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COMPARATIVE ANALYSIS OF THE MORPHOLOGICAL FEATURES OF NaY ZEOLITE AT DIFFERENT SEM MAGNIFICATIONS

Abdullakhonova Gulrukh

Basic Doctoral Student, Kokand State University

E-mail: gulrukhabdullakhonova@gmail.com

Esonkulova Nazirakhon

Doctoral Student, Namangan State Technical University

E-mail: naziraxon.esonqulova@mail.ru

Giyosova Rano

Clinical Resident, Republican Specialized Scientific and Practical Medical Center for Maternal and Child Health

E-mail: ranogiyosova97@gmail.com

Abstract: ***This study presents a comparative analysis of the morphological features of hydrothermally synthesized NaY zeolite observed at different SEM magnifications. The analysis showed that increasing the magnification from ×2,000 to ×15,000 progressively reveals the structural organization of particle aggregates and their surface microrelief. The observed features include particle agglomeration, irregular contours, local depressions, protrusions, and faceted regions. The results demonstrate the heterogeneous and hierarchical morphological organization of the synthesized NaY zeolite and provide a basis for systematic comparison of its microstructural characteristics.***

Keywords: ***NaY zeolite, SEM, comparative analysis, morphology, particle aggregation, microstructure.***

INTRODUCTION

NaY zeolite is a crystalline aluminosilicate belonging to the FAU framework

type and is widely recognized for its well-developed porous structure, high specific surface area, and ion-exchange properties. These characteristics make NaY an important material for adsorption, separation, and catalytic applications [1-3]. Its functional properties are closely related not only to the crystalline framework but also to the morphology and organization of the particles.

The morphology of synthetic NaY strongly depends on hydrothermal synthesis conditions, which influence nucleation, crystal growth, particle shape, and aggregation [1-4]. Formation of primary crystalline units and their subsequent association may result in complex aggregates with heterogeneous surface characteristics. Therefore, systematic morphological analysis is essential for understanding the microstructural organization of synthesized NaY zeolite [3-5].

Scanning electron microscopy (SEM) enables the morphology of zeolite particles to be examined at different observation scales. Comparative analysis of images obtained at increasing magnifications provides information ranging from the general distribution and aggregation of particles to finer details of their surface microrelief [3-6]. In this study, the morphological features of hydrothermally synthesized NaY zeolite were comparatively analyzed at SEM magnifications from ×2,000 to ×15,000, with particular attention to changes in the observable structural characteristics of particle aggregates.

METHODOLOGY AND MATERIALS

NaY zeolite hydrothermally synthesized from chemically pure starting reagents was used as the investigated material. The morphological characteristics of the synthesized sample were examined by scanning electron microscopy (SEM) at an accelerating voltage of 15.0 kV.

SEM images obtained at magnifications of ×2,000, ×5,000, ×10,000, and ×15,000 were comparatively analyzed. Particular attention was paid to particle aggregation, shape and mutual arrangement of structural units, surface heterogeneity, and

microrelief. The observed morphological features at each magnification were systematically compared and summarized in tabular form to evaluate changes in the level of structural detail with increasing SEM magnification.

RESULTS AND DISCUSSION

Comparative analysis of SEM observations at different magnifications revealed a gradual increase in the level of morphological detail of the hydrothermally synthesized NaY zeolite. At ×2,000 magnification, the material is represented by numerous closely contacting particles forming relatively dense agglomerates. The general morphology is heterogeneous, while isolated large monolithic particles are not observed. At ×5,000 magnification, the internal organization of the aggregates becomes more distinguishable, revealing smaller structural units with irregular outlines and locally flat or faceted regions.

At ×10,000 magnification, the surface characteristics of individual aggregates are more clearly resolved. The surface exhibits a developed microrelief with protruding structural elements, local depressions, and visible boundaries between neighboring formations. Some structural units display relatively well-defined facets. At ×15,000 magnification, these features become particularly evident, showing that the aggregates consist of closely interconnected fine structural elements and contain both irregular and relatively flat or faceted surface regions.

The main morphological characteristics observed at different SEM magnifications are summarized in Table 1.

SEM magnification	**Scale bar**	**Main observed features**	**Morphological interpretation**
×2,000	10 μm	Dense agglomerates of closely contacting particles; heterogeneous surface	General aggregated morphology of the material

SEM magnification	Scale bar	Main observed features	Morphological interpretation
×5,000	5 μm	Smaller structural units, irregular contours, locally flat and faceted regions	Heterogeneous organization of particle aggregates
×10,000	1 μm	Protrusions, local depressions, particle boundaries and faceted elements	Developed and non-uniform surface microrelief
×15,000	1 μm	Closely interconnected fine structural units; flat and faceted fragments	Complex organization of the aggregate surface

Table 1. Comparative morphological characteristics of synthesized NaY zeolite at different SEM magnifications.

The comparative data demonstrate that increasing SEM magnification does not reveal fundamentally different types of particles but progressively exposes finer details of the same aggregated structures. Thus, the transition from ×2,000 to ×15,000 provides a hierarchical view of the material: from the overall distribution of particle agglomerates to the microstructural organization of their surfaces. This persistence of the main morphological features at different observation scales indicates that the heterogeneous aggregated morphology is characteristic of the investigated NaY sample.

The observed morphology is consistent with literature reports indicating that the synthesis conditions of NaY and other FAU-type zeolites strongly affect nucleation, crystal growth, particle size, and aggregation [1-6]. Formation and subsequent association of smaller crystalline units can lead to larger secondary aggregates with complex surface morphology. Therefore, comparative SEM analysis at different

magnifications provides a useful approach for systematically describing the morphological organization of hydrothermally synthesized NaY zeolite.

CONCLUSION

Comparative SEM analysis showed that hydrothermally synthesized NaY zeolite exhibits a heterogeneous and aggregated morphology at all investigated observation scales. Increasing the magnification from ×2,000 to ×15,000 progressively revealed finer structural details, including particle boundaries, local depressions, protrusions, and faceted regions. The preservation of the main morphological features at different magnifications confirms the hierarchical organization of the material, from micrometer-scale agglomerates to fine structural units forming their surfaces. The obtained results demonstrate the effectiveness of comparative SEM analysis for characterizing the microstructural organization of synthesized NaY zeolite.

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