Supplementary information

# Hydrolysis of Cellulose by a Mesoporous Carbon-$Fe_2(SO_4)_3$/γ-$Fe_2O_3$ Nanoparticle-Based Solid Acid Catalyst

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Legend

MCNC: mesoporous carbon-γ-$Fe_2O_3$ nanoparticle composite

MCNC-SA: MCNC-based solid acid catalyst

Table S1 | Brauner-Emmett-Teller (BET) surface areas, total pore volumes, and average pore sizes of MCNC-SA samples synthesized using different iron nitrate concentrations.

| Samples (with iron nitrate concentration) | BET specific surface area ($m^2\ g^{-1}$) | Total pore volume ($cm^3\ g^{-1}$) | Average pore size (nm) |
|---|---|---|---|
| 1.25 g $L^{-1}$ | 17.4 | 0.060 | 13.90 |
| 2.50 g $L^{-1}$ | 39.1 | 0.103 | 10.51 |
| 5.00 g $L^{-1}$ | 65.6 | 0.106 | 6.44 |
| 10.0 g $L^{-1}$ | 114.4 | 0.177 | 6.20 |
| 15.0 g $L^{-1}$ | 129.1 | 0.218 | 6.76 |

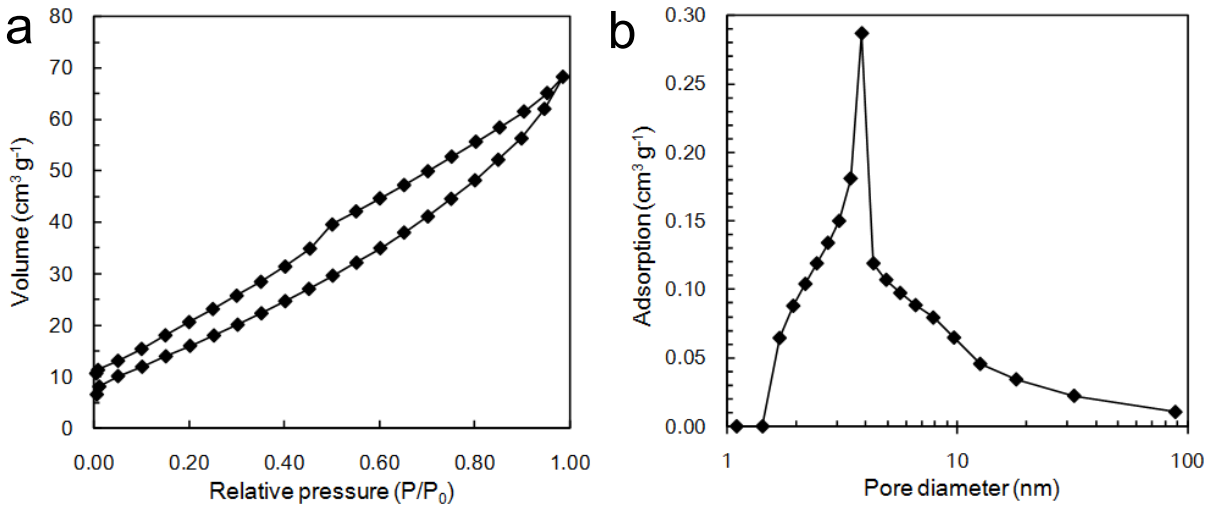


Figure S1 | Pore size distributions of MCNC-SA (concentration of iron(III) nitrate enneahydrate solution: 5.0 g $L^{-1}$). (a) Nitrogen adsorption-desorption isotherms. (b) Pore size distribution obtained from desorption isotherms as calculated by the BJH (Barret-Joyner-Halenda) method.

