World Journal of Materials Science
ISSN: 2960-0146
DOI: 10.61784/wjms240167

APPLICATION STATUS OF NEW ENERGY AND MINERAL MATERIALS

Bela Motta
California Institute of Technology, Pasadena, California 91125, United States.

Abstract: As energy and environmental issues become increasingly prominent, the development and utilization of new energy sources have received more and more attention. As the core and foundation of new energy technology, the research and development of new energy materials has quickly become a global research hotspot. Natural minerals have the characteristics of wide variety, low cost and environmental friendliness, which have attracted widespread attention in the preparation of new energy materials. This article reviews the application status of different types of natural minerals in the fields of supercapacitors, gas storage, lithium-ion batteries, photo/electrocatalysis, and phase change energy storage. The impact of the structural morphology of natural minerals on material preparation and performance is analyzed, and it is pointed out that The existing problems in the research of new energy mineral materials are analyzed, and its future research directions are prospected.
Keywords: New energy materials; Natural minerals; Mineral materials; Functional materials; Structural morphology; Material properties

1 INTRODUCTION

With the rapid development of economy and society, human consumption of fossil energy has increased exponentially, and excessive consumption has caused increasingly serious problems such as energy crisis and environmental pollution. New energy technology is not only an important means to solve the energy crisis and restore the ecological environment, but also ensures high-quality and sustainable development of the economy and society. The core and foundation of new energy technology development are materials. New energy materials are a powerful guarantee for promoting the rapid development of new energy technology [1-3]. New energy materials can significantly improve energy storage efficiency, accelerate energy conversion, and make energy utilization more efficient during the conversion and utilization of new energy [4]. In recent years, my country's new energy materials industry has developed rapidly. The increasing technical level and expanding industrial scale have helped my country's high-tech industries such as lithium-ion battery materials and fuel cell materials break through technical barriers and achieve rapid development.
Compared with traditional inorganic materials, natural minerals have the advantages of wide variety, low cost and environmental friendliness. They can be used in new energy materials. The field of materials is expected to improve its energy storage efficiency, energy conversion efficiency and reduce Low cost[5-6]. At present, new energy mineral materials mainly focus on super Level capacitors, gas storage, lithium-ion batteries, photo/electrocatalysis, phase change storage Can wait for the field. Conducting research on new energy mineral materials is of great significance in promoting high-value and efficient utilization of mineral resources, optimization of traditional industrial structures, development of high-tech industries, energy conservation and emission reduction, and ecological and environmental protection [7-8]. This article introduces the current application status of natural minerals in the field of new energy materials and analyzes the mechanism of natural minerals in material preparation and application, in order to provide reference for the sustainable development of new energy mineral materials.

2 SUPER CAPACITOR

Supercapacitors are new energy storage components between traditional capacitors and batteries[9], generally composed of electrodes, current collectors, electrolytes and separators [10]. According to differences in charge storage mechanisms, supercapacitors can be divided into three types: pseudocapacitors, electric double layer capacitors and hybrid capacitors. The energy storage principle of supercapacitors relies on surface adsorption/desorption to store and release energy. However, the low energy density and large self-discharge rate hinder the popularization and application of supercapacitors to a certain extent [11].
The use of natural minerals is expected to increase the capacity of supercapacitors, improve their long-cycle instability shortcomings, and thus improve their safety performance[12]. Natural minerals used in the field of supercapacitors are basically divided into four types: first, as electrode active materials, second, as electrode template materials, third, as electrode carrier materials, and fourth, as inorganic fillers for polymer electrolytes [13].

2.1 Electrode Active Material

Natural graphite is an essential mineral resource for the development of high and new technologies. source, has good conductive properties, and is used as a supercapacitor Extreme materials have broad application prospects[12]. LIM et al[14] to gather Acrylonitrile is used as the precursor, and a hard carbon coating is loaded on natural graphite to produce

Prepared hard carbon coated graphite electrode, capacity after 10, 000 cycles The retention rate reaches 74. 6%, which is suitable for use as a high-energy and high-power super battery. Anode material for container[15]. In addition to natural graphite, RAJCIC-VUJASINOVIC et al. [16] studied copper blue as a superelectrode material. Container electrode active material, under acidic electrolyte conditions, for the first time During the anodic polarization process, the specific capacitance of copper blue reaches 20F/cm2, and In alkaline electrolyte, it is reduced to 6. 7F/cm2. also, PHOOHINKONG et al. [17] prepared golden red by ball milling method. stone nanoparticles and use them as electrode active materials, thanks to the Highly active Ti^{3+} on red stone surface, making the electrode active material behave Excellent electrochemical performance. Natural minerals as active materials Greatly improve the specific capacitance, energy density and cycle stability of the electrode. Qualitative and has good application prospects in supercapacitors.

2.2 Template Material

Certain natural minerals have specific morphological structures, such as attapulgite, montmorillonite, halloysite, diatomite, etc., and are often used as templates to synthesize porous carbon materials with specific morphologies [18]. LUO et al[19] Pick Prepared by hard template method using attapulgite as template and citric acid as carbon source prepared a mesoporous carbon material that replicates the nanostructure of attapulgite Rod-shaped structure, specific surface area and total pore volume reach 707m2/g and 1. 22cm3/g; at 2 mA/cm2 At a current density of to a specific capacitance of 182F/g. After 1000 charge-discharge cycles, the The capacity retention rate is still as high as 95. 68%, showing excellent electrochemical chemical properties and cyclic stability. Cao Xi et al[20] natural nanofibers Using the vitreous mineral fiber serpentine as the template and sucrose as the carbon source, we prepared a One-dimensional tubular morphology of hierarchical porous structure carbon materials, template carbon materials The proportion of medium and large pores reaches 87%, and the rich medium and large pores make it have Excellent electrical conductivity and high power density; at 20A/g It can still maintain a specific capacitance of more than 75% under current density. After 10, 000 cycles at a current density of 10 A/g, the specific capacitance reaches 119 F/g.

