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Supplementary Information

Large-scale synthesis of 3D ordered microporous carbon at low temperature using cobalt ions exchanged zeolite Y as a template

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Results and Discussion

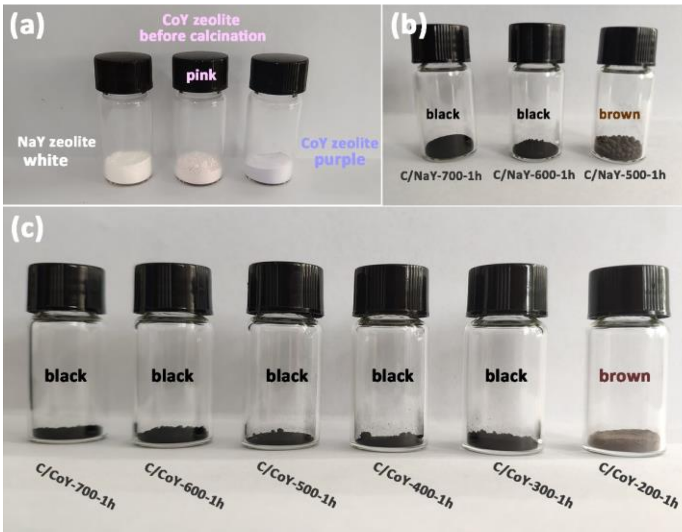

Fig. S1. (a) Photos of white NaY zeolite powders, pink CoY zeolite (before calcination) and purple CoY zeolite powders, (b) NaY zeolite and (c) CoY zeolite after CVD process at the different CVD temperature, respectively.

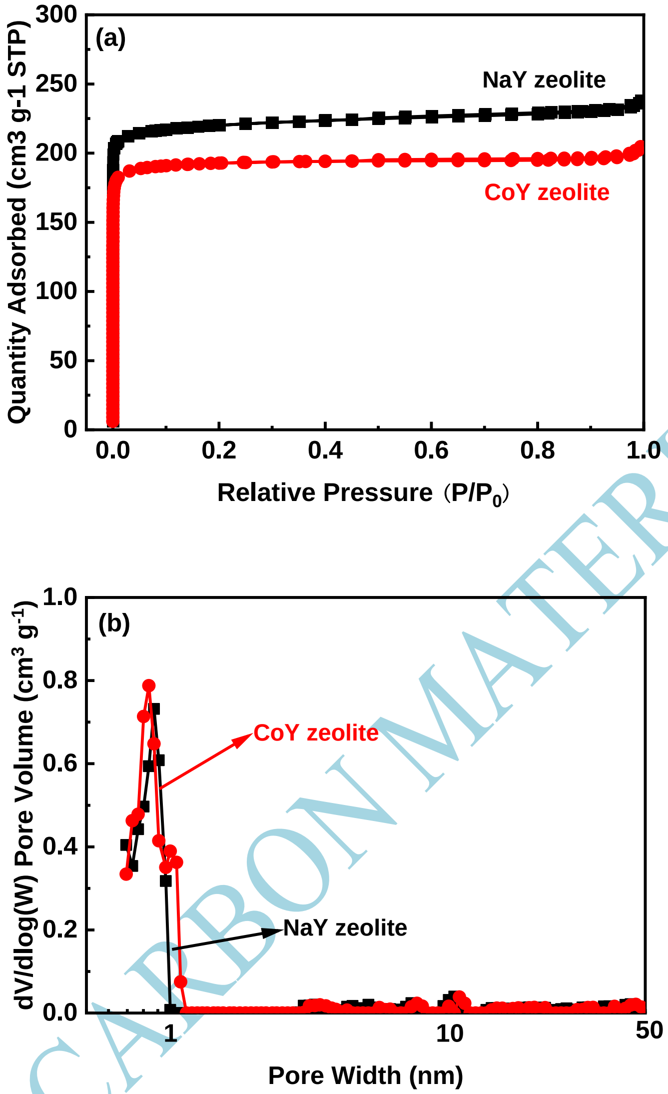

Fig. S2. (a) N_2 adsorption-desorption isotherms, (b) PSD calculated using the NLDFT model of the NaY and CoY zeolite.