Table S2 | Compositions of MCNC-SA.

| Sample [a] (with iron nitrate concentration) | C (1s) | N (1s) | O (1s) | Na (1s) | S (2p) | Fe ($2p_{3/2}$) |
|---|---|---|---|---|---|---|
| 5.0 g $L^{-1}$ | 71.7 | 1.3 | 23.5 | 0.2 | 2.4 | 0.9 |

a) Elemental compositions by XPS analysis, in atomic percent.

| Samples [b] (with iron nitrate concentration) | C | H | N | S | Fe [c] |
|---|---|---|---|---|---|
| 1.25 g $L^{-1}$ | 60.22 | 2.40 | 1.03 | 5.18 | 1.40 |
| 2.50 g $L^{-1}$ | 58.53 | 2.44 | 0.89 | 4.83 | – |
| 5.00 g $L^{-1}$ | 54.18 | 1.85 | 0.66 | 4.64 | 6.21 |
| 10.0 g $L^{-1}$ | 52.09 | 1.86 | 0.69 | 4.41 | – |
| 15.0 g $L^{-1}$ | 55.06 | 2.34 | 0.84 | 4.69 | 6.33 |

b) Compositions determined by elemental analyzer, in weight percent.
c) Calculated from ash ($Fe_2O_3$) weight percent.

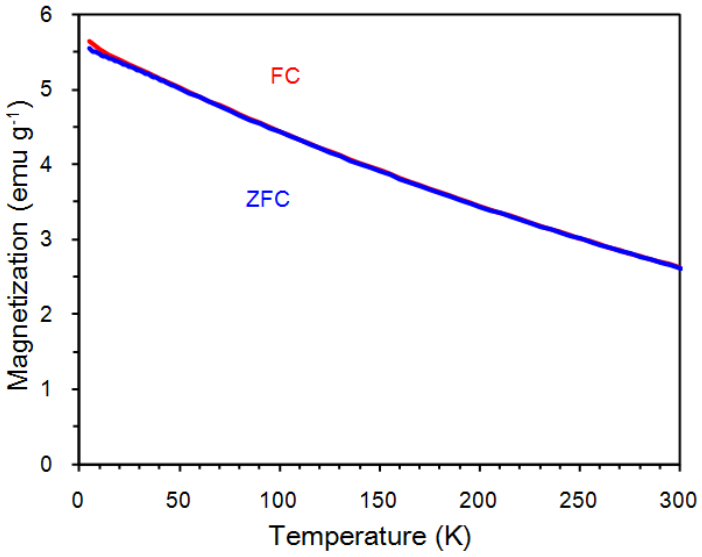


Figure S2 | Zero field cooled (ZFC) and field cooled (FC) magnetization for MCNC-SA (concentration of iron(III) nitrate enneahydrate solution: 5.0 g $L^{-1}$).

