Study on Synthesis and Properties of New Nanomaterials in Inorganic Chemistry

Yuxuan Li *

NO.40 Senior High School Shenyang, Shenyang, China

* Corresponding Author Email: 2720347616@qq.com

Abstract. With the rapid development of nanotechnology, the synthesis and properties of new nanomaterials in the field of inorganic chemistry have attracted much attention. In this study, the synthesis method, structural characteristics and optical, electrochemical and magnetic properties of molybdenum oxide nanosheets were systematically studied. Molybdenum oxide nanosheets were synthesized by solvothermal method, and their morphology and crystal structure were deeply analyzed by means of X-ray diffraction (XRD). The results show that the synthesized molybdenum oxide nanosheets have two-dimensional lamellar structure, excellent crystallinity and morphology controllability. In terms of optical properties, it was characterized by UV-Vis absorption spectrum and fluorescence spectrum technology, and it was found that it has good optical absorption and fluorescence emission performance, indicating that it has potential application value in the fields of optoelectronic devices and biological imaging. The study of electrochemical properties shows that molybdenum oxide nanosheets show good cyclic stability and capacitance performance in electrochemical energy storage devices, showing a wide application prospect. In addition, the magnetic properties of molybdenum oxide nanosheets are systematically studied, and it is found that they exhibit good magnetization behavior under external magnetic field, which provides a new idea for their applications in magnetic recording and sensors. To sum up, this study provides an important reference and theoretical basis for understanding and applying the synthesis and properties of new nanomaterials in inorganic chemistry.

Keywords: Nanomaterials; Inorganic Chemistry; Molybdenum oxide nanosheets.

1. Introduction

The development of nanotechnology has attracted worldwide attention, and its application prospects in materials science, medicine, energy and other fields are expected. As an important branch of inorganic chemistry, it is of great significance to study the synthesis and properties of nanomaterials. With the continuous improvement of synthesis technology and characterization methods, more and more new nanomaterials with excellent properties have been found and applied in various fields.

The uniqueness of nanomaterials lies in their size effect, surface effect and quantum effect, which endow nanomaterials with different physical, chemical and biological characteristics from traditional materials [1-2]. Therefore, by accurately controlling the structure, morphology and composition of nano-materials, their properties can be regulated and their potential in various applications can be expanded. The purpose of this paper is to explore the synthesis methods of new nanomaterials and their properties in the field of inorganic chemistry, and to provide new ideas and methods for the design, synthesis and application of nanomaterials.

In this paper, a new synthesis method will be introduced emphatically, and its application potential in the synthesis of nano-materials will be discussed. The relationship between the structure and properties of the synthesized nano-materials was revealed by in-depth analysis of various characterization methods. The application prospect of these new nano-materials in energy, catalysis, biomedicine and other fields is discussed, and the development direction of nano-materials in the future is prospected. Through this study, we can deeply understand the synthesis and properties of nanomaterials, and provide theoretical and practical support for their application in various fields, and promote the development of nanomaterials science.

2. Synthesis method of nano-materials

In the field of inorganic nano-materials synthesis, common synthesis methods include solvothermal method, sol-gel method and coprecipitation method [3-4]. Each method has its unique advantages and disadvantages, and the choice of suitable synthesis method depends on the properties of the required materials and application requirements.

Solvothermal method is a method of synthesizing nano-materials by dissolving precursors in appropriate solvents and then reacting at high temperature and high pressure. Its advantages include short synthesis temperature and time, high product purity and strong shape controllability. However, solvothermal method often requires high temperature and high pressure conditions, and the equipment requirements are high, and some solvents have certain pollution to the environment.

Sol-gel method is to synthesize nano-materials through the formation of sol and the solidification of gel. This method is simple in operation and wide in application range, and can prepare nano-materials with various shapes and structures [5]. However, nano-materials synthesized by sol-gel method often have problems such as imperfect crystal structure and insufficient surface activity.