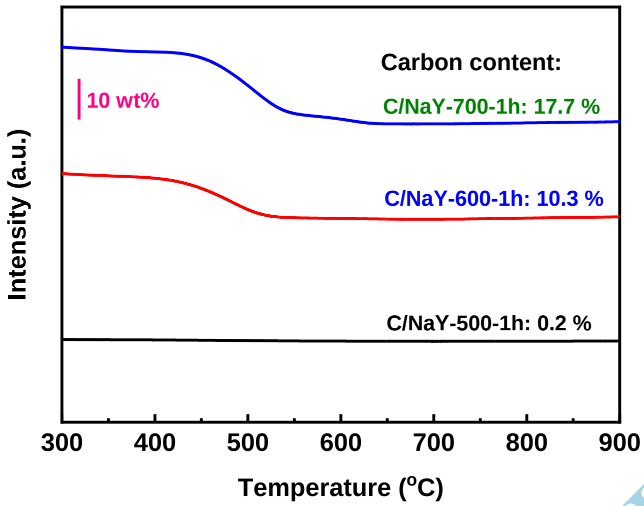

Fig. S3. Carbon deposition was calculated by the thermogravimetric analysis curves. TGA curves of the C/NaY-A-1h samples prepared at different CVD temperatures. The condition of the TGA test was that the sample was heated from room temperature to 900 °C in high-purity air with heating rate of 10 °C min^{-1}. Since the samples contain varying amounts of water, the water content needed to be excluded. The calculation TGA curves started at 300 °C.

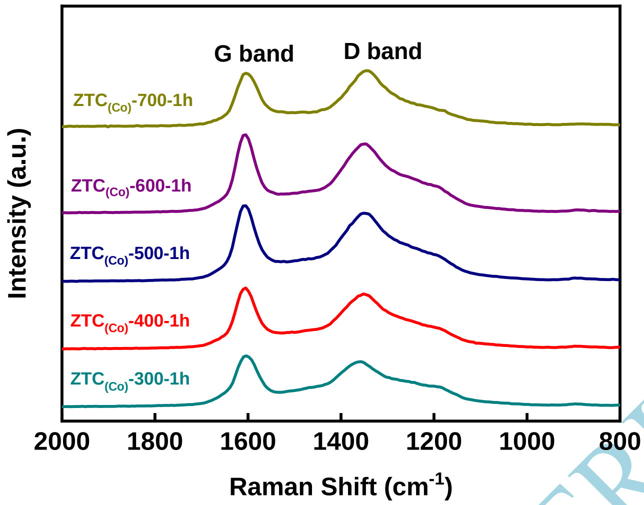

Fig. S4. Raman spectra of $ZTC_{(Co)}$-A-1h samples prepared at different CVD temperatures.

