Seeding on the Synthesis of MCM-22 (MWW) Zeolite by Dry-Gel Conversion Method and its Catalytic Properties on the Skeleton Isomerization and the Cracking of Hexane

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The effects of seeding on synthesis of MCM-22 (MWW) have been studied by the dry gel conversion (DGC) method. Highly reproducible crystalline MWW zeolite could be obtained by DGC method, using seeds of calcined sodium MWW with SiO$_2$/Al$_2$O$_3 = 31$. Crystalization of MWW phase was completed in the presence of seeds (2 mass% against SiO$_2$) at 150°C within two days. The small amount of seed (0.25 mass% against SiO$_2$) was sufficient for the required phase formation of MWW. The MWW with SiO$_2$/Al$_2$O$_3$ ratio from 35 to 66 was obtained as pure phase; however, the crystallinity of MWW decreased with further increase in the ratio: products were contaminated with impurities.

The catalytic properties of MWW were examined in the skeleton isomerization and the cracking of hexane, and compared to zeolites such as BEA, MFI, and MOR. The catalytic activities were in the order: MFI > BEA > MWW. These catalytic properties were due to the differences of structures and acid strength of zeolites.

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1. Introduction

MCM-22 (MWW) is a family of high silica zeolite, which was found by Mobil Oil Corporation in 1990. It has a similar structure as PSH-3, SSZ-25, borosilicate zeolites ERB, and pure silica zeolite ITQ-1. It has been claimed to be useful for a variety of hydrocarbon conversion reactions such as alklylation, disproportionation, isomerization, cracking, etc. MWW has been successfully synthesized by static condition, and compared its morphology with the rotating condition by Güray and his co-workers. It has also been reported that the formation of MWW by static condition depends on the SiO$_2$/Al$_2$O$_3$ by Cheng and his co-workers. Mochida and his co-workers reported that the addition of seeds could greatly accelerate the crystallization and reduce the synthesis time by hydrothermal synthesis (HTS).

New methods of zeolite synthesis, such as a dry-gel conversion (DGC) method and solid transformation have been well documented by some research groups. In comparison with the hydrothermal synthesis method, these new methods have the advantages such as expansion of the chemical compositions, the reduction of the structure directing agent (SDA) concentration, high conversion of the gel, fine particles with high crystallization, etc. Recently, Matsuoka and his co-workers have successfully crystallized MWW by DGC method, and compared the morphologies of products synthesized by the DGC and HTS methods. However, effects of seeds on the crystallization of MWW by DGC method have not been published so far to our knowledge. In the present study, an attempt has been made to synthesize MWW by DGC method, and to elucidate the effect of seeds, crystallization time, temperature, and SiO$_2$/Al$_2$O$_3$ ratios on the synthesis. The characterization of the zeolite and the isomerization and the cracking of hexane were also examined to know their properties.

2. Experimental

2.1 Synthesis of MWW

Vapor phase transport (VPT) method, which is a method of “dry-gel conversion (DGC) method”, was used as a typical synthesis procedure: 0.266 g of NaAlO$_2$ (42.8% Al$_2$O$_3$, 33.2% Na$_2$O and 23.5% H$_2$O; Nakalai Tesque) was mixed with 3.1 g of NaOH (4 mass% solution) and 8.0 g H$_2$O. The mixture was stirred for 10 min. The fumed silica of 2.403 g (Cab-O-Sil M5) and the rest of water (20.68 g) were added to the mixture, and the stirring was continued for 2 h. Then, the gel was dried at 80°C over an oil bath with continuous stirring to evaporate water (2–2.5 h) until the gel became thick and viscous, and the gel was homogenized by hand using a Teflon rod till dried. The white solid thus obtained was grounded into a fine powder. The powder was poured into a small Teflon cup, and then, kept into a Teflon-lined autoclave containing water (ca. 0.2 g per 1.0 g of dry gel) and hexamethylenimine 2.086 g (95% TCI, Tokyo, Japan), where the dry gel should not directly contact with water. The crystallization of the dry gel was carried out at desired temperature and time under the autogenous pressure. The autoclave was quenched in the cold water after the definite time. The solid product was separated by filtration, and repeatedly washed with distilled water, and dried at 110°C overnight. The addition of seeds (MWW (sodium form); SiO$_2$/Al$_2$O$_3 = 31$) was carried out by two different ways:

(1) Seeds were added to the gel and then they were dried (Table 2, entries 12–14).

