Supporting information

Enhanced leaching of manganese from zinc anode slime with a thiourea-assisted sulfuric acid solution

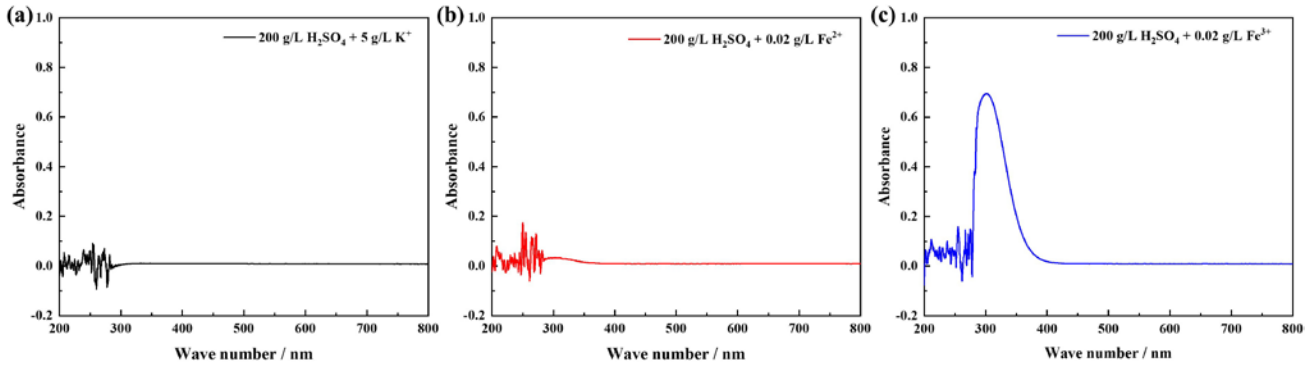

Figure S1 UV-vis spectra of (a) 200 g/L H_2SO_4 + 5 g/L K^+, (b) 200 g/L H_2SO_4 + 0.02 g/L Fe^{2+}, (a) 200 g/L H_2SO_4 + 0.02 g/L Fe^{3+}

