Electronic Supplementary Material (ESI) for Catalysis Science & Technology.

Supporting Information

Novel metallic electric heating monolithic catalyst towards VOCs combustion

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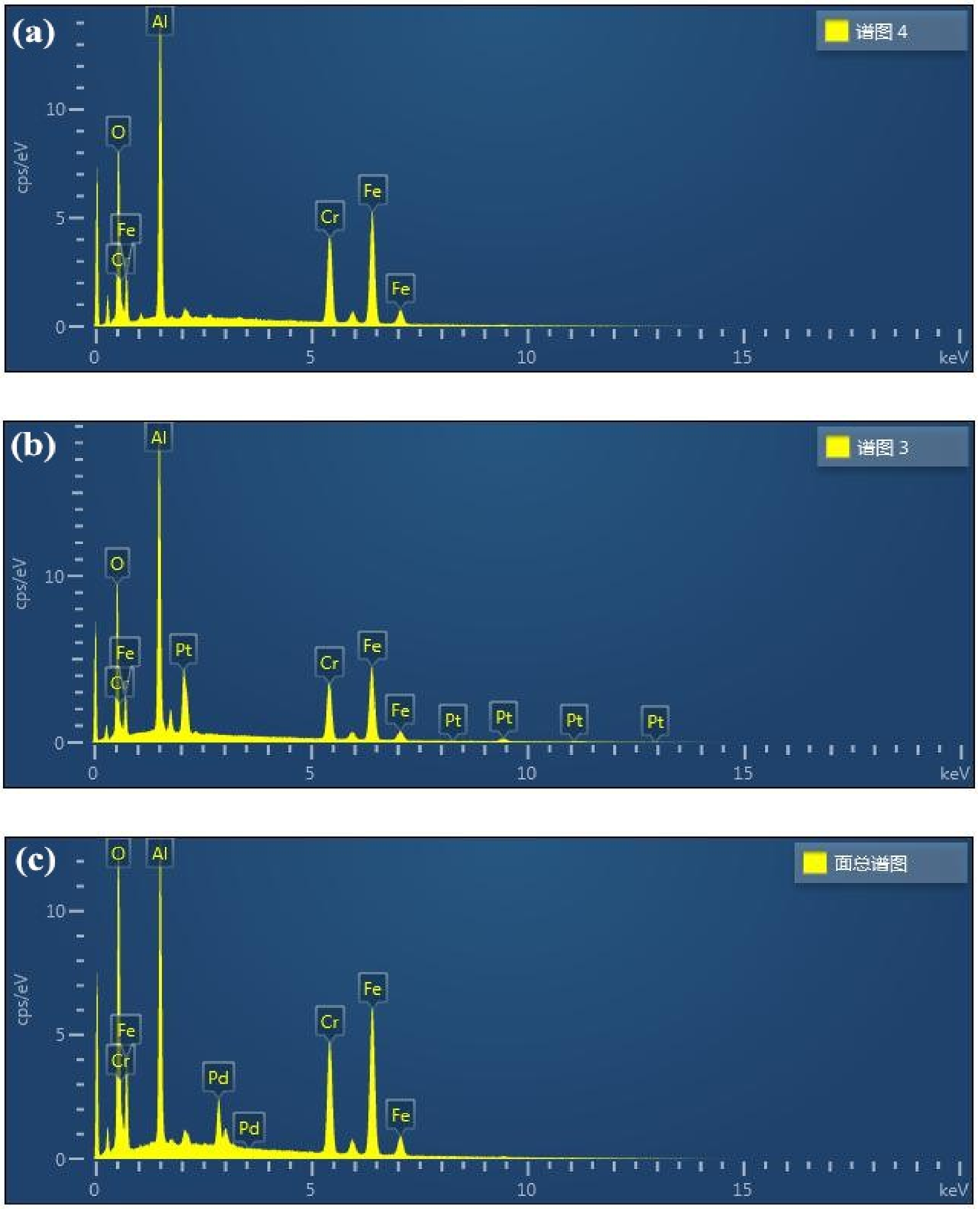
Supplementary Table 1 The adherence test of FeCrAl monoliths

