High-efficiency non-thermal plasma catalytic performance of cobalt incorporated mesoporous MCM-41 for toluene removal

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Introduction

For the abatement of low-concentration VOCs, many researches have proved that combining a non-thermal plasma system with a catalyst could reduce the formation of by-products as well as increased the removal efficiency because of the synergy effect between plasma and catalysis. In order to improve the removal efficiency and carbon balance, it is still necessary to select an appropriate catalyst in a plasma system. Up to now, most of the catalysts were different metal oxides (such as Mn, Ag, Ni) deposited on traditional porous materials (such as alumina, TiO_2) prepared via impregnation method[1, 2]. However, the surface area of alumina or TiO_2 is limited, while preparing catalysts using impregnation method is easy to stop up the passageway of the support and even leads to an unequal active constituent distribution. The recent study of MCM-41 and its potential modification has drawn great interest in chemical engineering and environmental science[3].

The major objectives of this work are: 1, to prepare a series of cobalt incorporated mesoporous MCM-41 catalysts; 2, to degrade toluene by the obtained catalysts using non-thermal plasma catalytic

Materials and Methods

The Co-MCM-41 samples were synthesized by a direct hydrothermal method and the cobalt-loaded MCM-41 catalysts were prepared by impregnation method. The weight ratio of Co to MCM-41 was 2%. For non-thermal plasma catalytic tests: A dielectric barrier discharge reactor was used in the experiment[4].

Results and Discussion

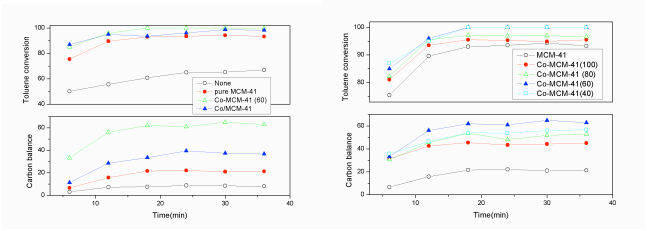
The main characteristics of as-prepared catalysts are summarized in Table. 1.

Table 1. Physicochemical characterization of MCM-41 and Co-MCM-41

CATALYSTS	d-spacing[a] (Å)	Unit cell Parameter[a] (Å)	Specific surface[b] area (m^2g^{-1})	Pore Size[b] (Å)	Pore Volume[b] (cm^3g^{-1})	Wall thickness (Å)
MCM-41	38.3	44.1	1118	35.0	1.14	9.1
Co-MCM-41(80)	38.5	44.3	958	36.2	0.89	8.1
Co-MCM-41(60)	38.9	44.8	843	36.8	0.83	8.0

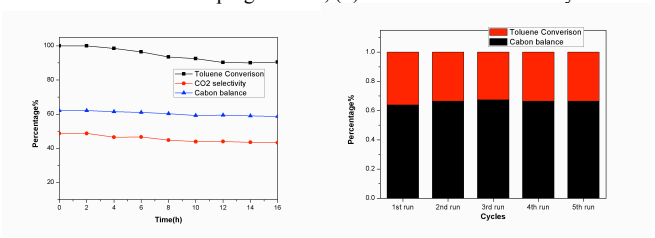
[a]- Values obtained from XRD studies
[b]- Calculated using the BJH method
[c]- Wall thickness = Unit cell parameter - pore size

The catalytic activity of the as-prepared MCM-41 and Co-MCM-41 catalysts (Fig. 2) was evaluated by toluene conversion and total carbon balance. Figure 3 investigate the stability of the Co-MCM-41 catalysts during the DBD plasma catalytic process.



(a) (b)

Fig. 2. Catalytic performance on toluene conversion and total carbon balance: (a)Effect of cobalt doping amount, (b) Effect of different catalysts



(a) (b)

Fig.3 Stabilty of the Co-MCM-41 samples: (a) Toluene conversions as a function of reaction time; (b) Influence of reused of Co-MCM-41 on toluene conversion and carbon balance

Significance

Highly well-ordered Co-MCM-41 samples were successfully synthesized by a hydrothermal method. Complete decomposition of toluene was achieved by a combining system with Co-incorporated mesoporous MCM-41 catalysts under conditions of room temperature and atmospheric pressure. Compared to the Co-loaded MCM-41 samples prepared by impregnation method, the Co-MCM-41 catalysts dramatically increased the toluene removal efficiency, carbon balance and CO_2 selectivity. The reason for this is the different presence of cobalt on the MCM-41 molecular sieve. Cobalt was highly dispersed in the silica framework in the Co-MCM-41 while cobalt on the Co-loaded MCM-41 samples existed as CoOx. The Co-MCM-41 catalysts also exhibited good stability during the DBD plasma catalytic process. This study undoubtedly proved that cobalt incorporated MCM-41 is a promising catalyst in the non-thermal plasma catalytic process.

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