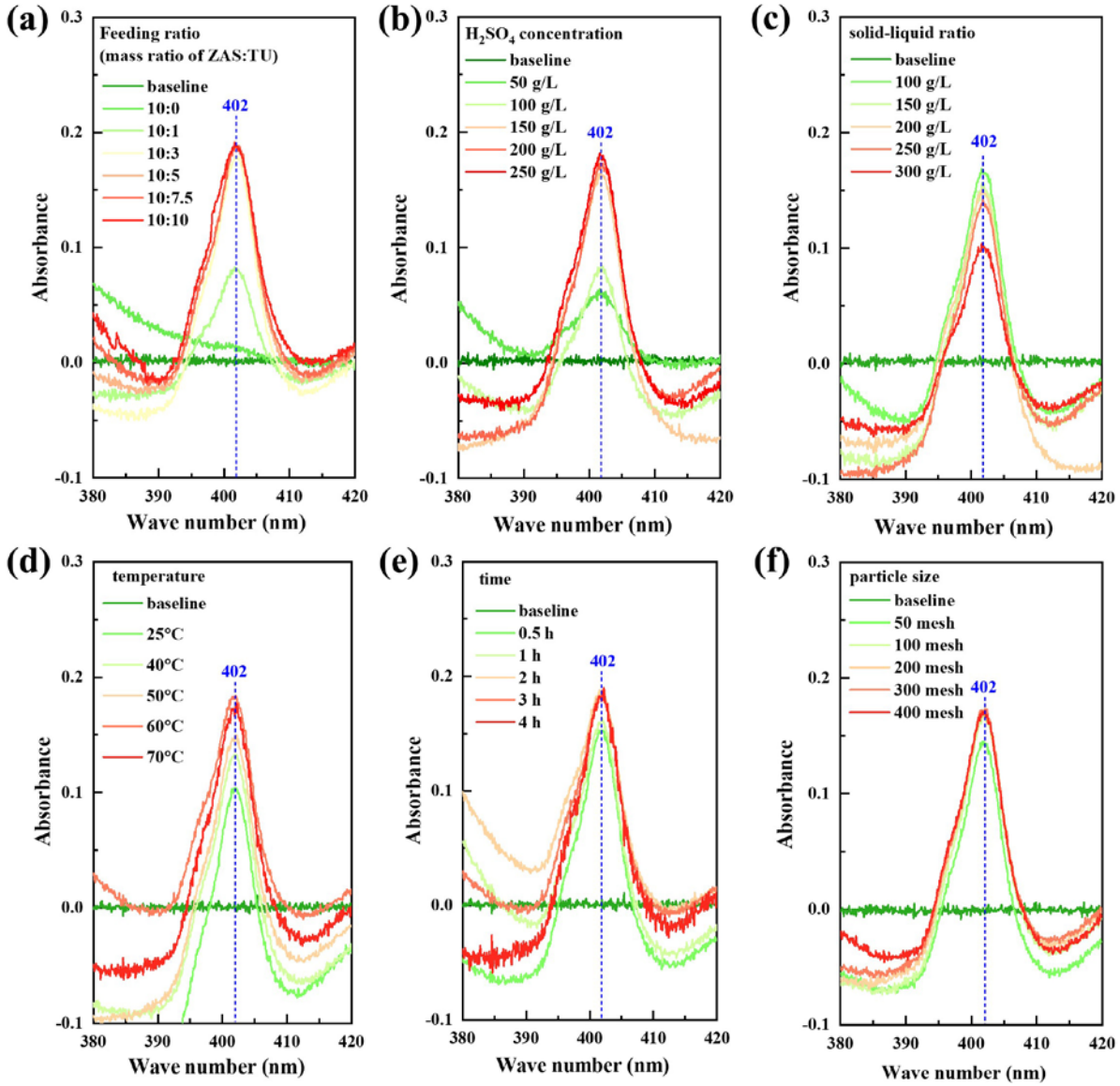

Figure S2 UV-vis spectra of acidic leaching solution obtained from ZAS at different (a) feeding ratio (mass ratio of ZAS:TU), (b) H_2SO_4 concentrations, (c) solid-liquid ratios, (d) leaching temperatures, (e) leaching time, and (f) ZAS particle size

Figure S3 Optical images of acid-leaching liquors and residues obtained at different feeding ratios (mass ratio of ZAS:TU)

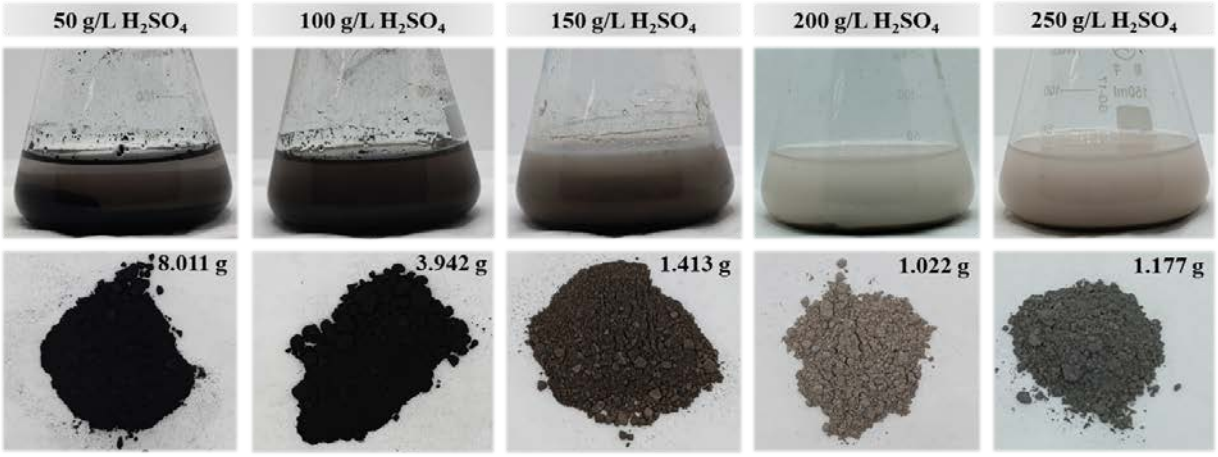

Figure S4 Optical images of acid-leaching liquors and residues obtained at different H_2SO_4 concentrations

Figure S5 Optical images of acid-leaching liquors and residues obtained at different solid-liquid ratios