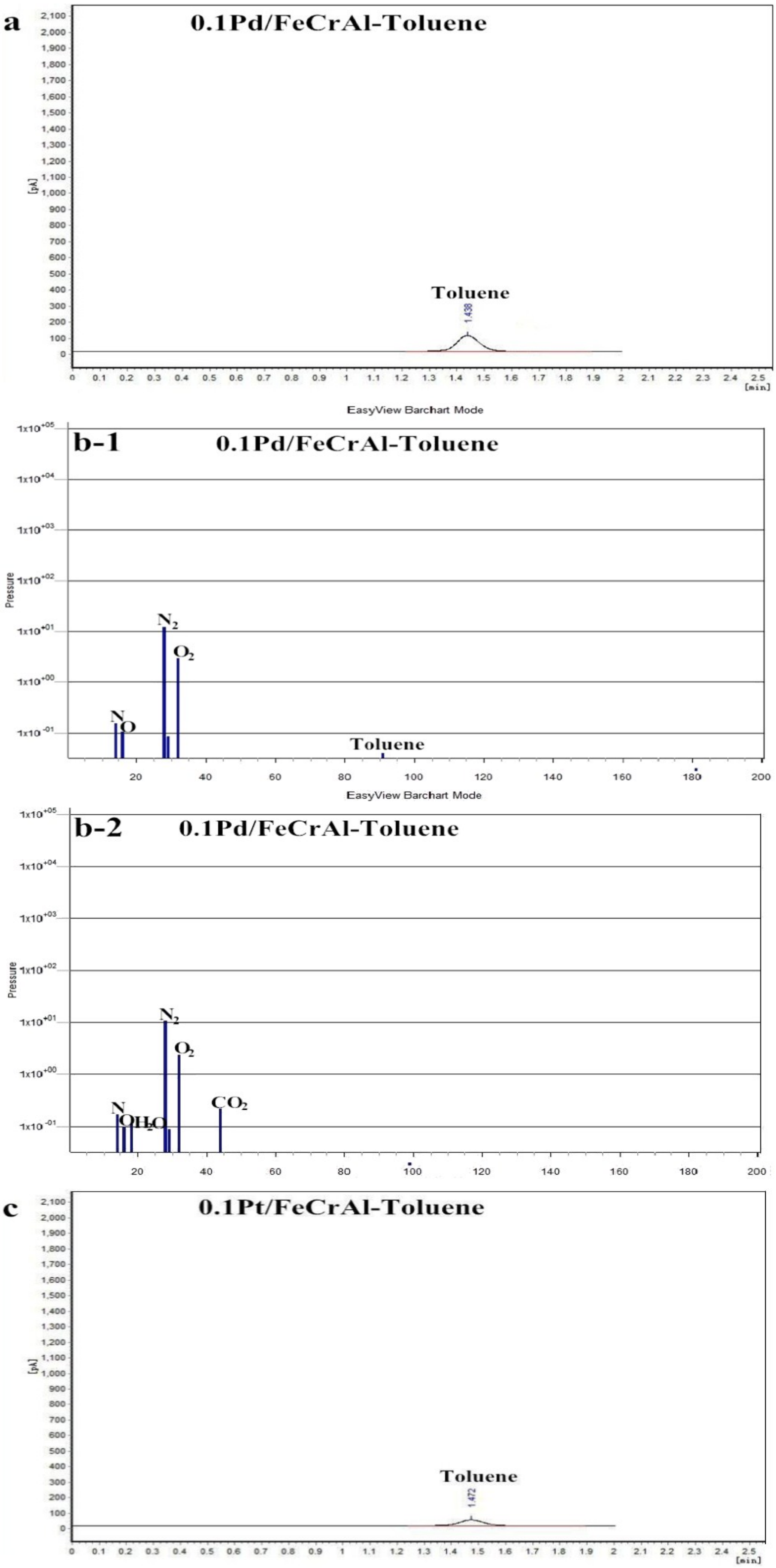
Sample	Before ultrasound(g)	After ultrasound(g)	δ(wt%)[a]
Calcined FeCrAl	2.0781	2.0779	6.45
0.1Pt/FeCrAl	2.0767	2.0756	5.31
0.1Pd/FeCrAl	2.0799	2.0795	1.97

