Electronic Supplementary Information

Absorption of SO₂ from Flue Gas by Aqueous Fulvic Acid Solution

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Summary:

Gas mixing chamber

Valve 2

Vent

Bypass

Rotameter

Valve 1   Valve 3

Flue gas analyzer

pH meter

N₂   O₂   SO₂

Bubbling reactor

（a）

N₂,SO₂ → Vent

Rotameter

Water outlet

Reflux condenser

Cold water inlet

Flask

N₂

Heater
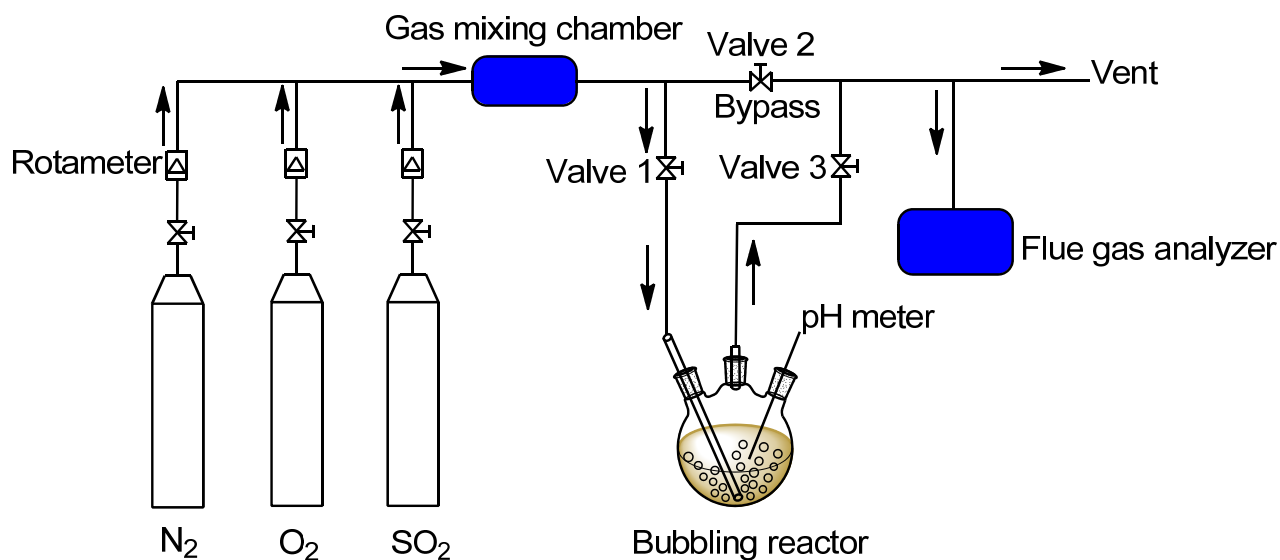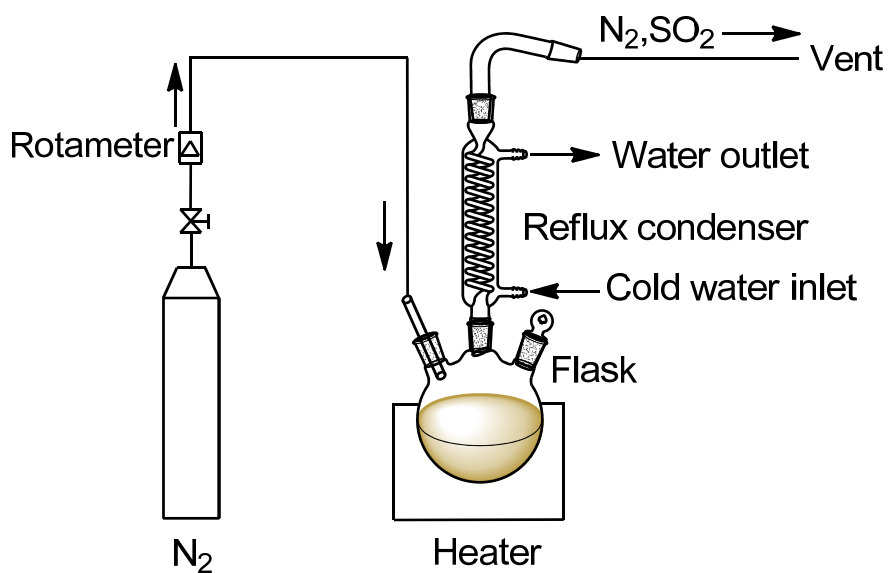
（b）

