A multi-scale porous composite adsorbent with copper benzene-1,3,5-tricarboxylate coating on copper foam

H .Wang[a], Z.G. Qu[a*], W. Zhang[b*], L.Q. Zhang[b]
[a] MOE Key Laboratory of Thermo-Fluid Science and Engineering, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China
[b]School of Science, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China
*Corresponding author. Tel/Fax: +86-029-82668543; E-mail address: zgqu@mail.xjtu.edu.cn

Material characterization

Scanning electron microscopy (SEM) is performed on the scanning electron microscope (Hitachi S-4800, Japan) for samples previously sputter coated with a thin layer of gold to avoid charging.

The crystal structure of nanomaterial is investigated by X-ray powder diffraction (XRD) using D-MAX 2200 VPC with Cu K radiation ($\lambda = 1.54\,\mathring{A}$), operating at 40 kV and 35 mA. Figure S1 shows the X-ray diffraction patterns of the pure Cu-BTC powder and copper benzene-1, 3, 5-tricarboxylate coating on copper foam (Cu-BTC/CF), respectively. The XRD pattern of the Cu-BTC/CF is similar to the pure Cu-BTC crystalline phase indicating well phase purity and homogeneity of Cu-BTC growing on CF.

The effective thermal conductivity of pure Cu-BTC and Cu-BTC/CF at 20, 40, 60, and 80 PPI is measured by $3-\omega$ method based on transient hot wire method (TC3000E, Xi'an Xiaxi), which is mainly used for film testing.[1]The accuracy of this instrument is 2%. The test is under the ordinary temperature and pressure.

The gases (N_2, CH_4 and CO_2) adsorption isotherms are measured using an automatic gas sorption analyzer (Quantachrome Autosorb IQ, USA). In the analysis, the samples are pretreated at 120 °C under vacuum for 12 h to remove any physically adsorbed gaseous from their surface. N_2 is then used to measure the adsorption and desorption on samples at different relative pressures and temperature of 77 K to test the surface area and pore diameter distribution. The adsorption and desorption isotherms at 77 K are shown in Fig. S2(a). The surface area and pore volume and loading ratio of different samples are shown in Table S1. The pore size distribution is estimated from nitrogen data using no-local density functional theory (NLDFT) as shown in Fig. S2(b). The other gases are used to measure the adsorption at different pressure and temperature (273.15K) in an ice-water bath. Fig. S3(a), (b), (c) and (d) shows the amount of adsorbed gases (N_2, CO_2 and CH_4) on pure Cu-BTC and Cu-BTC/CF at 20, 40, 60 and 80 PPI at different pressure range (0-100 kPa) and temperatures of 273.15 K based on adsorbent mass. Fig. S4(a), (b), (c) and (d) shows the amount of adsorbed gases (N_2, CO_2 and CH_4) on pure Cu-BTC and Cu-BTC/CF at 20, 40, 60 and 80 PPI at different pressure range (0-100 kPa) and temperatures of 273.15 K based on adsorbent volume.

The electric conductivity of Cu-BTC and Cu-BTC/CF is tested based on the resistance testing equipment (YR1030). The nature of Cu-BTC is insulating, while CF has rather good conductivity. Therefore, Cu-BTC/CF shows some electric conductivity, and it decreases slowly with increase of pore density because of the Cu-BTC coating on CF as shown in Fig. S5.

Table S1 The surface area, pore volume and loading ratio of different samples

Samples	Cu-BTC	Cu-BTC/CP	Cu-BTC/CP	Cu-BTC/CP	Cu-BTC/CP
macropore density	0PPI	20PPI	40PPI	60PPI	80PPI
BET （cm^2/g）	1504.912	37.067	67.711	95.927	69.309
micropore pore volume(cm^3/g)	0.794	0.037	0.088	0.080	0.061
Loading (%)	0	8.7	11.2	17.6	15.3

