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Applied Chemistry and Materials Science

CHEMISTRY GROUP

Applied Chemistry and Materials Science OPEN ACCESS JOURNAL

DOI: https://dx.doi.org/10.17352/acms

Review Article

Experimental analysis of Algerian diatomaceous earth aimed at silicon extraction

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Received: 27 November, 2023
Accepted: 13 December, 2023
Published: 14 December, 2023

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Keywords: Silicon; Silica; XRD; Acid cleansings; Electron microscopy

Abstract

Silicon, primarily derived from silica, plays a crucial role in creating glass, ceramics, and heat-resistant materials, making it indispensable across various industrial sectors. Moreover, it is fundamental in the manufacturing of semiconductors and electronic components. The main goal of our project is to study diatomite, particularly from Algerian deposits, such as western diatomite in order to extract silicon to achieve this, we will conduct experiments using electron microscopy and X-Ray Diffraction (XRD). These analyses highlight the significance of chemical methods in silicon extraction. Our focus is primarily on improving our study by examining the impact of various parameters, notably the use of acid cleansings, on the final product. These parameters are chosen based on the complex chemical reactions governing the aggregation of silica particles in the solution.

Introduction

The diatomaceous earth, also known as diatomite or diatomaceous silica, is a porous sedimentary rock formed from the fossilization of unicellular microalgae called diatoms, found in aquatic environments. These diatoms have external shells called frustules, primarily composed of silica [1,2].

This substance is renowned for its intricate structure, often characterized by precise geometric patterns. Due to its unique physical characteristics, diatomaceous earth finds applications across various fields [3].

Diatomaceous, as microscopic organisms, harness silica to build their outer shells. Their general chemical composition is silicon dioxide (SiO_2) [4]. However, the specific structure of diatom shells varies depending on the species and may contain various elements such as carbon, oxygen, nitrogen, phosphorus, sulfur, as well as minerals like potassium, magnesium, calcium, and trace elements such as iron, zinc, copper, etc.

Diatomaceous earth is widely employed across various sectors due to its distinctive properties. Its porosity renders it an essential filtering agent in the food industry, and it is also valued for its thermal insulation characteristics. It finds use in the creation of refractory materials, abrasives, and absorbent products. Because of its high silica content, diatomaceous earth is also used for silicon extraction, a crucial element in manufacturing electronics, solar panels, and other industrial applications.

Materials and methods

In our experiment, we undertook the analysis of elements present in diatoms with the aim of understanding their composition.

We utilized two types of diatomaceous earth: one was raw, and the other was treated with hydrochloric acid (HCl).

Citation: Zeboudj A, Hamzaoui S (2023) Experimental analysis of Algerian diatomaceous earth aimed at silicon extraction. Appl Chem Mater Sci 1(1): 008-010. DOI: https://dx.doi.org/10.17352/acms.000002

This stage involved preparing a solution containing diatomaceous earth powder with a concentration of 2 mol/L of HCl, heated at a temperature of 100 °C for a duration of 1 to 3 hours.

Subsequent to this stage, both samples underwent multiple rinses with distilled water to achieve a neutral pH.

The process is described by the following chemical reaction (1): [5].

$$SiO_2 + 4\ HCl \rightarrow SiCl_4 + 2\ H_2O \qquad (1)$$

The reaction between silicon dioxide and hydrochloric acid results in the formation of silicon tetrachloride ($SiCl_4$) and water (H_2O). Specifically, silicon dioxide reacts with the H+ ions from hydrochloric acid to produce hydrated silicon dioxide, which, being unstable, subsequently converts into silicon tetrachloride ($SiCl_4$) and two molecules of water. $SiCl_4$ is the main product generated by this reaction.

The X-ray diffraction (XRD) analysis was conducted utilizing a Shimadzu LabX XRD-6000 diffractometer equipped with CuKα radiation (λ = 1.54059 Å). Diffractograms were captured within the 2θ range of 20° - 80°, employing a step size of 0.02° and a scan speed of 2 deg/min.

For morphological assessment, Scanning Electron Microscopy (SEM) was employed, utilizing a JSM 6390 apparatus (JEOL Ltd.) represented in Figure (4.5), operated at an accelerating voltage of 1.8 kV.

Results and discussions

In this work , we are using diatomaceous earth powder from western Algeria, originally in block form. These blocks were ground and then utilized in our study, resulting in two types of samples: one remains as it is, while the other is treated with hydrochloric acid (HCl) (Figure 1).

After capturing the image following the experiment, we observed a drastic change in the color of the diatoms, shifting from white to a golden hue after exposure to heat.

The examination of morphology was conducted via Scanning Electron Microscopy (SEM).

Figure 2 displays the SEM images of Algerian Diatomaceous, aiming to capture high-resolution surface images, facilitating the observation of material surface morphology, texture, and topography at micro- or nanoscale levels.

In this section, our main objective is to apply X-ray diffraction for naturel diatomaceous and treated with acid (Figure 2) to precisely analyze and determine the crystalline structure of materials. This approach provides us with accurate details about atomic arrangement, interatomic distances, and crystal orientations.