Fig. S1 The experimental apparatus of (a) absorption and (b) desorption of SO_2.
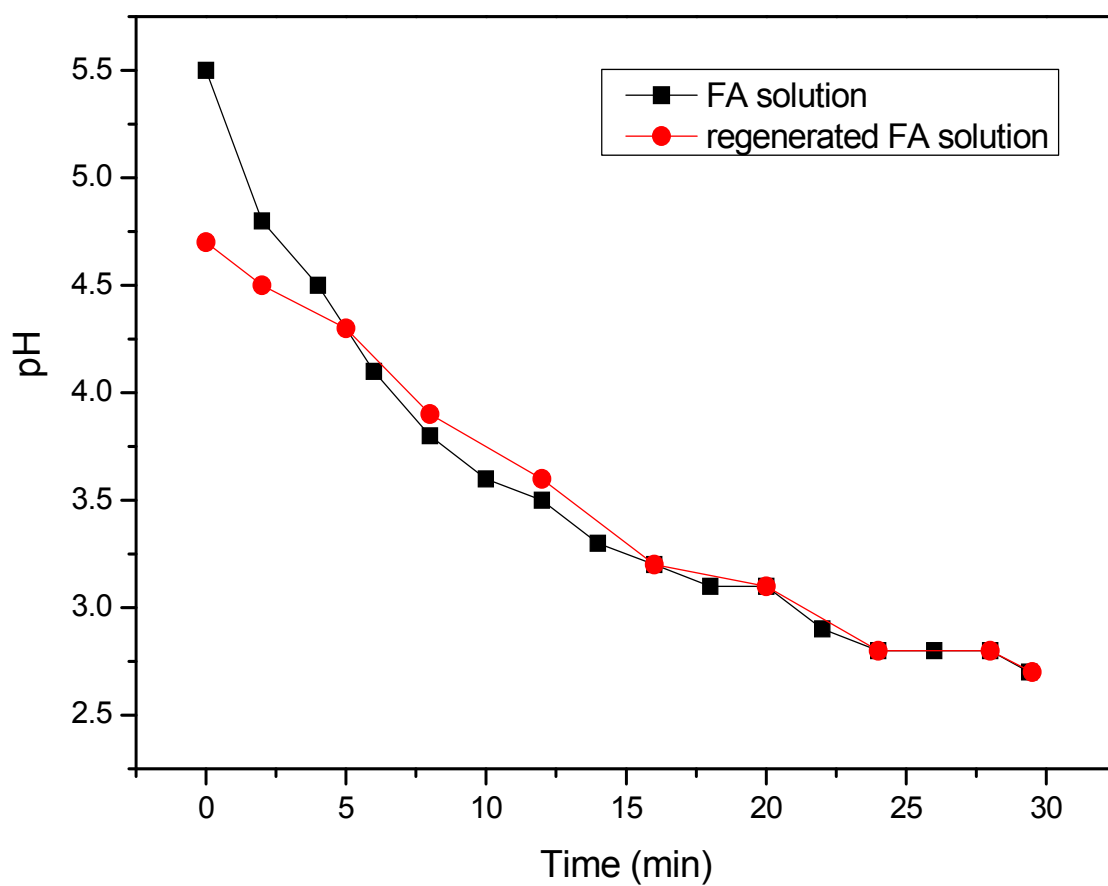
