



Study of catalytic decomposition of formaldehyde on Pt/TiO₂ alumite catalyst at ambient temperature

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ABSTRACT

Formaldehyde (HCHO) emitted from buildings, furnishing materials and consumer products is one of the most dominant volatile organic compounds (VOCs) in an indoor environment. In this work, a Pt/TiO₂/Al₂O₃ catalyst was prepared on an anodic alumite plate and was employed in the catalytic decomposition of formaldehyde at ambient temperature. Firstly, TiO₂ was deposited on the anodic alumite plate with electro-deposition technology. Then, platinum was supported on the anodic alumite plate with wet impregnation method. The developed catalyst exhibits good activity towards the decomposition of HCHO at ambient temperature. TPR (temperature programmed reduction) and TPD (temperature programmed desorption) analysis results indicate that oxygen adsorbed on the Pt/TiO₂/Al₂O₃ catalyst can be activated and generated to O:Pt_{surface} species quickly at ambient temperature. Hence, the developed catalyst experiences the high activity towards the catalytic decomposition of formaldehyde at ambient temperature.

Moreover, in accordance with the process requirements, the developed catalyst can be formed into various shapes such as a mesh, plate, fin, serrate etc., because aluminum can be formed into any shapes. The serrate type catalyst was prepared in this work and it also exhibits fine activity towards the decomposition of HCHO.

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1. Introduction

The indoor environment plays an important role in human health, because people generally spend more than 80% of their time in indoors, which contributes a higher risk from inhalation of pollutants than outdoors. In 1995, USEPA identified indoor air pollution is one of the top environmental risk. In general, three methods are suggested to improve indoor air quality, namely source control, increase ventilation and air cleaning [1]. Formaldehyde (HCHO) emitted from buildings, furnishing materials and consumer products is one of the most dominant volatile organic compounds (VOCs) in an indoor environment. HCHO is known to cause nasal tumors, irritation of the mucous membranes of the eyes and respiratory tract, and skin irritation. Due to growing concern over the major presence of this material inside buildings, the abatement of HCHO is of significant practical interest at low temperature, especially at room temperature [2–11]. A number of studies, related to the removal of HCHO by adsorbents, have been carried out both in

lab and in the field. However, the effectiveness of the removal materials was limited for a short period due to their removal capacities. The catalytic decomposition of formaldehyde at room temperature is a promising technology, because there is no need to employ a heater in the reactor, and the equipment is sufficiently stable in the presence of the catalyst. Recently, Álvarez-Galván et al. [2] developed a Mn-Pd catalyst for HCHO catalytic decomposition at 353 K. Zhang et al. [4–6] reported that HCHO could be completely oxidized into CO₂ and H₂O over a 1 wt% Pt/TiO₂ catalyst. Shen and co-workers [7,8] developed Au catalyst on FeO support. The catalyst exhibits fine catalytic activity at 353 K. However, it is known that the reactors with powdered or granular catalysts experience a very high pressure-drop. Furthermore, these powdered or granular catalysts cannot be formed into any shapes and cannot be readily used in indoor equipment such as air-conditioners or air-cleaners. Hence, structured catalyst is favorable because of its low pressure-drop, and forming property [12–14]. Recently, the catalysts supported on structured anodic alumite supports have been developed successfully in our group [15–20]. For example, the Pt catalyst has been developed on the support successfully and has been applied in the reactor for VOCs' catalytic combustion. The developed Ni catalyst was used in ethanol steam reforming reaction. These catalysts can be formed into any shape such as a mesh, fin, plate and serrate because aluminum has fine forming property.

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Thus, a Pt/TiO₂/Al₂O₃ catalyst will be prepared on the anodic alumite support in this work. Firstly, TiO₂ was supported on the anodic alumite plate via the electro-deposition technology [15–17]. Then, platinum was supported on the plate with wet impregnation method. The developed catalyst was then tested by performing the catalytic decomposition of formaldehyde at ambient temperature. The test result shows that the developed catalyst exhibits fine catalytic activity and no harmful products are generated in the reaction. H₂-TPR and O₂-TPD analysis results show that oxygen can be adsorbed and dissociated up to O:Pt_{surface} species quickly on the surface of the developed Pt/TiO₂/Al₂O₃ catalyst at ambient temperature, which brings the high catalytic activity for the developed catalyst.

A kind of structured Pt/TiO₂/Al₂O₃ catalyst was also prepared in our group with the developed technology. The developed serrate type catalyst exhibits fine activity towards the decomposition of HCHO.