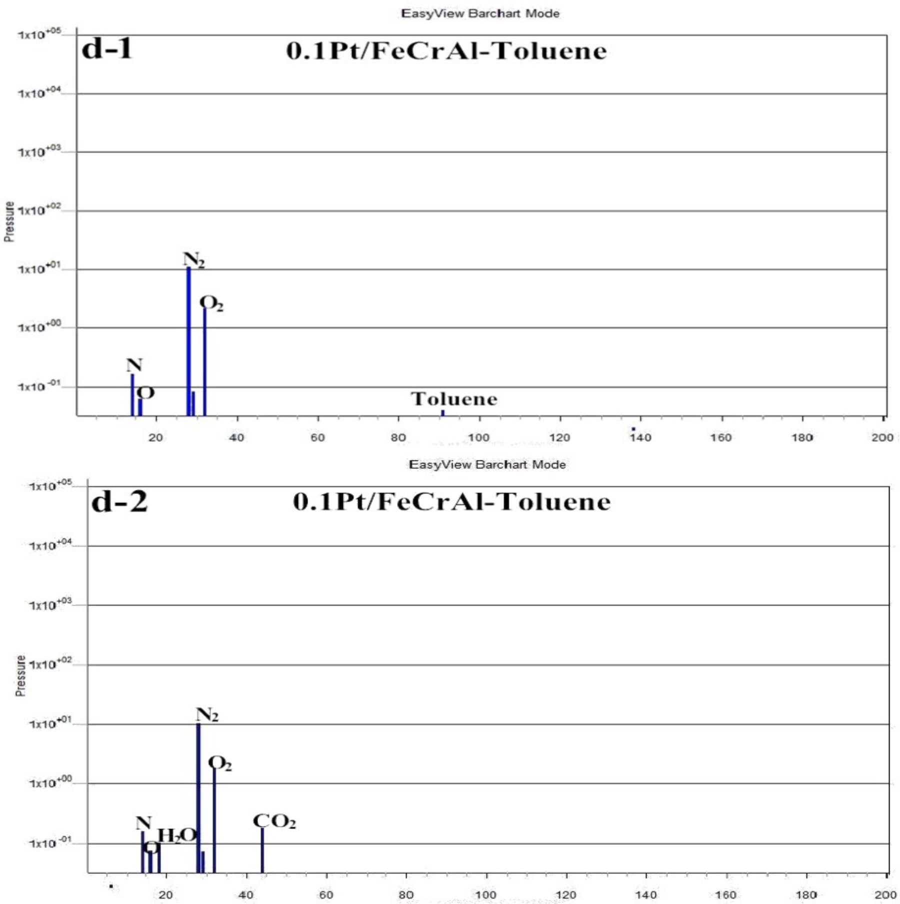
[a] Weight lost in adherence test (δ)



Supplementary Fig. 1 The EDS images of FeCrAl monoliths. (a) Calcined FeCrAl; (b) 0.1Pt/FeCrAl; (c) 0.1Pd/FeCrAl.

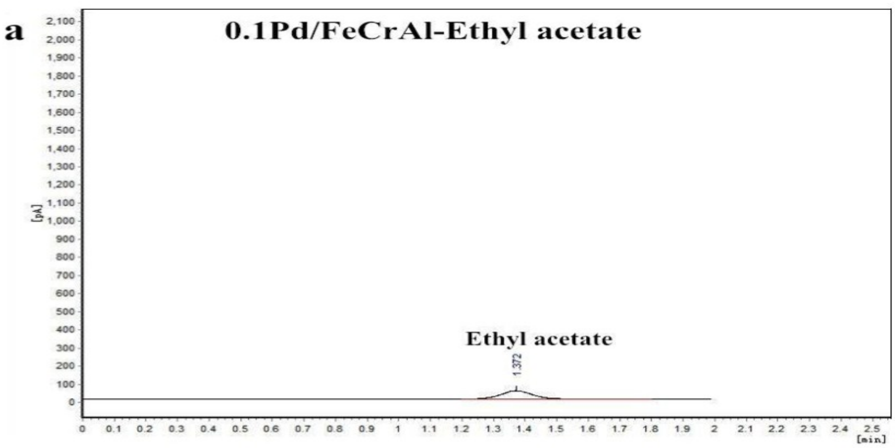
It demonstrated that a alumina coating was formed on the surface of FeCrAl metallic substrate. In addition, Pt and Pd bonded with metallic substrate.

