$ 4

$4\,Fe(OH)_2 + O_2 \rightarrow 2\,Fe_2O_3.H_2O\ (Rust)$ 5

Advantages of using nanotechnology to control steel corrosion

Many advantages were reported for protecting oil steel pipelines from corrosion as described in the following points:-

1. Nanotechnology has been employed to enhance the inherent corrosion resistance and performance of steel by achieving the finely crystalline microstructure.
2. Some materials exhibit physical, chemical and biological unique properties by modifying their chemical composition at the nanometer-scale.
3. Nano-particles are smaller than the wavelength of visible light range and consequently appear transparent to the human eye.

4. **Nano-particles produce an extra-ordinary high surface energy.**
5. **Nano-technology reduces the potential for environmental damage of materials during maintenance and installation because they can be stronger per unit volume than conventional one.**
6. **The physical property of nano-particles incorporated in a coating gets altered without affecting the clarity.**
7. **Nanostructure coatings have excellent adhesion and toughness because their powders have grains less than 100nm in size, which may be used to repair component parts instead of replacing them.**
8. **Metallic surfaces coated with nano-materials help in the process of super hardening.**
9. **The formation of nano-composite thin film coating on steel minimize the impact of corrosive environment by changing of the steel/ electrolyte interface.**
10. **The coating's nano-molecules improve long-term corrosion protection by forming a durable covalent bond with metallic molecules on steel surfaces.**
11. **The nano-coatings (NCoatgs) are stable at high degrees of temperature up to 180^{o}C.**
12. **The coating's nanomolecules form a smooth coating surface that provides low fluid friction to flow oil and water and consequently reduce oil pumping power losses and operation costs.**
13. **NCoatgs produce lower film thickness (10-12 µm) that ensures stable dimensions.**
14. **NCoatgs produce long lasting ceramics and nano-thermoplastics with unique abrasion and corrosion resistant properties.**
15. **NCoatgs can be applied on the aircraft's surfaces replacing the halogenated fire-retardants by nano-additive fillers eliminating the risk of generating heat and smoke.**

Nanotechnology applications

Nanotechnology is used in many areas and it is more specific to nano-materials which are used in various industrial processes, products and

applications. Most of the current applications of nano-materials represent evolutionary development of existing technologies with many effective modifications such as the reduction in size of electronic devices. The following are some applications of nano-particles in corrosion protection (Table 1).

1. Nanocomposites

The utilization of nano-tubes and nano-particles in composites is one of the designed applications to exhibit the best properties of each component of the nano-composite. This multi-functionality applied to mechanical, electrical, optic and magnetic properties. Recently carbon fibers and bundles of multi-walled Nano-tubes (CNTs) are used in polymers to enhance and control conductivity. One type of nano-composite is that one which acts as fillers in a matrix such as carbon black used to strengthen car (tiers?) (10-100 nanometers). Applications for nano-composites include: oxygen and gas barriers, thin-film capacitors for computer chips, automotive engine parts and fuel tanks, solid polymer electrolytes for batteries, impellers and blades and food packaging [4-6].

2. Nanopaints

The incorporation of nanoparticles to paints can improve their performance, impart them different beneficial properties for environment and making them more lighter. Examples of this application the light weighting, thinner paint coatings used on aircraft and the fouling-resistant marine paint as an alternative to tributyl tin (TBT) used in heat exchanger to save energy. Many speculations facing the effectiveness of fouling-resistant coating to reduce the use of biocides. Other recent applications of nano-particles might lie in paints that have reduced infra-red absorption and consequently reduce heat loss and paints that change color in response to change in temperature [7-9].

3. Nanolubricants

Recent studies reported the capability of nano-spheres of organic materials to serve as lubricants by acting as nano-sized ball

bearings, making them more durable than conventional solid lubricants and additives. These studies indicated that nano-particles reduce friction between metal surfaces especially at high normal loads and if the metal surfaces are not highly smooth [10,11].

4. Nanoclays

Nanoclays is another application of nanotechnology which can be defined as a clay from a family, which have a unique morphology, featuring one dimension in the nanometer range. Clay particle based composites containing plastics and nano-sized flakes of clay are also used in many applications such as in fabrication of car bumpers [12-15].

5. Tougher and Harder Cutting Tools

Application of nano-crystalline materials such as titanium-, tantalum- and tungsten carbides are more resistant to erosion and have the advantage to (of) last longer than their conventional counterparts and are used in the drills used to bore holes in circuits boards [16, 17].

6. Nanocoatings and nanostructured surfaces

Nano-structured surfaces and nano-coatings can be applied as chemically and catalytically functionalized surfaces. In recent years, the developed applications include the self-cleaning window coated with highly activated titanium dioxide, modified to be highly antibacterial, hydrophobic and coatings based on nanoparticulate oxides that catalytically degrade chemical agents [18-20].

Table 1: Some applications of nanoparticles in corrosion protection.

Application	Example	Reference
Nanocomposites	fillers in a matrix such as carbon black used to strengthen car	Gupta and Kumar, 2017 [21]

	tyers	
Nanopaints	Light weighting, thinner paint coatings used on aircraft	Krishnamoorthy and Kim, 2015 [22]
Nanolubricants	Metal surfaces that are not highly smooth	Shenderova et al., 2014 [23]
Nanoclays	fabrication of car bumpers	Rytwo, 2008 [24]
Tougher and Harder Cutting Tools	Drills used to bore holes in circuits boards.	Jackson and Dring, 2006 [25]
Nanocoatings and nanostructured surfaces	self-cleaning window coated with highly activated titanium dioxide	Carneiro et al, 2011 [26]

Conclusion

This review article describes briefly the advantage of using nanotechnology in corrosion protection of steel oil pipelines and the development of using recent applications in enhancing nano-materials to resist the corrosion damage. [Traditional types of insulation not efficiently protect steel oil pipelines under extreme environmental conditions and in some cases create negative effect in protection against corrosion.] (Rephrase- not comprehensible) The development of nanotechnology in coating steel pipelines, steel tanks and other petroleum equipments enhanced greatly the insulation of these materials. Recent advances in nanotechnology play a major role in improving the control of corrosion incidence and minimize the corrosion risks. More attention should be paid (from) by specialists in this field to invent new intelligent, nano-technological applications to prevent/control (face the) corrosion damage (against corrosive) aggressive environments.

Blue lettering = insert as appropriate

Red lettering = Remove or rephrase to make better comprehension

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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