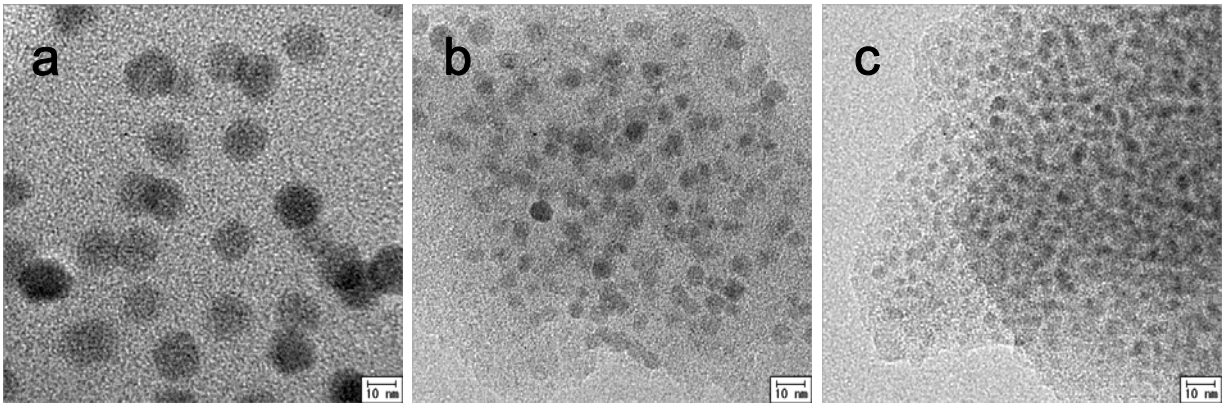


Figure S3 | Iron oxide nanoparticle sizes in the MCNC-SA carbon matrix. TEM images of MCNC-SA, prepared from iron(III) nitrate enneahydrate solutions with concentrations of (a) 1.25 g $L^{-1}$, (b) 5.00 g $L^{-1}$ and (c) 15.0 g $L^{-1}$.

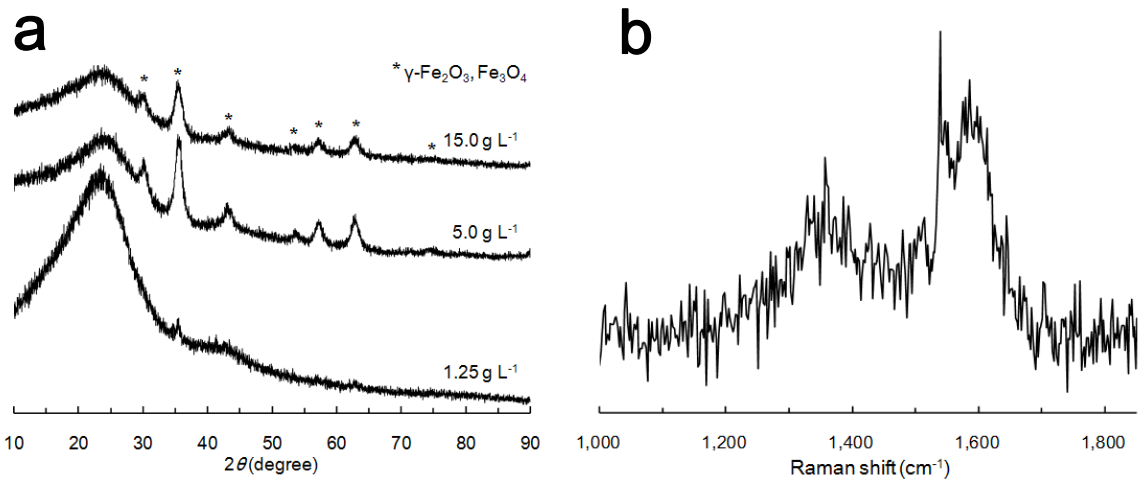


Figure S4 | Structures of MCNC-SA. (a) The XRD pattern of the samples. The diffraction peaks can be assigned to γ-$Fe_2O_3$ (JCPDS card No. 39-1346) or $Fe_3O_4$ (JCPDS card No. 19-0629). (b) Raman spectrum of the sample (concentration of iron(III) nitrate enneahydrate solution: 5.0 g $L^{-1}$).

Table S3 | Mössbauer effect parameters of MCNC-SA (concentration of iron(III) nitrate enneahydrate solution: 5.0 g $L^{-1}$).

| Temperature | Component | $\delta$ [a)] | $\Delta$ [a)] | $H$ [a)] | %Fe |
|---|---|---|---|---|---|
| 293 K | [1] | +0.26 | 0.34 | 0 | 62 |
| | [2] | +0.38 | 0.64 | 0 | 38 |
| 78 K | [1] | +0.46 | +0.03 | 506 | 18 |
| | [2] | +0.57 | −0.11 | 434 | 45 |
| | [3] | +0.53 | 0.61 | 0 | 37 |

a) $\delta$: isomer shift (mm $s^{-1}$), $\Delta$: quadrupole shift (mm $s^{-1}$), $H$: magnetic field (kOe).