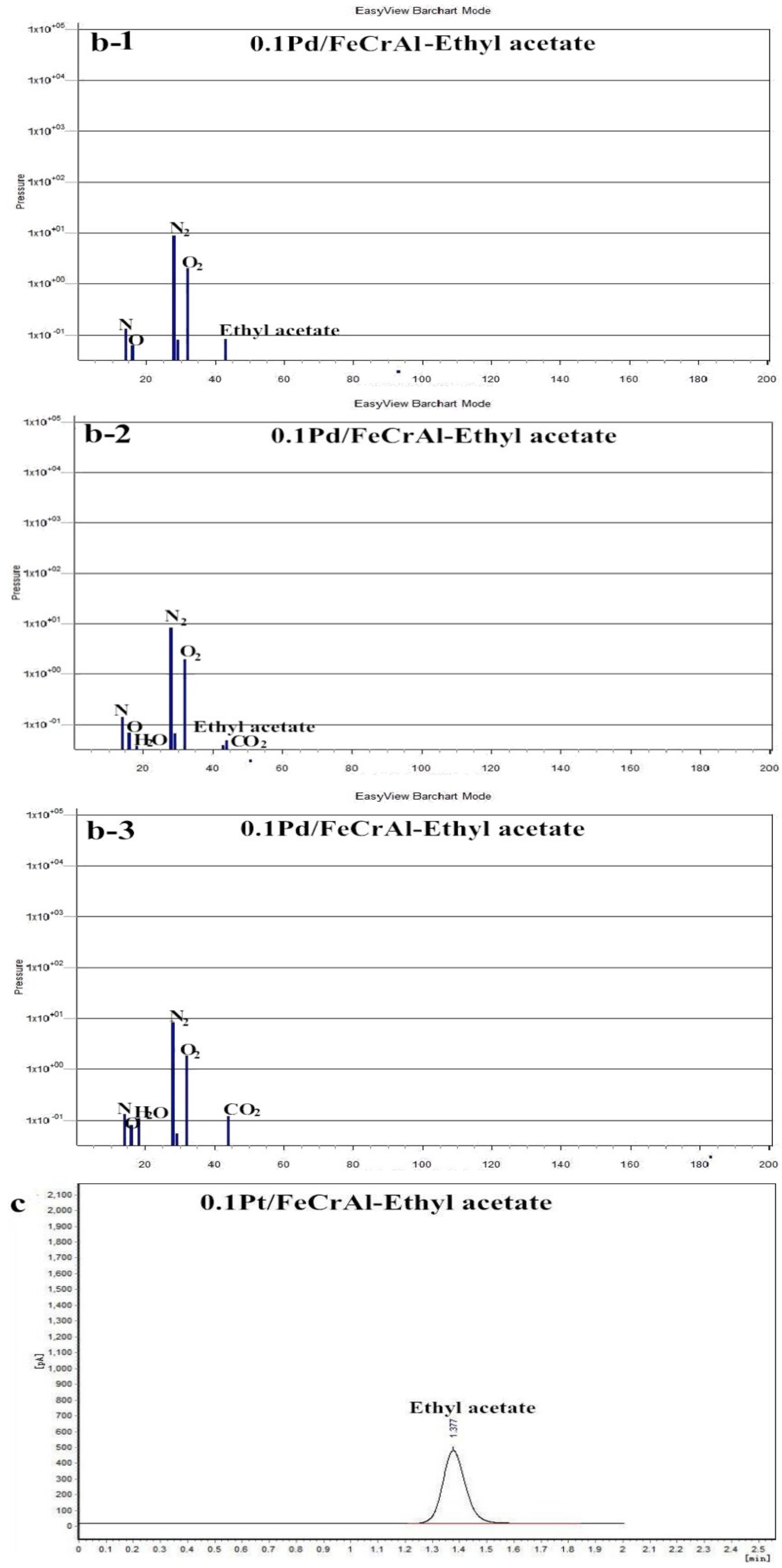

a
0.1Pd/FeCrAl-Toluene
Toluene
1.438
[pA]
[min]
EasyView Barchart Mode
b-1
0.1Pd/FeCrAl-Toluene
N$_2$
O$_2$
N
O
Toluene
Pressure
EasyView Barchart Mode
b-2
0.1Pd/FeCrAl-Toluene
N$_2$
O$_2$
N
O
H$_2$O
CO$_2$
Pressure
c
0.1Pt/FeCrAl-Toluene
Toluene
1.472
[pA]
[min]

