Structure of alumina supported vanadia catalysts for oxidative dehydrogenation of propane prepared by flame spray pyrolysis

A series of five vanadia on alumina catalysts for oxidative dehydrogenation of propane to propene were synthesized by flame spray pyrolysis (FSP) using vanadium(III)acetylacetonate and aluminium(III)acetylacetonate dissolved in toluene as precursors. The vanadium loading was 2, 3, 5, 7.5 and 10wt.%. The catalysts were subsequently characterized by BET surface area, X-ray diffraction (XRD), Raman, UV–vis diffuse reflectance and X-ray absorption spectroscopy (XAS) as well as measurement of the catalytic performance. The catalysts had specific surface areas from 143 to 169 m²/g corresponding to average particles diameters from 9.0 to 10.9nm and apparent vanadia surface densities from 1.4 to 8.4 VOₓ/nm². The only crystalline phase detected by XRD was γ-Al₂O₃, except at 10wt.% vanadium where traces of crystalline vanadia were observed. Raman spectroscopy showed vanadia monomers at 2 and 3wt.% V (1.4 and 2.1 VOₓ/nm²), a mixture of vanadia oligomers and monomers at 5wt.% V (3.6 VOₓ/nm²) and mainly oligomers at 7.5 and 10wt.% V (6.0 and 8.4 VOₓ/nm²). Diffuse reflectance UV–vis and extended X-ray absorption fine structure (EXAFS) spectroscopy measurements supported the results of Raman spectroscopy. In situ X-ray absorption near edge structure (XANES) spectroscopy showed that the vanadia can be reduced when operating at low oxygen concentrations. The catalyst performance was determined in fixed bed reactors with an inlet gas composition of C₃H₈/O₂/N₂=5/25/70. The main products were propene, CO and CO₂, with traces of ethene and acrolein. Comparing propene selectivity as function of propane conversion the most selective catalysts were the 2 and 3wt.% V samples, which contained mostly vanadia monomers according to Raman spectroscopy. The best propene yield of 12% was obtained with the 2wt.% vanadium catalyst while the best space time yield of 0.78gpropene/(gcat·h) at 488°C was obtained with the 3wt.% V catalyst.