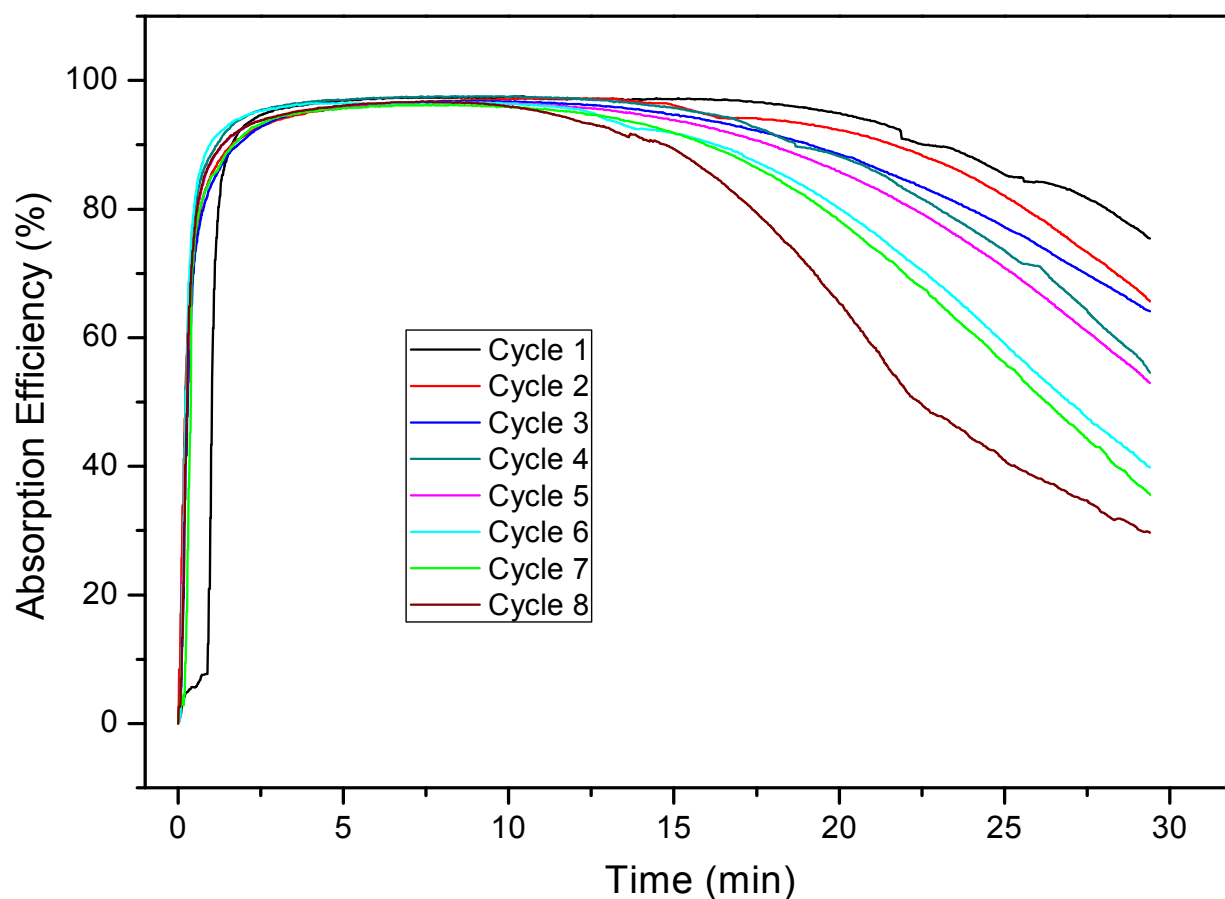**Fig. S2**   The pH of the FA solution and regenerated FA solution (Cycle 2) with SO_2 absorption time.