In addition, mineral template methods can be used to synthesize materials with specific morphologies. conductive polymer[21]. XIE et al[22] Using attapulgite as a model board, graphene/porous polyaniline superstructure was prepared by in-situ polymerization method The electrode material of the first-class capacitor has a specific capacitance of 654.75F/g at a current density of 1 A/g and a scanning speed of 50 mV/s. After 1000 charge and discharge cycles, the capacitance retention rate reaches 74. 36%. Graphene/porous polyaniline composite electrode material has a high specific Surface area and electrochemical performance are superior to pure graphene and polyaniline materials material. FAN et al[23] Using natural kaolin (HNTs) as template into polyaniline (PANI) nanotubes and serve as high-performance pseudocapacitors Electrode, the prepared PANI-HNTs composite material has a hollow junction With its structure and high specific surface area, after carbon coating, at a current density of 1 A/g, the specific capacitance of the PANI-HNTs/C electrode reaches 654F/g, its capacitance retention rate reaches 87%. Apply mineral template method to the synthesis of conductive polymers, in While retaining the large specific capacitance of conductive polymers, it improves its mechanical Stability, suitable for high energy density supercapacitors.

2.3 Electrode Carrier Material

In order to obtain active materials with specific morphology, while improving The specific capacitance of the material can improve the cycle stability, and the active material can be Loaded on the surface of minerals such as montmorillonite and halloysite [24]. CHANG et al.[25] organically modified sepiolite and used in-situ polymerization method Sepiolite/polypyrrole nanocomposites were prepared and used as super The maximum specific capacitance reaches 164. 9F/g when used as the electrode material of the first-grade capacitor. REN et al[26] New nitrogen-doped carbon using montmorillonite as carrier (NMC) as raw material, NMC/MnO2 was prepared by ultrasonic dispersion method Composite material, obtained by in-situ polymerization with aniline (ANI) NMC/MnO2/PANI composite material, exist 1 mol Na2SO4 In the electrolyte, at a current density of 0.25A/g, its ratio The capacitance reaches 228. 5F/g, and its ratio at a current density of 4A/g The capacitance reaches 140F/g, and the capacitance retention rate is 86% after 800 cycles at a current density of 1A/g. CHAI et al[27] Halloysite (HNTs) is the carrier and component, prepared by self-assembly method porous NiCo2SO4/HNTs composite material, at 1A/g The specific capacitance of the composite material reaches 589F/g under current density. After 1000 charge and discharge cycles, its capacitance retention rate is 86%. The NiCo2SO4/HNTs composite material has a large number of active sites. 3D porous structure with high specific surface area and short diffusion paths. sky Natural minerals can effectively avoid the agglomeration of materials and increase the charge storage space and ion transmission speed, the composite electrode material prepared The material exhibits high active sites.

2.4 Composite Polymer Electrolyte

Natural minerals as inorganic fillers for preparation of composite polymer electrolysis It can improve the ionic conductivity of polymer electrolytes [28-29]. WANG et al. [30] used montmorillonite and polyethylene glycol methyl ether propylene respectively. Acid ester and polyethylene glycol diacrylate are used as additives and raw materials to prepare a composite solid electrolyte; the ultra-high-performance composite solid electrolyte level capacitor, after 400 cycles at a rate of 0.3C, its electrical The capacity retention rate is as high as 98%, showing excellent electrochemical stability. sex. LIN et al.[31] used halloysite nanotubes as supercapacitors Solid electrolyte filler, at a rate of 4C, has a specific discharge capacity of 809mAh/g, the specific discharge capacity is still high after 400 cycles reaches 386 mAh/g, its ionic conductivity is greatly improved, and it can Maintain high capacity and long service life at 25~100℃. The addition of clay minerals can significantly improve the performance of polymer electrolytes. It is an ideal choice for polymer electrolyte fillers.

The presence of natural minerals can improve the electrochemical performance and cycle stability of supercapacitor electrode materials, making up for the shortcomings of high cost. In the future, research on supercapacitor electrode materials should strengthen the design of the material's microstructure, and use the special structure of natural minerals to control the surface morphology of the electrode material, increase the number of active sites and reaction kinetics, thereby improving the electrochemical performance of the material.

3 GAS STORAGE MATERIALS

The increasing consumption of fossil fuels has caused mankind to face the severe test of energy shortage, and the effective development and utilization of new energy sources such as hydrogen and methane has become increasingly urgent. Because gaseous fuels are explosive, their transportation and storage research has become the core of development and utilization[32]. Porous solid adsorbent materials use the huge specific surface area and rich pore structure of the adsorbent to adsorb and store gases. When inflated, the external pressure is high, and the gas is stored in the pore structure of the adsorbent. When deflated, the external pressure is low, and the gas escapes from the adsorbent. desorbed from the pore structure. It is generally believed that excellent gas adsorption materials should have the following characteristics: huge specific surface area, abundant micropores and appropriate pore size distribution; fast adsorption/desorption rate; good heat transfer performance; long service life and simple synthesis process [33].

3.1 Hydrogen Storage Materials

With the development of science and technology, the preparation of hydrogen is no longer a problem, but due to the special physical and chemical properties of hydrogen, the storage of hydrogen is a key link in the use of hydrogen energy [34]. As the most promising hydrogen storage method, solid-state hydrogen storage technology has excellent hydrogen storage energy density and safe and reliable properties[35]. Based on the advantages of high physical adsorption hydrogen storage efficiency and good adsorption/desorption of hydrogen under mild conditions, it has developed rapidly in the field of solid-state hydrogen storage[36]. At present, physical adsorption hydrogen storage materials mainly include: carbon-based materials and their derivatives, zeolite molecular sieves, silicon nanotubes, metal-organic framework compounds and covalent organic frameworks, etc. [37]. Compared with the above hydrogen storage materials, natural minerals themselves have rich nanopore structures, which can provide a large number of adsorption sites for hydrogen, and their stable chemical properties can also ensure the safe storage of hydrogen.

Cheng Jipeng et al[38] Take C2 H2 is the carbon source, Co is the catalyst, Under the condition of 750 ℃, the chemical vapor deposition method was used to Carbon nanotubes were successfully grown on the surface of the onyx mineral; Polygonite original The hydrogen storage capacity of site-grown carbon nanotubes has reached 0.41%. Rice tubes grown in situ on porous mineral surfaces eliminate the need for blunt Chemicalization can improve hydrogen storage capacity. JIN et al[39] studied at room temperature Next 3 different treatment methods (heat treatment, acid treatment, palladium treatment) Hydrogen adsorption capacity of halloysite nanotubes (HNTs) under conditions, result table It is shown that under the condition of 2. 63 MPa/298K, the hydrogen absorption of HNTs The attached quantity is 0. 436%, heat treated (T-HNTs), acid treated (A-HNTs) and palladium modified (Pd-HNTs) under the same conditions The hydrogen adsorption capacities of the final HNTs were 0. 263%, 1. 371% and 1. 143%. It can be seen that A-HNTs after acid treatment and Pd-HNTs after palladium treatment show excellent hydrogen absorption ability It is an effective method to improve the hydrogen storage capacity of HNTs. HNTs and processed HNTs have excellent stability and strong The hydrogen adsorption capacity shows the potential as a greenhouse hydrogen storage medium. Jiang Cuihong[40] prepared BaO-modified sage by using hydrolysis precipitation method. Stone, the hydrogen storage capacity of this hydrogen storage material under the conditions of 298K and 7MPa Reached 2. 35%.