2. Experimental

2.1. Catalyst preparation

A catalyst support was prepared by anodization of a 4 × 8 cm² (0.3 mm thick) aluminum plate (JIS A1050). Each plate was first rinsed with acetone and degreased in an aqueous solution of 20 wt% NaOH for 3 min at room temperature, then successively washed again with deionized water and immersed in a 30 wt% HNO₃ solution for 1 min at room temperature. The plate was washed again with deionized water and dried. The treated plate was then oxidized as the anode in an oxalic solution against a cathodically polarized graphite plate counter-electrode. The solution was controlled at a constant temperature of 293 K, while the oxalic concentration was set at 4 wt%. The distance between the two electrodes was set at 8 cm. Under a direct current density of 50 A m⁻², the anodic oxidation was carried out for 4 h. After, the plate was dried at an ambient temperature for 12 h and then calcined in air at 623 K for 1 h to decompose the residual oxalic in the film. Then, in order to increase the BET-area of the support, the support was exposed to hot water treatment (HWT). The support was immersed in deionized water at 353 K for several hours. After the treatment, the support was dried at ambient temperature for 4 h and then calcined in air at 773 K for 3 h. Finally, the dried support was stored in a desiccator prior to use in the experiments.

TiO₂ was supported on the anodic alumite plate by using the electro-deposition technology [15,16], where the support was soaked in (NH₄)[TiO(C₂O₄)₂] solution at ambient temperature and employed as one electrode against a stainless steel plate counter electrode at a distance of 2 cm for several minutes. The power (50 Hz, 110 V) used in the experiment, was regulated with a voltage regulator to maintain a low constant voltage. Once supported, the plate was dried at 298 K for 4 h, and then calcined in air at 773 K for 3 h. The modified support was immersed in H₂PtCl₆ solution of concentration 1 g L⁻¹ at 298 K for 1 h to support platinum. The pH of the solution was adjusted at 11.4 with NH₃·H₂O. Lastly, the plate was dried at 298 K for 4 h, and then calcined in air at 773 K for 3 h.

2.2. Catalyst characterization

In this study, the anodic alumite film was observed and the thickness of the film was measured under an optical microscope. The specific surface area and pore distributions could be obtained via a nitrogen adsorption method (SA3100, Beckman Coulter Inc.), where the outgas conditions were set at 573 K for 1 h. An inductively-coupled plasma spectrometer (ICPS-7510, Shimadzu Corp.) was

used to measure the platinum and titanium loading after the catalysts were dissolved in nitrohydrochloric acid. The element distributions on the anodic alumite film were analyzed with an electron probe microanalysis analyzer (EPMA) (JXA-8900M, JXOL Ltd.). Surface micrographs of the catalysts were taken with a field-emission scanning electron microscope (FE-SEM) (S-4800, HITACHI Ltd.). Platinum dispersion and average size of the particles could be measured by CO-pulse adsorption, where pre-treatment conditions were set at 373 K for 30 min in 70 mL min⁻¹ nitrogen gas, and then at 673 K for 30 min in 70 mL min⁻¹ helium gas. Sample reduction was carried out at 673 K in 70 mL min⁻¹ hydrogen gas for 1 h. Finally, the sample was cooled in 70 mL min⁻¹ helium gas. Based on the amount of CO adsorbed and assuming an adsorption stoichiometry of CO:Pt = 1:1, the metal dispersion was obtained. H₂-TPR (temperature programmed reduction) was applied to analysis the interaction between the supported Ti atoms and Pt atoms. Firstly, the sample was oxidized at 773 K with air and then was cooled to room temperature in argon gas. Lastly, the sample was reduced in 50 mL min⁻¹ H₂/Ar gas. The heating-rate was set at 5 K min⁻¹. O₂-TPD was applied to analysis the oxygen adsorption amount and the interaction between oxygen and the surface of catalyst. Firstly, sample was dried in helium gas at 773 K for 1 h and then was reduced by H₂. Then the sample was cooled to 298 K in helium gas. The adsorption of oxygen was carried out for 30 min at 298 K in O₂/He gas (with 35 % O₂). Lastly oxygen was desorbed in 70 mL min⁻¹ helium gas. The heating-rate was set at 10 K min⁻¹.

2.3. Activity experiments

In this work, air from a compressor flowed into a saturator that was filled with formaldehyde solution (concentration of formaldehyde is 35% and 5% methanol is used as stabilizer in the solution) and then mixed with the formaldehyde stream that was evaporated from the solution. The mixed stream was then fed into a reactor. The concentration of formaldehyde in the mixed gas was 100 ppm, as adjusted by the temperature of saturator which was set at ~283 K in the work. The catalyst (2 × 2 cm² cut into pieces 2–4 mm²) diluted with 4 g quartz sand (30–50 mesh, Kishida Chemical Co., Ltd.) was packed into a straight-tube Pyrex reactor with an i.d. of 10 mm. The upper and lower parts of the reactor were filled with quartz fibers. The reactor was then placed inside an electric furnace. A K-type thermocouple was placed in the centre of the catalytic bed to record the reaction temperature and control the furnace. The reactant flow rate was about 120 mL min⁻¹ under atmospheric pressure. Since the activity experiments were carried out at ambient temperature, the adsorption of HCHO on catalysts cannot be avoided, hence the outlet concentration was analyzed after the adsorption reaches saturate. Both reactants and products were analyzed using a gas chromatograph (GC-390B, GL Sciences Inc.) equipped with a flame ionization detector (FID) and platinum catalyst converter, which was used for converting the formaldehyde quantitatively into methane in the presence of hydrogen prior to being analyzed by the detector. The conversion of formaldehyde was calculated using the degree of formaldehyde consumption.