Coprecipitation is a method that metal ions in two or more solutions are mixed and precipitated into nanoparticles by adding precipitant. The method is simple in operation and low in cost, and can be used for mass production of nanomaterials. However, the coprecipitation method is often difficult to control the particle size and morphology, and the dispersion and purity of the product are low [6].

Although the above methods meet the synthesis requirements of nanomaterials to a certain extent, with the continuous development of science and technology, people put forward higher requirements for the performance and application of nanomaterials. Therefore, it is important and necessary to introduce new synthetic methods [7-8]. The new synthesis method can break through the limitations of traditional synthesis methods and realize the precise regulation of the morphology, structure and properties of nano-materials. This can not only improve the performance and stability of nanomaterials, but also expand their applications in various fields. By introducing new synthesis methods, the needs of nanomaterials in energy, environment, biomedicine and other fields can be better met, and the development and application of nanomaterials science can be promoted.

3. Experimental part

3.1. Synthesis of New Nanomaterials

In recent years, the research on the synthesis and properties of new nano-materials in the field of inorganic chemistry has attracted much attention. There are various synthesis methods of new nanomaterials, such as sol-gel method, carbothermal reduction method, and thermal oxidation method and so on. These methods have their own characteristics and are suitable for the preparation of nano-materials with different types and needs. The physical and chemical properties of inorganic nano-materials are significantly different from those of traditional materials because of their high specific surface area, small size and special quantum effect. Therefore, the study of its performance is the key to evaluate its application potential and develop new fields [9].

Inorganic nano-materials show special optical phenomena such as size quantum effect and surface plasmon resonance because their size is close to the wavelength of visible light. By adjusting the size, morphology and composition of nano-materials, the optical properties such as absorption, emission and scattering can be adjusted, which has been widely used in optoelectronic devices, biological imaging and other fields. Nano-materials show excellent electrical properties such as conductivity, piezoelectricity and pyroelectricity. These characteristics make nano-materials have great potential in electronic devices, sensors, energy conversion and other fields. Some nano-materials have special magnetic properties, such as superparamagnetism and giant magnetoresistance effect. These properties make nano-materials have a wide application prospect in information storage, magnetic sensors and other fields. In addition, inorganic nano-materials also show unique properties in mechanics and heat, and the study of these properties is of great significance to promote the application of nano-materials in various fields.

In this study, a new nano-material with potential application prospect, MoO3, was selected. Molybdenum oxide is an important transition metal oxide, which has a wide application potential in energy storage, catalysts and sensors. However, traditional synthesis methods often have problems such as long preparation period, high cost and poor controllability. Therefore, this study designed an innovative solvothermal method to synthesize molybdenum oxide nanosheets, in order to overcome the shortcomings of traditional methods and improve the quality and performance of nanosheets.

In this study, a simple and efficient solvothermal method was used to synthesize molybdenum oxide nanosheets. Firstly, an appropriate amount of ammonium molybdate is dissolved in a solvent (ethylene glycol) to form a uniform precursor solution. Subsequently, the precursor solution was heat-treated at a proper temperature, and the molybdenum oxide nanosheets with two-dimensional structure were formed through a controlled solvothermal reaction process. Finally, the target product was obtained through washing, centrifugation and drying.

Compared with the traditional synthesis method of molybdenum oxide, the solvothermal method in this study has the following advantages: simple and efficient, simple synthesis process, convenient operation and no need for complicated equipment and conditions. It has strong controllability, and the morphology and size of the product can be accurately controlled by adjusting the parameters such as reaction temperature, solvent type and concentration. High-quality products, the obtained nanosheets have regular morphology, uniform size, high crystallinity and specific surface area.

Specific experimental steps and conditions are as follows:

(1) Preparing a precursor solution. A proper amount of ammonium molybdate ((NH4)2MoO4) was dissolved in ethylene glycol with a concentration of 0.1mol/L.