Upon reviewing the prior analyses, a distinction emerges between the untreated diatomaceous earth and the one exposed to acid treatment. This discrepancy becomes apparent in the elemental composition post application of HCl under specific conditions: neutral pH and a temperature of 100 °C. This process leads to an enhancement in silicon purity.

The X-ray diffraction patterns depicted in Figure 3 reveal sharp peaks, indicating a high level of crystallinity in the respective samples. The presence of the quartz phase was indicated by X'Pert Highscore analysis.

Figure 3 illustrates the XRD peaks for two diatomite samples, both before and after undergoing chemical treatment. The peak with the highest intensity was observed at 2θ = 26.68°; notably, its intensity increased following acid treatment (from 1028 to 2150 counts per second), as did the other peaks. However, the chemical treatment, specifically the acid treatment, did not affect the interplanar distance or the 2θ values, as detailed in Table 1.

Conclusion

Chemical procedures are crucial in diatomaceous earth synthesis, catering to various industrial uses like photovoltaic technologies and microelectronics. Our goal is to enhance the manufacturing process by examining how solution temperature, reaction duration,v pH, and acid cleansing affect the end result. Choosing these parameters is guided by the intricate chemical reactions governing the gathering of silica particles in the solution.

Patents

Author contributions: Contributions Asmaa Zeboudj. wrote the main manuscript text, prepared the figures and performed all experiments. Saad Hamzaoui. oversaw the project and assisted with the writing of the overall manuscript. Additional

Figure 1: Diatomaceous earth powder presentation.

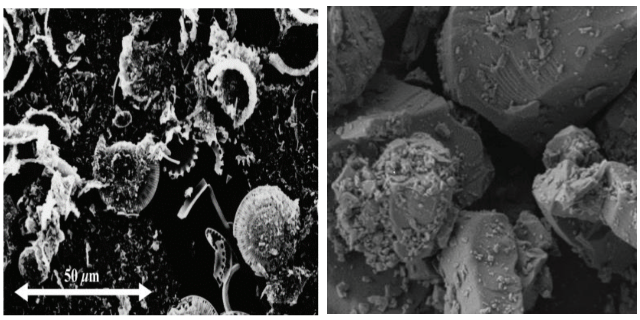

Figure 2: Scanning electron micrograph of Algerian diatomaceous after and before treatment.

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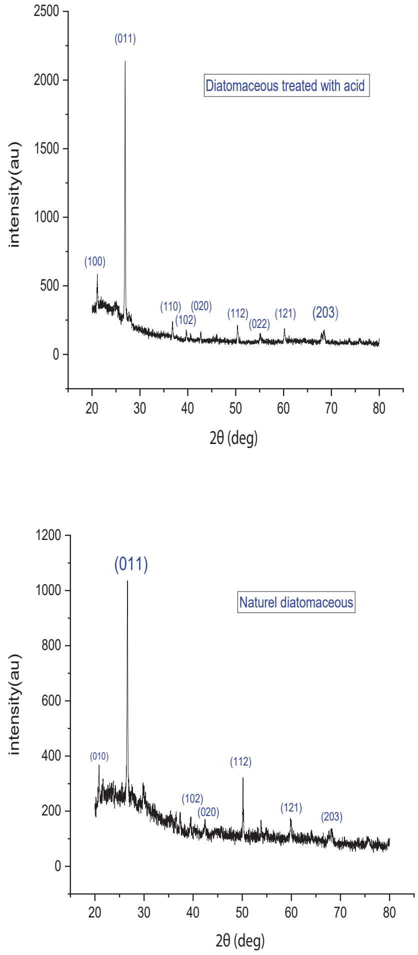

Figure 3: XRD patterns image of Algerian daitomous.

Table 1: The variation of inter-reticular distance and 2θ of daitomous before and after chemical treatment.

	Diatomaceous treated With Acid		Naturel Diatomaceous	
(hkl)	d(A)	2θ	d(A)	2θ
10	4,24	20,92	4,24	20,88
11	3,33	26,73	3,34	26,6
110	2,44	36,658	2,45	36,51
102	2,27	39,623	2,28	39,44
111	2,22	40,42	2,23	40,26
200	2,12	12,58	2,12	42,42
201	1,97	45,94	1,95	45,77
112	1,81	50,32	1,81	50,12
3	1,79	50,84	1,67	50,11
22	1,66	55,07	1,65	55,31
13	1,65	55,56	1,62	55,94
210	1,3	57,41	1,45	59,02
121	1,53	60,16	1,53	60,16
113	1,44	64,3	1,45	64,73
30	1,41	66	1,41	65,77
122	1,37	67,99	1,372	67,73
203	1,369	68,42	1,375	68,13
31	1,367	68,55	1,372	68,3
104	1,28	73,81	1,28	73,46

Information Competing Interests: Te authors declare no competing interests.

Data availability statement: Data are provided in the figures of the article.

Acknowledgement

Acknowledgements We would like to thank the LMESM Laboratory, Physics Department, University of Science and Technology Mohamed Boudiaf in "Instrumentation aux limites".

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