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Nano-Coating Used in the Electric Vehicle Structures

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Abstract:
Nanotechnology presents significant opportunities for advancing the performance, durability, and sustainability of electric vehicle(EV) structures. Conventional materials traditionally used in automotive glass, such as silicon dioxide, calcium oxide, and magnesium oxide, often suffer from limitations including scratch susceptibility, accumulation of environmental pollutants, and insufficient resistance to ultraviolet radiation. To address these shortcomings, nanomaterials such as titanium dioxide and aluminum oxide have been employed to engineer photocatalytic and superhydrophobic surfaces. Titanium dioxide-based nanocoating's, in particular, can harness solar energy to degrade organic pollutants, while tailored surface modifications enhance hydrophilicity and extend photocatalytic activity into the visible light spectrum. In addition, superhydrophobic nanostructures facilitate the removal of water droplets, dust, and other contaminants, thereby maintaining windshield transparency and prolonging service life. Beyond glass applications, nanotechnology contributes to lightweighting and structural enhancement of EV frames through the incorporation of carbon-based nanofillers and advanced nanocomposites. These materials enable mass reduction without compromising mechanical strength, directly improving vehicle efficiency and driving range. Furthermore, nanostructured protective coatings provide superior resistance against scratches, corrosion, and environmental degradation, with emerging self-healing functionalities offering extended durability and reduced maintenance. Collectively, these advances highlight the multifunctional role of nanotechnology in improving safety, energy efficiency, and environmental performance. By integrating nanomaterials into both critical structural components and protective layers, EVs can achieve enhanced reliability and sustainability, marking the foundation of the sustainability and multi-functional capabilities of the next-generation vehicles.

Keywords: Superhydrophobic; self-cleaning; photocatalytic activity light weight; nanomaterial.

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1. Introduction

Electric car is one of the most creative things in the world, like to meet daily travel needs, and the appropriate price. There are different material choices for car in the different period depend on the technology develop in different times. For example, in 1996, when the EV1 car was be produced, they want to reduce the weight of the car, so the engineer put the aluminum in the car chassis and panels by used plastic body, magnesium was be used in the car seat structure, to achieve the lightweight function [1, 2]. nowadays, following some new materials was be founded, which means for new electric cars, it not only cares about the exterior, but also the function and application need to improve and be more polybasic and useful. To achieve that, there are more material choices that can used in the electric vehicle structure. Carbon-based Nano-fillers in the car Door panels, car bumpers and car hood [3]. Silicon dioxide Nano-coating in the car structure, such as car window to achieve the superhydrophobic to resist the dust, pollutant water and avoid fog [4]. There are widely range for nanotechnology used in the car structure, like car paint, tires, windshield and glass. Using nanoparticle coating in car paint to protect the car from scraping and corrosion, CNT in the car structure can prolong the overall strength and durability of the car, reduce the weight with high thermal properties. Apply nanotechnology in the car glass and windshield can resist the sun light and car light, produce the waterproof function raise the safety [5]. The key point for this essay is based on the nanotechnology, by research the way of nanotechnology can used in the electric vehicle paint and other part, also for the advantages of the nano-material used in the car surface, to make the car weight lighter, make the car have the self-cleaning function, make a clear view and increase the strength of the car structure, to keep safety.

2. The Application of Nanomaterials in Vehicle Body Structures

2.1 Nanomaterials for Photocatalytic Self-Cleaning Car Windows

The windows and windshield are the most important parts for the electric vehicle structure. The car windows usually using the silicon dioxide, calcium oxide and magnesium oxide, for this kind of materials, it also causes some problems like when the water drop and some pollutant fall in the car windows surface, it will reduce the use time of the car windows, get some scratch on the surface even can't avoid UV light that hurt the car chair. Try to use the nanomaterials in the car glass surface to protect it. Using ultra-thin aluminum oxide reflective layer which is less than 100 nanometer in the car windows surface can achieve the self-cleaning function. There are two ways to make the photocatalytic self-cleaning surface in the car windows, one way is using nanocrystalline titanium dioxide thin film paint in the car surface, utilize the sun light to stimulate the light activation step make the self-cleaning function. Other way is adding the non-materials elements in the titanium dioxide, can increase the hydrophilicity and the induced phot catalytic activity of the visible light. The surface roughness combine with the heterostructure also can used in the photocatalytic self-cleaning material [6]. Photocatalytic induction to make the self-cleaning function is by using the photocatalytic active materials, like the titanium dioxide, to produce the charge carrier influenced by sunlight to clean and degradation the pollutant from the car glass surface. By exposure the UV light, it stimulates electronic in the titanium dioxide, to make the light generates electrons and holes, because they have few use times, so the function and practical application is limited. These charge carriers will move to the surface of the catalyst. At that place chemical reaction will happened with other materials or decompose to lose the activity in the high temperature. Because the photo-generated holes have the high redox potential, so it can release more electronic by reaction with organic matter to promote degradation for the pollutant. Superhydrophobic combine with the photocatalytic activity give the double function for the windows surface for the self-cleaning ability in the complex environment, show the superior performance. At the superhydrophobic photocatalytic surface, non-biodegradable particles be eliminated supported by the superhydrophobic effect, rolling of water droplets, for the biodegradable pollutants, it effects by the sun light be catalyzed to the non-toxic gas [7]. To make Cold Spraying Technology preparation the fluorine-free superhydrophobic, like the titanium dioxide paint have the environmental stability and photocatalysis, show the excellent photocatalytic degradation activity deal with various of dyestuff and chemical, favorable mechanical and thermal stability, and outstanding mold resistance at the superhydrophobic photocatalysis surface. The main reason is to prevent the bacterial aggregation, to avoid the car glass and pollutant from another car surface to protect the car microstructure [8]. There are some issues for the photocatalysis, because it based on the sun, so like the cloudy and night, the efficiency become decrease, that is a challenge try to find the photocatalysis material which can keep the high-activity at the low light level situation, and reduce the negative environmental impact.