3. Results and discussion

3.1. Effect of HWT on catalytic activity

As shown in Fig. 1(a), the anodic alumite film can be thought of as a series of parallel tubes with smooth pore walls. This results in a relatively low surface area. Therefore, the HWT technology was applied to increase the BET-area of the support. The HWT time was set to 0, 30, 60 and 120 min. In the HWT process, the alumina in

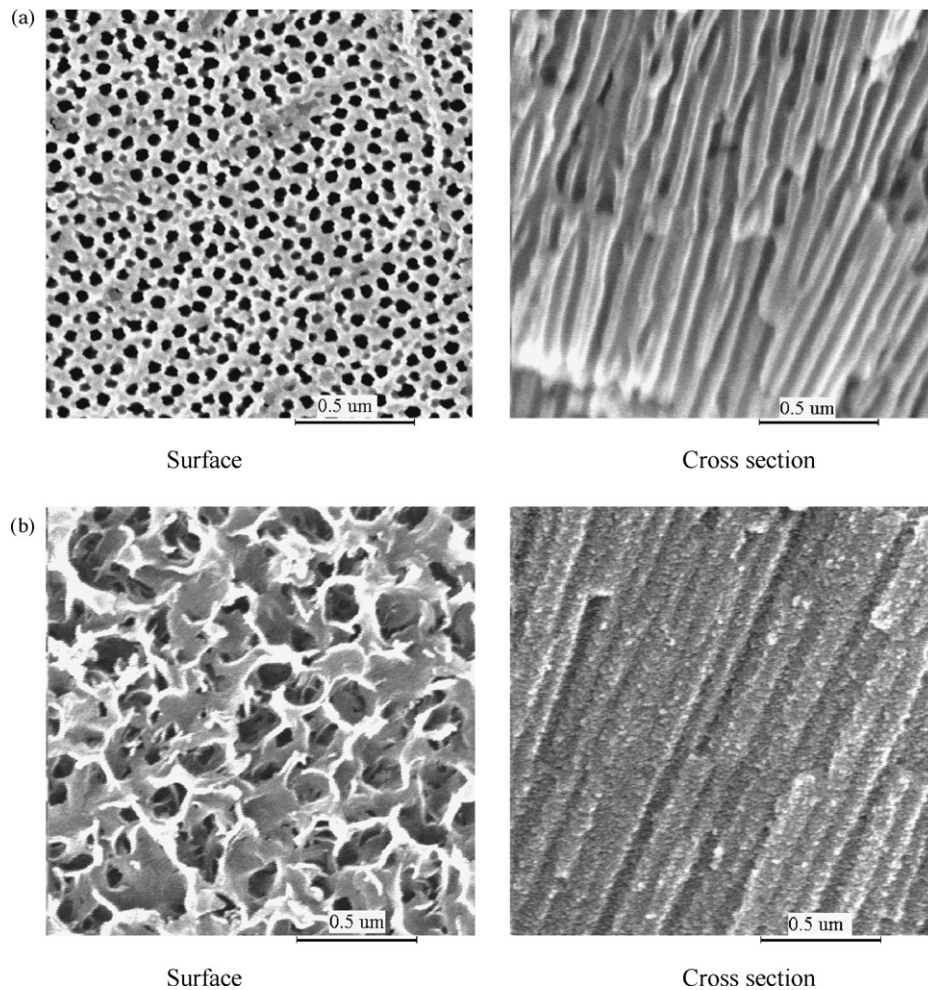


Fig. 1. Micrograph of anodic alumite film. (a) Before HWT (b) after HWT.

the anodic alumite film reacts with hot water to form hydrated alumina (i.e. $\text{Al}_2\text{O}_3 + n\text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$), and further gelatifies into hydrated alumina sol. The sol accumulates on the main pore skeleton formed after anodization. As shown in Fig. 1(b), after the calcinations at 773 K, the main pore skeleton formed after anodization is packed by alumina particles. The transformation of the film structure increases the BET-area of the support. From Table 1, it can be found that the anodic alumite film prepared without HWT treatment has the lowest BET-area of $16.5 \text{ m}^2 \text{ g}^{-1}$. After HWT treatment, the increase in the BET-area of the support is very obvious. Cat 4 has the BET-area of $164.1 \text{ m}^2 \text{ g}^{-1}$. Moreover, Table 1 also indicates that the BET-area of the support increases with the HWT time increased and it increases very slowly when HWT time exceeds 1 h.