(2) Seeds were added after drying the gel (Table 2, entries 15–31).

The calcination of synthesized zeolite was carried out in a
muffle furnace to remove the organic template occluded inside the zeolite pores by heating the furnace from room temperature to 550°C over a period of 8.4 h in a flow of air (flow of air: 50 mL/min). The sample was kept at the same temperature for the period of another 8.0 h, and finally, the sample was cooled to room temperature.

The calcined sample was refluxed with ammonium nitrate solution at 80°C for 12 h under constant stirring. The amount of nitrate used was the same as the zeolite, and the ratio of H2O and zeolite was 50:1 (w/w). The zeolite was then filtered. This process was repeated two more times, and then the sample was washed thoroughly with water, and dried overnight at 100°C. Finally, NH4-form of the zeolite was calcined under air flow for 8 h at 550°C to obtain the H-form.

2.2 Characterization of MWW

Phase purity and crystallinity of the as-synthesized sample were determined by powder X-ray diffraction (XRD) (XRD-6000, Shimadzu Corporation) with Cu Kα radiation (λ = 0.15418 nm). Crystal size and morphology of the sample were determined by scanning electron microscopy (SEM) using a TOPCON ABT-60 microscope. Elemental analyses were performed by inductively coupled plasma atomic emission spectroscopy (ICP) (JICP-PS-1000 UV, Leeman Labs Inc.). Thermal analyses of the as-synthesized samples were performed on a Shimadzu DTG-51 analyzer. Nitrogen adsorption measurements were carried on a Belsorp 28SA (Bel Japan Inc.) apparatus. The acidic properties were measured by ammonia temperature programmed desorption (NH3-TPD) using BEL TPD-66 (Bel Japan Inc.) using H-form of MWW: the zeolite was evacuated at 500°C for 1 h, exposed to ammonia at 100°C for adsorption, and then, evacuated for a further 1 h. The sample was heated from 100 to 710°C at 10°C/min under constant helium flow.

2.3 Catalytic isomerization of hexane

2.3.1 Catalysts

MWW (Table 2, entry 20) was used as the catalyst. BEA(30) was synthesized by DGC method in the literature.33) MFI(29) (HSZ-840NHA) and MOR(30) (HSZ-670HOA) were obtained from Tosoh corporation Ltd. Tokyo, Japan. All zeolites were used as catalysts as H-form.

2.3.2 Catalytic experiments

Catalytic isomerization and cracking of hexane were carried out using a 9 mm (OD) quartz tubular down flow reactor. The zeolite (1 g; 18/32 meshes) was placed between two layers of quartz wool, and heated in a stream of 20 mL/min of nitrogen at 550°C for 1 h before introducing hexane. The reaction was performed at a temperature of 350–650°C. The products were analyzed with on-line gas chromatographs using fused silica capillary columns with FID detector. The capillary columns were CP-Al2O3/KCl (Varian, 50 m × 0.53 mm, 10 μm film thickness) for the analysis of C1–C6 hydrocarbons, and HR-1 column (Shimadzu Chem. Ind., 30 m × 0.53 mm, 5 μm film thickness) for C7 hydrocarbons, benzene, toluene, and xylenes.

The conversion of hexane and the selectivity for the products were calculated on carbon basis: Fed hexane (mol/min) = \[ \sum \text{Area}_i \times \frac{C_i}{X_i} \times \frac{F_i}{N_i} \]

Conversion (%) = \[ \frac{(\text{Fed hexane} - \sum \text{Area}_i \times C_i \times \frac{F_i}{N_i})}{\text{Total amount}} \times 100 \]

Yield, of each component (%) = \[ \frac{(\sum \text{Area}_i \times C_i \times \frac{F_i}{N_i})}{\text{Fed hexane}} \times 100 \]

Selectivity for each component (%) = \[ \frac{(\text{Yield} / \text{Conversion})}{100} \]

Abbrevations in formula are expressed as Areai = GC area of each component; Areao = GC area of hexane; Fi = Response factor of each component; F0 = Response factor of hexane, Ni = concentration of each component; No = concentration of hexane; Ci = carbon numbe of hexane; Cc = carbon number of each component.