3.2 Methane Storage Materials

At present, people are beginning to try to replace traditional adsorption natural gas storage technology with economical, easy to use and high safety performance. Compressed natural gas technology and liquefied natural gas technology. The key to achieving efficient natural gas storage lies in the synthesis of stable, economical natural gas adsorbents with high adsorption capacity [41], among which the natural gas adsorption materials with more research and better performance mainly include molecular sieves, porous carbon materials and metal-organic framework compounds [42].

Studies[43] have shown that clay minerals have a negative impact on the formation of shale gas reservoirs. It has certain positive significance and has gas storage performance. LIU et al. [44] studied the effects of montmorillonite, kaolin and The adsorption performance of illite on methane is as follows: 18MPa/60℃ Under the conditions, montmorillonite, kaolin, and illite all showed higher The adsorption capacities are 6. 01, 3. 88, and 2. 22cm3/g respectively, clay The structure and surface properties of minerals are important parameters for evaluating gas storage capacity. number. Li Quanzhong[45] studied the adsorption effect of chlorite on methane. Using it, it was found that the mesopores of chlorite accounted for 75.36% of the total pore volume. Compared with the table 90. 65% of the area, and the maximum

adsorption capacity of methane is 2. 69 cm3/g. The adsorption of methane by clay minerals is mainly controlled by the mineral The mesopore specific surface area and the maximum adsorption capacity are positively correlated with it.
With the development of solid gas storage materials, research on the application of natural minerals in gas storage materials will become a hot topic. At present, the relationship between the structure of natural minerals and gas storage performance and the research on gas storage mechanism are still insufficient. In-depth basic research on natural mineral -based gas storage materials is needed.

4 LITHIUM BATTERY MATERIALS

Lithium-ion batteries have become a hot research topic in secondary batteries due to their advantages such as high specific energy, long cycle life, no memory effect, safety and reliability, and fast charge and discharge [46]. Irreversible physical and chemical reactions of internal materials in lithium-ion batteries during charge and discharge cycles can lead to battery degradation, resulting in performance degradation and even explosion accidents. Therefore, the development of new lithium battery materials has always been a research hotspot in the field of energy storage [47]. Based on the unique crystal structure and micromorphology of natural minerals and excellent physical and chemical properties [48], using it to manufacture key components such as lithium-ion battery electrodes, separators and solid electrolytes is expected to improve the energy density and safety of lithium-ion batteries. It will not only save battery production costs, but also promote the high-value development and development of mineral resources. Take advantage of [6].

4.1 Electrode Material

Due to their limited theoretical specific capacity, traditional electrode materials have It cannot meet the current market demand for high-specificity lithium batteries [49]. Natural minerals used as composite cathode materials for lithium-sulfur batteries can effectively Complement the defects of polysulfides such as poor conductivity and easy dissolution[50], PAN etc[51] Using sepiolite and sulfur as raw materials, using vacuum heat treatment method Sepiolite/sulfur composite cathode material was prepared at a rate of 0.2C down, the initial specific discharge capacity reaches 1436mAh/g, after 300 times The specific discharge capacity is still as high as 901 mAh/g after cycling. Natural sepiolite has strong adsorption and low cost. The dissolution problem of polysulfides has been significantly improved after adding sepiolite, thereby obtaining stable electrochemical properties.
XIE et al[52] Using graphene nanosheets (GNs) and functionalized concave Pylonite (ATTP) and sulfur are used as raw materials, and are produced by melt diffusion method. ATTP@GNs/S composite anode material is prepared; this material has 1143. Initial specific discharge capacity of 9mAh/g, at 0.1C Cycle under magnification The reversible specific discharge capacity after 100 times is 512 mAh/g, the capacity decay rate under a single cycle is 0. 5%. Zhao Mingyuan et al[53] Using natural halloysite as the precursor and using low-temperature thermite Silicon nanotubes were synthesized by reduction and self-templating methods; based on halloysite When the silicon nanotube is used as the negative electrode of a lithium-ion battery, its initial specific discharge Capacity up to 3150. 2mAh/g, current density at 0. 5A/g It can still maintain a high specific discharge capacity of 1786.0mAh/g after 50 cycles at high temperatures, which is more than twice that of commercial silicon materials. sky However, the aluminum-oxygen octahedron of halloysite is beneficial to maintaining the halloysite-Wiener The tube-like structure effectively compensates for the loss of silicon anode during the process of removing lithium. cracking and crushing defects of active materials caused by volume changes, and improve circulation Structural stability during ringing.

4.2 Diaphragm Material

At present, commercial lithium battery separator materials are mainly polyolefin materials, which have poor heat resistance. The thermal deformation temperature of PE and PP separators themselves does not exceed 100°C. Moreover, PE and PP separators are non-polar materials and have poor liquid absorption and retention properties. Bad[54]. Natural minerals can effectively make up for the defects of polyolefin separators, thus greatly improving the performance of lithium-ion batteries [55].
Zhang Hongtao et al[56] With zeolite, silica sol and ethylenediaminetetraacetic acid As raw materials, zeolite-based lithium-ion batteries were prepared using a sintering process. Separator: The average pore diameter of the prepared porous zeolite separator is about 200 nm, and the porosity is as high as 72%. After heat treatment at 160°C for 0.5 hours, the thermal shrinkage rate is 0, and the electrolyte contact angle is close to 0°. porous zeolite Capacity of lithium-ion battery assembled with separator after 300 charge-discharge cycles The quantity attenuation rate is only 4. 2%. Porosity and thermal stability of zeolite membranes Qualitative, electrolyte affinity and capacity retention are better than traditional Polyolefin separator. YANG et al[57] passed the test on the surface of PE separator Coated with nano-polypyrrole/organic montmorillonite (nano-ppy/OM-MT), a nano-ppy/OMMT coated separator was prepared; The initial specific discharge capacity of the lithium-ion battery assembled with the separator is 125. 9 mAh/g, Coulomb efficiency is 99. 6%, after 100 times The specific discharge capacity after cycling is 99. 12mAh/g, which is approximately the initial discharge capacity. 80% of discharge capacity. The organic coating is evenly distributed on the PE diaphragm The membrane surface shows a complex three-dimensional multi-layer structure and a high specific The surface area not only facilitates the absorption of electrolyte, but also reduces the internal resistance of the battery at high temperatures. SONG etc[58] attapulgite (ATP) nanofibers incorporated with biodegradable biodegradable material

extracted from brown algae The polysaccharide sodium alginate (SA) was prepared by phase inversion method. SA/ATP porous composite separator; the average pore size of the composite separator is about 25nm, almost no thermal shrinkage occurs at 250°C, electrolysis Liquid absorption rate is 420%. Use SA/ATP composite separator for The lithium-ion battery has a specific discharge capacity of 115 mAh/g at a rate of 5C, and the capacity retention rate is 82% after 700 cycles.

