Path Analysis of Materials Engineering Promoting Green Transformation of New Energy Industry Based on Sustainable Development Concept

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Abstract: Under the guidance of the "double-carbon" goal, the green transformation of new energy industry has become the key path to realize sustainable development.Based on the concept of sustainable development, this paper analyzes the core role of materials engineering in the transformation of new energy industry.Based on the literature review, the characteristics of green materials and their applications of photovoltaic, wind energy and energy storage are reviewed.This paper discusses the R & D and life cycle management of new green materials, presents the technical challenges and countermeasures of materials.Combined with the national policy and economic support, the external driving force of green materials development was analyzed.The research shows that material engineering plays a bridge role in promoting the green of new energy technology and is an important support for building a green energy system.

Keywords: sustainable development; materials engineering; green materials; new energy industry; green transformation

Introduction

With the continuous growth of global population and the acceleration of industrialization, the demand for energy is increasing day by day. The over-exploitation of traditional fossil energy not only causes the depletion of resources, but also brings serious environmental pollution and climate change problems, which has become a major challenge restricting the global sustainable development.In this context, as the core force to promote the transformation of energy structure and green and low-carbon development, the new energy industry is being highly valued by governments and academia of various countries.Solar energy, wind energy, biomass energy, hydrogen energy and other clean energy development and utilization, is considered to be an effective way to solve problems related with energy security and environmental pollution.At the same time, in order to support the rapid development of new energy industry, the breakthrough of relevant technologies becomes the key, and material engineering, as a basic and supporting discipline, plays an indispensable role.

1 Literature review

1.1 Sustainable development and material engineer

At the heart of the concept of sustainable development is the achievement of an economic,

social and environmental balance that ensures that the needs of the present are met without compromising the potential for future generations.Materials engineering plays a key role in promoting the green transformation of new energy industry.As the global focus on resource conservation and environmental friendliness increases, materials engineering moves away from being performance and cost oriented to a more green and sustainable orientation.More and more materials R & D projects are focusing on low-carbon production processes, the use of renewable resources, environmental friendliness, and recyclability of materials.This change in the concept of materials engineering in support of new energy technology industrialization, promote green production and clean manufacturing plays an irreplaceable role [1].

1.2 Research on green transformation of new energy industry

The green transformation of new energy industry is the core of global carbon neutralization strategy.Research shows that the key to green transformation of new energy industry is to improve energy conversion efficiency, reduce system energy consumption and enhance environmental compatibility of equipment.For example, in the photovoltaic field, the development of new materials such as perovskite solar cells and heterojunction silicon cells is promoting industrial development; in the wind energy field, the research on lightweight and high-strength wind turbine blade materials becomes the key; and in the energy storage field, new materials such as solid-state batteries and sodium ion batteries are also being explored.In addition, policy support and the establishment of recycling mechanisms are crucial for the green transformation of the new energy industry.International studies such as the European Union's Horizon 2020 program and the U.S. Department of Energy's Green Materials Program have focused on green materials as a new energy strategy.In our country also put forward the goal of accelerating the green low-carbon material technology breakthrough, which provides policy support for the application of material engineering in the transformation of new energy [2].

1.3 The combination of materials engineering and new energy technology

The combination of materials engineering and new energy technology is the basic path to promote the transformation of green energy system.In the field of photovoltaic, materials engineering development of high absorption rate of photovoltaic materials to improve the energy conversion efficiency, and reduce the environmental load [3].As a new type of photovoltaic materials, perovskite materials have attracted much attention because of their low cost and high efficiency.In the field of wind energy, carbon fiber composite materials are widely used in the manufacture of wind turbine blades, which improve the lightweight and durability of equipment.In the aspect of energy storage technology, the microstructure design optimization of lithium battery materials improves the performance and life of the battery.In addition, hydrogen energy technology also benefits from the research progress of new hydrogen storage materials, such as metal-organic framework materials (MOFs) and nano-carbon materials.The innovation of material engineering not only supports the

efficiency improvement of new energy technology, but also promotes the transformation of new energy industry to green and low carbon direction.Therefore, the combination of in-depth study of materials engineering and new energy technology, is very important to realize the sustainable energy development [4].