Fig. S3 SO$_2$ absorption efficiency with absorption time for Cycle 1-8. Cycle 1 was the FA solution (FA, 0.04 g mL^{-1}, 100 ml) without any SO$_2$ absorption and desorption. Cycle 2 was the first regenerated FA solution, which was obtained by the desorption of the first SO$_2$-loaded FA solution, and so on. The SO$_2$ absorption parameters for Cycle 1-8 were equal (100 ml, 0.04 g mL^{-1}, FA solution; gas flow of 0.14 m^3 h^{-1}; inlet SO$_2$ of 2200 ppm; inlet O$_2$ of 5 vol%; SO$_2$ absorption time, 29.4 minutes; at 298K and ambient pressure). And the desorption of Cycle 1-8 were carried out in nitrogen gas by heating at 343K under ambient pressure.
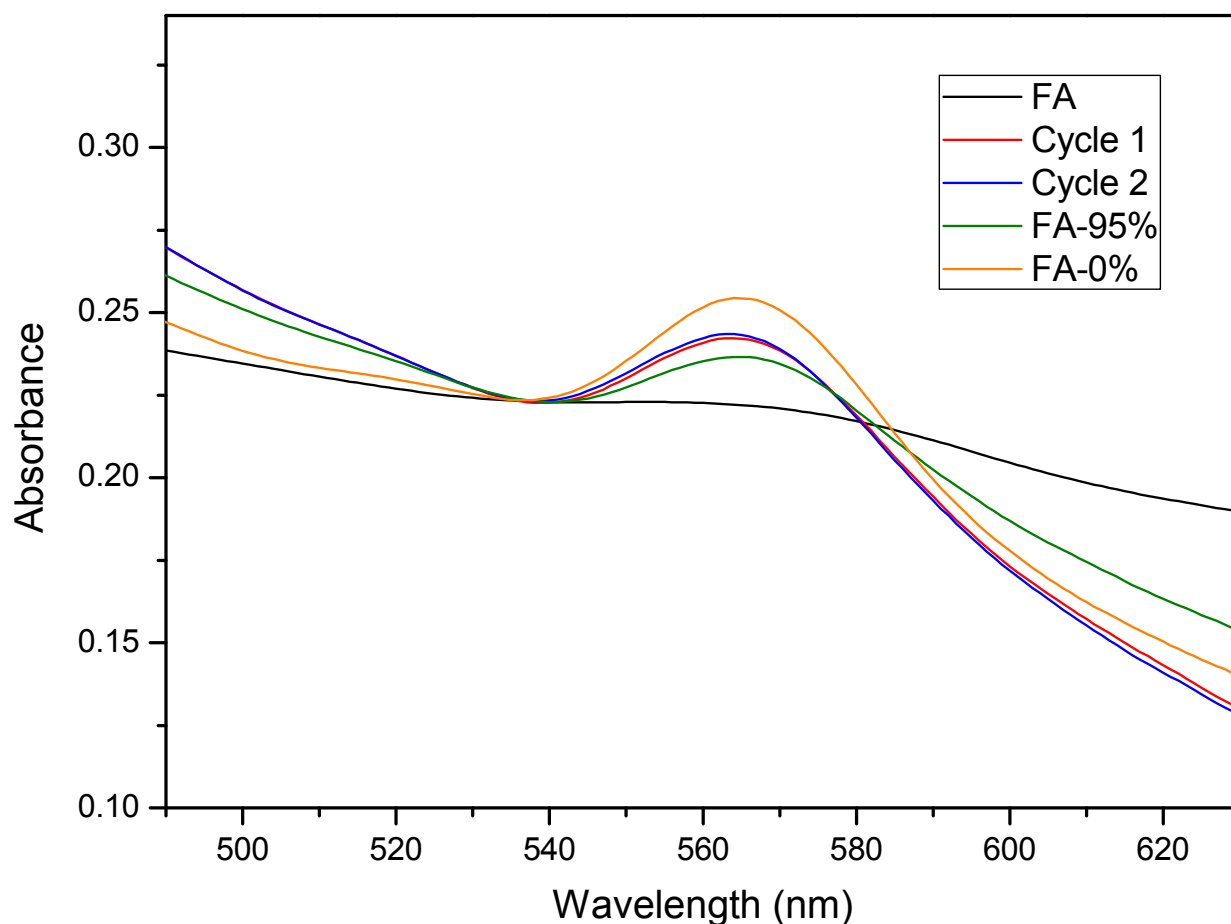
Fig. S4 The absorption spectra of rhodamine-based fluorescent probe (50 μmol L^{-1}) in water-ethanol (90/10, v/v) buffered at pH4.8 upon mixing with FA solution before and after absorbing SO_2. FA, Cycle 1, Cycle 2, FA-95% and FA-0% are 100-fold diluted FA solution (FA, 0.04 g mL^{-1}; SO_2 absorption time, 0 minutes), the SO_2-loaded FA solution of