4.3 Electrolyte Materials

Traditional liquid electrolytes are generally composed of carbonate or carboxylate esters. It is composed of sub-substances, has a low flash point and is flammable and explosive. Once in a lithium battery Leakage can easily lead to safety accidents[59]. Lithium ion battery positive From liquid electrolytes with serious hidden dangers to solid electrolytes with better safety performance and better processing performance [60]. natural Minerals, with their special morphology and structure and high Li^+ conductivity, enable It has become a new material for constructing composite solid electrolytes, which can effectively suppress Uncontrolled growth of lithium dendrites in lithium-ion batteries [61], at the same time However, the abundant oxygen-containing functional groups on the surface of minerals can form interactions with polymers. Form chemical bonds, hydrogen bonds and other chemical interactions to effectively improve solid-state electricity Mechanical strength of the solute [62].

LUN etc[63] by PVDF as matrix, halloysite (HNTs) as filler, a PVDF/HNTs composite solid electrolyte was prepared by solution casting method; the ionization of the composite solid electrolyte The sub-conductivity is 3.5×10^{-4} S/cm, assembled lithium-ion battery The first specific discharge capacity at a rate of 1C is 71. 9 mAh/g, and the specific discharge capacity after 250 cycles is 73. 5 mAh/g. YAO et al[64] Using palygorskite (ATP) nanofibers as ceramic filler material, prepared PVDF/ATP composite solid electrolyte, when When the added amount of ATP is 5%, the elasticity of the composite solid electrolyte The sexual modulus increased from 9MPa to 96MPa, and the Li^+ diffusion coefficient increased from 0.21 increased to 0.54; PVDF/ATP composite solid electrolysis The quality is used in lithium -ion batteries, and the capacity retention rate is as high as 97% after 200 cycles at a rate of 0.3C. Halloysite, palygorskite and other natural The addition of minerals solves the problem of PVDF-based polymer electrolyte mechanical The problem of low strength has improved the safety performance of solid-state lithium batteries.

The basic theoretical research on natural minerals in lithium-ion battery separators, electrodes and electrolyte materials is relatively mature. In the future, we should focus on industrialization issues: it is necessary to combine the structural characteristics of natural minerals, simplify material synthesis methods, reduce material costs, and realize natural mineral-based lithium. Industrial application of ion battery materials.

5 PHOTO/ELECTROCATALYTIC MATERIALS

Catalytic reaction technology is considered to be one of the most promising and effective technologies, and its core is highly active catalytic materials[65]. The in-depth development of highly active catalytic materials is of great significance for the research of efficient catalytic reaction technology [66]. Some minerals with shelf-like, layered, and chain-layered structures are widely used as catalyst carriers and composite catalyst materials due to their complex pore structure and high specific surface area. They can not only reduce the cost of catalyst preparation, but also improve the dispersion and dispersion of the catalyst. Recyclability [67].

5.1 Photocatalytic Materials

In recent years, domestic and foreign scholars have used porous minerals as carriers and raw materials to prepare green and efficient porous mineral composite photocatalytic materials and have been used in fields such as photocatalytic hydrogen production and photocatalytic degradation of organic matter [67-68].

Zhang Li et al[69] Using hydrotalcite as precursor, grinding hydrothermal The $ZnCr_2O_4$-ZnO composite photocatalytic material was synthesized by this method. After roasting at 500 °C, the spherical nanoparticles formed had a particle size of 34. 2 nm. Evenly dispersed, the specific surface area is 53. 3 m^3/g, and the hydrogen production efficiency is 0. 956mmol/(h·gcat). In addition, kaolinite has strong adsorption The adhesion ability and good settling ability can make up for the pure semiconductor photocatalytic The chemical agent has its own defects and is an ideal catalyst material. Zhao Yunpu [70] used graphite phase carbon nitride (g-C_3N_4) and kaolinite as raw materials, A one-pot method was used to synthesize g-C_3N_4/kaolinite composite photocatalytic material. material, the hydrogen evolution rate of this composite photocatalytic material is that of pure g-C_3N_4 1. 5 times, g-C_3N_4 Closely combined with negatively charged kaolinite, Promoted g-C_3N_4 The separation of photogenerated electron-hole pairs improves Its photocatalytic hydrogen production performance. To solve the problem of nano TiO_2 exist in water The problems in the medium that are difficult to recycle, easy to lose, and difficult to disperse, Liao Sensitive etc.[71] Using sepiolite (SEP) as carrier and powder sintering Nano-TiO_2/SEP composite photocatalytic materials were prepared by this method; The addition of SEP significantly inhibited the nano-TiO_2 the phenomenon of reunion, Enhanced light absorption in the ultraviolet to visible light wavelength range degree, thereby improving the photocatalytic activity of the composite material.

Natural minerals are not only excellent photocatalyst carriers, but also It is also an excellent photocatalyst[72]. Shen Jianfei et al[73] used Tian However, the semiconductor mineral wolframite is used as a photocatalyst to degrade wastewater Oxytetracycline, at an initial concentration of 5.0 mg/L, a pH of 4.5, and a solid Under the conditions of a liquid ratio of 1.0g/L, a light intensity of 60 W, and a time of 120 minutes, the removal rate of oxytetracycline reached 94.3%.

5.2 Electrocatalytic Materials

Electrocatalysis is the transfer of charge at the interface between electrodes and electrolytes A catalytic effect that accelerates reactions and has been widely used in electrocatalysis Hydrogen evolution, oxygen evolution, denitrification and other fields [74]. Today's precious metal-based materials It is still the most widely used electrocatalytic material, but it has problems such as small reserves, high cost and toxicity. Currently, researchers have been working on developing efficient and cheap electrocatalysts as alternatives to precious metal electrocatalysts[75]. Some natural minerals themselves have certain electrocatalytic activity, and the prepared electrocatalytic materials have excellent catalytic properties [76].

