

# Heat-Treatment Control during Preparation of V<sub>2</sub>O<sub>5</sub>/TiO<sub>2</sub> Catalysts for H<sub>2</sub>S Abatement

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## INTRODUCTION

Hydrogen sulfide (H<sub>2</sub>S) generated from landfills or chemical processes is harmful to environmental and human health. Vanadium pentoxide (V<sub>2</sub>O<sub>5</sub>) is an effective active metal oxide for selective oxidation of H<sub>2</sub>S, which has led to the extensive investigation of vanadium-based catalysts for desulfurization (Soriano, López et al., 2012). Moreover, TiO<sub>2</sub>-supported vanadia catalysts exhibit much higher sulfur yield than those of bulk V<sub>2</sub>O<sub>5</sub> and the other vanadium oxide catalysts supported with alumina or zirconium oxide (Li and Chien, 1999).

Heat-treatments can increase the concentration of oxygen vacancy on the catalysts surface under reducing atmospheres. This reduces the valence state of the active species, inducing the formation of surface oxygen vacancies. In this study, the influence of heat-treatment conditions, including atmospheric gas and temperature, is investigated to determine an effective heat-treatment step during the preparation of V<sub>2</sub>O<sub>5</sub>/TiO<sub>2</sub> catalysts for selective oxidation of H<sub>2</sub>S.

## MATERIALS AND METHODS

### Catalyst preparation and performance evaluation

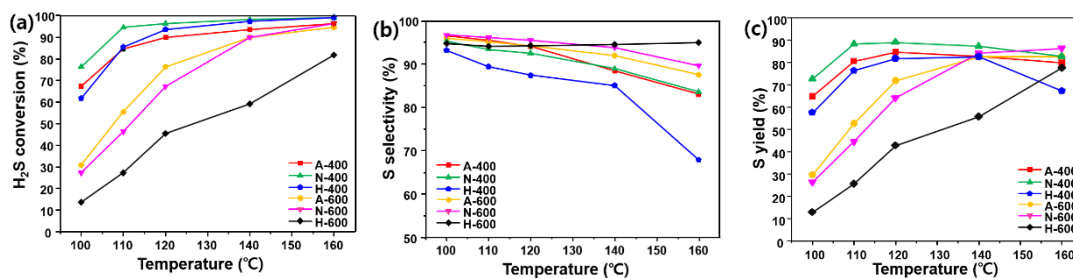
A series of V<sub>2</sub>O<sub>5</sub>/TiO<sub>2</sub> catalysts was prepared using a typical wet impregnation method using ammonium metavanadate as a vanadium precursor and the TiO<sub>2</sub> powder. The heat-treatments were performed on the sample using a tube furnace with different atmospheres (Air, N<sub>2</sub>, and H<sub>2</sub>) and temperatures (400 and 600 °C). Catalytic activities of H<sub>2</sub>S selective oxidation were investigated using a conventional fixed-bed reactor system. A gas mixture with the H<sub>2</sub>S concentration of 1.0 vol% was used as a reaction gas, and the total flow rate was 250 mL/min, corresponding to a gas hourly space velocity (GHSV) of 75,000 mLg<sup>-1</sup>h<sup>-1</sup>.

## RESULTS AND DISCUSSION

### Catalytic performance of the different samples

Catalytic activities of the various catalysts were investigated within the temperature range of 100–160 °C; the results are presented in Figure 1. The H<sub>2</sub>S conversion performance decreases in the following order: N-400 > H-400 > A-400 > A-600 > N-600 > H-600 (Figure 1(a)). The H<sub>2</sub>S conversion of N-400 exhibits 76% at 100 °C and reaches 99% at 160 °C. Figure 1(b) shows the sulfur selectivity of all the catalysts along with the temperature. Contrary to the H<sub>2</sub>S conversion, the sulfur selectivity decreases by elevating the reaction temperature. Figure 1(c) shows the curves of sulfur yield with respect to temperature. The varying yield trends for the catalysts heat-treated at 400 °C are different from those of H<sub>2</sub>S conversion; the sulfur yields are

maximum at 120 or 140 °C, and then decreases after that.



**Figure 1 Catalytic performance on (a) H<sub>2</sub>S conversion, (b) sulfur selectivity, and (c) sulfur yield for different catalysts**

The catalytic performance of V<sub>2</sub>O<sub>5</sub>/TiO<sub>2</sub> catalysts can be understood considering redox properties. Re-oxidation of the reduced vanadia by gas-phase oxygen is the rate-determining step. The highest portion of O<sub>ads</sub> in N-400 indicates that O vacancies on the surface of the partially reduced V<sub>2</sub>O<sub>5</sub> facilitate the re-oxidation rate of N-400. Moreover, the reducibility from V<sup>5+</sup> to V<sup>4+</sup> also plays an important role in catalytic performance. The H<sub>2</sub>-TPR result shows excellent reducibility of N-400 with the highly dispersed V<sub>2</sub>O<sub>5</sub> species that are readily reducible compared to the aggregated V<sub>2</sub>O<sub>5</sub>. The dispersion of V<sub>2</sub>O<sub>5</sub> on TiO<sub>2</sub> support is related to the degree of V-Ti interaction. The strong metal oxide-support interactions promote the high dispersion of vanadia and favor the formation of an oxygen vacancy by improving electron transfer between active metal and support oxides. Additionally, the V-Ti interaction is enhanced when anatase TiO<sub>2</sub> is used; however, the rutile TiO<sub>2</sub> phase induces weak interaction. The results of XRD, XPS, and FT-IR showed that the heat-treatment with 600 °C transforms anatase TiO<sub>2</sub> into a rutile phase irrespective of atmospheres. Moreover, the maximally reduced temperatures of the dispersed V<sub>2</sub>O<sub>5</sub> are higher in the 600 °C-treated catalysts, suggesting the decreased reducibility. Finally, the presence of rutile TiO<sub>2</sub> in the V<sub>2</sub>O<sub>5</sub>/TiO<sub>2</sub> catalyst can contribute to the low reducibility related to the poor catalytic performance.

## CONCLUSION

The different characteristics of the catalysts result in the different catalytic performance of H<sub>2</sub>S removal. N-400 shows the highest performance among the six catalysts, which is attributed to the proper heat-treatment conditions: mild reducing gas and temperature forms partially reduced vanadia and strong V-Ti interaction by anatase phase, which facilitates a high portion of oxygen vacancies on the surface of N-400.

## ACKNOWLEDGEMENT

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