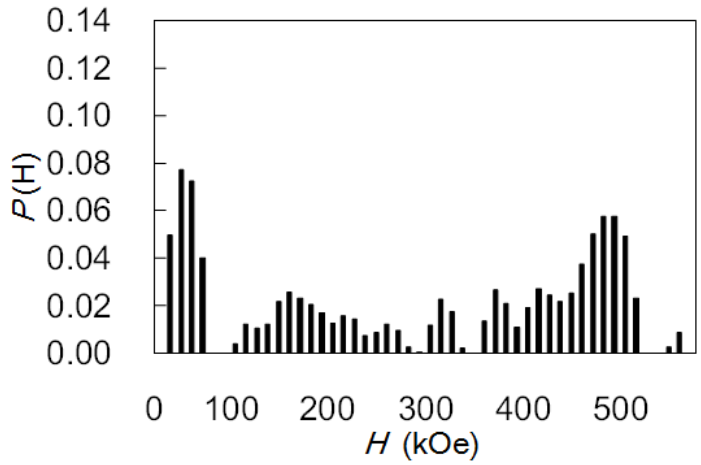


Figure S5 | The magnetic field distribution analysis for MCNC-SA at 78 K, assuming that the paramagnetic component gives a quadrupole shift doublet (concentration of iron(III) nitrate enneahydrate solution: 5.0 g $L^{-1}$).