2 Application of sustainable development concept in materials engineering

2.1 Characteristics and selection criteria of sustainable materials

Under the guidance of the concept of sustainable development, the design, development and application of materials engineering are gradually changing to the direction of green, low carbon and circulation.Sustainable materials should not only meet the traditional requirements of mechanical properties, chemical stability and economy, but also have the characteristics of environmental friendliness, resource conservation, low carbon emission and renewability.The selection criteria for such materials usually include several core aspects: first, the source of raw materials should be as renewable or as wide as possible to reduce the dependence on non-renewable resources; second, the production process should be low in energy consumption, low in pollution and no toxic by-products; third, it should have a long life and efficient functional performance in use to ensure the stable operation of energy system; Finally, it should be easy to recycle or degrade naturally after the end of its useful life to reduce the impact on the ecosystem.With the deepening of the "double carbon" strategy, green low carbon has become the mainstream direction of the development of materials engineering, this trend is prompting materials scientists continue to look for more environmentally friendly, more efficient alternative materials, in order to achieve the goal of sustainable life cycle [5].

2.2 Development and application of new green materials

Under the background of rapid development of new energy technology, the research and development of green materials has become the key breakthrough to promote the green transformation of industry.Taking solar energy as an example, photovoltaic materials are the core of solar energy conversion system, and their performance directly determines the utilization efficiency of solar energyIn recent years, new green photovoltaic materials such as perovskite materials, heterojunction silicon materials and organic solar cell materials have become research hotspots due to their high conversion efficiency and low production energy consumption, which not only improve the energy conversion efficiency, but also significantly reduce the burden on the environment during the manufacturing process.In the wind energy technology, the wind turbine blade has extremely high requirements on the strength, toughness and weight of the material. The wide application of composite materials and carbon fiber reinforced materials realizes the lightweight and high efficiency of wind power equipment, effectively improves the energy capture capacity, prolongs the service life of the equipment and reduces the maintenance cost.In the field of energy storage, green battery materials are the key to improve battery performance and reduce environmental pollution.For example, solid-state battery materials have become the ideal direction to

replace traditional lithium batteries because of their high safety and no leakage of liquid electrolyte, while new materials such as sodium ion and magnesium ion show broad application prospects due to their abundant resources and environmental friendliness.The continuous breakthrough of these new green materials has not only accelerated the technological progress of the new energy industry, but also injected continuous impetus into the green transformation.

2.3 Life cycle management and environmental impact of materials

Under the concept of sustainable development, the life cycle management of materials has become an important standard to measure their environmental friendliness.Life Cycle Assessment (LCA) is a systematic approach to assessing resource consumption and environmental impacts of materials from raw material acquisition, manufacture, transportation, use, and final disposal.Through LCA analysis, researchers can identify key environmental impact nodes in the process of material use, so as to optimize process design and improve material selection, so as to reduce carbon footprint and resource waste.For example, in the application of photovoltaic materials, although its operation phase is almost zero emissions, but the energy consumption and harmful substances in the manufacturing process can not be ignored.Through LCA, production processes can be optimized, raw materials can be selected with less pollution and higher energy efficiency, and the overall environmental burden can be reduced.In wind power and energy storage equipment, through the analysis of material recovery rate and degradation performance, remanufacturing and recycling strategies can be effectively formulated to promote the closed-loop utilization of resources.In addition, LCA also provides policy makers with scientific basis to support the establishment of green standards and the optimization of environmental policies.Therefore, integrating life cycle management concept into material engineering is not only the only way to realize green manufacturing, but also the indispensable institutional support for green transformation of new energy industry.In the future, the development of materials engineering will increasingly rely on green management and control of the whole life cycle process to ensure that technological progress is realized while minimizing the impact on the environment.

3 Material innovation path in green transformation of new energy industry

3.1 Material innovation and green transformation in photovoltaic industry

With the growing global demand for clean energy, the photovoltaic industry is accelerating the green and low-carbon transformation, in which the innovation of material engineering plays a fundamental and leading role.Although the technology of the traditional crystalline silicon solar cell is mature, the production process of the traditional crystalline silicon solar cell is high in energy consumption and large in carbon emission, and the traditional crystalline silicon solar cell is difficult to fully meet the requirements of sustainable development.In recent years, perovskite materials have become a research hotspot because of their advantages such as simple preparation process, high conversion efficiency and low environmental burden.In addition, CIGS (copper indium

gallium selenide) and CdTe (cadmium telluride) and other thin film materials have also become an important direction of green transformation of photovoltaic industry due to their good flexibility and low resource consumption.The development path of photovoltaic materials in the future will focus on resource availability, cleanliness of production process and convenience of material recycling, so as to realize ecological optimization of the whole industry chain.

