Structured Metal-Zeolite Catalysts for the Catalytic Combustion of VOCs

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Introduction

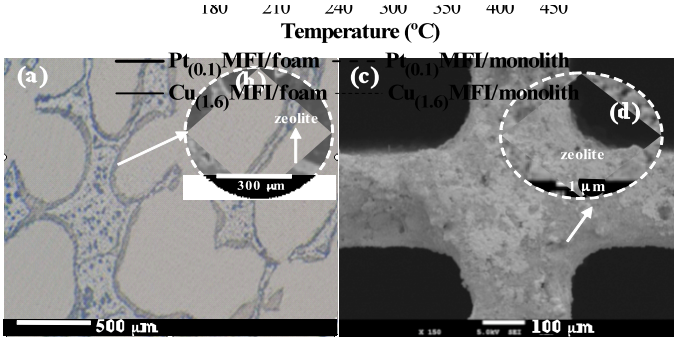
Volatile organic compounds (VOCs) primarily emitted from transportation sources, industrial printing and organic coating processes cause significant air pollution, becoming a strong driver for stringent environmental regulations. Catalytic combustion has become one of the most suitable ways for VOCs elimination [1]. Noble metals such as platinum and palladium (Pt, Pd), and transition metal (Cu, Co, Cr) supported on alumina, silica or zeolites have been widely explored as catalysts. Nonetheless, recent developments concerning the use of structured highly porous catalyst carriers, such as ceramic foams, proved to be a potential technological improvement in the efficiency of the catalytic combustion [2]. In this work, Pt and Cu-based MFI zeolites were supported on cordierite foams by a newly washcoating method [3]. Additionally, and for structural effects evaluation, conventional carriers such as cordierite monoliths were also washcoated. The structured catalysts were then catalytically evaluated for the toluene combustion, a representative aromatic VOC.

Experimental

A direct foaming method [4] was used to produce open-cell cordierite ($Mg_2Al_4Si_5O_{18}$) foams. Metal-based zeolite catalysts were prepared by ionic exchange of MFI zeolite (Si/Al =15), in order to introduce 1.6 wt.% of Cu and 0.1 wt.% of Pt into the zeolite. These catalysts were then supported on the ceramic foams using a newly developed washcoating method, described in detail elsewhere [3]. The same method was used for coating commercial cordierite monoliths (400 cpsi, from Corning). The final structured catalysts were named as $Cu_{(1.6)}$MFI/foam, $Cu_{(1.6)}$MFI/monolith, $Pt_{(0.1)}$MFI/foam and $Pt_{(0.1)}$MFI/monolith. These structured catalysts were characterised by means of optical microscopy, scanning electron microscopy (SEM), powder X-ray diffraction (XRD), chemical analysis and permeability. Catalytic performances were evaluated by toluene oxidation in a fixed bed reactor, performed under temperature programmed surface reaction conditions (TPSR) with an heating rate of 1ºC min^{-1} and an air flow of 15Lh^{-1} containing 800 ppm of toluene (GHSV=3965 h^{-1}).

Results and discussion

Open-cell cordierite foams formed by a highly porous cellular structure (porosity: 90 ± 2 %) [4], were successfully coated using a newly washcoating method. A typical optical micrograph of a zeolite-coating layer deposited on the foams surface is illustrated in Fig. 1 (a, b). It reveals homogeneous and tightly-adherent coating layers, with mean thickness between 35 to 44 μm for catalyst contents ranging from 5 to 12 wt.% [3]. The coating of cordierite monoliths (porosity: 80 ± 2 %), requires at least a second impregnation in order to achieve similar catalysts contents. Fig. 1 (c, d) illustrates a representative SEM micrograph of a coated monolith, revealing that uniform and well-adherent catalyst coating layers are also obtained for these supports.



(e)

Figure 1. (a, b) Optical micrographs of the zeolite coating distribution at the core of the foam; (c, d) SEM images of a zeolite-coated monolith, showing morphology details of the zeolite coating deposited its surface; (e) Toluene conversion into CO_2 on zeolite structured catalysts.

The catalytic performance of the prepared structured catalyst foams and monoliths was evaluated for the combustion of toluene, using a similar catalyst quantity (95 ± 5 mg). Both Pt and Cu-based structured catalysts evidenced a better catalytic behaviour for foam supports when compared to the coated monoliths (Fig.1 (e)), with a decrease of light-off temperature (T at 50% toluene conversion into CO_2) of about 10 ºC. The Pt-based catalysts also reveal higher CO_2 conversion relatively to the Cu-based ones, which is attributed to the higher activity of Pt and selectivity for CO_2. Furthermore, for the Cu-based catalysts the formation of CO and coke was also detected. Nonetheless, for CuMFI/foams higher conversions into CO_2 are obtained relatively to the CuMFI/monolith counterparts. The improvements obtained with the foam based catalysts are related to their highly porous structure that can provide some advantages when compared to conventional monoliths. Its structure enables higher radial mixing of gas through the pores, leading to enhanced mass/heat transfers performances [3].

Conclusions

Copper (Cu) and Platinum (Pt) based MFI catalysts supported on cordierite foams revealed promising catalytic behaviour for toluene combustion, when compared to conventional cordierite monoliths supports. The light-off temperature was found to decreases of about 10 ºC on foam catalysts. These improvements can be attributed to hydrodynamic and both axial and radial mixing/turbulence effects, provided by the tortuous network of the foam.

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