Zhang Haiqin et al[77] Using electrochemical deposition method on natural graphite Transition metal phosphorus nickel molybdenum compounds were grown directly on the chip to prepare Mo-Ni-P/C composite electrocatalytic material; the current density at the cathode is 10mA/cm2 When, the overpotential is 67 mV, and the Tafel slope is 66. 7mV/dec. Prepared by low-cost and simple synthesis method electrocatalytic material with high electrocatalytic hydrogen evolution activity and stable Qualitative. DEDZO et al.[78] studied 1: 1 clay mineral loading Hydrogen evolution reaction on palladium nanoparticle-modified carbon paste electrode, discovered Its hydrogen evolution efficiency is five times higher than that of p-nitrophenol direct reduction method. Zhao Ran et al[79] Using monazite as carrier, Fe2 O3 as raw materials, using Composite electrocatalyst prepared by impregnation in ferric nitrate solution and muffle furnace roasting Material; when the ferric nitrate concentration is 0. 5 mol/L and the reaction temperature is Monazite loading Fe2 O3 at 300 °C The active powder removes The best nitrate efficiency is 80. 52%, which is much higher than pure monazite 50. 2% denitrification efficiency. Zhang Sheng et al[80] Based on attapulgite (ATP) body, graphite-like phase carbon nitride (g-C3N4) through in-situ deposition and drying ATP/g-C3N4 was prepared by drying, freezing and roasting processes Composite electrocatalyst chemical material; when the ATP mass fraction is At 50%, ATP/g-C3N4 Composite electrocatalytic materials have optimal catalytic oxygen evolution performance, at 10mA/cm2 The oxygen evolution overpotential at the current density is 410 mV, and the Tafel slope is 118mV/dec. Will g-C3N4 load on the surface of attapulgite, increasing its specific surface area and surface activity position, its oxygen evolution capacity is greatly improved.

Photo/electrocatalysis technology is favored by many scholars because of its low price and simple process. However, there are still problems such as large dosage of catalyst, difficulty in recycling, and easy agglomeration. Natural minerals as catalyst carriers and catalytic materials are of great significance for improving catalytic performance and practical application value. In the future, in-depth exploration of the composite methods of carrier materials and the development of efficient and economical natural mineral-based composite materials will contribute to the development and application of photo/electrocatalytic materials.

6 PHASE CHANGE ENERGY STORAGE MATERIALS

Phase change energy storage material (PCM) is a new type of functional material that uses materials to absorb or release heat during phase change to store or release heat [81]. Natural minerals play an important role in the field of phase change energy storage. On the one hand, natural minerals themselves are good inorganic phase change materials. After adding appropriate nucleating agents and thickeners, they can be processed into phase change storage materials with excellent performance. Energy materials; on the other hand, the pore structure inside minerals can serve as an excellent carrier for phase change energy storage materials [82]. YI et al.[83] peeled natural montmorillonite into two-dimensional montmorillonite nanoparticles Rice flakes are then self-assembled into a three-dimensional mesh-like montmorillonite skeleton for packaging. Stearic acid is used to prepare composite PCM, and the three-dimensional skeleton of montmorillonite provides High porosity and specific surface area, can encapsulate 95% of stearic acid and No leakage occurs, making compounding PCM The latent heat of phase change reaches 198.78J/g. Composite PCM has low cost, simple preparation and conversion With high efficiency and excellent energy storage performance, it has great potential in the field of renewable energy. great application potential. Zhang Yonghui[84] In sodium thiosulfate pentahydrate Add nucleating agent and thickening agent, and then mix it with TiO2-sepiolite porous matrix Sodium thiosulfate pentahydrate/TiO2-sepiolite composite phase change energy storage material was successfully prepared by combining bulk materials; after 205 heating-cooling cycles, the latent heat of phase change of the composite phase change energy storage material was 176.85 J/ g, the decrease is only 7. 79%, the weight loss rate is 7. 53%, TiO2-sea Foam stone is beneficial to the preservation of moisture in phase change energy storage materials. material service life. Based on the good adsorption of organic matter by attapulgite Performance, Shi Tao et al[85] Using attapulgite (ATP) as the adsorption medium and paraffin (PW) as the adsorption object, an ATP/PW composite phase was prepared. Variable energy storage material; heat storage/release performance of the composite phase change energy storage material Excellent, able to store heat as the ambient temperature changes and release, not only greatly improves the inertness of the ambient temperature, but also Realizes the migration of heat in space and time, and achieves good results energy saving effect. FU et al. [86] used direct dipping method to prepare Citric acid/diatomite composite phase change energy storage material, the composite PCM The melting temperature is 40. 9°C, the crystallization temperature is 38. 7°C, and the melting potential The heat reaches 57. 2J/g; in addition, the phase between the composite PCM and concrete is Good capacitance, can be used as passive solar space heating or cooling room Energy storage materials with internal temperature fluctuations have huge potential in the construction field application potential.

The combination of natural minerals and inorganic/organic phase change materials integrates the advantages of various materials and is a key direction for future research and application of phase change energy storage materials. The diversity of natural mineral types and the particularity of their structures should be utilized to enrich phase changes. Energy storage material systems to expand their application scope.

7 OTHER ENERGY MINERAL MATERIALS

In recent years, with the in-depth research on mineral materials, natural minerals The application range of materials has been further expanded, and achievements have also been made in new energy fields such as solar photovoltaics, insulated fireproof cables and dielectric capacitors. achieved fruitful results. Liu Lei et al. [87] prepared a mineral insulated copper tape interlocking armored flexible fireproof cable with a rated voltage of 0. 6/1kV by combining mica and ceramic composite tapes. The cable has excellent insulation performance, fire resistance and Flame retardant properties. FU et al. [88] successfully exfoliated layered mica nanosheets in DMF through mechanical stirring. Adding exfoliated mica nanosheets to the PVDF matrix, when mica When the addition amount is 5% and the scanning speed is 450mV/s, the The maximum discharge energy density of composite dielectric materials is 7. 93 J/cm3, about 3 times that of pure PVDF polymer matrix, improved The breakdown strength of PVDF/mica composite dielectric materials was determined to prepare Flexible, high-energy-density polymer dielectric materials provide This provides a cost-effective way to expand the application fields of mica. Lu An Huai et al. [89] found birnessite, goethite, hematite, etc. Natural semiconductor minerals can produce mineral light under sunlight radiation Electrons have obvious visible light photoelectric effect and thus have stable Stable and sensitive photoelectric conversion performance.