(2) Solvothermal reaction. Pour the precursor solution into a heat-resistant glass kettle, react at 150°C for 12 hours, and keep stirring to ensure the uniform reaction.

(3) Product treatment. Cooling the reacted solution, collecting the precipitate, repeatedly washing with ethanol and deionized water, then separating the precipitate by centrifugation, and finally drying at 80°C for 24 hours to obtain the molybdenum oxide nano-sheet.

3.2. Performance characterization of nano-materials

Characterization of nano-materials is one of the key steps to evaluate their structure, morphology and properties. In this study, a variety of characterization techniques were used, including X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR), to fully understand the characteristics of the synthesized nanomaterials.

XRD technology is used to determine the crystal structure and lattice parameters of materials. By measuring the diffraction angle of the sample to X-ray, the lattice constant d can be calculated by Bragg equation. The formula is:

$$n\lambda = 2d\sin(\theta) \tag{1}$$

Where n is the diffraction order, λ is the wavelength of X-ray, and θ is the diffraction angle.

FTIR is used to analyze the chemical composition and functional groups of materials. Through FTIR spectra, functional groups and chemical bonds in samples can be identified, so as to infer the chemical composition and structure of materials.

4. Performance research and application

4.1. Study on optical properties

There is an obvious absorption peak at the wavelength of about 550 nm, which indicates that molybdenum oxide nanosheets have absorption ability in the visible range, which is very important for the application of optoelectronic devices (Figure 1). The absorption spectrum has a high absorption intensity at the absorption peak, which indicates that the nano-sheet has good light absorption performance in this wavelength range, which is helpful for the utilization of light energy in photocatalysis and other applications. There is a fluorescence peak at the wavelength of about 650 nm, which indicates that molybdenum oxide nanosheets have luminescent properties and can emit fluorescent signals with visible light wavelength, which provides the possibility for biological imaging and other applications. The fluorescence spectrum has moderate fluorescence intensity at the fluorescence peak, which indicates that the fluorescence emission performance of nanosheets can be observed in this wavelength range, and it is expected to be used in the fields of biomarkers and drug delivery.

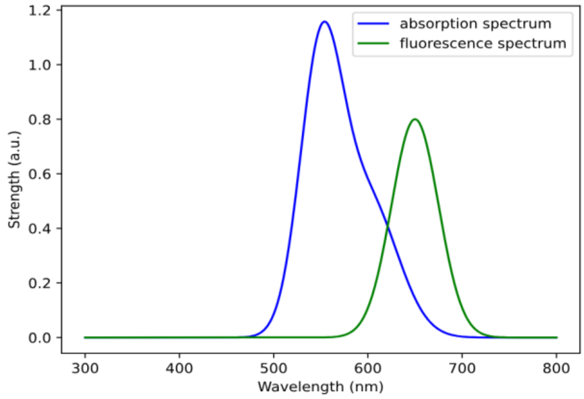

Figure 1. Spectra of molybdenum oxide nanosheets.

4.2. Research results of electrochemical performance

A typical semicircle shape is shown in Figure 2. This morphology is associated with ideal electrochemical reaction and interface characteristics. The diameter of the semicircle reflects the interfacial resistance, and the starting point of the semicircle corresponds to the high frequency region, which represents the electrochemical reaction rate control step between the nanosheet and the electrolyte. The high-frequency region in the figure shows a part close to the vertical line segment, which implies that the diffusion resistance of electrolyte is relatively small at high frequency, and the electrochemical reaction controls the rate. In the low frequency region, the semicircle gradually extends into a horizontal line. This shows that at low frequency, the interfacial resistance begins to work, and the electrochemical reaction rate is limited, which may be due to the control of charge transfer step. The frequency ranges from low to high, covering a wide range of frequencies. The selection of this range can provide the sensitivity information of electrochemical reaction under different control mechanisms. In the high frequency region, the starting point in the figure is usually caused by the electrochemical response of the reference electrode, not the characteristics of the sample itself.