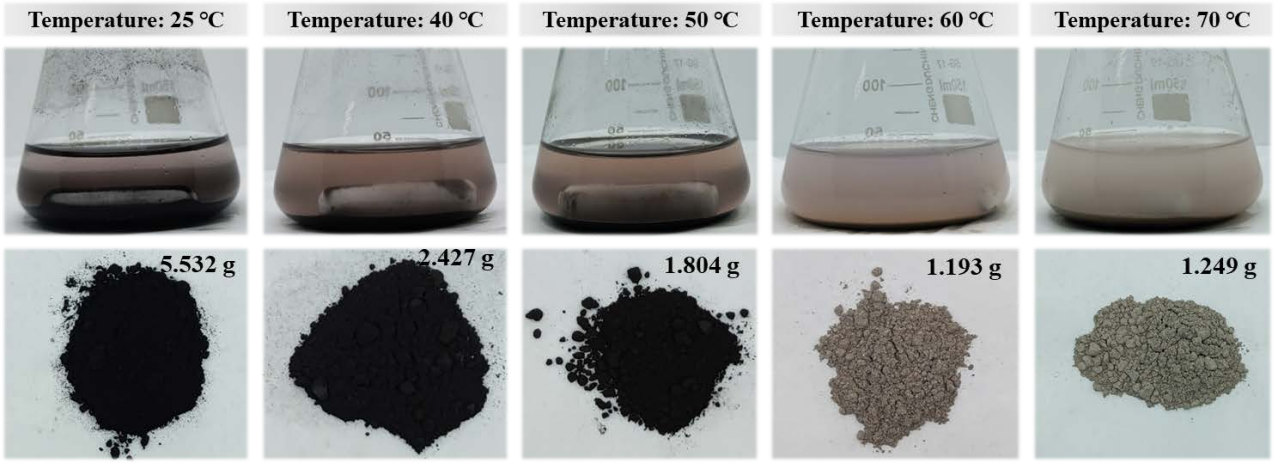

Figure S6 Optical images of acid-leaching liquors and residues obtained at different leaching temperatures

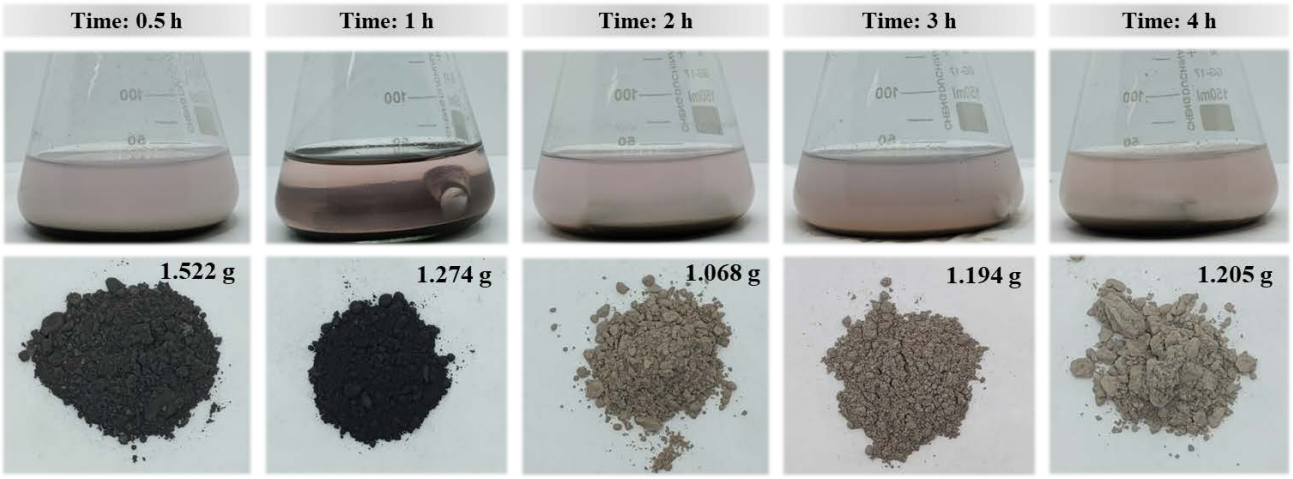

Figure S7 Optical images of acid-leaching liquors and residues obtained at different reaction time

