RESULTS AND DISCUSSION

Figure 1 (a) shows the cross-sectional image of the NaX beads. It is possible to identify the typical octahedral shape of the NaX crystals. Figure 1 (b) shows the top-view image of the NaX film grown in the one step of 6 h and 40 min. The film is not continuous and the NaX crystals look etched. Large sediments and hydroxysodalite (HS) crystals, probably originating from the combined effect of Al-leaching from the support and the thermodynamics of the system, were also observed. In order to minimize Al-leaching and sedimentation, a multiple step synthesis procedure was performed. Sediments and zeolite crystals other than NaX may be a disadvantage in PSA applications in terms of reduced separation performance. The synthesis duration of 6 h and 40 min was therefore divided in 5 steps of 1 h and 20 min.

Further investigations are needed in order to prove this hypothesis.

Table 1. Sample characteristics.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Synthesis duration</th>
<th>Film thickness (μm)</th>
<th>Weight gain (gzeolite/gsample)</th>
<th>CO2 ads. capacity (mmol/gsample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaX beads</td>
<td>6 x 1h 20 min</td>
<td>0.83</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Structured adsorbent</td>
<td>5 x 1h 20 min</td>
<td>1.5</td>
<td>0.036</td>
<td>0.19</td>
</tr>
</tbody>
</table>

* From BET analysis. 
1 From weight increase of the support after hydrothermal treatment.

Figure 2 (a, b) represent the cross-sectional images of the NaX film samples grown in one long hydrothermal treatment (a) and with the multiple step synthesis (b). The film thickness of the samples grown in 6 h and 40 min is lower (0.7 μm) than the one of the structured adsorbent grown in 5 steps (1.5 μm), although the weight gain of the two samples is of the same order of magnitude. This indicates that more sediments are deposited on the monolith after 6 h and 40 min, according to SEM observations.

Table 1 shows the sample characteristics of the NaX beads and structured adsorbent. The zeolite loading of the beads was 0.83 gzeolite/gsample, and was 23 times higher than the weight gain of the structured sample (0.036 gzeolite/gsample). This shows that the adsorption capacity of the structured sample should be about 23 times lower than the beads for any adsorption measurement, due to the lower amount of zeolite per gram sample of the former one.

Figure 3 shows the carbon dioxide isotherms at 0°C of the beads and structured adsorbent. As expected, the CO2 adsorption capacity of the structured adsorbent is 25 times lower than the one measured for the NaX beads. High cell density monoliths will lead to increased zeolite loading.

The pressure drop was measured at different air volumetric flow rates in a single PSA column for the structured adsorbent and the beads, and the results are shown in Figure 4. The pressure drop measured in the packed bed is 100 times higher than for the structured adsorbent, although the volume of the packed bed and the monolith is the same. This suggests that there is considerable scope to increase the monolith cell density and therefore increase the zeolite loading while still maintaining a lower pressure drop than that of a packed bed.

The results of this work suggest the potential of structured adsorbents as competitive alternative to traditionally used packed beds in PSA processes. The adsorption capacity of the structured adsorbents may be increased by growing thicker NaX films on the cordierite monoliths or by using substrates with a higher cell density. In addition, heat and mass transport phenomena in the film should be investigated and PSA cycles evaluated to explore the possibilities of these novel adsorbents.

Acknowledgements

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References


Figure 1. SEM top – view image of the NaX molecular sieve zeolite beads (a) and of the film grown on the cordierite support in one step of 6 h and 40 min (b) and 5 steps of 1 h and 20 min (c).

Figure 2. Cross - section image of the NaX film sample grown in one step of 6 h and 40 min (a) and in 5 steps of 1 h and 20 min on the 400 cpsi ceramic substrate (b).

Figure 3. CO2 equilibrium isotherm measured at 0°C on the NaX beads and the structured adsorbent.

Figure 4. Pressure drop measured on the NaX beads and the structured adsorbent.