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Vanadium and titanium oxides on SBA-15 as model catalyst for the oxidative dehydrogenation of propane

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Introduction

Switching from crude oil to natural gas and renewables as feedstock for the production of commodity chemicals in the coming decades is a significant and challenging task. In petrochemistry today, short-chain olefins are key intermediates, which are mainly produced by energy demanding processes, such as thermal or catalytic cracking of crude oil fractions. An alternative, forward-looking route for the synthesis of olefins is the oxidative dehydrogenation (ODH) of alkanes. To avoid total oxidation and to achieve high olefin selectivity, which is an essential requirement for industrial application, it is necessary to understand the reaction mechanism and to elucidate relations between structural and electronic characteristics of the catalyst surface and the catalytic performance. Vanadium containing catalysts have been studied extensively in ODH of propane [1]. Very selective catalysts have been synthesized by supporting vanadia on mesoporous silica (SBA-15 or HMS) [2]. However, the hydrolysis of V-O-Si bonds that leads to oligomerisation and segregation of vanadia is a major problem with the silica support. The nature of the support strongly influences the catalytic properties giving rise to the assumption that the oxygen atom in the V-O-support moiety may be involved in the catalytic cycle [3]. In the present work, we have studied the vanadia-support-interaction by modifying SBA-15 with titania.

Results and discussion

We have modified well-defined mesoporous silica (SBA-15) with either titania or vanadia, synthesizing two series of catalysts containing 1-20 wt.-% of the metal. Moreover, the vanadium content has been varied using Ti/SBA-15 with different titania loadings as support. The comprehensive catalyst matrix required the availability of well-defined SBA-15 in large scale to avoid batch effects of the SBA-15 support, because the pore width and thickness of the framework walls of SBA-15 strongly depend on the synthesis conditions. The controlled and reproducible synthesis of SBA-15 in large amounts has been successfully achieved in an automated laboratory reactor that allows for an accurate control of the synthesis conditions [4]. In the present study we have synthesized catalysts *via* wet impregnation with vanadium and titanium alkoxides. The catalysts were characterized using a variety of techniques including nitrogen adsorption/desorption, transmission electron microscopy, X-ray diffraction (XRD), thermal analysis (TGA), X-ray fluorescence analysis (XRF), UV-vis and Raman spectroscopy. Discrimination of the different surface metal oxide species was addressed studying NH_3-adsorption by FTIR spectroscopy (Fig. 1). The catalysts were tested in the ODH of propane varying the reaction conditions in a broad range. The structure-reactivity relationships will be discussed.

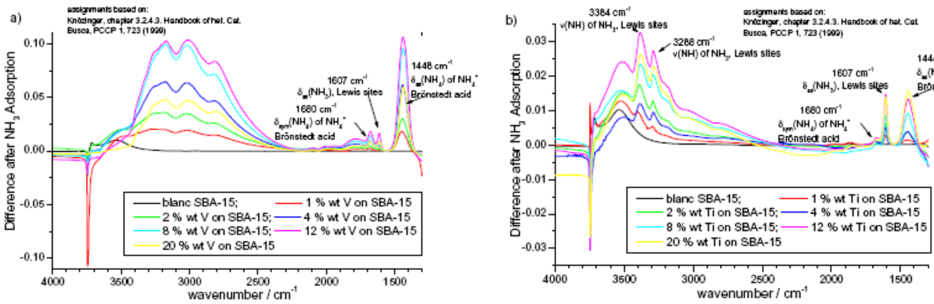

Fig. 1: IR spectra of NH_3-adsorption on vanadium oxide (a) and titania (b) on SBA-15.

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