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Application of Graphene in Coatings: A Survey

Hongfei Guo[1,2], Ru Zhang[1,4], Zengqi Zhao[3], Min Zou[6], Xiangyue Chen[6], Zhihui He[5], Ting Qu[1], Congdong Li[1], Guoquan Huang[1]

[1]Institute of Physical Internet, Jinan University, Zhuhai, China

[2]School of materials, Inner Mongolia University of Technology, Hohhot 010051, China

[3]Baotou Research Institute of Rare Earths, Baotou 014010, China

[4]Finance Department of International Bussiness School, Jinan University, Zhuhai, Guangdong Province, China

[5]Institute of Metrology and Physics, Inner Mongolia North Heavy Industries Group, Baotou,China

[6]School of Translation Studies, Jinan University Zhuhai 519070, China;

Correspondence: Ru Zhang, Finance Department of International Business School, Jinan University, Qianshan Road 206#, Zhuhai City, Guangdong Province, Post No. 519070, China.

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Abstract

Graphene has been applied and demonstrates its excellent functions in various functional coatings by virtue of its excellent thermal, mechanical and electrical properties. This paper mainly introduces the application status and effect of graphene in conductive coating, anticorrosive coating, flame retardant coating, thermal conductive coating and high-strength coating. Finally, the application prospect of graphene in the field of coating is prospected.

Keywords: grapheme, coating; review, conductive coating, anticorrosive coating, fire retardant coating

1. Introduction

Graphene is a novel two-dimensional nano-material of sp2 carbon atom, and it is a planar film whose atomic orbital hybridization is in form of is sp2 hybridization in hexagonal honeycomb lattice (Zhang, Z., et al, 2013.). Graphene was once thought to be a hypothetical structure. As a two-dimensional crystal, graphene could not exist independently and stably at a finite temperature (Materials N, 2007). It wasn't until 2004 that Konstantin Novoselov and Andre Geim successfully isolated graphene from graphite and demonstrated that graphene could be stable on its own. They also won the 2010 Nobel Prize in Physics for their pioneering work in the field of graphene (Meyer J C, et al. 2007. Novoselov K S,et al. 2004,2005.). Since then, graphene and its composite polymer materials have received much attention from the research community and become a hot area of research in the field of materials science. Graphene has the advantages of high electronic mobility, good thermal stability, excellent conductivity and high hardness, which has been widely used in the coatings field and has achieved excellent application results. This paper aims at summarizing the research status of graphene coatings at home and abroad, focusing on the application of graphene in the coatings field and providing guidance for the industrialization of graphene.

2. Conductive Graphene Coating

As the most conductive material in the present, graphene has a resistivity of only $10\,\Omega\cdot m$, and because of its conjugate structure, it has very high electron mobility and thus has excellent electrical conductivity. Conventional conductive coatings are classified into intrinsic conductive coatings and additive conductive coatings. Intrinsic conductive coating relies on the conductivity of the resin to achieve conductivity, mainly polyaniline and polypyrole, whose processing is difficult; the additive conductive coating achieves the conductive function by using the metal powder and the carbon powder as the conductive material. However, the metal powder as conductive material has problems that it is easy to settle and not resistance to oxidation. As a result, more preferred carbon-based powder as additive conductive coating becomes a mainstream conductive coating with better performance of the conductivity and mechanical properties. Since the graphene has a large specific surface area and low conductivity permeation threshold, the amount of unit addition required to achieve the conductive function is small. Polyaniline graphene composite (PANI/RGO) was prepared by one-step emulsion polymerization, which has excellent conductivity, good thermal stability, water-dispersibility, antistatic property, adhesion, flexibility, impact-resistance and acid resistance (Zhao Y, 2017); (Wang Yanfeng, 2016) synthesized nano-ferrite/graphene composites and rod ferrite/graphene composites by hydrothermal and solvent-thermal methods respectively, and prepared of water-based electromagnetic shielding coatings by using those composites as fillers; The redox method was used to prepare graphene coatings, and further discussed the effect of dispersion and addition on the electrical conductivity of the system (Xu Hui et al. 2015); Mixed dispersion of graphene oxide and hydrazine hydrate which is subjected to a reduction reaction to form a graphene conductive layer was prepared in (Pham et al. 2010); Amination surface functionalization was used on graphene, and added epoxide resin to prepare an electrostatic conductive coating (Zhang Yong, 2013); Graphene oxide was used to prepare a thin film and obtained a graphene transparent conductive film by chemical reduction (Zheng et al. 2013. Nekahi et al.2014. Wang et al. 2012).