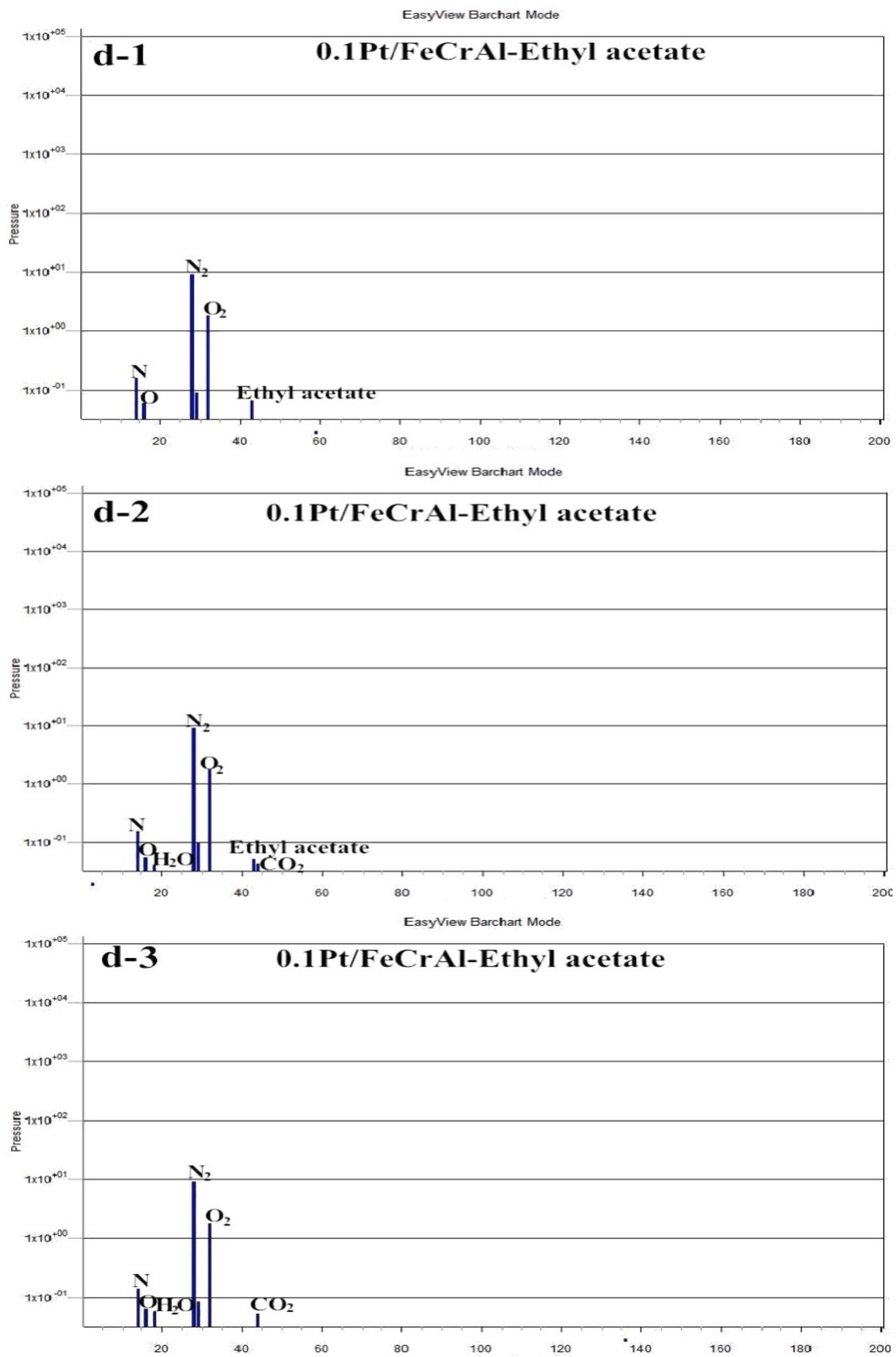


Supplementary Fig. 2 GC (a, c) and MS (b, d) tested results of toluene combustion over 0.1Pd/FeCrAl and 0.1Pt/FeCrAl.