Under the same preparation conditions, the Pt/TiO₂/Al₂O₃ catalysts were supported on the anodic alumite plate after HWT. The properties of the developed catalyst also are expressed in Table 1 which shows that Ti loadings of these catalysts are about 0.15 g m^{-2} , are almost identical and platinum loadings increase with the HWT time increased. The platinum loading of Cat. 1 is about 0.62 g m^{-2} and that of Cat. 4 is about 1.26 g m^{-2} . In our previous research [20], it has been proved that the metal loading will be determined by the electrical current according to the Faraday's law when the electro-deposition technology was applied. The conditions in the electro-deposition process of Ti were identical, hence there is no difference in the Ti loading of the developed catalysts. During the Pt impregnation process, the metal loading is determined by the interface conditions between the solid and the solution. The higher

Table 1
Properties of the developed catalysts.

Catalyst no.	Catalyst	HWT time [min]	BET-area [m^2/g] [*]	Pt dispersion [%]	Metal loading [g/m^2] ^{**}	
					Pt	Ti
Cat. 1	Pt/TiO ₂ /Al ₂ O ₃	0	16.5	13.8	0.62	0.15
Cat. 2	Pt/TiO ₂ /Al ₂ O ₃	30	105.3	20.1	1.19	0.15
Cat. 3	Pt/TiO ₂ /Al ₂ O ₃	60	140.2	23.1	1.25	0.15
Cat. 4	Pt/TiO ₂ /Al ₂ O ₃	120	164.1	24.6	1.26	0.15
Cat. 5	Al ₂ O ₃	120	202.4	–	–	–
Cat. 6	Ti/Al ₂ O ₃	120	186.2	–	–	0.15
Cat. 7	Pt/Al ₂ O ₃	120	192.5	32.7	1.32	–

^{*} Calculation based on Al₂O₃ mass only.

^{**} Calculation based on the surface area of the catalyst.

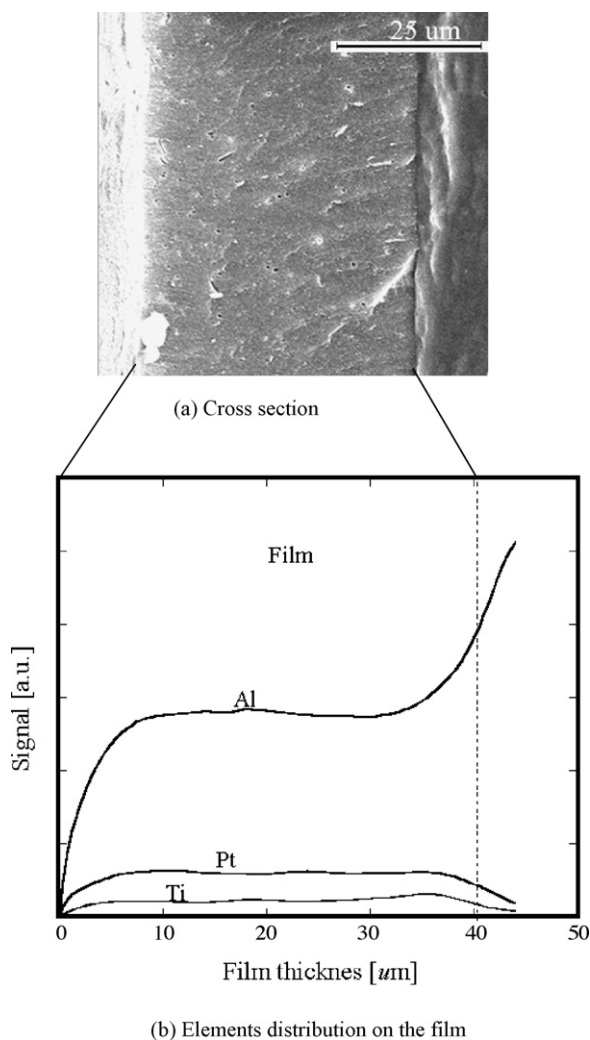


Fig. 2. Distributions of elements on the anodic alumite film.

BET-area in support will result in higher interface between the support and platinum solution. Therefore, Cat. 4 has the highest platinum loading. The dispersion of platinum was also analyzed and the result is also expressed in Table 1. It was observed that the dispersion of platinum on the developed catalysts increases with the HWT time increased. The dispersion of Cat. 1 is only 13.8% and it increases to 24.6% when the HWT time is increased to 2 h. Hence, it also can be concluded that the high BET-area surface will bring the high dispersion of platinum.