Cycle 1 (FA, 0.04 g mL^{-1}; SO_2 absorption time, 29.4 minutes), the SO_2-loaded FA solution of Cycle 2 (FA, 0.04 g mL^{-1}; SO_2 absorption time, 29.4 minutes), the SO_2-loaded FA solution (FA, 0.04 g mL^{-1}; SO_2 absorption time, 19.8 minutes, when the SO_2 absorption efficiency was 95%) and the SO_2-saturated FA solution (FA, 0.04 g mL^{-1}; SO_2 absorption time, 180 minutes, when the SO_2 absorption efficiency was 0%), epsectively. For Cycle 1, Cycle 2, FA-95% and FA-0%, the same SO_2 absorption conditions were gas flow of 0.14 m^3 h^{-1}, inlet SO_2 of 2200 ppm, inlet O_2 of 5 vol%, at 298K and ambient pressure. The ratio of rhodamine-based fluorescent probe solution to each sample was 8 (v/v). Our fluorescent probe was synthesized according to the synthetic route proposed by Yang et al.[1] Ultraviolet absorbances in the wavelength range of 400-680nm were determined using a UV-visible spectrophotometer (EV300, Thermo Electron, USA).
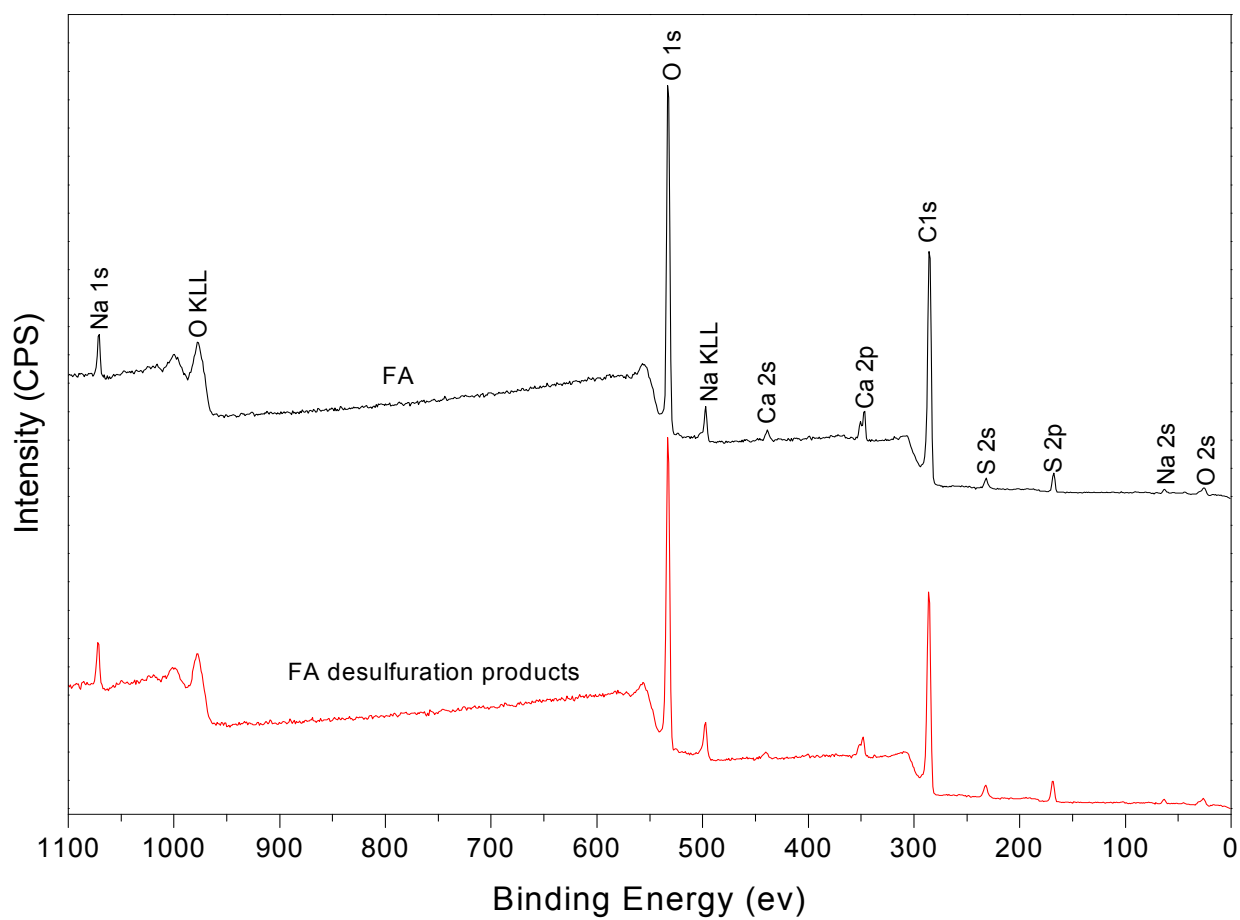
Fig. S5 XPS survey spectra of FA and FA desulfuration products.