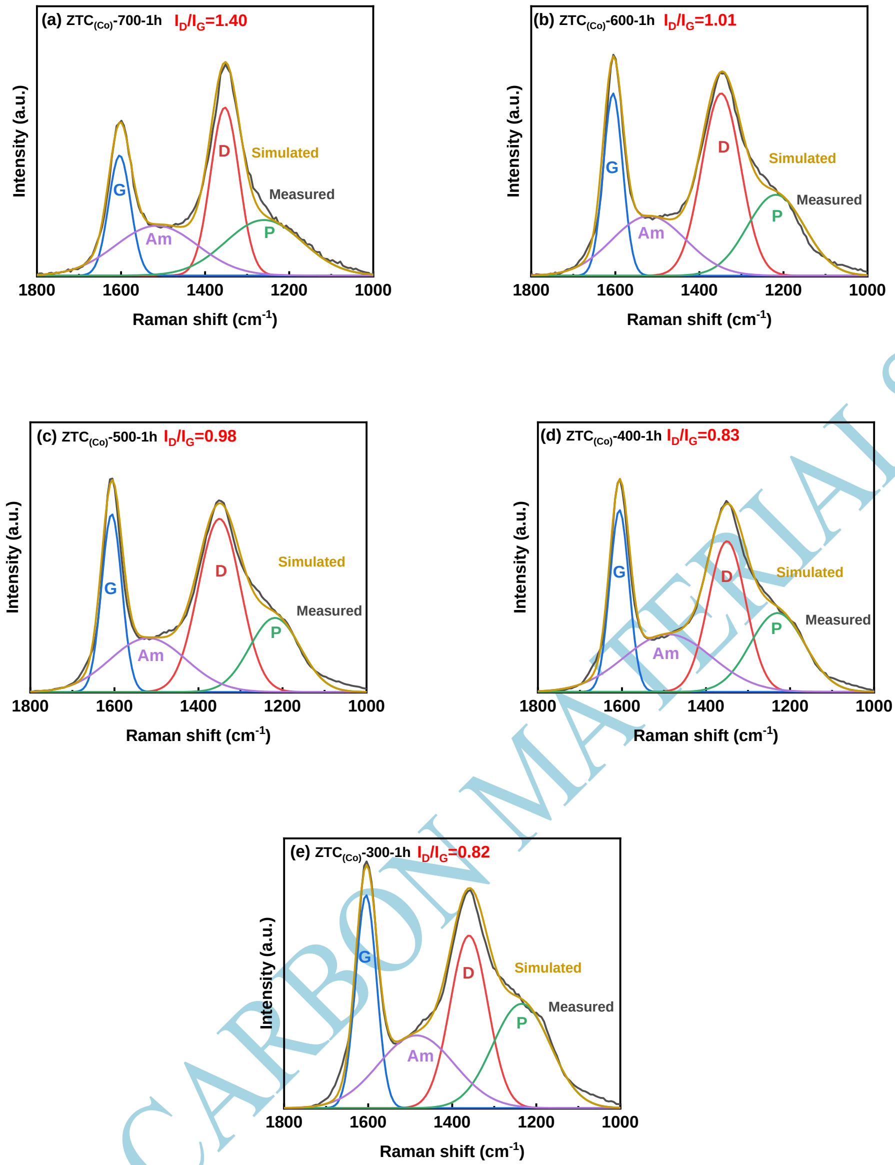

Fig. S5. (a)~(e) Deconvoluted components (D, G, P, Am), fitting result and the values of I_D/I_G are shown for $ZTC_{(Co)}$-A-1h samples. The graphitic peak (G band) at ca. 1600 cm^{-1}; the disorder peak (D band) at ca. 1300 cm^{-1}; the peak ascribed to amorphous carbon (Am peak) at ca. 1515 cm^{-1}; the peak ascribed to sp^3-bonded carbon atoms (P peak) at ca. 1200 cm^{-1} [1].

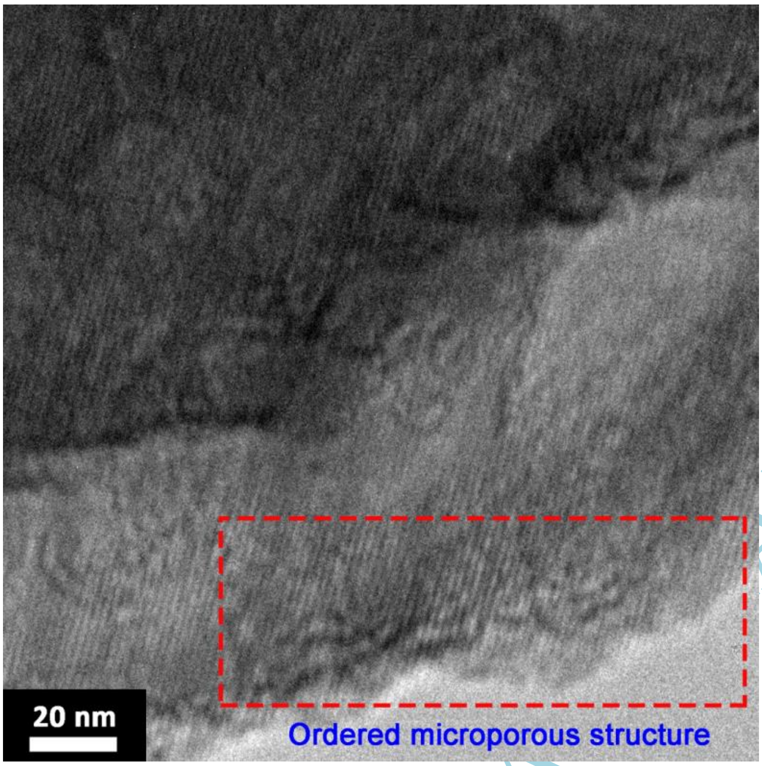

Fig. S6. TEM image of ZTC$_{(Co)}$-400-1h.