Methylpentanes (2- and 3-methylpentanes and 2,2-dimethylbutane), methylbutanes (2- and 3-methylbutanes and 2,2-dimethylpropane), and 2-methylpropane were abbreviated as bC6, bC5, and bC4, respectively. Combined selectivity for the isomerization is sum of b-C6, b-C5, and b-C4.

3. Results and Discussion

3.1 Synthesis of MWW by DGC method

The synthesis conditions and the products obtained by DGC method with different gel compositions are listed in Table 1. Table 1 shows the effects of NaOH concentration and silica source on the synthesis of MWW using DGC method. Figure 1 shows the XRD patterns for the products. The effects of molar concentration of NaOH on the synthesis of MWW were thoroughly studied from 0.07–0.27 mol/L using fumed silica Cabo-O-Sil M5 (Table 1, entries 1–9). Only 0.15 mol/L concentration of NaOH gave MWW phase although trace amounts of impurities were accompanied. MWW phase appeared at lower than 0.15 mol/L of the NaOH concentration although MOR was also co-crystallized. The formation of MWW disappeared at a concentration of NaOH higher than 0.17 mol/L; MOR and/or MFI phases were produced. These results clearly show that the molar concentration of NaOH played a critical role in the formation of MWW phases.

The influence of silica source has been studied for the synthesis of MWW. Cab-O-Sil M5 as silica source gave MWW phase although trace impurities were accompanied; however, colloidal silica sources such as Ludox HS-40 and Snowtex-40 did not afford MWW phase, but MOR and/or MFI phases appeared from them as shown in Fig. 2 (Table 1, entries 10 and 11). The reasons for these differences are not clear currently; however, one of the reasons is due to change in the NaOH concentration. The synthesis of MWW was studied without seeds by changing NaOH concentration and silica sources; however, MWW with trace impurities (Table 1, entry 4) and mixture of MWW and MOR was obtained, although Matsukata and his co-workers found pure MWW by DGC method without seeds.30,31) We tried to synthesize the MWW under the conditions as per Table 1 (entry 4) to check the reproducibility, and the results show
the formation of different phases with good reproducibility through our studies. From these discussions, fumed silica was the best silica source to obtain MWW phase by DGC method, and we chose Cab-O-Sil M5 as silica source for further studies.

### 3.2 Seeding on the synthesis of MWW

Table 2 summarizes the influence of seeding on the synthesis of MWW by DGC method. The seeds were calcined sodium MWW with SiO$_2$/Al$_2$O$_3$ = 31, and used on the basis of mass% against SiO$_2$ in the gel composition. The addition of seeds in the synthesis was carried out by two different ways:

1. The seeds were added to the gel and then they were dried.
2. The seeds were added after drying the starting gel, and mixed well with the gel.

The addition of seeds to the starting gel increases NaOH concentration, i.e., the pH of gel composition, to result in the formation of MOR and MFI phases. As shown in Table 1, MWW appeared as principal products at the NaOH concentration of 0.15 mL/L; however, the formation of impurities and MOR was enhanced by the addition of seeds (Table 2, entries 12–14). However, the formation of MWW was enhanced by the addition of seeds to dry gel, and MWW was formed although a layered silicate was accompanied (Table 2, entry 15). Hence, we focused on the addition of the seeds to dry gel. Stepwise increase in temperature from 150°C (for initial 2 to 3 d) to 175°C (3 or 4 d to 2 or 7 d) led to the formation of MWW; however, it accompanied the formation of MOR and impure phases (Table 2, entries 15–18).

We examined the isothermal synthesis to know the effect of temperature. Although the MWW and MOR phases were co-crystallized at 175°C, the pure MWW phase appeared by the isothermal synthesis at 150°C. Stepwise increase in temperature from 150°C (for initial 2 to 3 d) to 175°C (3 or 4 d to 2 or 7 d) led to the formation of MWW; however, it accompanied the formation of MOR and impure phases (Table 2, entries 15–18).

The effects of synthesis time on the crystallinity of MWW

![Fig. 1](image1.png)

**Fig. 1** Effects of NaOH concentration on the crystallization of MWW. Synthesis conditions: gel composition: SiO$_2$:HMI:NaOH:Al$_2$O$_3$:H$_2$O = 1:0.5:(0.07–0.27):0.028:44; temperature: 175°C. Samples: entries 1–9 in Table 1.