8 CONCLUSION

Natural minerals, with their unique structural morphology and excellent physical and chemical properties, have shown a booming trend in the field of new energy materials and are expected to become one of the important forces in promoting the transformation and upgrading of the energy industry and responding to challenges such as climate change and environmental protection. However, the research on new energy mineral materials still has the following limitations: First, the basic theoretical research on new energy mineral materials is relatively lagging behind and has not yet formed a mature theoretical system; second, the preparation processes of new energy mineral materials are mostly in the laboratory preparation stage, and there are There are difficulties in large-scale application; third, the research and development of new energy mineral materials lacks market orientation, and there is still a large gap between research results and actual demand.

Under the "double carbon" goal vision, the development of new energy technologies in the next 10 to 15 years will become a key part of my country's participation in international industrial competition. How to give full play to the advantages of new energy mineral materials and help my country's new energy technology continue to improve requires reasonable guidance and encouragement from the government, and the deployment of industrial technology routes for new energy mineral materials from a low-carbon economic thinking and perspective. At the same time, universities and research institutes We should strengthen basic research, continuously improve the economy and practicality of new energy mineral materials, and lay the foundation for better development and utilization of new energy and mineral resources.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] MAY J, MAY, WANG QS. High-entropy energy materials: challenges and new opportunities. Energy& EnvironmentalScience, 2021, 14(5): 2883-2905.

[2] Cui Boxiang, Liu Yanhong, Niu Pengbin. New energy materials and their applications in batteries. Information Recording Materials, 2021, 22(10): 234-236.

[3] Yan Liyun. Analysis of the application of new energy materials in new energy vehicles. New Industrialization, 2021, 11(12): 131-132+135.

[4] Deng Yanjie. A brief discussion on new energy materials. Shandong Chemical Industry, 2020, 49(9): 95.

[5] Chen Tianxing, Kong Jing. Research progress on natural mineral modified lithium-ion battery separators[J/OL]. Chemical Minerals and Processing: 1-9[2023-03-10]. http: //kns. cnki. net/kcms/detail/32. 1492. TQ. 20220928. 1548. 002. html.

[6] Liu Hao, Wang Xiaofei, Zhou Bin. Research progress on the application of minerals in the field of electrochemical energy storage. Journal of Ceramics, 2021, 49(10): 2130-2143.

[7] GAO DC, SUN YJ, FONG AM. Mineral-basedform-stable phase change materials for thermal energy storage: a review on encapsulation techniques, performance enhancements and practical applications. Energy Storage Materials, 2022, 46: 100-128.

[8] Lu Guocheng, Liao Libing, Li Yuxin. Rapidly developing mineral materials research in my country—ten years of progress (2011~2020). Bulletin of Minerals, Petrology and Geochemistry, 2020, 39(4): 714-725.
[9] POONAM, SHARMA K, ARORAA. Review of super-capacitors: materials and devices. Journal of Energy Storage, 2019, 21: 801-825.
[10] ZHANG D, TAN C, ZHANG W Z. Expanded graph-ite-based materials for supercapacitors: a review. Molecules, 2022, 27(3): 716.
[11] Shi Wenming, Liu Yihua, Lu Xianglian. Research progress on supercapacitor materials and applications. Micro-Nano Electronics Technology, 2022, 59(11): 1105-1118.
[12] Yang Fang, Wu Qiqi, Li Hongyu. Research progress on the application of mineral materials in supercapacitor electrodes. Chinese Chemical Bulletin, 2022, 85(10): 1161-1169.
[13] ZHANG L, ZHANG W B, CHAIS S. Clay mineral materials for electrochemical capacitance application. Journal of The Electrochemical Society, 2021, 168 (7): 70558.
[14] LIM Y G, PARK J W, PARK M S. Hard carbon-coated natural graphite electrodes for high-energy and power lithium-ion capacitors. Bulletin of the Korean ChemicalSociety, 2015, 36(1): 150-155.
[15] GAOXY, ZHAN CZ, YU XL. A high performance lithium-ion capacitor with both electrodes prepared from Srilanka graphite ore. Materials, 2017, 10(4): 414.
[16] RAJCIC-VUJASINOVIC M, STEVICZ, BUGARINOVIC S. Electrochemical characteristics of natural mineral covellite. Open Journal of Metal, 2012, 2(3): 60-67.
[17] PHOOHINKONG W, PAVASUPREE S, WANNAGON A, etal. Electrochemicalpropertiesofnanopowdersderived from ilmenite andleucoxene naturalminerals. Ceramics International, 2017, 43: 717-722.
[18] Li Aijun, Chuan Xiuyun, Cao Xi. Research progress in preparing porous carbon materials by mineral template method. Functional Materials, 2017, 48(2): 2063-2070.
[19] LUO HM, CHEN YZ, MU B. Preparation and elec-trochemicalperformance of attapulgite/citric acid template carbon electrode materials. Journal ofApplied Electro-chemistry, 2016, 46(3): 299-307.
[20] Cao Xi, Chuan Xiuyun, Li Aijun. Synthesis of porous carbon using nanofiber mineral fiber serpentine as template and its application in supercapacitors. New Carbon Materials, 2018, 33(3): 229-236.
[21] YUYA O, KOSUKE S. Nanoarchitectonics for conductive polymers using solid and vapor phases.. Nanoscale Advances, 2022, 4(13): 2773-2781.
[22] XIE AJ, TAOF, SUN W L. Design and synthesis of graphene/porous polyaniline nanocomposite using attapul-giteastemplateforhigh. JournalofTheElectrochemical Society, 2016, 164(2): 70-77.
[23] FAN P, WANG S N, LIU H. Polyaniline nanotube synthesized from natural tubular halloysite template as high performance pseudocapacitive electrode. Electro-chimica Acta, 2020, 331: 135259.
[24] YANG CH, GAOR J, YANG H M. Application oflayered nanoclay in electrochemical energy: current status and future. EnergyChem, 2021, 3(5): 100062.
[25] CHANG Y, LIU Z H, FU Z B. Preparation and cha-racterization of one-dimensional core-shell sepiolite/poly-pyrrole nanocomposites and effect of organic modification on the electrochemical properties. Industrial & Engi-neering Chemistry Research, 2014, 53(1): 38-47.
[26] REN ZB, YING ZR, LIU XD. Synthesisand electro-chemical capacitive performace of montmorillonite-based nitrogen-doped porous carbon @ MnO2 @ PANI ternary composite. New Chemical Materials, 2017, 45(3): 49-51.
[27] CHAI H, DONG H, WANG Y C. Porous NiCo2S4-halloysite hybrid self-assembled from nanosheets for high-performance asymmetric supercapacitor applications. AppliedSurface Science, 2017, 401: 399-407.
[28] ARANEE T, MAKOTO O. Interactions of layered clay minerals with water-soluble polymers; structural design andfunctions. AppliedClay Science, 2022, 222: 106487.
[29] PEYMAN G B, AHMAD P M, FATEMEH Z. Clay mineral/polymer composite: characteristics, synthesis, and application in Li-ion batteries: a review. Applied Clay Science, 2022, 228: 106632.
[30] WANG Y, LIXY, QIN YY. Localelectricfield effect ofmontmorillonite in solid polymer electrolytes for lithium metalbatteries. Nano Energy, 2021, 90: 106490.
[31] LIN Y, WANG X M, LIU J. Naturalhalloysite nano-clay electrolyte for advanced all-solid-state lithium-sulfur batteries. Nano Energy, 2017, 31: 478-485.
[32] ANASTASIA M, INDERJEET T, RAO K R. Porous carbon-based material as a sustainable alternative for the storage of naturalgas(methane) andbiogas(biomethane): a review. Chemical Engineering Journal, 2022, 446: 137373.
[33] LIU H, DING W, ZHOU FB. An overview and out-look on gasadsorption: fortheenrichmentoflow concentration coalbed methane. Separation Science and Technology, 2020, 55(6): 1102-1114.
[34] Ma Tongxiang, Gao Leizhang, Hu Mengjun. Research progress of solid hydrogen storage materials. Functional Materials, 2018, 49(4): 4001-4006.
[35] Liu Yun, Jing Chaojun, Ma Zequn. Research progress on new solid hydrogen storage materials. New Chemical Materials, 2021, 49(9): 11-14+19.
[36] Wang Lu, Jin Zhijun, Su Yutong. Research progress on new solid hydrogen storage materials. Acta Petroleum Sinica (Petroleum Processing), 2023, 39(1): 229-239.
[37] Zhang Lizhi, Liu Cong, Yu Guojun. Research progress on microporous hydrogen storage materials based on physical adsorption. Applied Chemical Engineering, 2021, 50(12): 3407-3410.