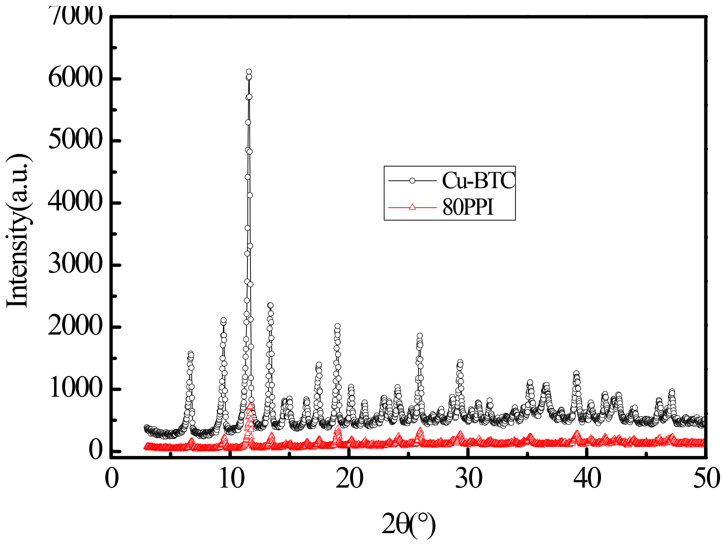
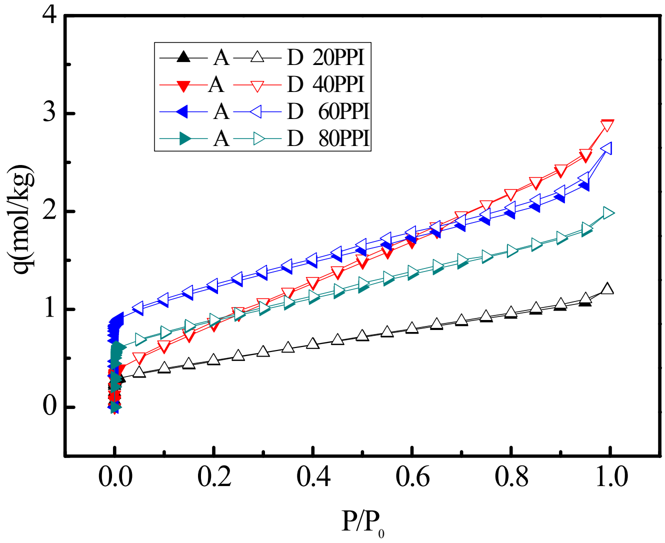
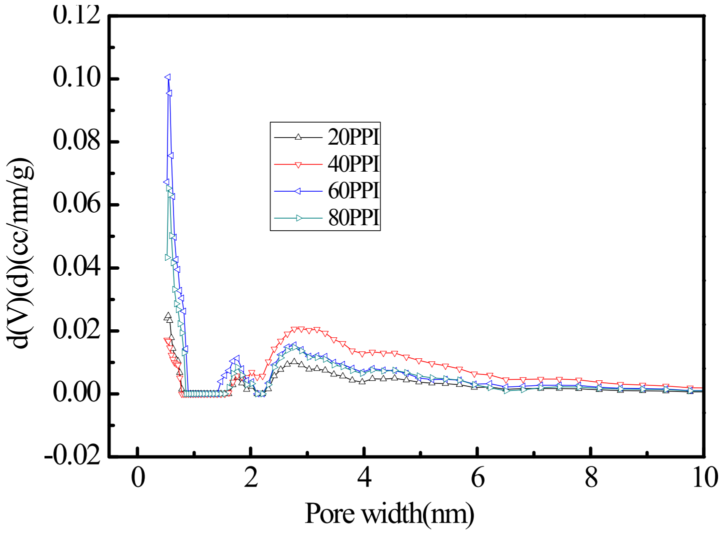


Fig. S1 Powder XRD pattern of synthesized Cu-BTC.

