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An alumina-coated, egg-shell Pd/α-Al_2O_3@SiC catalyst with enhanced ethylene selectivity in the selective hydrogenation of acetylene

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Supporting Information

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S1. SEM photographs of the Al_2O_3 layer on SiC

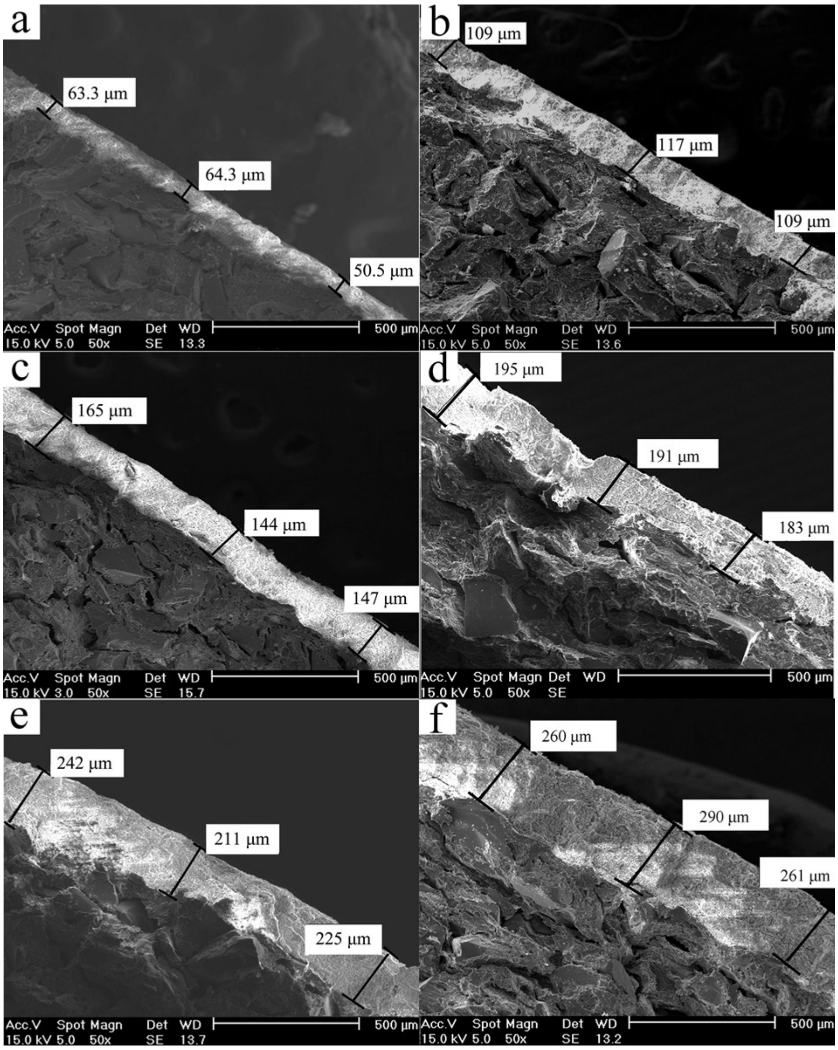

Figure S1. SEM photographs of the Al_2O_3 layer at the different Al_2O_3 loadings on SiC: (a) 7.3 wt%, (b) 9.0 wt%, (c) 12.0 wt%, (d) 14.1 wt%, (e) 16.5 wt%, (f) 18.3 wt%.

As shown in Fig. S1, the interfaces of Al_2O_3 layer/SiC substrate are obvious and clear, which could be distinguished in all of the samples. The cross-section morphologies of Al_2O_3 layer on SiC substrate also exhibited excellent adhesion: the Al_2O_3 layer seemed to be firmly attached on SiC substrate with no visible gaps. Meanwhile, it also indicated that the formation of α-Al_2O_3 or θ-Al_2O_3 obtained from boehmite sol can improve the binding between Al_2O_3 layer and SiC substrate after being calcined at 1020 °C for 4 h in air. Moreover, it was found that the changing thicknesses of Al_2O_3 layer on SiC substrate respectively are 60 ± 10 μm, 110 ± 10 μm, 145 ± 20 μm, 190 ± 10 μm, 225 ± 20 μm, 260 ± 30 μm, which correspond to the different amounts of Al_2O_3 loading on SiC substrate. In fact, the thickness of Al_2O_3 layer was the egg-shell thickness of Pd catalyst which can be tuned in the range of 50-300 μm.

