Electronic Supplementary Information for the manuscript

"Design of mesoporous SO_4^{2-}/ZrO_2-SiO_2(Et) hybrid material as an efficient and reusable heterogeneous acid catalyst for biodiesel production"

Wei Li [a], Zijiang Jiang [b], Fengyan Ma [a], Fang Su [a], Ling Chen [a], Shengqu Zhang [a] and Yihang Guo*[a]

[a] *School of Chemistry, Northeast Normal University, Changchun 130024, PR China*

[b] *National Analytical Research Center of Electrochemistry and Spectroscopy, ChangChun Institute of Applied Chemistry,Chinese Academy of Sciences*

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*Corresponding author

Tel. or fax: +86 431 85098705.

E-mail address: guoyh@nenu.edu.cn (Y. Guo).

Catalyst characterization

^{13}C CP-MAS NMR and ^{29}Si MAS (b) NMR spectra were obtained on a Bruker NMR spectrometer. Chemical shift for both ^{29}Si and ^{13}C NMR were referenced to the peak for trimethylsilane at 0 ppm. Fourier transform infrared (FT-IR) spectrum on the powder sample mixed with KBr was recorded on a Nicolet Magna 560 FT-IR spectrometer at a resolution of 4 cm^{-1}. The concentration of the sample in KBr was kept around 0.25-0.3%. X-ray photoelectron spectra (XPS) were performed on a VG-ADES 400 instrument with Mg Kα-ADES source at a residual gas pressure of below 10^{-8} Pa. All the binding energies were referenced to the C 1s peak at 284.6 eV of the surface adventitious carbon. Nitrogen porosimetry was performed on a Micromeritics ASAP 2020M instrument. The surface areas were calculated using the BET equation. Pore size distributions were calculated using the BJH model based on nitrogen desorption isotherms. The samples were outgassed under vacuum at 90 ^{o}C for 1 h and then 200 ^{o}C for 12 h.

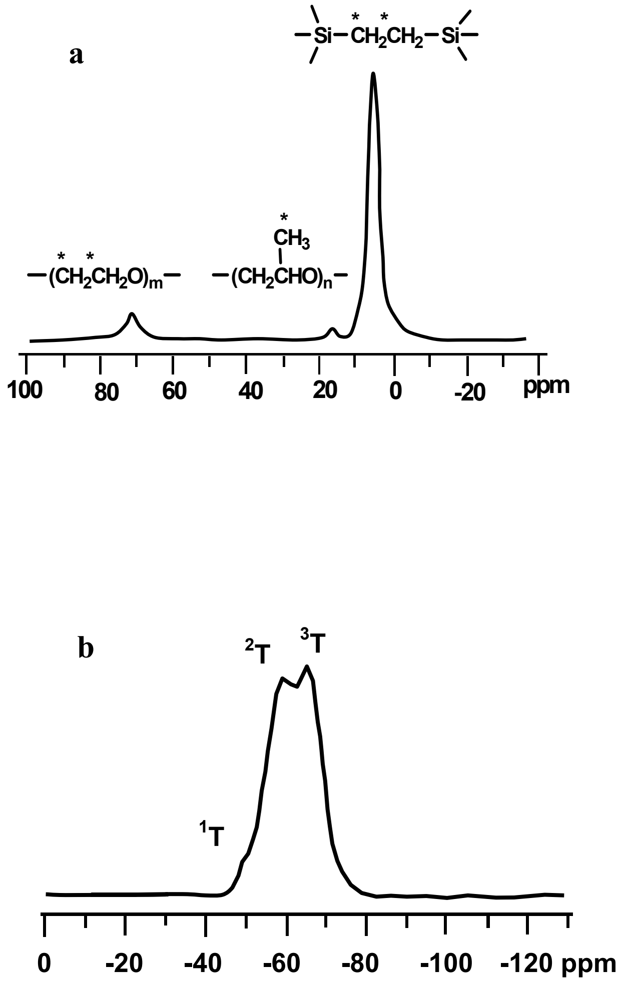

Fig. S1 ^{13}C CP-MAS NMR (a) and ^{29}Si MAS (b) NMR spectra of the SO_4^{2-}/ZrO_2-SiO_2(Et) material.

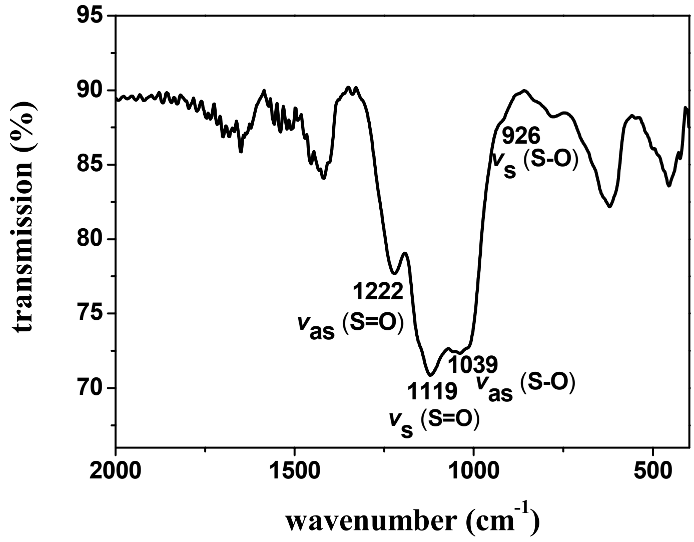
95
90
85
80
75
70
transmission (%)
926
v_s (S-O)
1222
v_{as} (S=O)
1039
1119
v_{as} (S-O)
v_s (S=O)
2000
1500
1000
500
wavenumber (cm^{-1})

Fig. S2 FT-IR spectra of the SO_4^{2-}/ZrO_2-SiO_2(Et) material.