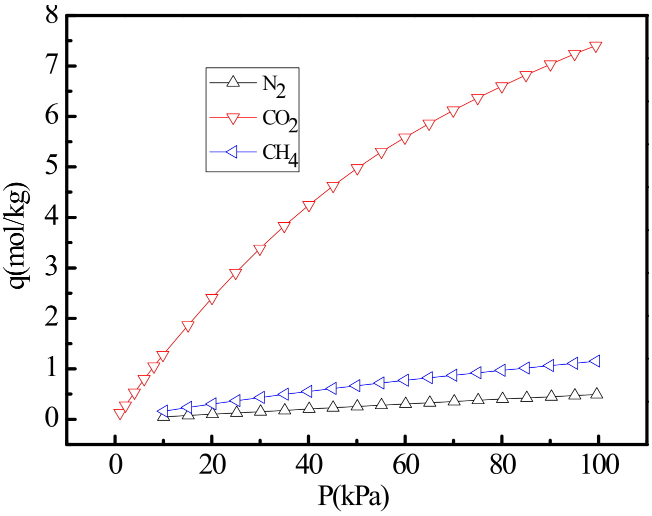


(a) The N_2 adsorption isotherm at 77 K

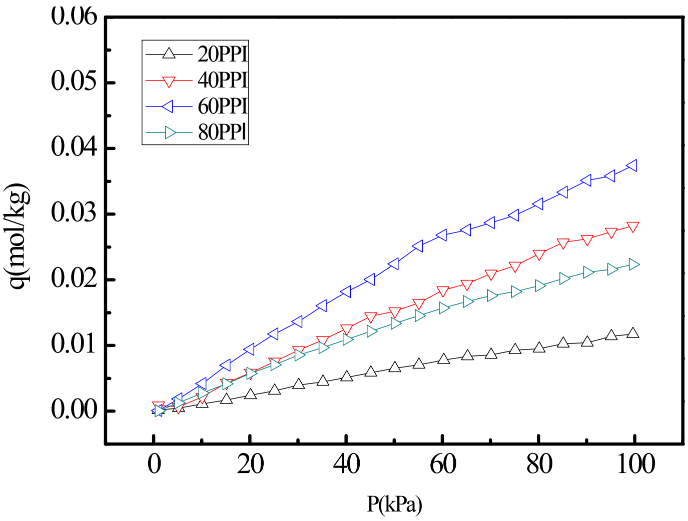


(b) The pore size distribution

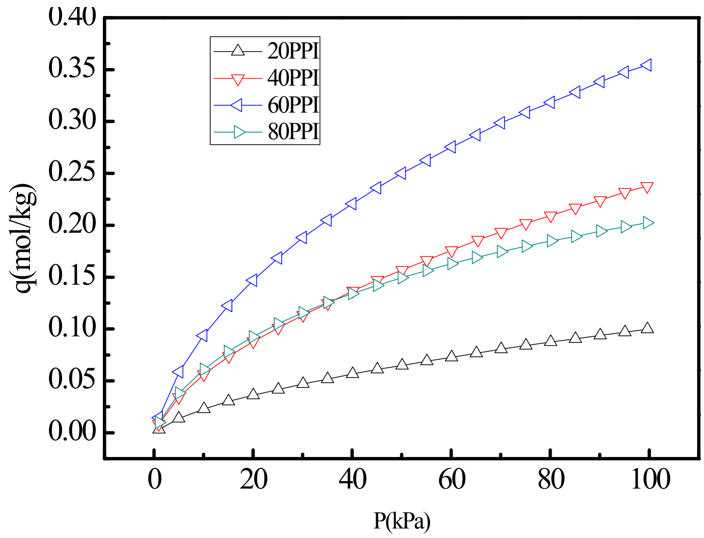
Fig. S2 the characteristics of different samples.