The element distributions on the anodic alumite film were analyzed by EPMA and the results are set out in Fig. 2, which shows that Ti and Pt were not supported on the surface only; the elements were uniformly distributed on the film from the film bottom to the film surface. It also indicates that the supporting methods in this work are suitable for the catalyst preparation.

The catalytic decomposition reaction of HCHO was used to evaluate the catalytic activity of the developed catalysts. The obtained results are expressed in Fig. 3 which shows the conversion on Cat. 1 is only about 71.4% and it on Cat. 4 is about 92.4%. It also can be found that the conversion increases with the HWT time.

Hence it can be concluded that the BET-area of the support increases greatly after the HWT treatment. The catalyst supported on the support with high BET-area has high platinum loading and high platinum dispersion, which results in the fine catalytic activity towards the catalytic decomposition of HCHO at ambient temperature.

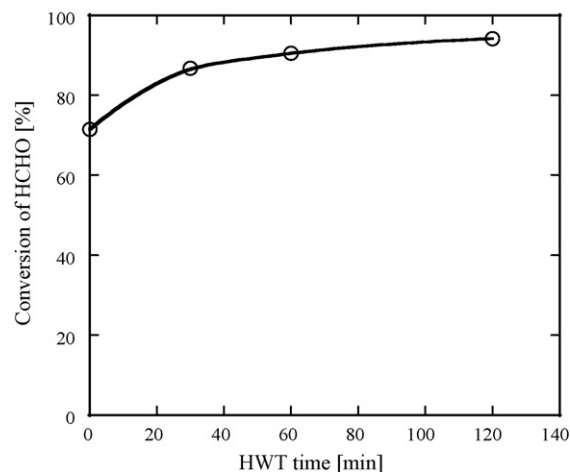


Fig. 3. Effect of HWT time on catalytic activity. (HCHO: 100 ppm; reaction temperature: 303 K).

3.2. Effect of Pt and TiO₂ on catalytic activity

In order to explore the effect of Pt and TiO₂ on the catalytic activity of Pt/TiO₂/Al₂O₃ catalyst, Al₂O₃ (Cat. 5), TiO₂/Al₂O₃ (Cat. 6) and Pt/Al₂O₃ (Cat. 7) were also prepared. The properties of the prepared catalysts were analyzed and the results are also expressed in Table 1. Ti loading of Cat. 6 is about 0.15 g m⁻². Pt loading on Cat. 7 is 1.32 g m⁻².

Catalytic activity experiments were also carried out and the results are expressed in Fig. 4. The activity of Al₂O₃ was found to be the lowest. The TiO₂/Al₂O₃ catalyst has a conversion of 21%. The conversion of HCHO on Cat. 7 is about 37.1% initially and decreases to 14% during the reaction time. Cat. 4 has the highest activities toward HCHO catalytic decomposition, where the conversion is about 94%. The research result indicates that the Al₂O₃ support, Pt/Al₂O₃ and TiO₂/Al₂O₃ almost have no activity, the existence of both Pt and TiO₂ brings in high catalytic activity. Hence it can be concluded that the high catalytic activity can be attributed to the interaction between Pt and TiO₂.

Zhang et al. [21] investigated the interaction between Pt and TiO₂ under oxidizing atmosphere by means of XPS and Ar⁺ sputtering test. It was reported that Pt⁰ atoms can thermally diffuse into TiO₂ crystal lattice and be oxidized to Pt²⁺ to substitute for Ti⁴⁺ or form the interstitial ions. Mao et al. [22] have proved that a new

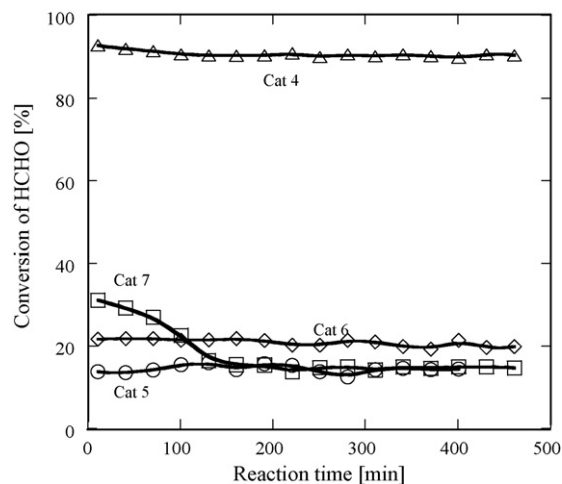


Fig. 4. Results of the activity experiments (HCHO: 100 ppm; reaction temperature: 303 K).

surface state forms on the TiO_2 surface when Pt is deposited and the electrons can transfer from TiO_2 conduction band to the surface Pt at air flow. Li et al. [23] also reported that a strong metal-support interaction (SMSI) between Pt and TiO_2 has been found by means of XPS and in situ Ar^+ sputtering test after Pt/ TiO_2 films being calcinated at 673 K under oxygen for 2 h and Pt atoms on the surface thermally diffuse into the lattice of TiO_2 grains. It can be confirmed that a strong interaction between Pt and TiO_2 support exists on Pt/ TiO_2 by these literatures.