3. Anticorrosive Graphene Coating

Graphene has a large specific surface area, nanometer size, and flaky structure, which has excellent insulation performance and generates a "maze effect", that is, a curved passage in the graphene coating, which can delay the penetration of the corrosive medium in contact with the surface of the substrate, so graphene can be used to enhance the corrosion resistance of the resin coating.In order to improve the wear resistance of polyurethane, graphene was used as a lubricant and a barrier material to modify the polyurethane to improve its wear resistance and corrosion resistance (Mo et al.2015); In order to solve the defects such as micropores and microbubbles generated by high temperature curing of epoxide resin, TiO2-GO nanohybrids were experimentally synthesized to disperse and block micropores, and improved anticorrosion performance (Yu et al.2015,2016); A conductive marine heavy-duty anti-corrosion coating was developed with graphene as a filler, which greatly improved the comprehensive anti-corrosion performance of the coating (Lan Xijian et al 2014); Graphene oxide (GO), reduced graphene oxide (RGO) and functionalized graphene were used as anti-corrosion reinforcing material for waterborne polyurethane (PU) coating (Li et al. 2016); A cathodic electrophoretic deposition method was used to coat a surface of carbon steel with a graphene oxide film in order to avoid defects such as voids in the anodization process of graphene oxide (Huang H et al. 2017); The corrosion behavior of Ni-P coatings with different concentrations of reduced graphene oxide(RGO) co-deposited was studied. The morphology, composition, crystal structure and hardness of the coatings were also analyzed. Inspired by some hydrophobic biological surfaces in nature (Tamilarasan T R, et al. 2017), Biomimetic hydrophobic graphene coatings successfully prepared on Al alloy substrates (Zheng et al. 2016); (Xue et al. 2016) successfully synthesized for aluminum alloys Corroded graphene films; Long-term corrosion protection of steels was studied to use in chloride environments such as seawater (Raghupathy et al. 2017); The effect of reduced graphene oxide (RGO) and molybdenum on the corrosion resistance of bipolar plate amorphous nickel phosphorus (Ni-P) in proton exchange membrane fuel cells was discussed in (PEMFC) (Lv et al. 2016).

4. Fire Retardant Graphene Coating

Graphene has excellent thermal stability and excellent flame retardancy. In order to solve the problem of high flammability and large amount of smoke produced by epoxide resin, (Liu et al. 2016)obtained ZHS/RGO hybrids with higher flame retardancy by in-situ hydrothermal method, which was used as a flame retardant and smoke suppressant and added with epoxide resin; In order to solve the problem of poor dispersibility of pure graphene in the polymer matrix, graphene oxide was used as flame retardant and smoke suppressing synergist, waterborne acrylic emulsion as film forming material, titanium dioxide as pigment and formulated an intumescent waterborne fire retardant coating and studied its flame retardant and smoke suppression effects using a large plate combustion method, a cone calorimeter and a smoke density test method (Li Hongfei et al. 2015); A high-density PE/brominated polystyrene/graphene nanosheet composite was prepared with good dispersibility and became a flame retardant composite with excellent performance by melt blending method (Ran et al. 2015); Graphite oxide (GO) and a hyperbranched flame retardant containing nitrogen and phosphorus was functionalized, and then the obtained functional graphene oxide (FGO) was introduced into the cross-linked polyethylene(XLPE) to enhance the flame retardancy of the matrix (Hu et al. 2014); The effects of different particle sizes and shapes of carbon additives on the flame retardancy and mechanical properties of isotactic PP were studied in (Dittrich class Group 2013); An intumescent flame retarder (IFR), carbon nanotubes (CNTs) and graphene were incorporated into the PP matrix to prepare a new PP nanocomposites (Huang et al. 2014); The surface hydrophobicity of graphene was changed by functionalizing the surface functionalized graphene oxide (FGO) grafted with pentaerythritol (PER) in water, and then introduced FGO into the intumescent flame retardant polypropylene system (Xu et al. 2016); GO-modified N-containing organic zirconium phosphate was nano-composited with PP and evaluated its flame retardancy (Nie et al 2015); A covalently grafted FGO/PP nanocomposites with better flame retardant properties was reported in (Yuan et al. 2014).

5. High Thermal Conductivity and Heat Dissipation Graphene Coating

Graphene has a thermal conductivity of up to 5300 W/ (m Ⱪ). Therefore, the heat-dissipating coating prepared by graphene has high thermal conductivity and the high specific surface area of graphene can increase the heat-dissipation area of the coating and effectively reduce the surface and internal temperature of the object. At present, Grafoid in Canada has signed a cooperation agreement with Captherm to develop graphene heat-dissipating coatings for LEDs; Graphene directly dispersed in Su-8 UV curable epoxide resin to prepare photocuring coating with high conductivity and thermally conductivity was prepare in (Sangermano et al.2015). The process of adjusting the thermal conductivity of RGO modified epoxide resin by controlling the morphology (such as average size, thickness) and degree of reduction of RGO was studied in (Sun et al. 2016); A graphene composite heat-dissipating coating was obtained by coating a layer of graphene on the surface of the infrared emitting powder (Xue Gang et al. 2013).

6. High Strength Graphene Coating

The addition of graphene coating will form a dense network structure during the curing process of the paint film, which greatly enhances the adhesion of the paint film and the substrate, significantly improves the hardness and wear resistance of the coating, and is beneficial to solve the problem of low hardness of water polyurethane coatings, while graphene can capture free radicals in the coating and prolong the life of the coating.

7. Conclusion

The excellent properties of graphene make it show great potential and application prospects in various fields, and it has become a hot spot in scientific research at home and abroad. However, there are few reports on the application of graphene and its composite materials in the field of coatings. The research is still in its infancy, and there are still some key technical problems to be solved, such as: How to produce high quality graphene on a large scale and at low cost, and how to realize the controllability of its structure; broadening of the field of graphene application and innovation of graphene functional modification method; study on the compatibility of graphene with polymer and its action mechanism in coating system as a theoretical basis provided for the application in the field of coating; how to realize the industrial molding synthesis of graphene-polymer nanocomposites and its industrial application in the field of coatings. With the deepening of research, the above problems will be gradually solved, and graphene will play an important role in promoting the development and innovation of the coatings industry.

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