S2. Adhesion strength

The adhesion strength of Al_2O_3 layer on SiC substrate was crucial for Pd/α-Al_2O_3@SiC catalyst, which was measured by dropping the Pd/α-Al_2O_3@SiC catalyst along a 4.2 meter metal tubule, simulating catalyst packing mode in the reactor. The adhesion test results of Pd/α-Al_2O_3@SiC catalyst at the different Al_2O_3 loadings on SiC were listed in Table S1. It should be noted that the amounts of weight loss have a minimum value for Pd/α-Al_2O_3@SiC catalyst at the different Al_2O_3 loadings on SiC in Table S1. The weight loss values of Pd/α-Al_2O_3@SiC catalyst present a decreasing tendency as the amount of Al_2O_3 loading on SiC substrate increases. However, along with the amount of Al_2O_3 loading on SiC substrate continually increasing, the weight loss values of Pd/α-Al_2O_3@SiC catalyst become an increase tendency when the amount of Al_2O_3 loading on SiC substrate was more than 14.1 wt%. For 14.1 wt% Al_2O_3 loading on SiC, the amount of weight loss was the lowest, which indicates that there is the best adhesion of Al_2O_3 layer on SiC. It certifies that the optimal thickness of Al_2O_3 layer on SiC was 190 ± 10 μm for getting the best adhesion. Therefore, it is highly valuable to achieve alumina coated egg-shell Pd/α-Al_2O_3@SiC catalyst which possesses the good adhesion of Al_2O_3 layer on SiC substrate.

Table S1 The weight loss of Pd/α-Al_2O_3@SiC catalyst in the adhesion test.

Sample	Al_2O_3 loading on SiC (wt%)	Thickness of Al_2O_3 layer (μm)	Weight loss (%)
1	7.3	60 ± 10	0.87
2	9.0	110 ± 10	0.48
3	12.0	145 ± 20	0.47
4	14.1	190 ± 10	0.27
5	16.5	225 ± 20	0.45
6	18.3	260 ± 30	0.55

S3. Attrition resistance

Abrasion resistance test: there are different test methods to determine the abrasion resistance of catalyst coating. In this work, a rotary drum was used to implement the test of the abrasion resistance of Pd/α-Al_2O_3@SiC catalyst at different Al_2O_3 loadings on SiC. The rotary drum specifications: diameter 100 cm, long 135 cm, volume 1060 mL and single baffle.

Test method: the 100 g of Pd/α-Al_2O_3@SiC catalyst was placed into the stainless steel rotary drum, and then sealed the rotary drum. The rotating speed of the rotary drum was at 60 rpm and the rotating time is 2 h. The weight loss was defined as follows:

$$\Delta W(\%) = \left[\frac{W_1 - W_2}{W_3}\right] \times 100\% \qquad (1)$$

Wherein W_1 is the weight of Pd/α-Al_2O_3@SiC catalyst before abrasion resistance test, W_2 is the weight of Pd/α-Al_2O_3@SiC catalyst after abrasion resistance test and W_3 is the weight of Al_2O_3 loading on SiC substrate. The abrasion resistance test results of Pd/α-Al_2O_3@SiC catalyst at the different Al_2O_3 loadings on SiC were listed in Table S2. It should be noted that the weight loss values of Pd/α-Al_2O_3@SiC catalyst present a decreasing tendency as the amount of Al_2O_3 loading on SiC substrate increases. However, along with the amount of Al_2O_3 loading on SiC substrate continually increasing, the weight loss values of Pd/α-Al_2O_3@SiC catalyst become nearly the same when the amount of Al_2O_3 loading on SiC substrate was more than 14.1 wt%. For 14.1 wt% Al_2O_3 loading on SiC, the amount of weight loss was 10.56 wt%, which indicates that there is a good abrasion resistance of Al_2O_3 layer on SiC. It shows that the thickness of Al_2O_3 layer on SiC should be more than 190 ± 10 μm in order to achieve good abrasion resistance. Meanwhile, considering the adhesion test results, it is significant to obtain alumina coated egg-shell Pd/α-Al_2O_3@SiC catalyst with 14.1 wt% Al_2O_3 loading on SiC.

Table S2 The weight loss of Pd/α-Al_2O_3@SiC catalyst in the abrasion resistance test.

Sample	Al_2O_3 loading on SiC (wt%)	Thickness of Al_2O_3 layer (μm)	Weight loss (%)
1	7.3	60 ± 10	38.71
2	9.0	110 ± 10	25.57
3	12.0	145 ± 20	14.95
4	14.1	190 ± 10	10.56
5	16.5	225 ± 20	10.13
6	18.3	260 ± 30	9.89