In this work, the TPR analysis was carried out to explore the interaction between TiO_2 and Pt. Profiles of temperature programmed reduction for $\text{TiO}_2/\text{Al}_2\text{O}_3$ (Cat. 6) and Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ (Cat. 4) are illustrated on Fig. 5. TPR graph to Cat. 4 presents one peak of hydrogen consumption around 450 K, which may be related to the reduction of Pt^{2+} to Pt^0 . $\text{TiO}_2/\text{Al}_2\text{O}_3$ can be reduced at 550 K which is higher than the reduction temperature of Cat. 4. There is no any peak at 550 K on the TPR graph of Cat. 4, which means TiO_2 reduction temperature may migrate to 450 K on Cat. 4. Zhang et al. [5,6] also found that TiO_2 can be reduced at lower temperature when platinum was supported on TiO_2 . Moreover, TPR analysis of Pt/ Al_2O_3 (Cat. 7) was also carried out and the main different between Cat. 4 and Cat. 7 is the peak area. Cat. 4 has the higher H_2 consumption area than that of Cat. 7, although the platinum loading of Cat. 4 is lower than that of Cat. 7. It indicates that TiO_2 can be reduced with PtO together. Combined with the results reported by Zhang et al. [21] and Mao et al. [22], it can be assumed that the platinum atoms can insert into TiO_2 crystal lattice after calcined in air at 773 K for 3 h and the oxygen adsorbed on the catalyst may be activated and be shared by Pt^{2+} and Ti^{4+} together, because it has been proved that Pt^0 atoms can thermally diffuse into TiO_2 crystal lattice and be oxidized to Pt^{2+} and the electrons can transfer from TiO_2 conduction band to the surface Pt. Therefore, it can be concluded that the electrons transfer between Pt and TiO_2 results in the increase of the amount of activated oxygen on Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$, compared with Pt/ Al_2O_3 or $\text{TiO}_2/\text{Al}_2\text{O}_3$. Alexeev et al. [24] also reported that the high activity of Pt/ TiO_2 for the oxidation of CO can also be attributed to the ability of TiO_2 to provide or stabilize highly reactive oxygen species at the metal-support interface after the oxidation of CO was carried out on Pt/ TiO_2 catalyst.

Zhang et al. [4–6] also proposed the reaction mechanism for the catalytic decomposition of HCHO at ambient temperature on Pt/ TiO_2 catalyst. It was reported that HCHO firstly is oxidized into formate surface species with active oxygen species at ambient temperature. Formate surface species then directly decompose into

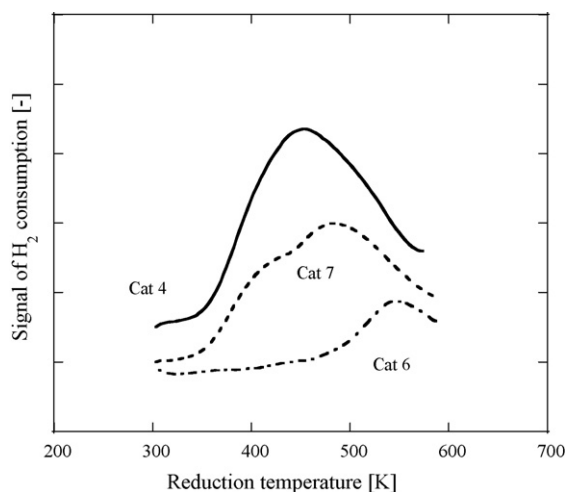


Fig. 5. TPR analysis of the developed catalysts (flow rate of H_2/Ar : 50 mL min^{-1} ; heating-rate: 5 K min^{-1}).

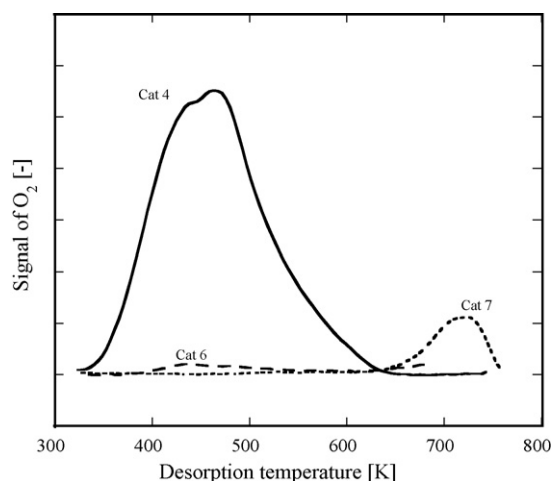


Fig. 6. O_2 -TPD analysis of the developed catalysts (flow rate of He: 70 mL min^{-1} ; heating-rate: 10 K min^{-1}).

adsorbed CO species and H_2O , and the CO species finally reacts with O_2 to produce CO_2 . The similar result also was reported by T. Kecskés et al. where the adsorption of HCHO on Pt/ TiO_2 and Au/ TiO_2 was explored with FT-IR [25]. The amount of active oxygen species and the formation rate of the activated oxygen species will determine the decompose rate of HCHO.

