

The Application of Natural Elements in Industrial Materials

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Abstract: With the pursuit of a balance between industrial development and environmental protection, the importance of natural elements in the application of industrial materials is becoming increasingly prominent. The article mainly focuses on the definition and classification of natural elements in industrial materials, as well as their mechanism of action in improving material properties. The article analyzes the unique contributions of plant-based materials, mineral materials, and bio-based polymers in enhancing material properties. Meanwhile, the article also points out the cost, technological, and environmental regulatory challenges faced by natural elements in industrial applications, as well as innovative solutions to address these challenges. These solutions include technological innovation, policy support, and building sustainable supply chains. This comprehensive analysis not only reveals the key role of natural elements in industrial material innovation but also provides profound insights for future research and applications.

Keywords: Natural elements; Industrial materials; Application

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1. Introduction

In the context of globalization, the balance between industrial development and environmental protection has increasingly become a core issue in the social, economic, and scientific fields. Natural elements, due to their unique environment-friendly properties and excellent material properties, are gradually becoming a key element of industrial material innovation. However, many problems have emerged in the incorporation of natural materials into industrial materials. These problems not only affect the popularity of natural elements in industrial materials but also become a key factor limiting their development potential. Therefore, the exploration and implementation of effective solutions are not only crucial for the future development of industrial materials but also a key part of achieving the Sustainable Development Goals.

2. Principles of the definition of natural elements and industrial application

2.1. Definition and classification of natural elements

Natural elements, as a key component in the field of industrial materials, refer to materials that are directly

extracted from or based on natural substances. These elements are valued for their unique properties and low impacts on the environment. In terms of classification, natural elements are mainly divided into three categories: plant source materials, mineral materials, and biological base polymers. The first one is plant-based materials, such as wood, cellulose, and natural rubber, which are derived from plants. They are widely used in industry and are involved from architecture to textiles. Taking cellulose as an example, its crystal structure offers excellent mechanical strength, making it an ideal material for making paper and textiles. Data shows that the resistance of cellulose fiber can reach 1.5-2.8 GPa, which is higher than some synthetic materials. The second one is mineral materials, such as graphene, quartz, and mica, which are extracted from mineral resources. These materials have important applications in the fields of electronics, buildings, and aviation due to their unique physical and chemical properties. Graphene is known for its ultra-thin structure and superior conductive performance. Its conductivity can reach 10^6 S/m, making potential material for increasing the conductivity of electronic devices. Furthermore, bio-based polymers, such as polylactic acid (PLA) and bio-synthesized polyethylene, are materials extracted or synthetic from biomass. These materials are not only biodegradable but also similar to traditional petroleum-based polymers in terms of mechanical and thermal properties, making it an environmentally friendly alternative.

2.2. The role of natural elements in industrial materials

Natural elements offer unique physical and chemical properties. These properties enable them to improve the performance of materials in terms of strength, heat resistance, and electrical properties. Plant-based materials, minerals, and bio-based polymers play an important role in these aspects ^[1]. Taking plant-based materials as an example, its polymer structure and natural fiber form increase mechanical strength and offer lightweight characteristics. Data shows that nano-cellulose can increase the strength of polymer composites by 40–60%. Secondly, mineral-based materials like graphene improve thermal conductivity due to their high surface area and electronic migration speed. The thermal conductivity of graphene is as high as 5000 W/mK, which is five times that of copper, making it very useful for manufacturing high-performance radiator devices. In addition, bio-based polymers offer similar characteristics as traditional plastics while being biodegradable. While maintaining strength and flexibility, these materials can decompose naturally, which reduces environmental pollution. Therefore, the advantages of natural elements in industrial materials are mainly reflected in their unique physical and chemical attributes. These attributes enable them to provide environmentally friendly solutions while enhancing material performance.

3. Challenges and restrictions in applying natural elements

3.1. Cost versus economic benefits

Cost and economic benefits are some of the most important challenges in applying natural elements in manufacturing industrial materials. Firstly, the collection and processing of natural elements are often more costly. For example, some natural elements such as graphene result in a much higher production cost compared to using traditional materials. It is estimated that the production cost of high-quality graphene is about hundreds of dollars per gram, which is much higher than ordinary industrial materials. In addition, the unstable supply of raw materials and high processing costs also contribute to the challenges in using natural elements. The production cost of bio-based plastics is 1.5 to 3 times of traditional petroleum-based plastics. This directly leads to the high price of the final product and limits its competitiveness in the market. Another important aspect is the economic benefits. Although natural elements will bring environmental and social benefits in the long run, the short-term economic returns are often less obvious ^[2]. This constitutes a major obstacle for companies that

rely on rapid returns to maintain operations. The uncertainty of economic benefits is a major risk factor for many companies.

