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STUDY OF THE SORPTION PROPERTIES OF MESOPOROUS MATERIALS BASED ON ALUMINUM OXIDE AND TITANIUM DIOXIDE IN CHROMATOGRAPHIC PROCESSES

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A B S T R A C T

This article presents the results of a study of the sorption properties of mesoporous materials based on aluminum oxide (Al_2O_3) and titanium dioxide (TiO_2) used in chromatographic processes. The synthesis features and structural characteristics of the obtained sorbents, including their porosity, surface area and pore size distribution, are considered. By conducting model chromatographic experiments, the influence of the oxide nature, material structure and modification conditions on the efficiency of component separation is established. The mechanisms of sorption, as well as the influence of acid-base and hydrophilic properties of the surface on the selectivity of interaction with the analyzed substances are analyzed. The results indicate high promise for the use of mesoporous oxide materials as effective stationary phases for various chromatographic methods.

K E Y W O R D S

Mesoporous materials, aluminum oxide, titanium dioxide, sorption properties, chromatography, stationary phase, porosity, selectivity, surface properties, sorption, SEM, sol-gel technology.

Introduction

Modern analytical methods place high demands on efficiency, selectivity, and sensitivity in the separation and analysis of complex multicomponent mixtures. Chromatography, as one of the most universal and widely used analytical methods, is largely dependent on the properties of the sorbents used. In recent years, special attention has been paid to mesoporous materials with high specific surface area, thermal stability, and the ability to modify the surface.

Aluminum oxide and titanium dioxide are promising inorganic matrices for creating sorbents used in chromatographic systems. Their physicochemical properties, such as acid-base activity, hydrophilicity, resistance to aggressive environments, and structural features, have a significant impact on the sorption efficiency. However, comparative studies of their sorption properties in chromatographic processes are not sufficiently presented in the scientific literature.

In particular, given the growing need to develop more efficient and selective sorbents for environmental monitoring, pharmaceutical analysis and quality control, a comprehensive comparative study of alumina and titanium dioxide as sorbents is of particular scientific and practical importance. The obtained data can be used to optimize chromatographic separation conditions and develop new materials for analytical chemistry. Titanium dioxide (TiO_2) is one of the most widely used oxide materials due to its unique physicochemical properties. It finds applications in various fields such as photocatalysis, sensors, solar cells and medicine. Optimizing its properties such as morphology, particle size and texture is a key factor in improving its functional performance.

Titanium dioxide has now established itself as a widely used sorbent and photocatalyst, valued for its resistance to photocorrosion, affordability, and catalytic properties. These properties are due, in particular, to the lifetime of photoinduced charge carriers, reaching ~250 ns [1]. However, TiO_2 faces a limitation in the form of low quantum efficiency due to inefficient separation of photoinduced charges. Over the past decade, there has been an increasing interest in the synthesis and study of nanometric mesoporous titanium dioxide powders, which is due to the decrease in the distance to the surface reaction region with decreasing particle size. This contributes to more efficient charge transfer and improved electron-hole separation. In addition, decreasing particle size leads to an increase in the specific surface area of titanium oxide, which enhances the number of surface reactions. Studies show that the anatase crystalline form of TiO_2 has higher catalytic activity compared to rutile and brookite [2]. Therefore, control over the phase composition, particle size and morphology of the material plays a key role in optimizing its performance. Alumina and titanium dioxide are promising inorganic matrices for creating sorbents used in chromatographic systems. Their physicochemical properties, such as acid-base activity, hydrophilicity, resistance to aggressive environments and structural properties, have a significant impact on the sorption efficiency.

Therefore, nanomaterials such as titanium dioxide (TiO_2) are attracting increasing attention in scientific and technical circles due to their unique properties and a wide range of potential applications. In this article, we discuss the synthesis process of TiO_2 nanoparticles and methods for studying their textural characteristics using scanning electron microscopy (SEM).

TiO_2 nanoparticles can be synthesized by various methods, including hydrolysis of titanium salts, hydrothermal synthesis, sol-gel method and thermal decomposition of precursors. One of the most common methods is the hydrolysis of titanium (IV) isopropoxides in an aqueous solution, followed by thermal treatment.