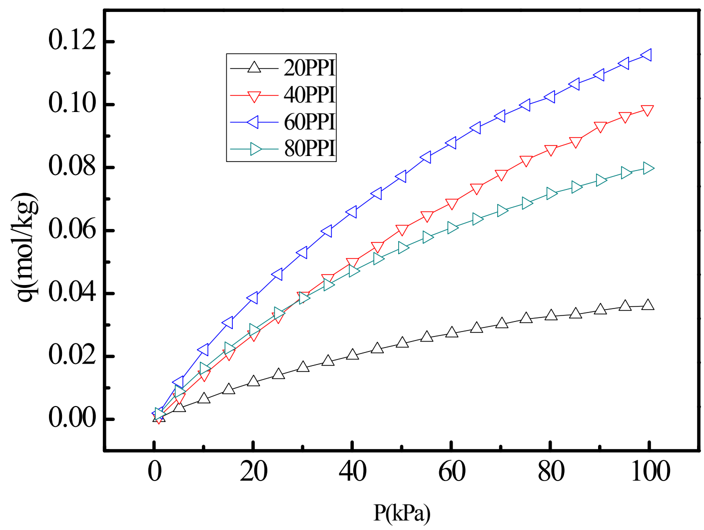
(a) The different gases adsorption isotherms in Cu-BTC at 273.15K



(b) The N_2 adsorption isotherm at 273.15 K

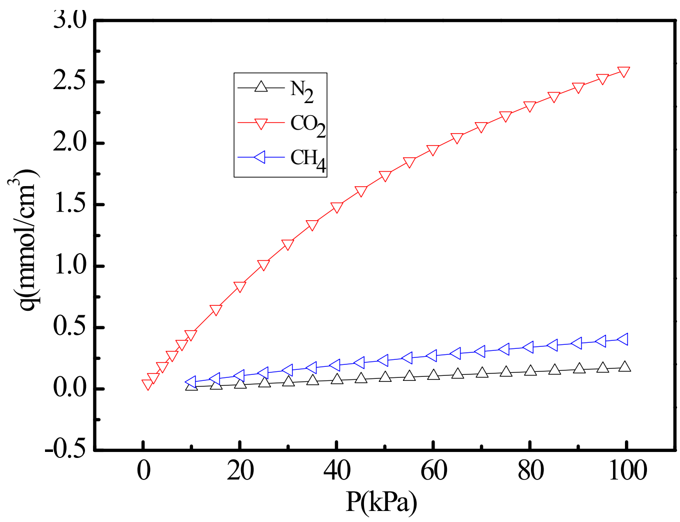


(c) The CO_2 adsorption isotherm at 273 K

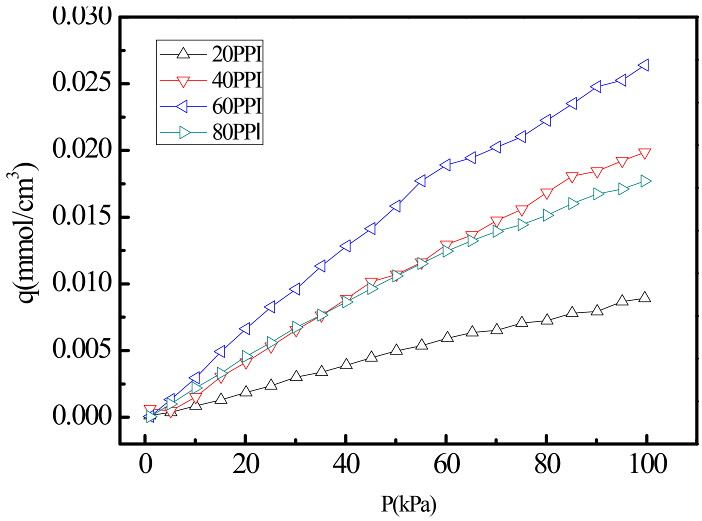


(d) The CH_4 adsorption isotherm at 273.15 K

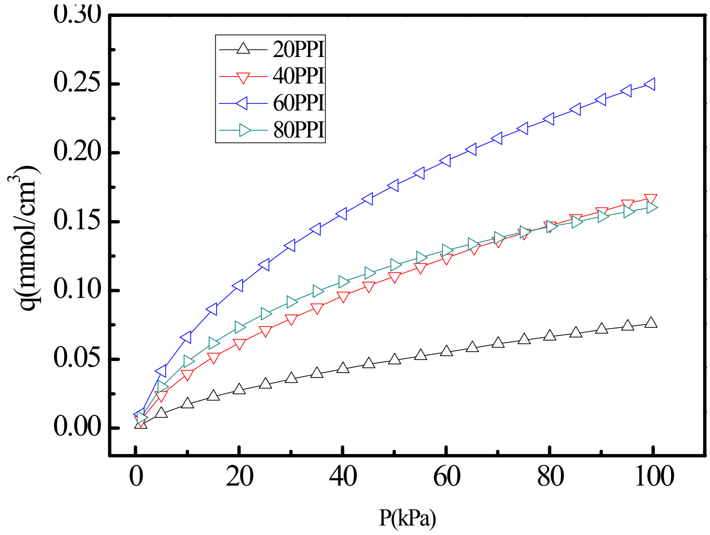
Fig. S3 The adsorption isotherms of different gases in adsorbent mass basis.