As shown in Fig. S2a and 2c, it demonstrated that catalytic combustion of toluene does not produce other products. In addition, the MS results (Fig. S2b, d) showed the product of catalytic combustion of toluene is CO_2 and H_2O.

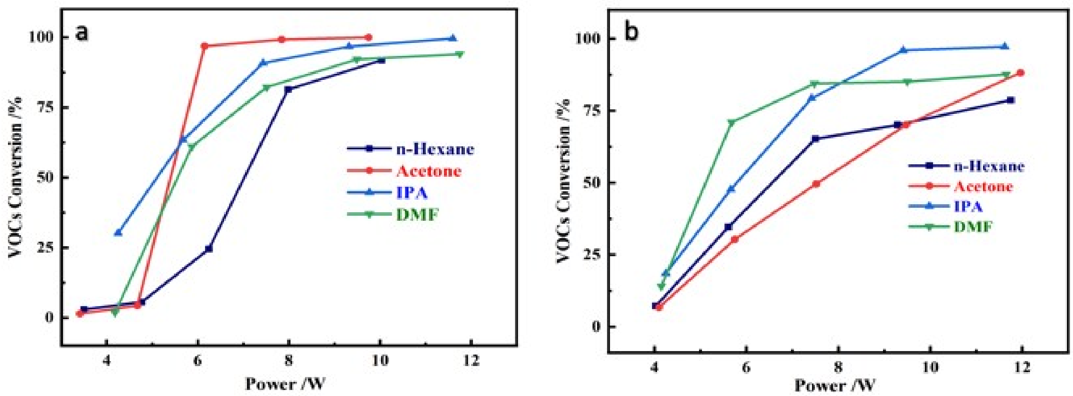



EasyView Barchart Mode
b-1
0.1Pd/FeCrAl-Ethyl acetate
Pressure
N₂
O₂
N
O
Ethyl acetate
EasyView Barchart Mode
b-2
0.1Pd/FeCrAl-Ethyl acetate
Pressure
N₂
O₂
N
O
H₂O
Ethyl acetate
CO₂
EasyView Barchart Mode
b-3
0.1Pd/FeCrAl-Ethyl acetate
Pressure
N₂
O₂
N
O
H₂O
CO₂
c
0.1Pt/FeCrAl-Ethyl acetate
[pA]
Ethyl acetate
1.377
[min]



Supplementary Fig. 3 GC (a, c) and MS (b, d) tested results of ethyl acetate combustion over 0.1Pd/FeCrAl and 0.1Pt/FeCrAl.

As shown in Fig. S3a and 3c, it demonstrated that catalytic combustion of ethyl acetate does not produce other products. In addition, the MS results (Fig. S3b, d) showed the product of catalytic combustion of ethyl acetate is CO_2 and H_2O. However, ethyl acetate combustion is more difficult than that of toluene.



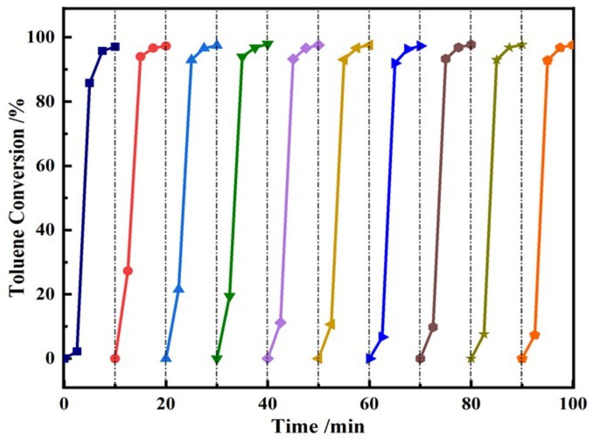
Supplementary Fig. 4 Light-off curves of VOCs combustion. (a) 0.1Pd/FeCrAl; (b) 0.1Pt/FeCrAl. Other Condition: VOCs concentration of 2500 ppm, WHSV of 10000 $mL \cdot h^{-1} \cdot g^{-1}$.

We tested the catalytic activities in the combustion of acetone, n-hexane, isopropyl alcohol (IPA), N,N-Dimethylformamide (DMF). The monolithic catalysts exhibited the excellent activity for VOCs, suggesting our catalysts are suitable to deal with most VOCs.