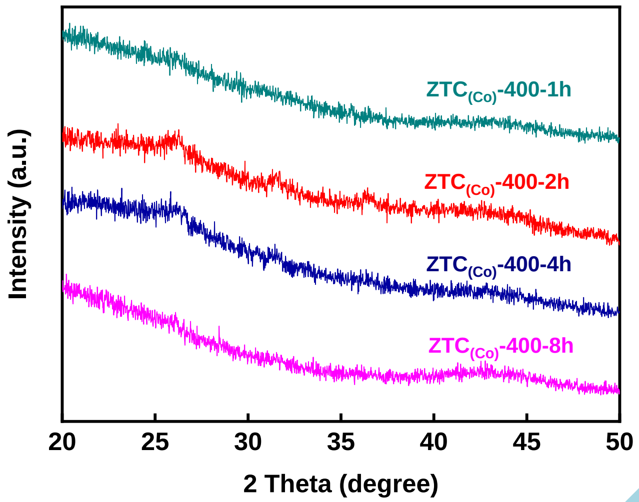

Fig. S7. Wide-angle XRD patterns of $ZTC_{(Co)}$-400-1h, $ZTC_{(Co)}$-400-2h, $ZTC_{(Co)}$-400-4h and $ZTC_{(Co)}$-400-8h.

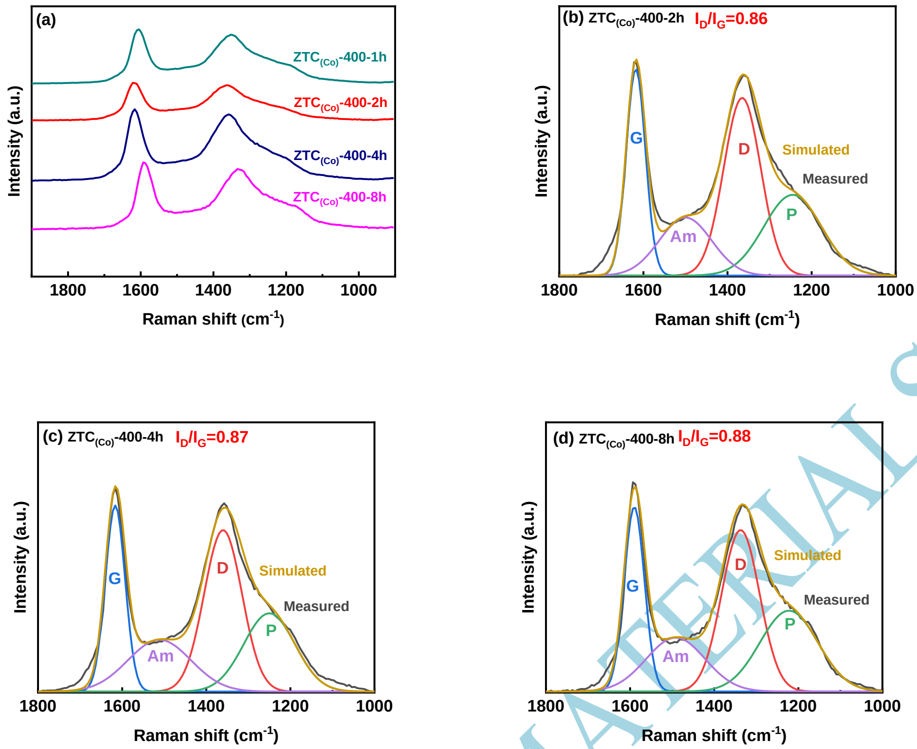

Fig. S8. (a) Raman spectra of all samples. (b)-(e) Deconvoluted components (D, G, P, Am), fitting result, the values of I_D/I_G are shown for ZTC$_{(Co)}$-400-2h, ZTC$_{(Co)}$-400-4h and ZTC$_{(Co)}$-400-8h. The graphitic peak (G band) at ca. 1600 cm^{-1}; the disorder peak (D band) at ca. 1300 cm^{-1}; the peak ascribed to amorphous carbon (Am peak) at ca. 1515 cm^{-1}; the peak ascribed to sp^3-bonded carbon atoms (P peak) at ca. 1200 cm^{-1} [1].

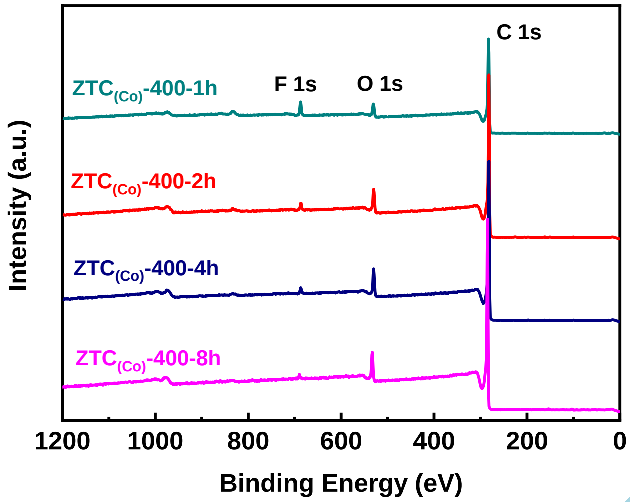

Fig. S9. XPS survey spectra of $ZTC_{(Co)}$-400-1h, $ZTC_{(Co)}$-400-2h, $ZTC_{(Co)}$-400-4h and $ZTC_{(Co)}$-400-8h.