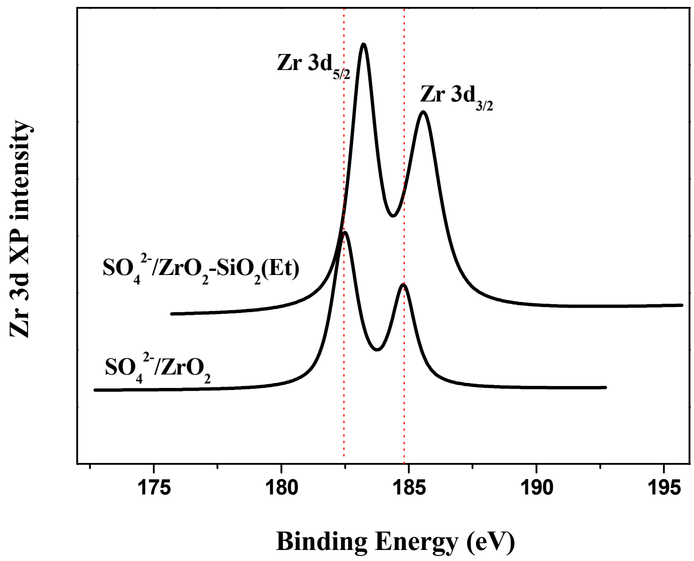

Fig. S3 XPS survey spectra for as-prepared SO_4^{2-}/ZrO_2-SiO_2(Et) and SO_4^{2-}/ZrO_2 materials in the Zr3d and S2p binding energy regions.

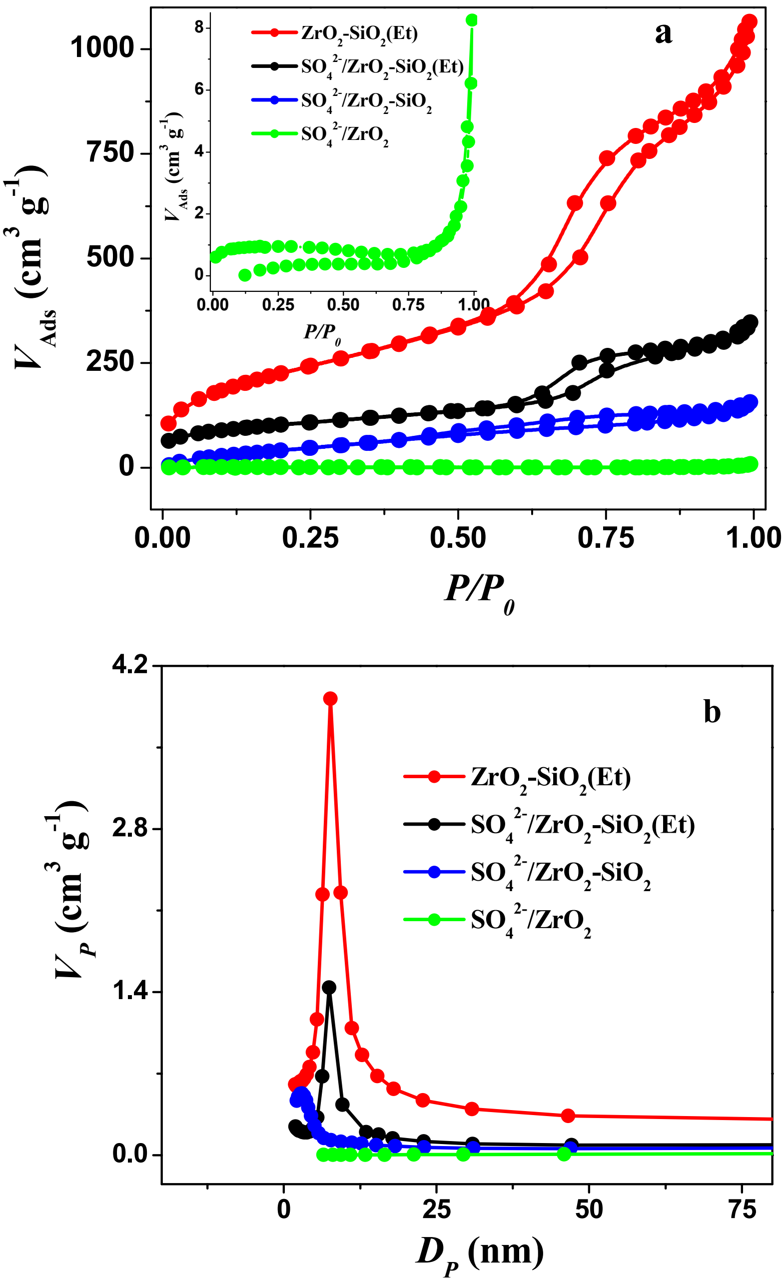

Fig. S4 Nitrogen adsorption-desorption isotherms (a) and pore size distribution (b) profiles of $ZrO_2–SiO_2$(Et), $SO_4^{2-}/ZrO_2–SiO_2$(Et), $SO_4^{2-}/ZrO_2–SiO_2$, and SO_4^{2-}/ZrO_2 (insert) catalyst.