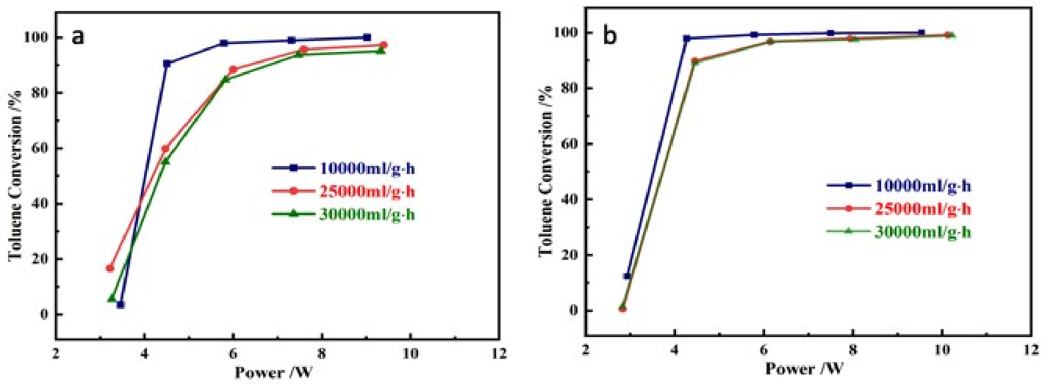
Supplementary Tab. 2 Catalytic oxidation of VOCs over Pt and Pd alumina-supported catalysts.

Catalyst	VOCs	concentration / ppm	Space velocity	T90 / °C	Reference
Pt/Al_2O_3	Toluene	300	30000 $mL \cdot h^{-1} \cdot g^{-1}$	200	[1]
0.12 wt% Pt/Al_2O_3	n-Hexane	1500	13001 h^{-1}	>260	[2]
$Pt/Al_2O_3/Al$	Toluene Acetone	225	3680 h^{-1}	200 282	[3]
0.3% $Pt/\gamma\text{-}Al_2O_3$	Ethyl acetate	2000	3000 h^{-1}	310	[4]
0.1Pt/FeCrAl	**Toluene** **n-Hexane** **Ethyl acetate** **Acetone**	**2500**	**10000 $mL \cdot h^{-1} \cdot g^{-1}$**	**242** **295** **374** **300**	**This Work**
1 wt% Pd/Al_2O_3	Toluene	1000	15000 h^{-1}	190	[5]
Pd/Al_2O_3	o-Xylene	100	50000 h^{-1}	145	[6]
0.3% $Pd/\gamma\text{-}Al_2O_3$	Ethyl acetate	2000	30000 h^{-1}	272	[4]
1 wt% $Pd/\gamma\text{-}Al_2O_3$	Toluene	1000	28000 h^{-1}	240	[7]
0.1Pd/FeCrAl	**Toluene** **Ethyl acetate**	**2500**	**10000 $mL \cdot h^{-1} \cdot g^{-1}$**	**250** **328**	**This work**

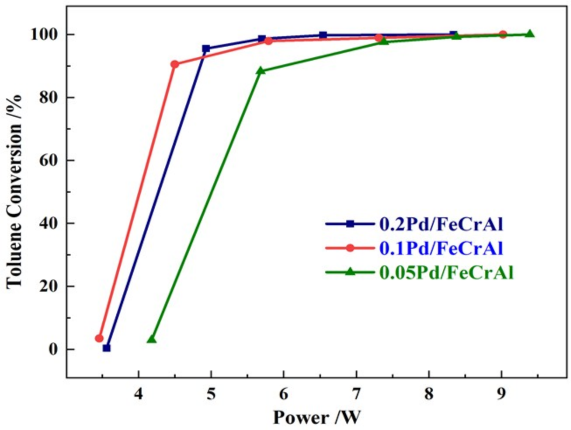
We reported the preparation of novel electrically heated monolithic Pt or Pd catalysts supported on FeCrAl metal wire, the catalysts exhibited high catalytic activity for the combustion of VOCs to CO_2 and H_2O under low-current of DC power. Different from traditional catalytic combustion of VOCs, the power is an indicator of catalytic activity instead of temperature. However, the temperature of electrically heated monolithic catalysts was measured by thermocouple, and the temperature refers to the surface temperature of catalysts. Therefore, the temperature of electrically heated monolithic catalysts is higher than traditional catalysts, in other words, the temperature of our catalysts is higher than literature. Further, the Pt and Pd loadings of our catalysts are extremely low. The catalysts exhibited high catalytic activity for the combustion of VOCs to CO_2 and H_2O under low-current of DC power. In summary, our Pt and Pt catalysts exhibited superior performance for catalytic combustion of VOCs.