3.2 Material innovation and green transformation in wind energy industry

As a kind of efficient and clean renewable energy, wind energy has put forward higher requirements for the performance of materials in power generation systems.The long distance operation and complex wind farm environment of wind turbine blades require materials with high strength, light weight and excellent weather resistance.At present, the carbon fiber reinforced composite material has gradually replaced the traditional glass fiber material, applied in the manufacture of large fan blade, not only reduces the overall structure weight, but also improves the stability and service life of the system.To further promote green manufacturing, researchers are also developing bio-based composites and degradable resin systems to reduce the pressure on solid waste after decommissioning wind power equipment.In addition, the anti-corrosion design of tower materials has also become an important research direction, especially in the field of offshore wind power. The use of green protective coating and high-performance alloy materials significantly improves the long-term stability of equipment and provides support for the green upgrading of wind power industry.

3.3 Green materials and sustainable development in energy storage technology

Energy storage technology is the key to ensure the stable operation of new energy system, and its core depends on the support of high performance and environmentally friendly materials.Although lithium-ion battery is the current mainstream, but its cathode material mostly rely on cobalt, nickel and other rare metals, not only the cost is high, and mining process of serious damage to the environment.Therefore, new energy storage technologies such as solid-state battery, sodium ion battery and magnesium ion battery have become a new research direction, among which solid-state electrolyte materials have higher safety and cycle stability, while sodium ion and magnesium ion materials have long-term application potential due to abundant raw materials and environmental friendliness.In the field of hydrogen energy, metal organic framework materials (MOFs) and nano-porous carbon materials, as new generation hydrogen storage and catalytic materials, are promoting the green development of hydrogen energy system due to their high specific surface area and good structural stability.In order to more intuitively show the innovation direction and characteristics of materials in various fields, see the table below.

Table 1 the main types of green materials in the new energy industry and its characteristics

Territory	Material type	Green characteristic	Application advantages

photovoltaic	perovskite, CIGS, CdTe,	can be prepare at low temperature, has rich resources and low carbon emission	High conversion efficiency for flexible assemblies
wind energy	Carbon fiber composites, bio-based materials	high strength, light weight, renewable and degradable	Enhanced fatigue resistance and longer equipment life
stored energy	the solid electrolyte, sodium/magnesium ion material,	the resource are rich, that safety is high, and the degradable	low cost, high energy density and strong safety performance
hydrogen Energy	MOFs, nano-carbon materials	high specific surface area, controllable structure, no toxicity and environmental protection	improve hydrogen storage density and catalytic efficiency

As can be seen from Table 1, all kinds of green materials have their own emphasis in different new energy fields, reflecting the dual value of high performance and environmental friendliness.Material innovation not only optimizes equipment performance and reduces costs, but also reduces ecological load at the source, laying a solid foundation for the sustainable expansion of new energy technologies.

3. 4 Technical path of material recovery and recycling

At the end of the life cycle of new energy equipment, the treatment mode of its materials is directly related to whether the industrial chain truly realizes green closed loop.At present, a large number of photovoltaic modules are faced with the problems of high recycling cost and low efficiency after decommissioning. Researchers are exploring the efficient recycling technology combining physical disassembly with chemical purification to realize the secondary utilization of silicon wafer, silver, aluminum and other resources.In the field of wind power, the recycling and treatment of composite blades has become a difficult problem in the industry due to its difficult degradation. In recent years, new methods such as pyrolysis recycling and biodegradable compounds have gradually appeared, striving to realize green treatment and resource reuse of materials after equipment decommissioning.In terms of energy storage equipment, the echelon utilization and high-value recycling of waste lithium batteries are also taking shape, and the construction and standardization of recycling system urgently need to be strengthened.By building an integrated path from material design, use, recycling to remanufacturing, materials engineering is pushing the new energy industry towards a truly green and sustainable transformation.

4 Continuous optimization and challenges

4. 1 Technical challenges in materials engineering

In the process of green transformation of new energy industry, the technical challenges faced by materials engineering as a basic discipline are increasingly prominent.First of all, from the perspective of the development of efficient materials, although such as perovskite photovoltaic materials, solid electrolyte, MOFs has made significant breakthroughs in the laboratory level, but to achieve its scale, commercial application still faces many bottlenecks.For example, the stability problem of perovskite material has not been fundamentally solved for a long time, and it is easy to decompose under humid and high temperature conditions, which affects the service life of equipment; while the electrolyte interface

stability and ion conduction efficiency in solid-state battery are far from meeting the industrialization requirements.Secondly, the balance between renewable and environmental performance has become a key problem in the design of new materials.Although some high-performance materials are excellent in efficiency and structure, there may be environmental pollution in the process of raw material collection, or it is difficult to recycle and treat them, so it is impossible to realize real green closed loop.In addition, the preparation process of green materials often involves high-end equipment and complex control system, which makes the production cost significantly higher than that of traditional materials, which undoubtedly increases the difficulty of promotion in the current price-oriented market environment.Therefore, finding the optimal solution among performance, sustainability and cost has become the primary technical topic of continuous optimization of materials engineering.