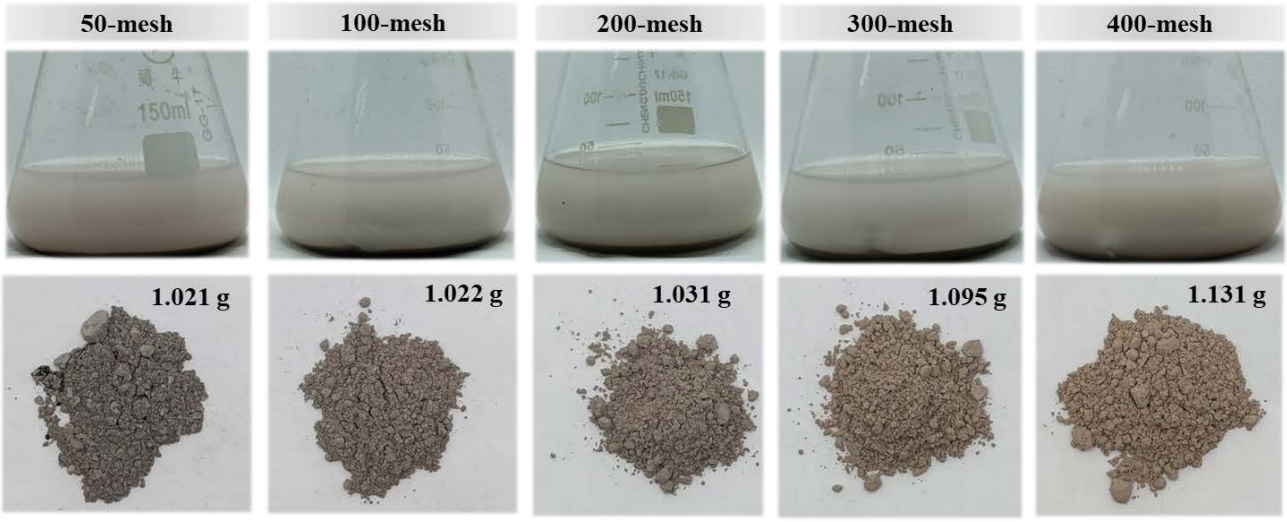

Figure S8 Optical images of acid-leaching liquors and residues obtained at different ZAS particle sizes

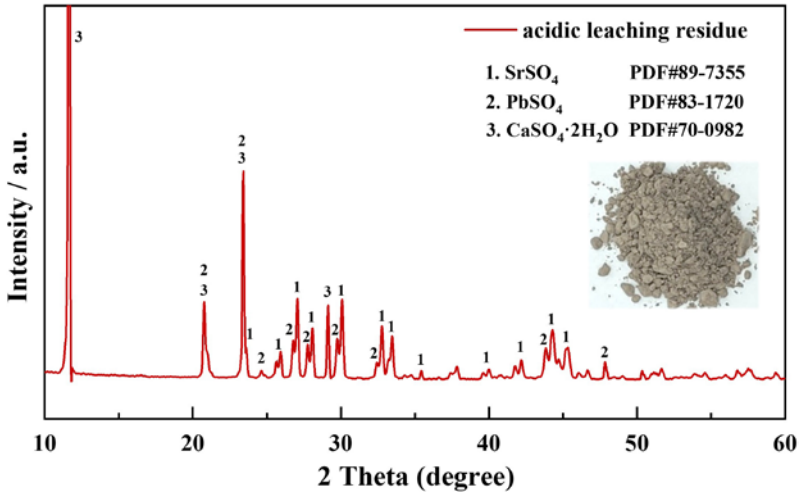

Figure S9 The XRD pattern of acidic leaching residue. The inset is the optical image of acidic leaching residue