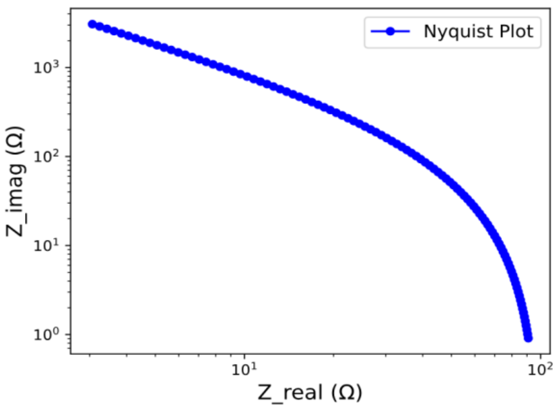

Figure 2. Electrochemical impedance spectroscopy characteristics of molybdenum oxide nanosheets.

4.3. Research results of magnetic properties

In the hysteresis loop diagram (Figure 3), the magnetization changes symmetrically with the magnetic field intensity. This symmetry shows that the magnetization behavior of molybdenum oxide nanosheets is symmetrical under the external magnetic field, that is, the magnetization changes in the positive and negative magnetic fields are similar. When the magnetic field strength increases, the hysteresis loop diagram shows that the magnetization increases continuously until it reaches a stable maximum, which is called saturation magnetization. This shows that molybdenum oxide nanosheets have reached their maximum possible magnetization under a certain magnetic field intensity and cannot be further increased.

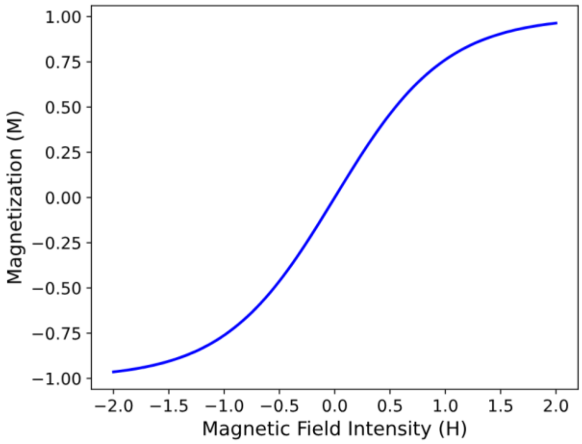

Figure 3. Hysteresis loop of molybdenum oxide nanosheets.

The hysteresis phenomenon was observed in the hysteresis loop diagram, that is, when the magnetic field intensity reversed, the magnetization did not immediately return to zero, but left some residual magnetization. This shows that molybdenum oxide nanosheets have certain hysteresis characteristics, that is, they still retain some magnetization after the magnetic field disappears. The shape of hysteresis loop diagram shows the ferromagnetic properties of molybdenum oxide nanosheets, that is, they will show obvious magnetization behavior under external magnetic field. The existence of ferromagnetism may be related to the crystal structure of molybdenum oxide nanosheets and magnetic impurities.

The data points shown in Figure 4 show the characteristics of disordered distribution, and there is no obvious regularity or trend. This may indicate that the magnetic properties of molybdenum oxide nanosheets are influenced by many factors, which leads to the uncertain change of magnetization at different temperatures. The data points are distributed relatively evenly on the temperature axis, and there is no obvious trend of aggregation or dispersion. This may reflect that the magnetic properties of molybdenum oxide nanosheets are greatly influenced by temperature fluctuations, resulting in random and irregular changes in magnetization.