Uner et al. [26] studied oxygen adsorption over Pt/ TiO_2 sample. The result indicates that oxygen adsorption at ambient temperature over Pt/ TiO_2 is dissociated up to $\text{O}:\text{Pt}_{\text{surface}}$ stoichiometry of approximately one quickly and the excess oxygen adsorbed over Pt/ TiO_2 samples could be attributed to direct adsorption of molecular oxygen over TiO_2 surfaces.

O_2 -TPD was used to analysis the interaction between oxygen and the catalysts in this work. The results are expressed in Fig. 6. The samples were reduced by H_2 and then oxygen was adsorbed on the reduced samples at ambient temperature. The samples were purged in helium gas at 323 K before analysis. The results show that there is a very small peak on $\text{TiO}_2/\text{Al}_2\text{O}_3$ (Cat. 6) at 440 K and there are two peaks at 430 K and 470 K on Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ catalyst (Cat. 4). It is stated [27] that chemisorption of oxygen in the molecular form can be observed on metals at low temperatures, as the temperature is raised to 200–300 K adsorbed molecular oxygen either desorbs or transforms to more stable atomically adsorbed stated. Therefore, the detected signal can be assigned as the active, dissociative oxygen adsorbed on the catalyst, since the molecular oxygen directly adsorbed over the catalyst can be desorbed by the 323 K purge process. The analysis result of Cat. 7 shows only one peak appears at 720 K. Moreover, the area of the peak is smaller than that of Cat. 4. Hence, it also can be concluded that a little of active oxygen can be generated on Pt/ Al_2O_3 surface and the amount of the active oxygen is less than that on the Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ catalyst surface. Based on the research, it can be proved that oxygen can be adsorbed on the surface of Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ and dissociated up to $\text{O}:\text{Pt}_{\text{surface}}$ species at ambient temperature.

From TPR and TPD analysis results, we can conclude that the generation rate from molecular oxygen to $\text{O}:\text{Pt}_{\text{surface}}$ species can be improved on the Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ catalyst and the amount of activated oxygen can be increased because of the interaction between Pt and TiO_2 . Hence, the Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ catalyst has fine catalytic activity towards the decomposition of HCHO at ambient temperature.

3.3. Preparation of structured Pt/ $\text{TiO}_2/\text{Al}_2\text{O}_3$ catalyst

It is known that structured catalysts with high surface and low pressure-drop have been adopted in reactors design and honey-

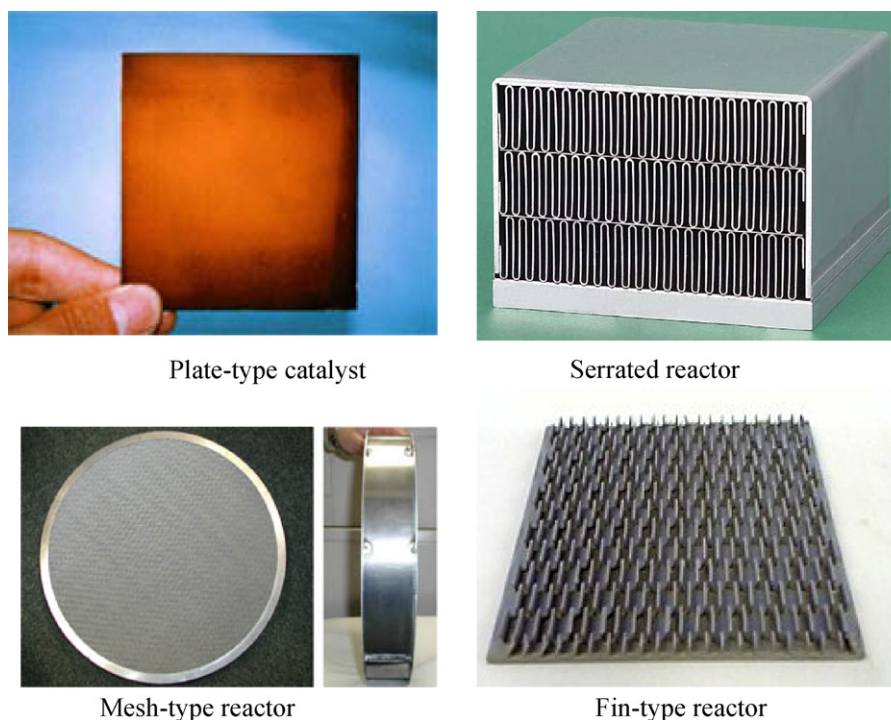


Fig. 7. Structured catalysts developed in our group.