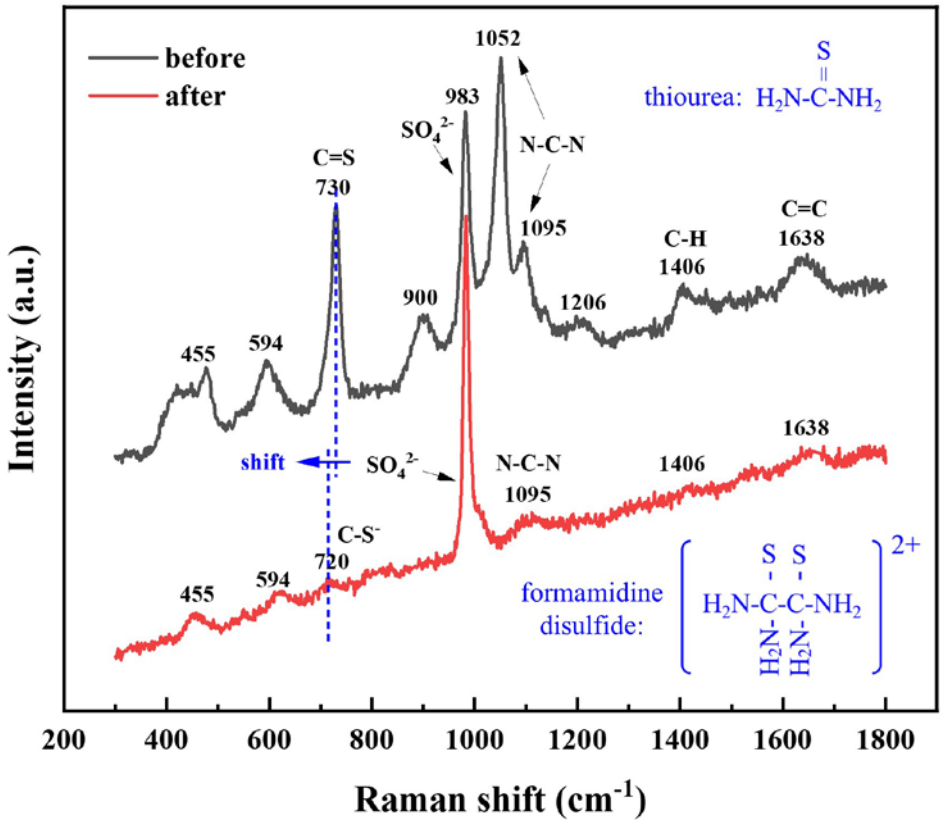

Figure S10 Raman spectra of TU in 200 g/L H_2SO_4 (before) and the leaching solution in this work (after)

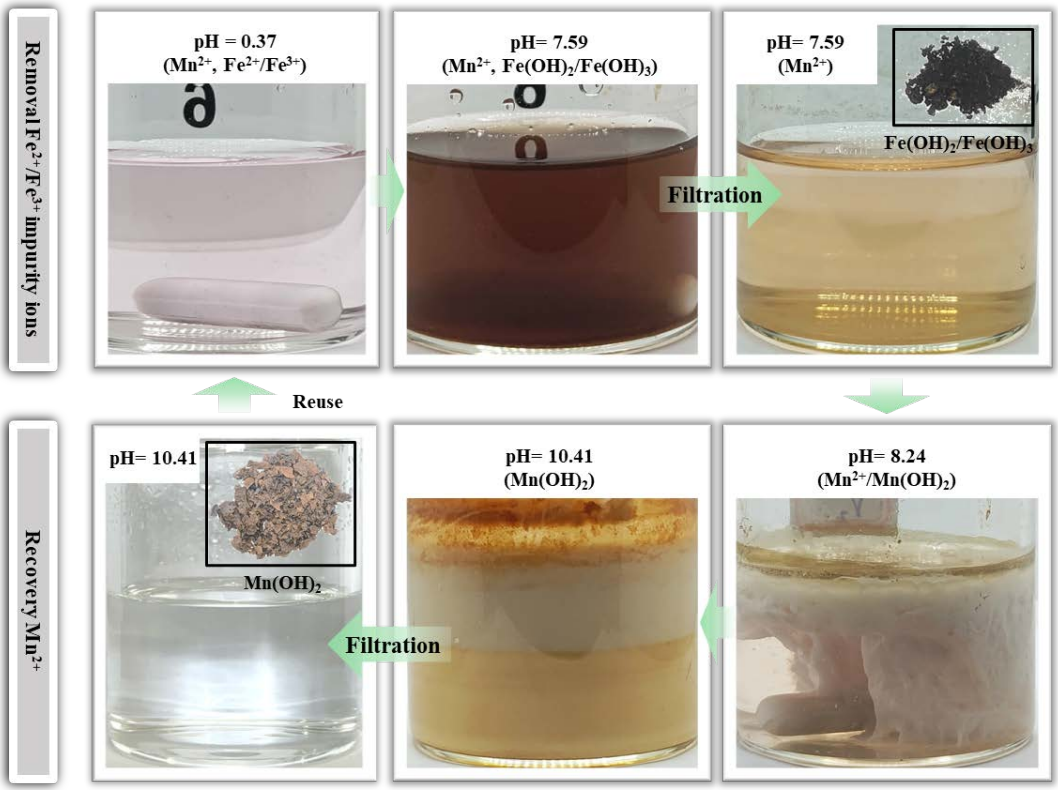

Figure S11 The removal of Fe^{2+}/Fe^{3+} impurities and the recovery of valuable Mn^{2+} from the acid-leaching liquor by adjusting the pH