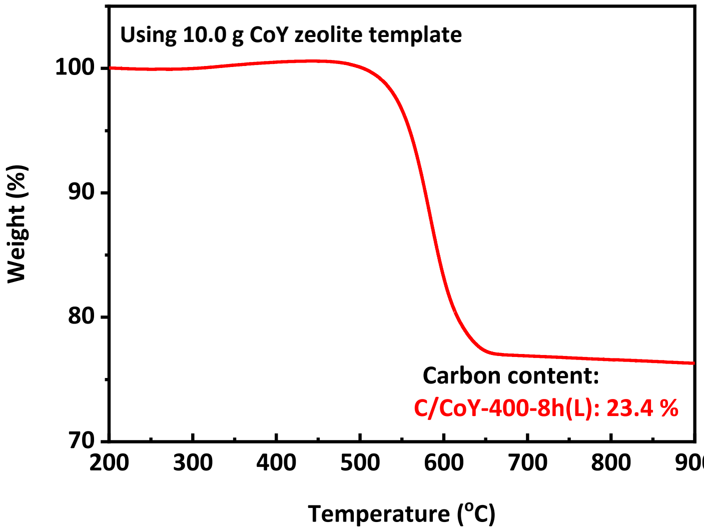

Fig. S10. Carbon deposition of C/CoY-400-8h(L) was calculated by the thermogravimetric analysis curves. The preparation conditions of C/CoY-400-8h(L) are as follows: the 10.0 g of CoY zeolite was placed in a large horizontal quartz reactor, and the air was purged by pure Ar gas flow at room temperature for 1 h in the reactor. The CVD temperature of the synthesis device was heated up to 400 °C under pure Ar gas flow with a heating rate of 5 °C min^{-1}. Then acetylene gas (50 % in Ar, acetylene: 30 sccm; Ar: 30 sccm) was passed through the reactor for 8 h. After the carbonaceous deposition, the graphitization temperature was increased to 900 °C and was maintained for 1 h under pure Ar gas again. Cooling to room temperature, the carbon compounds are indicated as C/CoY-400-8h(L).