[38] Cheng Jipeng, Zhang Xiaobin, Liu Fuye. Natural nano-mineral in-situ composite carbon nanotubes and their hydrogen absorption properties. Journal of Solar Energy, 2002(6): 743-747.

[39] JIN J, ZHANG Y, OUYANG J. Halloysite nanotubes as hydrogen storage materials. PhysicsandChemistry of Minerals, 2014, 41(5): 323-331.

[40] Jiang Cuihong. Preparation and hydrogen storage properties of palladium-modified palygorskite ore. Electromechanical Technology, 2009, 32(4): 101-103.

[41] Tong Wen. Design, synthesis and application of functionalized nanoporous materials in methane storage. Beijing: Beijing University of Chemical Technology, 2017.

[42] Xie Huifang, Liu Yanchun, Feng Baomin. Research progress on methane storage materials. Journal of Dalian University, 2014, 35(3): 43-50.

[43] JIAO BC, DING WL, GU Y. The reservoir charac-teristics ofmarine shale and its effect on the adsorption of methane in Northern Guizhou. Petroleum Science and Technology, 2019, 37(21): 2199-2206.

[44] LIU D, YUAN P, LIU HM. High-pressureadsorption of methane on montmorillonite, kaolinite and illite. AppliedClay Science, 2013, 85: 25-30.

[45] Li Quanzhong, Cai Yongle, Hu Haiyang. Structural characteristics of clay mineral nanopores in mud shale and their impact on methane adsorption. Journal of Coal Science, 2017, 42(9): 2414-2419.

[46] KULOVATL. A briefreview of post-lithium-ion batteries. InternationalJournalofElectrochemicalScience, 2020, 15(8): 7242-7259.

[47] Huan, Yuan Ge, Zhang Ning. Research progress on the application of clay minerals in the battery field. New Energy Progress, 2020, 8(1): 56-61.

[48] ALVAREZ ED, LAFFITA YM, MONTORO LA. Electrical, thermal and electrochemical properties of disor-dered carbon prepared from palygorskite and cane molasses. Journal of Solid State Chemistry, 2017, 246: 404-411.

[49] Sheng Dongdong, Wang Qianqian, Shi Yingjie. Patent analysis of high-power electrode materials for lithium batteries. New Chemical Materials, 2022, 50(5): 16-20+31.

[50] Pan Junan. Research on sepiolite-based cathode materials for lithium-sulfur batteries. Xiangtan: Xiangtan University, 2017.

[51] PANJ N, WU C, CHENG JJ. Sepiolite-sulfur as a high-capacity, high-rateperformance, and low-costcathode material for lithium-sulfur batteries. Journal of Power Sources, 2015, 293: 527-532.

[52] XIE QX, ZHENG AR, XIE C. Graphene functionalized attapulgite/sulfur composite as cathode of lithium-sulfur batteries for energy storage. Microporous & Mesoporous Materials, 2016, 224: 239-244.

[53] Zhao Mingyuan, Yang Shaobin, Dong Wei. Preparation and lithium storage performance of silicon nanotubes based on halloysite. Journal of Ceramics, 2021, 49(7): 1457-1465.

[54] YU HB, SHIYK, YUAN B. Recent developments of polyimide materials for lithium-ion battery separators. Ionics, 2021, 27(3): 907-923.

[55] Kang Le, Li Donghong, Zhang Yanyan. Research progress on ceramic separator materials for lithium-ion batteries. Light Metals, 2022(9): 53-58.

[56] Zhang Hongtao, Shang Hua, Gu Bo. Preparation and properties of zeolite-based lithium-ion battery separators. Materials Engineering, 2017, 45(12): 83-87.

[57] YANG S, QIN HY, LIX. Enhancement of thermal stability and cycling performance of lithium-ion battery at high temperature by nano-ppy/OMMT-coated separator. Journal of Nanomaterials, 2017, 2017: 1-10.

[58] SONG QQ, LIA J, SHIL. Thermally stable, nano-porous and eco-friendly sodium alginate/attapulgiteseparatorforlithium-ion batteries. Energy Storage Materials, 2019, 22: 48-56.

[59] Li Zikun, Li Junhuan. Research progress on polymer solid electrolytes and their applications in lithium batteries. Electronic Components and Information Technology, 2022, 6(11): 34-38.