![Fig. 2](image2.png)

**Fig. 2** Effects of silica source on the synthesis of MWW. Synthesis conditions: gel composition: SiO$_2$:HMI:NaOH:Al$_2$O$_3$:H$_2$O = 1:0.5:0.15:0.028:44; temperature: 175°C. Samples: entries 4, 10 and 11 in Table 1.

### Table 1 Effects of NaOH concentration and silica source for the synthesis of MCM-22 by DGC method.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Gal composition</th>
<th>Temperature °C</th>
<th>Time (d)</th>
<th>Product Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 1 0.5 0.07 0.028 44</td>
<td>175</td>
<td>7</td>
<td>amorphous</td>
</tr>
<tr>
<td>2</td>
<td>1 0.5 0.09 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MWW + MOR</td>
</tr>
<tr>
<td>3</td>
<td>1 1 0.5 0.12 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MWW + MOR</td>
</tr>
<tr>
<td>4</td>
<td>1 0.5 0.15 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MWW + impurity (trace)</td>
</tr>
<tr>
<td>5</td>
<td>1 0.5 0.17 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MWW + MOR</td>
</tr>
<tr>
<td>6</td>
<td>1 1 0.5 0.19 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MOR + MFI</td>
</tr>
<tr>
<td>7</td>
<td>1 0.5 0.21 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MOR + MFI + layered silicate</td>
</tr>
<tr>
<td>8</td>
<td>1 0.5 0.25 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MOR + MFI + impurity</td>
</tr>
<tr>
<td>9</td>
<td>1 1 0.5 0.27 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MOR + impurity</td>
</tr>
<tr>
<td>10</td>
<td>1 0.5 0.15 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MOR + impurity</td>
</tr>
<tr>
<td>11</td>
<td>1 0.5 0.15 0.028 44</td>
<td>175</td>
<td>7</td>
<td>MOR + MFI</td>
</tr>
</tbody>
</table>

*aCab-O-Sil M5; bLudox HF-40; cSnowtex-40.*
phase were examined at the same gel composition using 2.0 mass% seeds against SiO$_2$. Typical results are listed in the Table 2 (entries 20–23), and their XRD patterns are shown in Fig. 3. The crystallization of MWW phase was started after 1 d among amorphous phase. Amorphous phase was completely converted to MWW phase after two days, and the pure MWW was obtained after crystallization for 4 d.

The amount of seeds was varied from 0.125 to 2.0 mass% against SiO$_2$ in the synthesis of MWW as in Table 2 (entries 20, 24–28), and the XRD patterns are shown in Fig. 4. The pure phase of MWW appeared by adding seeds from 0.25 to 2.0 mass% against SiO$_2$. However, MWW phase along with amorphous phase was observed by the addition of 0.125 mass% seeds (Table 2, entry 27). These results indicate that 0.25 mass% seeds against SiO$_2$ are minimal for complete crystallization of MWW, and the addition of 0.125 mass% seeds is not sufficient for the nucleation of MWW phase.

The effects of SiO$_2$/Al$_2$O$_3$ ratio on the synthesis of MWW were examined at 150°C by varying the SiO$_2$/Al$_2$O$_3$ ratio in the synthesis of MWW.
from 35 to 150 (Table 2, entries 20, 29–31). XRD patterns are shown in Fig. 5. The pure MWW phase appeared only at SiO\(_2\)/Al\(_2\)O\(_3\) ratios from 35 to 75. However, MWW phase was formed with trace of amorphous materials and/or impurities at SiO\(_2\)/Al\(_2\)O\(_3\) of 100 and 150. These results indicate that the SiO\(_2\)/Al\(_2\)O\(_3\) ratio from 35 to 75 is optimal for pure MWW phase by DGC method.

The yields of MWW were quantitative (97%) on the synthesis at SiO\(_2\)/Al\(_2\)O\(_3\) = 35 (Table 2, entry 20); the SiO\(_2\)/Al\(_2\)O\(_3\) ratio in the MWW by the ICP analysis is very close to the ratio in the gels. However, the yield of MWW decreased with the decrease in aluminum content of the gel, and SiO\(_2\)/Al\(_2\)O\(_3\) ratio of the resultant MWW was lower than the ratio in the gel (Table 2, entry 29). This shows that the optimal amounts of aluminum was essential for the crystallization of MWW, and the some of excess of the SiO\(_2\) did not take part in the synthesis of MWW.