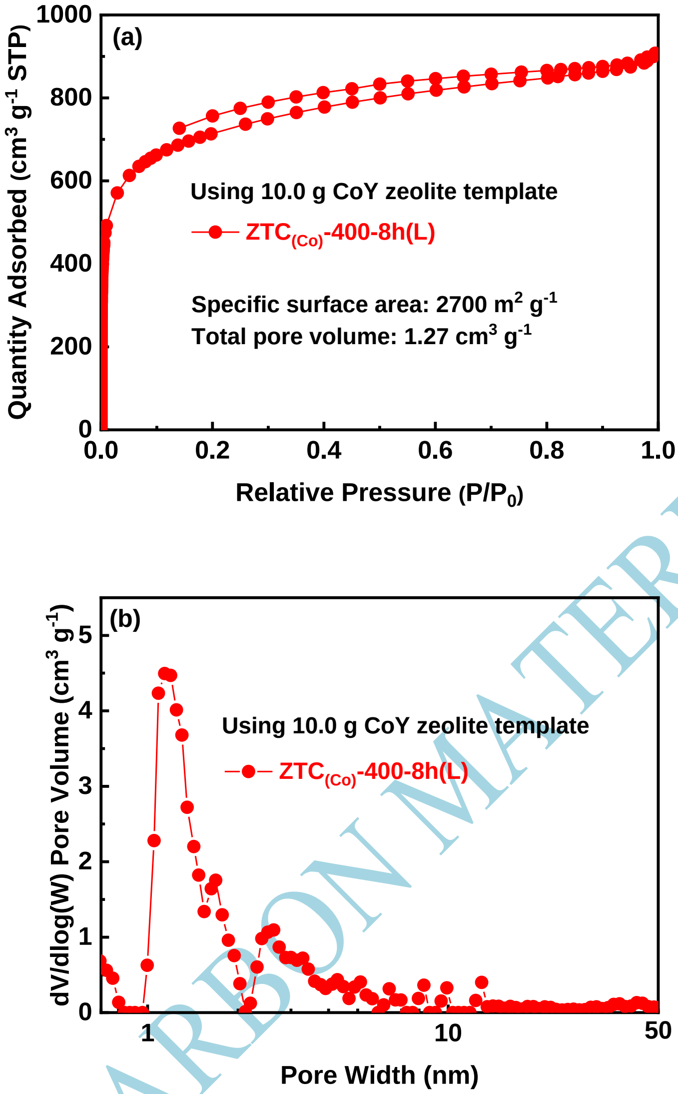

Fig. S11. (a) N_2 adsorption-desorption isotherms and (b) NLDFT pore size distribution of $ZTC_{(Co)}$-400-8h(L).

Table S1. Summary of SSA and pore volume from the N_2 adsorption-desorption isotherms at -196 °C and synthesis condition for each sample.

Samples	Temperature[a]	SSA[b]	V_1[c]	V_2[d]
NaY	-	650	0.33	0.16
CoY	-	570	0.28	0.22
$ZTC_{(Co)}$-700-1h	700	1370	0.67	0.46
$ZTC_{(Co)}$-600-1h	600	1480	0.87	0.48
$ZTC_{(Co)}$-500-1h	500	2060	0.94	0.71
$ZTC_{(Co)}$-400-1h	400	2200	1.00	0.80
$ZTC_{(Co)}$-300-1h	300	1400	0.67	0.47

Temperature[a]: CVD temperature (°C), SSA[b]: BET specific surface area, $m^2\ g^{-1}$, V_1[c]: total pore volume, $cm^3\ g^{-1}$, V_2[d]: micropore volume, $cm^3\ g^{-1}$.

Table S2. Surface elements content (at%) of the $ZTC_{(Co)}$-400-1h, $ZTC_{(Co)}$-400-2h, $ZTC_{(Co)}$-400-4h and $ZTC_{(Co)}$-400-8h.

Samples	C 1s	O 1s	F 1s
$ZTC_{(Co)}$-400-1h	90.2	5.8	4.0
$ZTC_{(Co)}$-400-2h	92.6	6.1	1.3
$ZTC_{(Co)}$-400-4h	92.3	6.5	1.2
$ZTC_{(Co)}$-400-8h	92.8	6.7	0.5

Table S3. A list of ZTCs prepared by CVD methods.

Zeolite	Method	Mass[a]	Carbon Source	T[b] (°C)	SSA[c] (m^2 g^{-1})	V_1[d] (cm^3 g^{-1})	V_2[e] (cm^3 g^{-1})	Ref.[f]
CoY zeolite	CVD	1.0 g	Acetylene	400	3000	1.33	1.03	This work
CoY zeolite	CVD	10.0 g	Acetylene	400	2700	1.27	0.92	This work
β zeolite	CVD	-	Propylene	800	2025	1.30	0.90	2
β zeolite	CVD	0.5 g	Acetonitrile	850	2272	1.96	0.45	3
NaY zeolite	CVD	-	Propylene	800	2300	1.50	0.51	4
NaY zeolite	CVD	-	Benzene	650	1511	0.92	0.36	5
β zeolite	CVD	0.3 g	Acetonitrile and H_2O vapor	750	1860	-	1.4	6
HY zeolite	CVD	0.8 g	Acetonitrile	750	1322	0.84	0.47	7
LaY zeolite	CVD		Ethylene and H_2O vapor	600	-	1.40	1.20	8
CaX zeolite	CVD	0.3 g	Ethylene and H_2O vapor	600	2770	1.32	1.05	9
CaX zeolite	CVD	200 g	Ethylene and H_2O vapor	600	2400	1.16	1.00	9
CoY zeolite	CVD	1.0 g	Ethylene and H_2O vapor	600	1613	1.18	0.82	10
CaY zeolite	CVD	0.3 g	Nitrogen-containing precursor and H_2O vapor	600	2540	1.25	1.00	11

Mass[a]: the mass of zeolite templates used; Temperature[b]: CVD temperature (°C); SSA[c]: BET specific surface area, m^2 g^{-1}; V_1[d]: total pore volume, cm^3 g^{-1}; V_2[e]: micropore volume, cm^3 g^{-1}; Ref[f]: References.

Reference

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