The hydrolysis of titanium isopropoxides produces a gel, which after drying and thermal treatment is converted into TiO_2 nanoparticles. Synthesis parameters such as precursor concentration, solution pH, temperature and reaction time can be optimized to obtain particles with specified sizes and shapes.

Scanning electron microscopy (SEM) is a powerful technique for visualizing the surface of materials at the nanoscale. It allows one to study the surface morphology and structure of samples with high spatial resolution.

Materials and Methods

Surface morphology: SEM images show that the synthesized TiO_2 has an agglomerated structure with irregularly shaped particles up to 300 nm in size. The particle size is 50. At high magnification, the shape and surface of individual TiO_2 nanoparticles can be observed.

It can also be seen from the image that the surface of the TiO2 nanomaterial obtained by sol-gel technology consists of spherical and octahedral particles. Such polydispersity of the surface is usually explained by temperature changes.

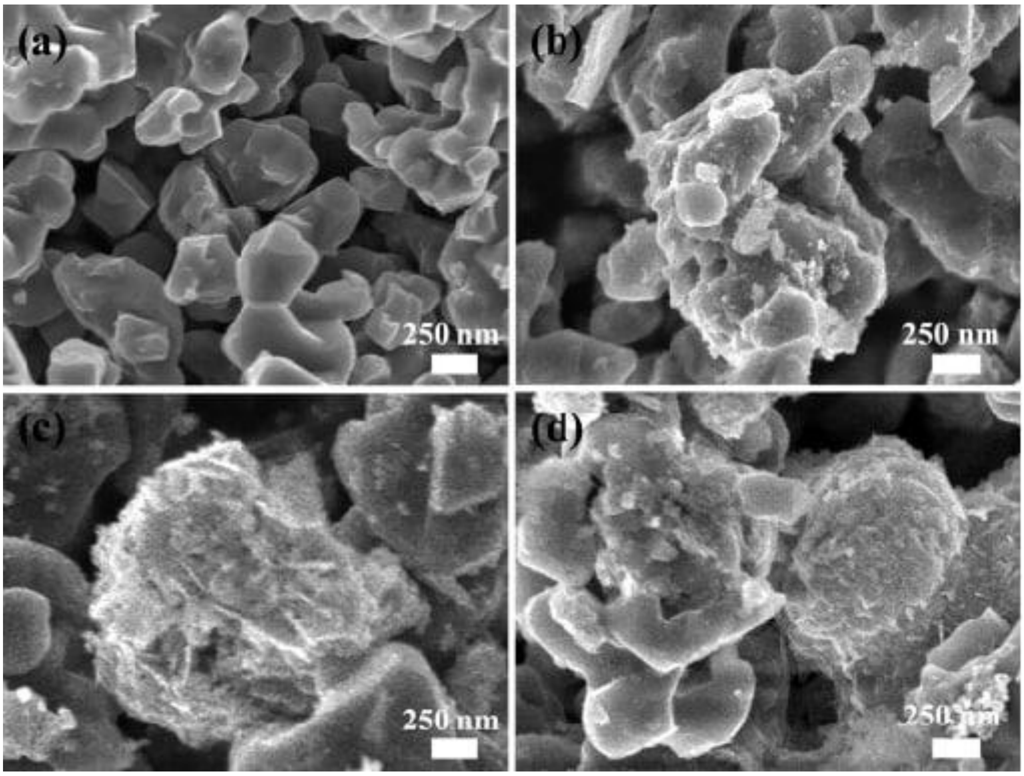

Figure 1.SEM images of TiO_2

Particle size and shape: Image analysis shows that the particles are mostly spherical or octahedral, typical of the anatase form of TiO_2. Both large agglomerates and small individual particles occur, which necessitates additional grinding to achieve a uniform particle distribution.

Surface structure: The surface of the particles is smooth with small pores, which confirms the successful hydrolysis and dehydration of TiO_2. SEM studies of the synthesized TiO_2 indicate that the resulting particles are nanometer-sized and have a characteristic morphology for anatase. The observed porous structure and algomerates of the particles indicate that they are of practical importance.