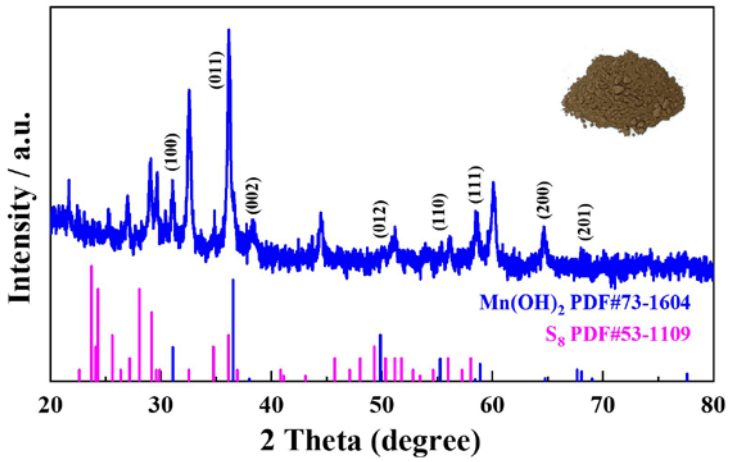

Figure S12 The XRD pattern of the chemically precipitated $Mn(OH)_2$

Table S1 Common metal ion precipitation pH (20°C)

metal ion	The concentration of metal ion (mol/L) and the corresponding solubility product constant of hydroxide					
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	pK_{sp}
	The pH value at which metal ions begin to precipitate					
In	3.27	3.60	3.93	4.26	4.59	33.20
Sn^{2+}	0.57	1.07	1.57	2.07	2.57	27.80
Sn^{4+}	0.25	0.50	0.75	1.00	1.25	56.00
Cd	7.70	8.20	8.70	9.20	9.70	13.60
Pb^{2+}	7.04	7.54	8.04	8.54	9.04	14.90
Pb^{4+}	–	–	–	–	-1.13	65.53
Tl	-0.27	0.06	0.39	0.72	1.05	43.80
Fe^{2+}	7.00	7.50	8.00	8.50	9.00	15.10
Fe^{3+}	1.90	2.20	2.50	2.90	3.20	37.40
Co^{2+}	7.15	7.65	8.15	8.65	9.15	14.70
Co^{3+}	-0.23	0.10	0.43	0.76	1.09	43.70
Al	3.40	3.70	4.00	4.40	4.70	32.88
Cr	4.30	4.60	4.90	5.30	5.60	30.20
Cu	4.70	5.20	5.70	6.20	6.70	19.60
Ni	7.20	7.70	8.20	8.70	9.20	14.70
Mn	8.10	8.60	9.10	9.60	10.10	12.73
Mg	9.10	9.60	10.10	10.60	11.10	10.74
Zn	6.04	6.54	7.04	7.54	8.04	16.92
Sb	0.53	0.86	1.19	1.52	1.85	41.40
Ti	1.00	1.33	1.66	2.00	2.33	40.00
Bi	4.20	4.53	4.86	5.19	5.52	30.40

Table S2 The elemental contents in acidic leaching residue tested by XRF

Element	Mn	Pb	Fe	Sr	Ca	K	Zn	Ba	Si	S	O
Content (wt.%)	0.19	16.67	–	27.81	13.14	0.11	0.04	0.08	0.78	21.88	18.99

Table S3 The national standard of Mn_2O_3 product

Product	Mn	K	Na	Pb	P	S
Battery grade Mn_2O_3 (QB9801-3)	≥ 70%	≤ 0.001%	≤ 0.001%	≤ 0.002%	≤ 0.5%	≤ 0.5%
Mn_2O_3 (this work)	69.40%	0.001%	0.003%	0.002%	–	–