Figure 6 shows the calcination of MWW with 35.2 and 66.4 of SiO\(_2\)/Al\(_2\)O\(_3\) ratio (Table 2, entries 20 and 29) at 550°C for 8h under air stream. Both MWW zeolites gave typical clear MWW patterns.

3.3 Characterization of MWW

The SEM images of MWW prepared by DGC method are shown in Fig. 7. The shape of the sample (Table 1, entry 4) obtained without seeds was aggregated sphere with a diameter of about 15 \(\mu\)m, which are formed by aggregation of the leaflets into lamellar particles. This type of crystals was also found for HTS method under static conditions.\(^{13}\) MWW crystals by DGC method (Table 1, entries 20 and 29) were
small leaflets. These types of crystal resemble to the crystals of MWW by DGC method by Matsukata et al.,30,31

Typical results of thermal analysis of MWW (SiO$_2$/Al$_2$O$_3$ = 35.2, Table 2, entry 20) are shown in Fig. 8. The TG profile showed that the total weight loss of a sample up to 800°C was 21.2 mass%; the 2.9 mass% loss to 150°C is assigned to the loss of water and volatile organics, and the 18.4 mass% loss from 150 to 800°C is assigned to the decomposition of organic template occluded in the zeolite channels. The DTA pattern showed four stages, viz. 50–100, 100–350, 350–500, and 500–700°C.10 The first step is assigned to an endothermic process by desorption of water, the second and third steps are assigned to exothermic processes by the oxidation of the organic template. The last step is assigned to an exothermic process by the combustion of residual coke formed from organic template. These observations indicate that the organic template is strongly retained inside the zeolite pores.

The N$_2$-adsorption isotherm of the calcined samples of MWW (SiO$_2$/Al$_2$O$_3$ = 35.2 and 66.4; Table 2, entries 20 and 29) is shown in Fig. 9. The pore volume 0.1397 cm$^3$/g and high surface area 479 m$^2$/g indicate that the sample had excellent crystallinity and that the pores were not blocked by any non-removable occluded material. However, pore volume and surface area decreased with increasing SiO$_2$/Al$_2$O$_3$ ratio: pore volume 0.1381 cm$^3$/g, and surface area 367 m$^2$/g with SiO$_2$/Al$_2$O$_3$ ratio of 66.4.

The acidic properties of H-MWW were measured by temperature programmed desorption of ammonia (NH$_3$-TPD). The profiles of MWW with different SiO$_2$/Al$_2$O$_3$ ratios (SiO$_2$/Al$_2$O$_3$ = 35.2 and 66.4; Table 2, entries 20 and 29) are shown in Fig. 10. The two broad desorption peaks were observed in the profile. The first peak (l-peak) was observed at the lower temperature region (100–240°C): these peaks are assigned to desorption from weak van der Waals adsorption. The second peak (h-peak) at the higher temperature region (240–500°C) is due to desorption of chemisorbed NH$_3$, and assigned to strong acid sites in the MWW, which are effective for the acid catalysis. The peak area of h-peak of MWW with the ratio of 35.2 was larger than that of MWW with the ratio of 66.2: the acid amounts are related to the amount of aluminum, because appearance of acid sites is due to aluminum substitution with SiO$_2$. However, the peak temperatures of NH$_3$ desorption were almost identical for both samples: acid strength of MWW is not changed by the aluminum contents.

