Using Ion-beam Sputtering to modify Heterogeneous Nanodispersed Catalysts

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Introduction

Ion beam engineering is one technique which is used for the development of such technically advanced materials[1]. This work shows how ion beam sputtering can be used to controllably modify the surface of solid heterogeneous catalysts. By strategically manipulating the surface nanostructure of the materials, their catalytic performance and resistance to aging can be enhanced. This can also reduce the noble metal substitution on the catalysts oxide support[2]. The technique has been investigated using a $Pt/Ce_{0.5}Zr_{0.5}O_2$ catalyst; a conventional emission control catalyst used on mobile combustion engines[3][4]. The technique has been studied by changing different parameters of the ion beam to understand how they independently effect the catalyst. Modeling of the treatment has also been introduced to the describe erosion of the surface through ion sputtering, and how this is influenced by the type of ion used, the number of doses and the current of the ion beam.

Materials and Methods

A sample of Pt (1% w/w) $Ce_{0.5}Zr_{0.5}O_2$ was commercially sourced. Three samples were then bombarded with N^+ ion beams with an energy of 1.5KeV, a current of 20mA and an incident angle of 28˚ to the catalyst surface. The samples are denoted as Pt1.5(***X***), where ***X*** represents the number of times the sample was treated. The samples were mechanically agitated between each dose to expose fresh surfaces. The treated samples were compared with an untreated sample, denoted as 'Fresh'. Catalytic testing was carried by using a reaction mixture composed of 10% O_2, 4.5% H_2O, 2000ppm of each CO, CH_4, C_3H_6, and 200ppm NO with a total flow of 100ml/min. The temperature was increased from 303K to 773K at a rate of 5K/min. This cycle was repeated three times to test the stability of the catalyst. The outlet from the reactor was analysed using an online Pfeiffer Vacuum quadrupole mass spectrometer. Extended X-ray Absorption Fine Structure (EXAFS) tests were carried out at Diamond Light Source Ltd. UK, using fluorescence mode on beamline B18. Spectra were collect at the Pt L_3-edge on each of the samples to investigate the size and distribution of the Pt nanoparticles on the catalyst surface.

Results and Discussion

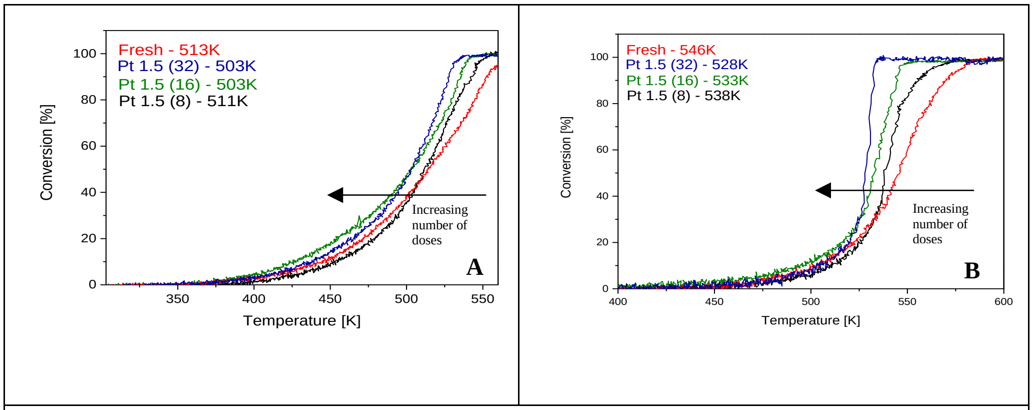

Figure 1. CO conversion (A) and C_3H_6 conversion (B) as a function of temperature for the Pt (1% w/w) $Ce_{0.5}Zr_{0.5}O_2$ fresh and traeted with different ion doses (8-16-32).

The catalytic activity was assessed and the results are reported in terms of CO and C_3H_6 conversion in fig. 1. The results show that the catalyst showed improved catalytic activity for oxidation of both CO and C_3H_6 after ion bombardment. The temperature at which 50% conversion was achieved (T_{50} values) for CO oxidation were 503K, 503K and 511K for Pt1.5(32), Pt1.5(16) and Pt1.5(8). This shows reduction of up to 10K for CO oxidation compared to the untreated sample Pt Fresh, which had a T_{50} values of 513K. The T_{50} values for C_3H_6 oxidation over Pt1.5(32), Pt1.5(16) and Pt1.5(8) were 528K, 533K and 538K respectively; a reduction of up to 18K compared to C_3H_6 T_{50} observed with Pt Fresh, which was 546K.

The results are in line with EXAFS Fourier transform analysis, which revealed that the sample, after ion bombardment, is characterized by a distribution of Pt nanoparticles which is decreasing with the intensity of the bombardment, as well as by the formation of atom vacancies and incomplete terraces (HRTEM and H_2 reduction FTIR studies).

Significance

The results show that Ion beam irradiation can be used as a method for the manipulation of the surface properties of the material, and thus the enhancement of its catalytic properties, lowering the temperature at which the material is active. This opens up the idea of using ion bombardment as a useful tool for the controlled processing of nanodispersed heterogeneous catalytic materials.

References

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