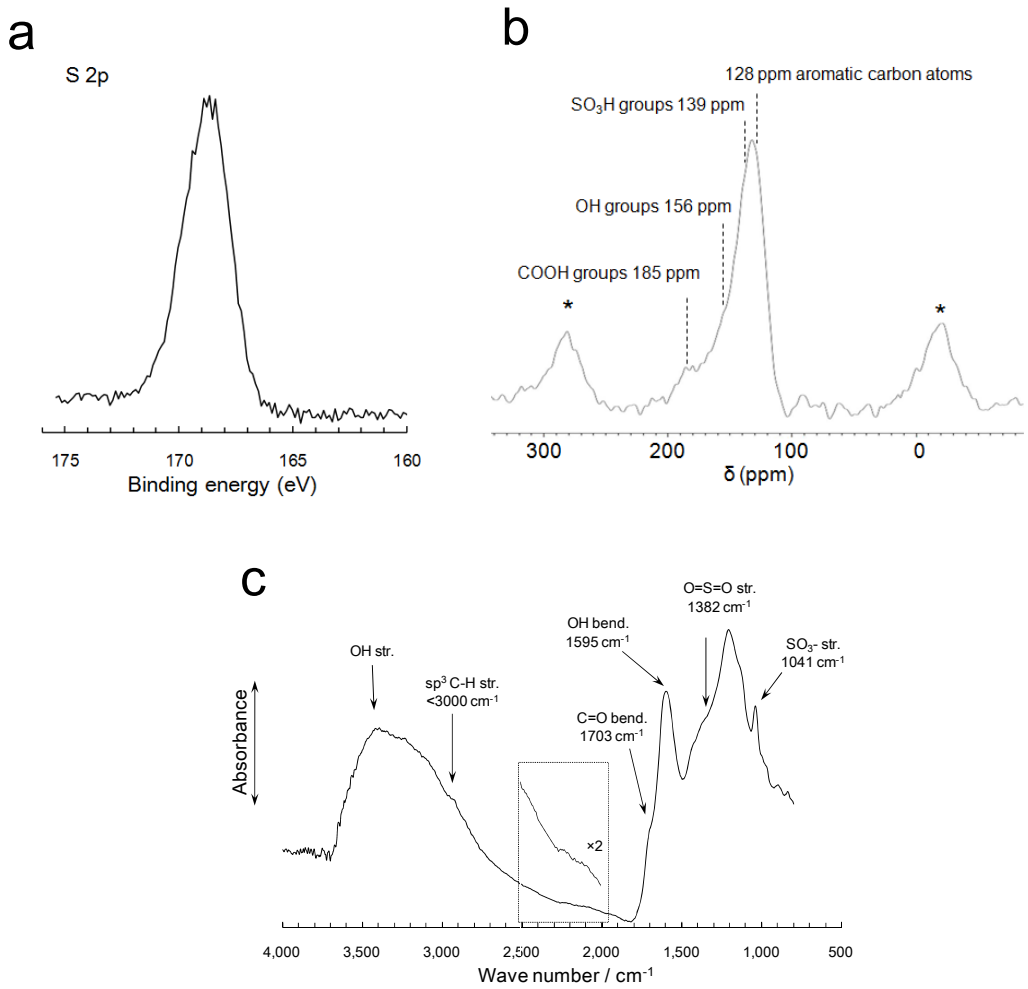


Figure S6 | Surface functional groups of MCNC-SA (concentration of iron(III) nitrate enneahydrate solution: 5.0 g $L^{-1}$). (a) S 2p peak in the XPS spectrum. (b) $^{13}$C-DD/MAS NMR spectrum (* denotes spinning side bands). (c) FTIR spectrum.

Table S4 | Magnetic remanence ($M_r$), saturation magnetization ($M_s$), and coercivity ($H_c$) of MCNC-SA samples synthesized using different iron nitrate concentrations.

| Samples (with iron nitrate concentration) | $M_r$ (emu $g^{-1}$) | $M_s$ (emu $g^{-1}$) | $H_c$ (Oe) | $M_r$ / $M_s$ |
|---|---|---|---|---|
| 1.25 g $L^{-1}$ | 0.05 | 0.51 | 42 | 0.089 |
| 2.50 g $L^{-1}$ | 0.05 | 1.61 | 25 | 0.028 |
| 5.00 g $L^{-1}$ | 0.17 | 5.70 | 28 | 0.030 |
| 10.0 g $L^{-1}$ | 0.20 | 8.38 | 23 | 0.024 |
| 15.0 g $L^{-1}$ | 0.03 | 5.58 | 9 | 0.006 |

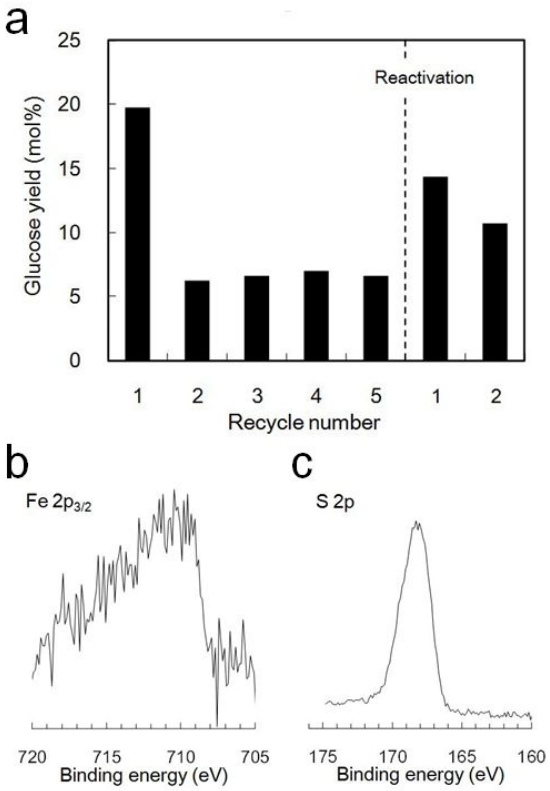


Figure S7 | Repeated hydrolysis of cellobiose using MCNC-SA (concentration of iron(III) nitrate enneahydrate solution: 1.25 g $L^{-1}$). (a) Reaction conditions: MCNC-SA, 0.10 g; cellobiose, 0.12 g; water, 0.7 g; reaction temperature, 90 ºC; reaction time, 3 h. (b) Fe $2p_{3/2}$ and (c) C 2p XPS spectra of the catalyst after one use.