

Synthesis of Hierarchically Porous Zeolites for Catalytic Applications

Ryong Ryoo*, Minkee Choi, Jeongnam Kim and Kyungsu Na,

Center for Functional Nanomaterials, Department of Chemistry, and Graduate School of Nanoscience and Technology (WCU), KAIST, Daejeon, 305-701 (Korea)

*rryoo@kaist.ac.kr

Introduction

Hierarchical pore systems (HPSs) are defined by the different porosity levels in two or multiple length scales. HPSs can be found ubiquitously in nature and human artworks, such as the circularly systems of plants and animals, the cellular shells of diatoms, animal nerve systems, man-made architectures, and traffic systems in modern cities. HPSs are naturally or artificially designed for accommodation of maximum functions in a limited volume or area, and also achievement of their maximum efficiencies (e.g., mass transfer or transportation). One of the most important structural effects of HPS as a catalytic material is the enhanced catalytic lifetime. In recent years, various routes to the HPS-type zeolite materials have been developed for catalytic applications, such as synthesis of zeolite samples with nanocrystalline morphologies (so that they can contain intercrystalline mesopores), layer-by-layer separation of zeolite structure, generation of mesopores within zeolite crystal via etching treatment, and use of nano-template as a mesopore generator during zeolite crystallization [1].

In the present work, two new synthesis routes to the HPS-type zeolites have been developed using amphiphilic surfactant-like molecules as the mesopore-directing agent. In the one method, organosilane surfactants are the mesopore-directing agent while the microporous zeolite frameworks are formed through the structure-direction by ordinary Na^+ ions or small organic amines [1]. In the second strategy, bifunctional surfactants can direct porous structures in the meso- and micro-length scales simultaneously. In this case, both pore systems are generated by a single kind of surfactant, without other zeolite structure-directing agents such as Na^+ and tetrapropylammonium [2]. The zeolite structure is directed by functional groups in the surfactants.

Materials and Methods

The organosilane surfactants were [3-(trimethoxysilyl)propyl] hexadecyldimethylammonium chloride and its analogs. These compounds were synthesized as reported elsewhere [1]. The bifunctional surfactants were also synthesized in our laboratory. HPS zeolites were hydrothermally synthesized by the addition of organosilane surfactants into the synthesis compositions for conventional zeolites, or by using the bifunctional surfactant alone. Zeolites were characterized by X-ray diffraction, N_2 adsorption, and electron microscopy. Catalytic properties were investigated in various reactions, in comparison with conventional zeolites and MCM-41-type materials.

Results and Discussion

Both synthesis strategies have led to the generation of HPS zeolites. These methods provide a means of decreasing zeolite framework thickness and hence achieving minimal diffusion path lengths (see Figure 1). It has been confirmed that such zeolites are suitable for

catalytic applications involving bulky species, due to catalytic activities at the mesopore walls [3]. In addition, the hierarchical zeolites exhibit a significantly prolonged catalytic lifetime in a number of small molecular reactions taking place inside micropores, as compared with bulk crystalline zeolite [4]. This effect is attributed to facile diffusion to/from micropores via mesopores. Details of the hierarchical zeolite synthesis, structure determination, and characterization of catalytic properties are discussed in this lecture.

Significance

The enhanced catalytic lifetime of HPS is remarkable for catalytic applications of zeolite.

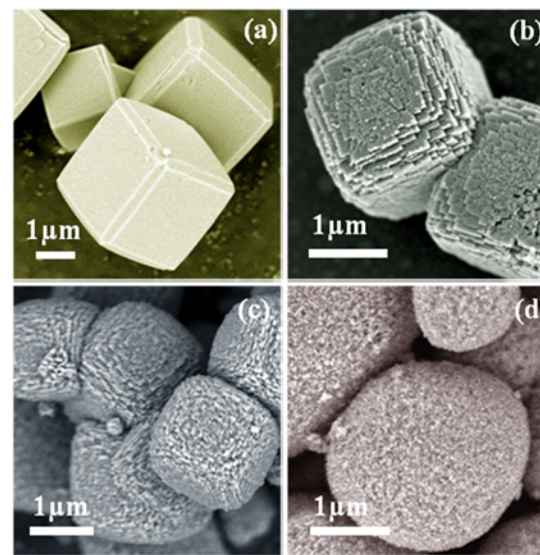


Figure 1. Scanning electron micrographs of zeolite: (a) bulk LTA crystals, (b) – (d) HPS LTA zeolite samples with increasing mesoporosity. HPS MFI zeolite with mesoporosity can be synthesized similarly.

References

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