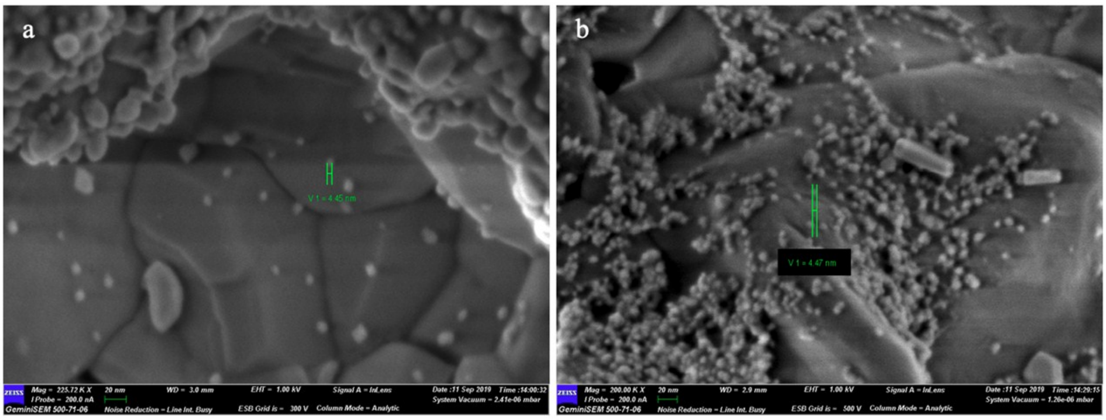
Supplementary Fig. 5 The reusability of 0.1Pd/FeCrAl for toluene combustion (I=0.9A). Condition: toluene concentration of 2500 ppm, WHSV of 10000 mL·h^{-1}·g^{-1}. It can be seen that 0.1Pd/FeCrAl reached 100% for toluene combustion after 10 cycles.



Supplementary Fig. 6 Effect of space velocity on toluene combustion over (a) 0.1Pd/FeCrAl and (b) 0.1Pt/FeCrAl. Other condition: toluene concentration of 2500 ppm.



Supplementary Fig. 7 Effect of Pd loading on the catalytic activities in the combustion of toluene. Condition: toluene concentration of 2500 ppm. WHSV of 10000 mL·h^{-1}·g^{-1}.



Supplementary Fig. 8 SEM of (a) 0.1Pd/FeCrAl and (b) 0.1Pt/feCrAl.

It was observed that the catalytic activity increase by the loading of Pd. When Pd loading is 0.05 wt%, and the Pd NPs could not completely cover the FeCrAl metallic substrate, it results to the worse activity. When Pd loading is 0.2 wt%, it will lead to the superposition and accumulation of Pd NPs, causing some active sites to be covered, so there is no obvious increase in catalytic activity. Therefore, the optimal Pd loading is 0.1 wt%.

References

1 Z.B. Rui, C.Y. Chen, Y.B. Lu and H.B. Ji, Chinese J. Chem. Eng., 2014, 22, 882-887.
2 B. Grbic, N. Radic and A. Terlecki-Baricevic, Appl. Catal., B, 2004, 50, 161-166.
3 N. Burgos, M. Paulis, M.M. Antxustegi and M. Montes, Appl. Catal., B, 2002, 38, 251-258.
4 P. Papaefthimiou, T. Ioannides and X.E. Verykios, Appl. Catal., B, 1997, 13, 175-184.
5 C.K. Sang, G.S. Wang, Properties and performance of Pd based catalysts for catalytic oxidation of volatile organic compounds, Appl. Catal., B, 2009, 92, 429-436.
6 S.Y. Huang, C.B. Zhang and H. He, Catal. Today, 2008, 139, 15-23.
7 S.C. Kim, H.Y. Jung, J.W. Nah and Y.K. Park, J. Nanosci. Nanotechno., 2016, 16, 4638-4642.