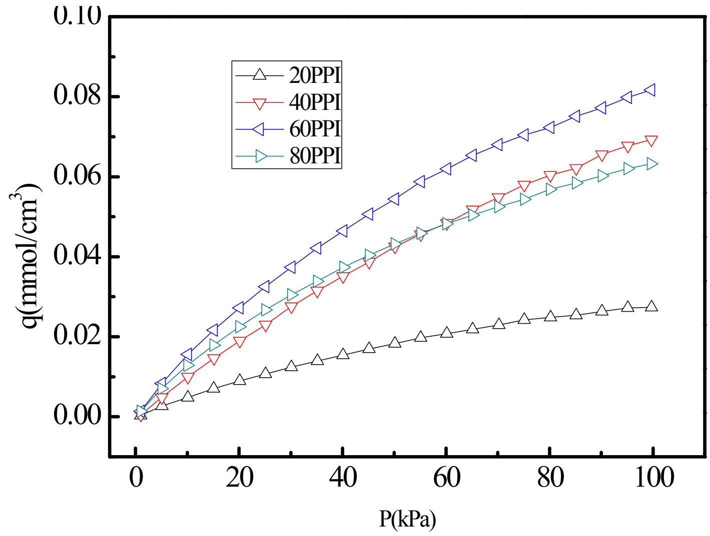
(a) The different gases adsorption isotherms in Cu-BTC at 273.15K



(b) The N_2 adsorption isotherm at 273.15 K



(c) The CO_2 adsorption isotherm at 273 K



(d) The CH_4 adsorption isotherm at 273.15 K

Fig. S4 The adsorption isotherms of different gases in adsorbent volume basis.

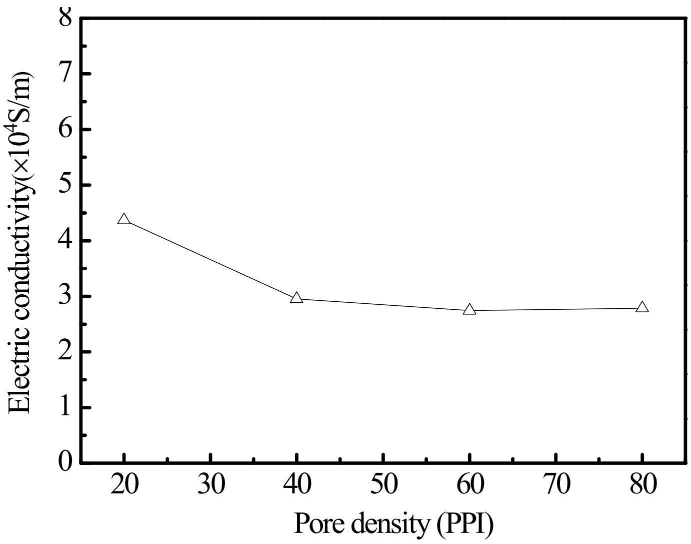


Fig. S5 The electric conductivity of CuBTC/CF at different pore densities.

Reference

1 S. W. Finefrock, Y. Wang, J. B. Ferguson, J. V. Ward, H. Y. Fang, J. E. PFuger, D. S. Dudis, X. L. Ruan and Y.Wu, Measurement of thermal conductivity of PbTe nanocrystal coated glass fibers by the 3ω method, *Nano Lett.,* 2013, **13**, 5006-5012.