### 3.4 Skeleton Isomerization and Cracking of Hexane over Zeolites

MWW zeolites synthesized by DGC method were used in the skeleton isomerization of hexane to elucidate the catalytic properties. Figure 11 shows the time on stream on the skeleton isomerization and cracking of hexane over zeolites. Table 3 shows the typical products distribution of MWW, BEA, MFI and MOR in the reaction. The order of catalytic activity after 2 h reaction time was in the order: MFI > BEA > MWW > MOR. The selectivity of the isomerization of hexane was in the order: BEA > MWW > MFI. The difference
of coke formation feature between zeolites is due to their pore structure. MFI showed the highest stable activity for the cracking of hexane; however, BEA, synthesized by DGC method with 30 of SiO\textsubscript{2}/Al\textsubscript{2}O\textsubscript{3} ratio, also had high activity although the deactivation occurred during the reaction. Although the activities of MWW were lower than those of MFI and BEA, the deactivation of MWW was not significant compared with BEA. The deactivation of these zeolites is caused by coking of the pores. MWW and MFI are more tolerant than BEA: polynuclear aromatics, precursor of coke cannot accommodate in MFI and MWW pores.

Figure 12 shows the selectivity of branched alkanes in the isomerization of hexane over typical zeolites. The selectivity for the isomerization (combined selectivity for branched alkanes which are sum of isomerization products including the lower alkane after the isomerization) was decreased in

![Figure 11](image1)

Fig. 11 Time-on-stream of catalytic activity over typical zeolites. Reaction conditions: catalyst: 1 g; temperature, 350°C; fed hexane, 2.29 mmol/min; carrier gas (N\textsubscript{2}), 0.89 mmol/min; W/F, 8.17 g/h/mol.

![Figure 12](image2)

Fig. 12 The selectivity of branched alkanes in the isomerization of hexane over zeolites. (a) in initial stage and (b) in similar conversion level. Reaction conditions: temperature 350°C; fed hexane, 2.29 mmol/min; carrier gas (N\textsubscript{2}), 0.89 mmol/min; W/F, 8.17 g/h/mol. Data was taken after 20 min from starting, (b) W/F, 8.17 (BEA and MWW), 0.52 (MFI) g/h/mol. Data: Conversion and selectivity: after 60 min from starting, coke deposition at 260 min time on stream. Legend: □: b-C6, □: b-C5, □: b-C4.
the following order: BEA>MWW>MFI at initial stages [Fig. 12(a)]. However, there is a possibility that the selectivity depends on the conversion; it is necessary to compare the selectivity at the similar level of the conversion to discuss their catalytic behaviors. Figure 12(b) shows selectivity for skeleton isomerization at ca. 13% of hexane conversion over BEA, MWW, and MFI by adjusting W/F, where data were taken after 60 min from starting: the similar change of the selectivities was observed in the similar conversion level. From these results, the selectivity for branched alkanes decreased in the order: BEA>MWW>MFI.

These catalytic properties of MWW in comparison with MFI and BEA are due to its pore structure and acid strength. MFI has the narrowest channels among the zeolites to result in the cracking as principal reaction. Because BEA has the largest channel and the weakest acid strength, the skeleton isomerization was predominant over cracking, and the deactivation occurs gradually by coke-formation. MWW has intermediate character of acid strength, and the space in the channels between MFI and BEA.

4. Conclusions

The crystallization of MCM-22 (MWW) zeolite was successfully enhanced by seeding in dry gel conversion (DGC) method. The phase selection depends on the gel composition during the synthesis, mainly OH/SiO$_2$ ratio and synthesis temperature. The addition of seeds accelerated the crystallization of MWW by DGC method: a small amount of seeds (0.25 mass% against SiO$_2$) enhances the formation of MWW to reduce the impurities and other phase, and the reduction of the crystallization time. The optimal SiO$_2$/Al$_2$O$_3$ ratio for the crystallization of MWW are around 30, and excess SiO$_2$ in higher gel composition with higher aluminum contents did not participate in the formation of MWW. The morphology of MWW by DGC method are aggregates sphere like crystal. The MWW obtained from optimal SiO$_2$/Al$_2$O$_3$ ratio gave higher surface area. The acid amounts also decreased with the SiO$_2$/Al$_2$O$_3$ ratio; however acid strength was almost in the same level for the MWW samples in this study.

The catalytic properties of MWW by DGC method were examined in the isomerization and the cracking of hexane, and compared with BEA, MFI, and MOR zeolites. The catalytic activities were in the order: MFI>BEA>MWW>MOR; however, the selectivity for isomerization were in the order: BEA>MWW>MFI>MOR. These catalytic properties are due to the differences of structures and acid strength of zeolites.

Seeding is one of the effective methods for synthesis of MWW by DGC method, and it can also be applied for other zeolite synthesis.

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