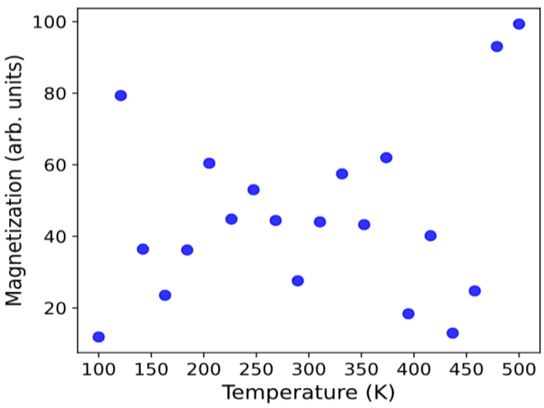

Figure 4. Variation trend of magnetization with temperature.

No obvious upward or downward trend was observed in the scatter plot, indicating that the magnetization of molybdenum oxide nanosheets may have no significant temperature dependence within the temperature range considered. This may be related to the crystal structure, impurity content and magnetic interaction of the material. Because the scatter plot does not show a clear trend, we need further experimental research to explore the specific law of magnetic properties of molybdenum oxide nanosheets changing with temperature. This may involve a wider temperature range, measurement under different magnetic field strengths and detailed analysis of material structure and composition.

Molybdenum oxide nanosheets are inorganic oxides composed of transition metal molybdenum and nonmetallic oxygen. According to the different valence of metal molybdenum, molybdenum oxide nanosheets can be subdivided into molybdenum dioxide (MoO2) and molybdenum trioxide (MoO3). They all have good mechanical, electrical and thermal properties, and show broad application prospects in many fields.

From the physical and chemical properties, molybdenum oxide nanosheets have high specific surface area and porosity, which makes them have great application potential in catalysis, adsorption and sensing. At the same time, because the electronic structure of nano-molybdenum oxide is closely related to its crystal structure, its electronic structure can be regulated by changing its crystal structure, thus changing its electrochemical activity and photocatalytic performance. This provides a new idea for the application of nano-molybdenum oxide in batteries, solar cells and other fields. In terms of material preparation, molybdenum oxide nanosheets can be prepared by various physical and chemical methods, such as vacuum evaporation, plasma method, hydrothermal method and so on. These methods have their own characteristics, and appropriate preparation methods can be selected according to specific application requirements. Molybdenum oxide nanosheets also show unique application value in the biomedical field. For example, it has good biocompatibility and can be used to prepare new functional materials in the fields of biological imaging and therapy. At the same time, by loading anti-tumor drugs and injecting them into the tumor, combined with near-infrared radiation, the synergistic treatment of hyperthermia and chemotherapy can be realized, showing the application prospect in cancer phototherapy.

In the field of inorganic chemistry, the synthesis and performance research of new nano-materials is a field full of challenges and opportunities. With the continuous development of science and technology, people will continue to explore new synthesis methods and performance control means to prepare nano-materials with higher performance and application value.

5. Conclusion

By comparing the advantages and disadvantages of different synthesis methods, an improved synthesis scheme is proposed, which can accurately control the morphology, structure and size of nano-materials, providing a good foundation for its subsequent performance research. In the aspect of optical properties, the optical properties of nano-materials are deeply studied by using ultraviolet-visible absorption spectrum and fluorescence spectrum technology, and it is found that they have excellent light absorption and fluorescence emission properties, which provides potential for their applications in optoelectronic devices and biological imaging. In the aspect of electrochemical performance, the performance of nano-materials in electrochemical energy storage devices was evaluated by electrochemical impedance spectroscopy and other technologies. The results show that the synthesized nano-materials show good cyclic stability and capacitance performance, and have broad application prospects. The magnetic properties of nano-materials are systematically studied, and the trend diagram of hysteresis loop and magnetization changing with temperature is drawn. It is found that nano-materials show good magnetization behavior under the external magnetic field, and the magnetization changes with temperature in a specific trend, which provides a new idea for their applications in magnetic recording and sensors. In this study, the synthesis and properties of new nano-materials are deeply discussed, which provides important reference and theoretical basis for their applications in optoelectronics, electrochemistry and magnetism. We believe that these research results will provide new ideas and directions for the future development and application of inorganic chemistry.

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