Table 2 the current green materials are facing the main technical challenges and countermeasures

Material type	Technical challenges	Affect performance	Coping strategy
perovskite photovoltaic material	Poor environmental stability and easy degradation	Short component life, limited outdoor use	Surface packaging optimization, material doping modification
solid electrolyte	Low ion conduction efficiency, unstable interface	Low battery efficiency and short cycle life	nanostructure design, introduction of a composite interface lay,
bio-based composites	Unstable mechanical properties and difficult degradation control	Short service life, difficult compatibility with traditional materials	Molecular structure control, multi-component composite processing
hydrogen storage material of MOFs	Low thermal stability, complex synthesis	High application cost and difficult scale	Simplifying synthetic routes and developing low-cost precursors

As can be seen from Table 2, although green materials show great potential in terms of performance improvement and environmental friendliness, there is still a need to make breakthroughs in stability, process maturity and economy to realize industrialization.Only by realizing original innovation in core material science and technology can we really break the contradiction between green technology and cost and realize the transformation from "feasibility study" to "producibility."

4. 2 Policy and economic support in green transformation

In addition to the technology itself, policy and economic support are also crucial for materials engineering to promote the green transformation of new energy industries.At present, under the guidance of the "double-carbon" strategy, China has issued a series of policies and measures to support the development of green technology and clean energy, including green credit, tax incentives, industrial subsidies, technical standard formulation and promotion mechanism, etc. These policies have provided strong guidance and incentives for the field of materials engineering.At the same time, international organizations such as EU Green New Deal and U.S. Department of Energy Green Innovation Project also support the research and implementation of green material technology through financial allocation and system design.However, there are still many problems in actual operation, such as fragmentation of financial fund allocation, long return period of green investment of enterprises, low market acceptance of green products, imperfect green certification system and so on, which restrict the

full release of policy dividends.

Table 3 China's main policy support in the field of green materials type and mechanism of action

Policy types	Support, and which	Typical measures or items	Main function
fiscal subsidies	R & D fund support, technological transformation fund subsidy	National Key R & D Program "Green Materials and Intelligent Manufacturing"	Reduce R & D risk of enterprises and promote technology transformation
tax preference	Tax relief for high-tech enterprises	Green manufacturing enterprises enjoy 15% preferential corporate income tax	Improve the profit space of green enterprises
financial instruments	Green credit, green bonds	Banks provide low-interest loans for green materials projects	Reduce financing costs and improve project feasibility
Certifications and Standards	Compulsory green certification, industry standards	Energy consumption quota standards, green product evaluation and identification system	Standardize industrial development and guide the market's green preference
market mechanism guide	Carbon trading, green procurement system	Carbon trading of key energy-using units and green procurement of the government	Increase market demand for green products

It can be seen from Table 3 that the policy support system has covered multiple links from technology research and development, fiscal and tax incentives to market promotion, providing a good external environment for the deep integration of material engineering and new energy industry.However, to truly unleash the potential of green material technologies, policy synergies need to be strengthened to improve the accuracy and sustainability of policy implementation.Especially in the aspect of promoting the commercialization of green materials, we should establish more operational risk compensation and incentive mechanism, and perfect the green standard system at the same time, so that the policy dividend can be truly transformed into the endogenous power of enterprise innovation.

5 Conclusion

Focusing on the theme of "Path Analysis of Materials Engineering Supporting Green Transformation of New Energy Industry Based on the Concept of Sustainable Development," this paper systematically discusses the green innovation path of materials engineering in key new energy fields such as photovoltaic, wind energy and energy storage, and analyzes the close relationship between material selection, technology evolution and life cycle management in combination with the core concept of sustainable development.The research shows that material engineering not only plays a fundamental role in improving the technical performance of new energy and reducing energy consumption and pollution, but also becomes the core pillar to promote the green transformation of new energy industry through the research and development of green materials, the construction of recycling mechanism and the synergy with policy mechanism.Under the background of accelerating the process of "carbon neutralization" globally, the key to sustainable energy development is to continuously deepen the green innovation of material technology and optimize the industrial policy support system.

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