Improvement of Preparation of a Microfabricated $\alpha$-Sb$_2$O$_4$/VSbO$_4$ Model Catalyst by Electron Beam Lithography and This Reaction

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1. Introduction

Most of catalytic reactions on a heterogeneous catalyst surface are generally understood as being controlled by nature of active sites at the surface. However, Delmon et al. proposed the remote-control mechanism where the several different natures on reaction sites interacted with each other to build a role of active sites [1]. $\alpha$-Sb$_2$O$_4$ phase in itself is not activity but it activate gas phase oxygen. And its oxygen activate VSbO$_4$ phase through a spillover process, and continuously creates active and selective sites on VSbO$_4$ phase. If this concept is correct, catalytic activity depends on the physical phase’s size, shape, and their arrangements. But there has been no proof for the concept yet, and basically it is difficult to control these physical parameters with powder form. In this report, we prepared a microfabricated $\alpha$-Sb$_2$O$_4$/VSbO$_4$ model catalyst with thin film form, by electron beam lithography (EB) [2]. We used home built reaction analysis chamber for propene selective oxidation reaction on the model catalyst. We have obtained preliminary data for the proof of phase interaction occurred on the $\alpha$–Sb$_2$O$_4$/VSbO$_4$ system. The results showed one knowledge, lead to a new catalytic research method and new types of catalysts.

2. Experimental

Fig. 2 shows the preparation method of a microfabricated $\alpha$-Sb$_2$O$_4$/VSbO$_4$ model catalyst. Step 1: The V–Sb-O sol solution was prepared by sol-gel method. Step 2: The V-Sb-O sol solution was deposited onto the Si substrate by spin coating. And the sample was calcined in air at 773K. Step 3: Sb$_2$O$_3$ powder was evaporated and deposited on the VSbO$_4$ sample. The sample was calcined in air at 673K to oxidize Sb$_2$O$_3$ to $\alpha$-Sb$_2$O$_4$. Step 4: The EB resist was deposited on the sample by spin coating. The sample was exposed to an electron beam to draw stripe pattern. And the resist pattern was developed and rinsed. At the stage, some parts of $\alpha$-Sb$_2$O$_4$, was unexposed to the surface. Step 5: The...
sample was sputtered by Ar+. Then the $\alpha$-Sb$_2$O$_4$ under the resist was not removed (the EB resist was sputtered) and $\alpha$ - Sb$_2$O$_4$ under nothing was removed until V$\text{SbO}_4$ appeared. The prepared model catalyst was characterized by XRD, XPS, AFM and SEM, which showed that the $\alpha$-Sb$_2$O$_4$/V$\text{SbO}_4$ system was structurally an compositionally similar to the powder form. However, the model catalyst has very small surface area compared to the powder form, only a very small amount of reaction products could be observed. Therefore, reaction experiments in lower background pressure to detect such a small amount of reaction products. We also adopted pulse reaction gas analysis method to enhance the signal to noise ratio.

3. Results and Discussion

We prepared model catalysts with distance between $\alpha$-Sb$_2$O$_4$ phases of 2.0$\mu$m, 4.0$\mu$m, 16.0$\mu$m, 32.0$\mu$m confirmed that model catalysts were precisely fabricated in accordance with our original design parameters by SEM and tapping-mode AFM. And we acquired preliminary reaction data. Fig. 3 shows that distance between $\alpha$-Sb$_2$O$_4$ phases of affects the catalytic activity of propene selective reaction. The smaller separation increases the catalytic activity. Interestingly, the 2.0$\mu$m of distance between $\alpha$-Sb$_2$O$_4$ phases shows lowest catalytic activity. The phenomenon is unexplained by traditional theory. The results suggested that the possibility of controlling catalytic activity by designing the physical phase’s size, shape, and their arrangement by electron beam lithography.

4. References

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