3.2. Technology and processing difficulties

Technology and processing difficulties are major issues in the industrial application of natural elements. Firstly, it is difficult to replicate the excellent characteristics of many natural elements observed in the laboratory environment in an industrial-scale production. For example, graphene has excellent physical properties, but it is extremely difficult to ensure consistency and quality on an industrial scale. Studies have shown that the success rate of performance stability and quality control in the industrial-scale production process of graphene is only about 30%. Besides, the processing of natural elements also presents certain challenges. For materials like bio-base polymers, specific conditions are required to maintain their functional characteristics. In addition, there is a gap between the speed and scope of technological innovation and the needs of industrial applications. Despite the continuous advancement in technology, the practical application of these materials in industries still takes time. For example, although there has been much investment in the scientific research of graphene, its penetration rate in actual industrial applications is still minimal, mainly due to high production costs and immature technology. This shows that although natural elements demonstrate huge potential, the industrialization of these elements is still hindered by significant technical barriers.

3.3. Environmental regulations

The application of natural elements in industrial materials is greatly restricted by environmental regulations. Firstly, there are strict requirements for the collection and processing of natural elements. For example, the use of some rare minerals must strictly abide by environmental regulations to prevent ecological destruction and resource exhaustion^[3]. Although these regulations help protect the ecological environment, they limit the availability and mining volume of natural elements. The collection of certain special plant fibers is limited due to their scarcity, which greatly limits their application on an industrial scale. In addition, the safety standards and certification processes of industrial materials also pose challenges to the application of natural elements. The safety, stability, and performance of natural element-based materials must undergo rigorous testing and be certified for long-term use. This prolonged certification process not only increases research and development costs but also delays the marketing of new materials. For example, a new type of bio-based plastic takes more than 5 years from the research and development process to marketing, which is a significant time cost for companies that pursue fast market response.

4. Innovative solutions for the application of natural elements in industrial materials

4.1. Technological innovation and research

In order to cope with the challenges of incorporating natural elements into industrial materials, technological innovation, and research are very important. To address this issue, there should be higher investment in the research and development of natural elements, especially in improving their industrial application and reducing production costs. For high-cost natural materials such as graphene, the focus can be placed on developing more economical production methods. In recent years, low-cost graphene preparation methods have been developed, such as chemical gas deposition (CVD), which is expected to greatly reduce the production cost of graphene. Moreover, technological innovation also includes improving existing processing technology to adapt to the characteristics of natural elements. In addition, optimizing the processing technology of bio-based materials

can improve its application performance in industrial products while reducing energy consumption^[4]. Studies show that the use of high-efficiency biological material processing technology can reduce up to 30% of energy consumption. Furthermore, cross-disciplinary cooperation is also an important way to promote technological innovation. By combining material science, chemical engineering, and biotechnology, research regarding the application of natural elements in industrial materials can be accelerated. For example, biotechnology facilitates the development of new bio-based materials. These materials should not only be environmentally friendly but also similar to traditional materials in terms of performance.

4.2. Sustainable supply chain construction

Establishing a sustainable supply chain is crucial to promote the application of natural elements in industrial materials. This involves the entire process from the collection and processing of raw materials, to the manufacturing and distribution of final products. As shown in **Figure 1**, the sourcing of natural elements serves as the foundation of the whole process. It is vital to adhere to environmental regulations when sourcing these materials to avoid over-mining and destroying biodiversity. For example, when collecting plant-based raw materials for the production of bioplastics, sustainable agricultural practices like crop rotation and water conservation should be adopted to minimize the impact on the environment. Next, the optimization of processing steps are crucial measures in reducing energy consumption and production waste. Efficient processing technology and recycling can greatly reduce environmental impacts^[5]. For example, by improving the processing steps of biological plastics, the conversion rate of raw materials can be increased and energy consumption and waste can be reduced. In addition, it is also important to build an efficient logistics and distribution system. This includes adopting energy-saving transportation methods and optimizing logistics routes to reduce carbon emissions. Studies show that optimizing the logistics network can reduce carbon emissions by up to 20%. Finally, improving the transparency and traceability of the supply chain is also the key to achieving sustainable supply chains. By establishing a comprehensive data monitoring and reporting system, enterprises can track the source, processing, and final distribution of materials to ensure the sustainability of the entire supply chain. For example, the use of blockchain technology can improve the transparency of the supply chain and tracking of data, which helps consumers and regulators verify the sustainability of products.



Figure 1. The concept of the sustainable supply chain of natural elements in industrial materials

5. Conclusion

This article comprehensively explores the application of natural elements in industrial materials, covering their importance, challenges, and corresponding solutions. Through an in-depth analysis, it was discovered natural elements play an indispensable role in producing industrial materials that are more environmentally friendly. However, several challenges associated with this application have been identified, which necessitate solutions spanning scientific and technological innovation, policy support, and sustainable supply chain management. Nevertheless, the utilization of natural elements in industrial materials will undoubtedly remain a significant focus for scientific research and industrial development, offering substantial momentum toward achieving environmental sustainability and fostering industrial innovation.

Disclosure statement

The author declares no conflict of interest.

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