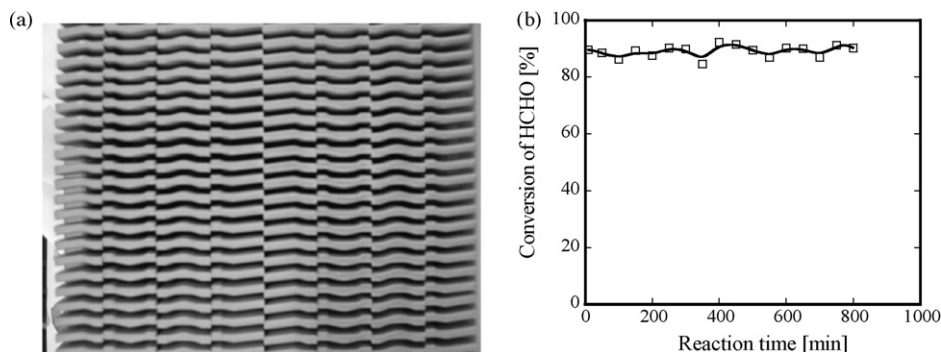


Fig. 8. Photo of the serrate catalyst and the test result. (a) Photo of the serrate catalyst; (b) conversion of HCHO on the serrate catalyst. (Volume of catalyst: 0.2 L; flow rate: 30 L min⁻¹; inlet concentration of HCHO: ~ pm; temperature: 303 K).

comb monoliths have become the standard catalyst shape in most applications of environmental catalysis, after their successful commercial application to the control of automotive exhausts and to the reduction of nitrogen oxides [12–14]. The plate Pt/TiO₂/Al₂O₃ catalyst has been developed in our research, it is necessary for us to prepare structured catalyst for the application of Pt/TiO₂/Al₂O₃ catalyst. By now, the platinum catalyst can be formed into some shapes as shown in Fig. 7 in our group. In this work, the Pt/TiO₂/Al₂O₃ catalyst was prepared in serrate type (50 × 40 × 100 mm³), where traditional long-straight channel was instead with novel short channel as shown in Fig. 8. Firstly, a structured aluminum unit was adopted as the support after anodic oxidation and HWT treatment. Then, TiO₂ and platinum was supported on the structured support with the electro-deposition technology and wet impregnation method, receptivity. Lastly, the catalytic activity was evaluated. The photo of the catalyst and the evaluated result are expressed in Fig. 8. The volume of the catalyst is 0.2 L and the flow rate was set at 30 L min⁻¹. The flow rate was not very steady and the inlet concentration of HCHO was also unsteady. Therefore, it is found that the conversion of HCHO always varies during the reaction process. The average conversion is about 91.4%, is slightly lower than it in

the small-scale experiment. The gas diffusion in the structured catalyst may draw back the catalytic activity of the developed catalyst. However, it can be proved that the Pt/TiO₂/Al₂O₃ catalyst can be manufactured with serrate type by the technology.

Moreover, the product distribution is very important in HCHO decomposition reaction. However, a carbon balance cannot be obtained because air was used in the study and the concentration of CO₂ cannot be measured accurately. CO and the other organic substances were not detected in the product; hence it can be thought that HCHO is decomposed into CO₂ and H₂O.

4. Conclusions

- (1) The developed anodic alumite support has a high BET-area after the HWT treatment. Pt/TiO₂/Al₂O₃ catalyst can be developed on the anodic alumite film with fine elements distribution by the electro-deposition technology and the impregnation method. It was found that platinum and TiO₂ can be deposited from the bottom to the surface of the anodic alumite film uniformly.
- (2) The developed Pt/TiO₂/Al₂O₃ catalyst experiences fine catalytic activity towards the catalytic decomposition of HCHO at ambi-

ent temperature. CO and other harmful organics were not detected in the work.

- (3) The research results show that the oxygen adsorbed on the catalyst may be activated and shared by Pt²⁺ and Ti⁴⁺ together because of the SMSI between Pt and TiO₂, hence amount of the activated oxygen on the developed Pt/TiO₂/Al₂O₃ catalyst increases greatly, comparing to the pure platinum catalyst. Moreover, the research results also prove that the molecular oxygen can be generated to O:Pt_{surface} species on the Pt/TiO₂/Al₂O₃ quickly at ambient temperature.
- (4) The serrate type Pt/TiO₂/Al₂O₃ catalyst was also developed successfully in the work and exhibits fine catalytic activity. It means that the catalyst can be manufactured as complex shape, according to application.

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