Table S1   Assignment of FTIR Absorption Bands of FA

Wavenumber (cm^{-1})	Assignment	Reference
3405	O–H stretching (phenols, alcohols and carboxyls), N–H stretching (amides and amines)	2
2940	aliphatic C–H stretching	2a-c
2844	aliphatic C–H stretching	2a-c
1705	carboxylic C=O stretching	2a-c, 3
1600	aromatic C=C, asymmetric C=O stretching of COO$^-$	2a, 2b, 3
1517	C=C stretching of aromatic rings	4
1460	C–H stretching of CH$_2$ and CH$_3$ groups of aliphatic chains	2a, 2d, 4-5
1426	symmetrical C=O stretching of COO$^-$, aliphatic C–H bendings	6
1330	Syringyl ring with C–O stretching	4, 7
1219	C–O stretching and O–H deformation of COOH	2a, 8
1118	SO$_4$ asymmetric stretching, aromatic C–H in plane deformation (syringyl)	7, 9
1043	Alcoholic and polysaccharide CO stretch and OH deformation, sulfonic acids	8b, 10
916, 830	out-of-plane deformation vibrations of aromatic C–H	6a, 7, 9d, 11
654	S–O stretching of sulphonic groups	9c, 12
603	asymmetric stretching and deformation vibrations of SO$_4^{2-}$ anion	9c, 13
532	Stretching of C–C	11

Table S2   Surface Composition Determined by XPS Quantification

Sample	Peak	Position BE (eV)	Atomic Concentration (%)[a]
FA	S 2p	167.9	2.0
	C 1s	286.3	61.7
	Ca 2p	347.5	1.5
	N 1s	399.7	0.3
	O 1s	532.9	33.0
	Na 1s	1071.7	1.6
FA desulfuration products	S 2p	169	2.6
	C 1s	286.2	57.6
	Ca 2p	348.3	1.2
	N 1s	400.8	0.3
	O 1s	533.2	36.3
	Na 1s	1071.8	2.0

[a] Hydrogen and Magnesium were not detected. Quantitation was performed by using peak areas, which were divided by atomic sensitivity factors to evaluate atomic concentrations of each elements.

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