To study the textural characteristics of TiO_2 nanoparticles using SEM, a sample is usually prepared by depositing a thin layer of particles on a substrate and then irradiating it with an electron beam. An electron detector device is then used to obtain images of the sample surface. The following textural characteristics of TiO_2 nanoparticles can be obtained using SEM:

Particle size and shape: SEM allows one to estimate the size of nanoparticles and determine their shape, such as spherical, plate-like or rod-like.

Size distributions: SEM images can be used to construct particle size distributions and determine the average size and dispersion.
Surface texture: SEM can also be used to investigate surface textural features such as porosity and structure.
TiO_2 nanoparticles have found wide application in various fields, including photocatalysis, solar cells, protective coatings and medical diagnostics. Studying their textural characteristics using SEM is a key step in the development of new materials and technologies based on them.
The synthesis of TiO_2 nanoparticles and the study of their textural characteristics using SEM are important steps in the development and optimization of new titanium dioxide-based materials [3]. The obtained data can be used to develop new applications in various fields of science and technology, as well as to understand the fundamental properties of nanostructured materials.
The creation of titanium dioxide nanoparticles and the analysis of their structural properties via scanning electron microscopy are key steps in the development and improvement of new titanium materials. The information obtained from these studies can be applied in various fields of scientific research and engineering, contributing to a deep understanding of the main attributes of nanostructured materials. To obtain titanium dioxide, a sol-gel method was used using titanium isopropoxide as the initial titanium-containing substance. Distilled water and aqueous solutions of NH_4F, NH_4OH, HF acted as hydrolyzing agents. In this case, the initial components were mixed in the reverse The synthesized materials were left for aging for 24 h at room temperature and then dried for 8 h in air at 100°C to remove water and alcohol. This was followed by heat treatment for 3 h at 400°C. TiO_2 powders obtained with different hydrolytic agents were designated as $TiO_2(H_2O)$, $TiO_2(NH_4F)$, $TiO_2(NH_4OH)$, $TiO_2(HF)$. The effect of fluorine and nitrogen on the structure and morphology of TiO_2 was studied by varying the H2O/NH4F ratio. A series of samples with different NH_4F contents (ratios R_f = 1.2; 0.6; 0.3; 0.2) were prepared, while the molar ratio of the hydrolyzing agent to the alkoxide was maintained at the level of R/IPOT = 3. The designations for these materials were as follows: TiO_2 (R_f =1.2); TiO_2(R_f =0.6); TiO_2 (R_f =0.3); TiO_2 (R_f =0.2).

Conclusion

In conclusion of the study on the synthesis of TiO_2 nanoparticles and their textural characteristics determined using scanning electron microscopy, the following main aspects can be highlighted:
1. Efficiency of the TiO_2 nanoparticle synthesis method: The experimental results convincingly confirm the high efficiency of the chosen method for synthesizing TiO2 nanoparticles. This is important because it provides the ability to control the size and shape of particles, which is important for their application in various technological and scientific fields.
2. Characteristics of the structure of TiO_2 nanoparticles: The study of the structural features of TiO_2 nanoparticles using scanning electron microscopy provided significant data on their morphology, size and surface structure. These characteristics are directly related to the physicochemical properties of the particles and their potential use in catalysis, photocatalytic processes, solar batteries and other areas.
In conclusion, we can draw the following conclusions:
1. In the course of the work, mesoporous materials based on aluminum oxide and titanium dioxide were synthesized and characterized. The data obtained showed that both materials have high sorption

capacity, but differ in a number of parameters. Al_2O_3 showed better selectivity for polar compounds, while TiO_2 was more stable in aggressive environments and effective in sorption of non-polar substances.

2. Comparative analysis made it possible to determine the relationship between the structural and surface properties of sorbents and their behavior in chromatographic systems. The results can be used to select the optimal sorbent for specific analytical chemistry tasks.

3. Information on TiO_2 nanoparticles and their synthesis was collected and analyzed based on a literature review.

4. The textural properties of TiO_2 nanoparticles were studied using a scanning electron microscope.

5. As a result, we can say that the conducted research not only deepened our understanding of TiO_2 nanoparticles, but also opened up new prospects for their use in various fields of science and technology. Further development of this topic can lead to the creation of innovative materials and technologies that contribute to progress in many areas of human activity.

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