[60] Fan Xiaohong, Deng Dingrong, Wu Qihui. Research progress on solid-state lithium battery polymer electrolytes. Journal of Jimei University (Natural Science Edition), 2022, 27(5): 447-455.

[61] ESER N, ÖNAL M, ÇELIK M. Preparation and characterization of polymethacrylamide/halloysite composites. PolymerComposites, 2020, 41(3): 893-899.

[62] Meng Guilin, Yang Yanfei, Wang Wankai. Research progress on the application of clay mineral nanomaterials in lithium battery separators and solid electrolytes. Bulletin of Silicates, 2022, 41(6): 2167-2180.

[63] LUN P Q, CHEN ZL, ZHANG ZB. Enhanced ionic conductivity in halloysite nanotube-poly(vinylidene fluoride) electrolytes for solid-state lithium-ion batteries. RSC Advances, 2018, 8(60): 34232-34240.

[64] YAO PC, ZHU B, ZHAIH W. PVDF/palygorskite nanowire composite electrolyte for4V rechargeable lithium batteries with high energy density. Nano Letters, 2018, 18(10): 6113-6120.

[65] SAKAR M, NGUYEN C, VU M. Materialsand mech-anisms ofphoto-assisted chemicalreactions under light and dark conditions: can day-night photocatalysis be achieved? . ChemSusChem, 2018, 11(5): 809-820.

[66] Shang Xi, Zhao Qixing, Yang Huaming. Research progress on clay mineral-based catalytic materials. Materials Herald, 2023, 37(17): 54-62.

[67] Sun Zhiming, Zhang Xinchao, Di Yonghao. Research progress and development trends of porous mineral composite catalytic materials. Chemical Minerals and Processing, 2021, 50(12): 42-48.

[68] WANG K, XU JM , WANG XT. The effects of ZnO morphology on photo catalytic efficiency of ZnO/RGO nanocomposites. Applied Surface Science. 2016, 360: 270-275.

[69] Zhang Li, Dai Chaohua, Liang Qingman. Preparation and hydrogen production performance of Zn-Cr2O4-ZnO composite photocatalyst based on hydrotalcite precursor. Journal of Fuel Chemistry, 2017, 45(10): 1266-1274.
[70] Zhao Yunpu, Cheng Hongfei, Cao Zhou. Research progress on the application of kaolinite-based composite materials in the field of photocatalysis. Journal of Artificial Crystallography, 2022, 51(1): 170-184.
[71] Liao Lingmin, Liang Hui, Wang Zaiqin. Research on the properties of nano-TiO2/sepiolite composite photocatalytic materials. People's Yangtze River, 2012, 43(24): 55-59.
[72] TANG XW, TANG RD, XIONG S. Application of natural minerals in photocatalytic degradation of organic pollutants: a review. Science ofThe TotalEnvironment, 2021, 812: 152434.
[73] Shen Jianfei, Chen Dong, Chen Tianhu. Application of natural wolframite ore in photocatalytic degradation of oxytetracycline. Journal of Process Engineering, 2023, 23(4): 580-589.
[74] ZHAO GQ, RUIK, DOUS X. Heterostructures for electrochemicalhydrogen evolution reaction: a review. AdvancedFunctionalMaterials, 2018, 28(43): 324-332.
[75] LINS R, XU HX, WANG Y K. Directly predicting limiting potentials from easily obtainable physical properties of graphene-supported single-atom electrocatalysts by machine learning. Journal of Materials Chemistry A, 2020, 332: 5663-5670.
[76] Bai Liqi, Zhang Yihe, Tong Wangshu. Mineral composite materials and their energy storage and energy catalysis applications. Science Bulletin, 2022, 67(8): 742-757.
[77] Zhang Haiqin, Meng Alan. Preparation of phosphorus nickel molybdenum/graphite sheet electrode material and its electrocatalytic hydrogen evolution and glucose detection properties. Journal of Qingdao University of Science and Technology (Natural Science Edition), 2021, 42(2): 22-29.
[78] DEDZO GK, YAMBOU EP, SAHEU M R T. Hydrogen evolution reaction atPdNPs decorated1: 1clay minerals and application to the electrocatalytic determina-tion of p-nitrophenol. Journal of Electroanalytical Chemistry, 2017, 801: 49-56.
[79] Zhao Ran, Wang Ying, Zhao Zengwu. Study on the denitration performance of NH3-SCR using monazite-supported Fe2O3 mineral catalytic materials. Rare Metals, 2022, 46(7): 913-925.
[80] Zhang Sheng, Jiang Yi, Ji Yuanyuan. Attapulgite/g-C3N4 Preparation of composite materials and study on electrocatalytic oxygen evolution performance. Journal of Inorganic Materials, 2019, 34(8): 803-810.
[81] LU DY, XU XF, ZHANG XL. Study on influencing factors of phase transition hysteresis in the phase change energy storage. Materials, 2022, 15(8): 2775.
[82] Gu Xiaobin, Qin Shan, Niu Jingjing. Research status and prospects of phase change energy storage mineral materials. Bulletin of Minerals, Rocks and Geochemistry, 2014, 33(6): 932-940.
[83] YIH, AIZ, ZHAO YL. Design of 3D-network mont-morillonite nanosheet/stearic acid shape-stabilized phase change materials for solar energy storage. Solar Energy Materials and SolarCells, 2020, 204: 110233.
[84] Zhang Yonghui. Preparation and performance testing of sodium thiosulfate pentahydrate/sepiolite composite phase change thermal storage material. Xi'an: Northwest University, 2017.
[85] Shi Tao, Sun Wei, Wang Qiannan. Preparation of attapulgite adsorption phase change energy storage composite materials and characterization of their thermophysical properties. Journal of Composite Materials, 2009, 26(5): 143 -147.
[86] FU XW, LIU ZM, XIAO Y. Preparation and proper-ties of lauricacid/diatomitecompositesasnovelform-stable phase change materials for thermal energy storage. Energy& Buildings, 2015, 104: 244-249.
[87] Liu Lei, Li Jianrong, Lai Quanbin. Research on the structure and application of mineral insulated cables. Anhui Science and Technology, 2022(3): 50-53.
[88] FU YJ, WANG YX, WANG S. Enhanced breakdown strength and energy storage ofPVDF based dielectric composites by incorporating exfoliated mica nanosheets. PolymerComposites, 2019, 40(5): 2088-2094.
[89] Lu Anhuai, Li Yan, Ding Hongrui. Photoelectric effect of natural minerals: non-classical photosynthesis of minerals. Frontiers of Earth Science, 2020, 27(5): 179-194.