2.2 Nanomaterials in the Car Frame

For most car structure, it always uses steel to created it, but because there is nothing can put in the car structure surface, so it may cause some safety problems. Nowadays, it always uses nanomaterials in the electric vehicle structure to keep driver safety and make the structure lighter. The nanoparticle coating is the best way to increase the car structure protection and scratch-resistant ability. Also, it prolongs the use time and beautiful appearance. Adding the silicon dioxide at the polymer coating help to improve the scratch resistance and wear resistance. Because there are many nano-particles at the coating that can increase the hardness, to protect the car structure avoid the gap. Self-healing coating can used for improving the anti-corrosion ability for metal. For tradition coating, the main point is protecting the surface and avoid corrosion. But if the time goes long, the ability of the coating may become decrease. In this situation, using the corrosion inhibitor is the way to created the active coating when metal exposed to corrosive electrolytes. The corrosive agent can be dissolved in corrosive electrolytes, by passivation process to protect the metal surface. To achieve the best results, it is important to choose the best rate of nano-particles deal with raise the coating's strength and durability during the long use time. Adding 3wt % of nano silicon dioxide on the coating shows the higher wear resistance. It can use Sol-gel technology add organic matrix improve scratch resistance. This technology can enhance anti-adhesion property, avoid the mechanical damage at the electric vehicle car surface [5].

Nanomaterial shows lots of preponderance at the anti-corrosion protection for the car body. It happened in three main ways, First, nanoparticles can significantly enhance the density of the coating, creating a more effective physical barrier that prevents the penetration of moisture and corrosive ions. Next, some functionalized nanomaterials (such as graphene oxide and carbon nanotubes) can induce the "maze effect", prolonging the diffusion path for corrosive media to reach the substrate, thereby enhancing the protection lifespan, at last, some nanoparticles possess active functions, like self-repairing or sustained-release anti-corrosion agents, which can continue to provide protection when the coating is broken. There is one biggest challenge for this technic is that the dispersion of nanoparticles in the coating, if it became rally, it can obstruct and reduce the effect and damage the mechanical properties of the coating [5].

2.3 Light Weight Used in the Electric Vehicle Structure

Lightweight vehicle body design was be seen as the key of improving the energy efficiency and range of electric vehicles and nanotechnology provides an important way for the development of new structural materials with high strength and low density. This lightweight design is mainly reflected in the body frame, roof, hood, doors, and interior panels, where metal parts can be replaced by nanocomposite-based materials According the research, the nanocomposite such as carbon nanotubes, graphene, nano-clays and metal oxides can keep even can improve the mechanical property and as the same time make the structure lose weight. For example, add less than 2wt% functionalized carbon nanotubes at the polymer or carbon fiber reinforced composite, it can significantly increase tensile strength and modulus and replace some metal parts to achieve lightweight function [9]. If use materials such as high-strength steel(HSS), aluminum alloy and composite materials it shows some components of the vehicle structure have relatively low stress during the testing process, so one thing can use is called dual-phase high strength steel, put it in the car body skeleton, it can make the car lose weight and as the same time to increase the strength of the car, to make the drive environment more safety [10].

3. Conclusion

The integration of nanotechnology into EV structures demonstrates transformative potential in addressing long-standing challenges of safety, durability, and efficiency. Conventional materials can used in vehicle windows, windshields, and body frames, while functional, remain constrained by issues such as surface degradation, pollutant adhesion, corrosion susceptibility, and excessive weight. By contrast, nanomaterials-including titanium dioxide, silicon dioxide, aluminum oxide, graphene, and carbon nanotubes-offer multifunctional enhancements that simultaneously improve performance and sustainability. These materials enable self-cleaning, hydrophobicity, scratch resistance, UV shielding, and anti-corrosion properties, while nanoparticle-based coatings further introduce self-healing functions, thereby extending the operational lifespan of EV components. In parallel, lightweight nanocomposites reduce structural mass without undermining strength or safety, directly contributing to improved energy efficiency, extended driving range, and lower environmental impact. Despite these advantages, challenges remain that hinder full-scale application. Photocatalytic coatings demonstrate limited efficiency under low-light conditions, and maintaining stable nanoparticle dispersion within matrices continues to be a critical obstacle. Addressing these limitations will require focused research on material optimization, scalable processing techniques, and

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cost-effective production methods. Future developments should also consider life-cycle assessments and recyclability to ensure that nanotechnology-driven solutions align with broader sustainability goals. In conclusion, while nanotechnology is not yet fully optimized for large-scale EV manufacturing, its demonstrated benefits in multifunctionality and lightweight performance establish it as a promising pathway toward safer, longer-lasting, and more energy-efficient electric vehicles. Continued advancements in this domain will play a pivotal role in accelerating the global transition to sustainable transportation systems.

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