Supplementary Material

Recycling Co and Li from spent lithium-ion batteries with the silicon of spent photovoltaics panels

Chuyang zhu [a], Jiangxin Qiu [c], Yikai Wang [c], Yulin Min[a,b], Yongsheng Liu [c,*], Penghui Shi [a,b,*]

a Shanghai Key Laboratory of Materials Protection and Advanced Materials in Electric Power, Shanghai University of Electric Power, Shanghai 200090, PR China

b Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200090, PR China

c College of Mathematics and Physics, Shanghai University of Electric Power, 201306, China

* Corresponding author. Tel.: +86 18801618059; E–mail addresses: shipenghui@shiep.edu.cn (P. Shi).

List of Texts, Figures and Tables

Text S1. Wafer pre-processing and economic analysis

The obtained wafers were first reacted in 18 wt.% HCl solution for 15 min to dissolve Al. After washing and drying, they were reacted in 30 wt.% HNO_3 solution at 50 °C for 10 min to dissolve Ag, and then further washed and dried. The resulting silicon wafer was crushed into powder to obtain silicon powder as shown in Fig. S2. Before and after the reaction, the Al peak disappeared, removing the effects of Al and Ag, and the pretreated silicon powder was obtained. Some studies have confirmed that the method can almost completely dissolve Al and Ag[1], and for the time being, the cost of the low concentration of HCl and HNO_3 used is low, and the amount of dissolved Al and Ag accounted for a relatively small percentage (3%), and the dissolving solution can be reused, but also the by-products of $AgNO_3$ and $AlCl_3$ for the benefit. The pretreatment process has low energy consumption and low cost.

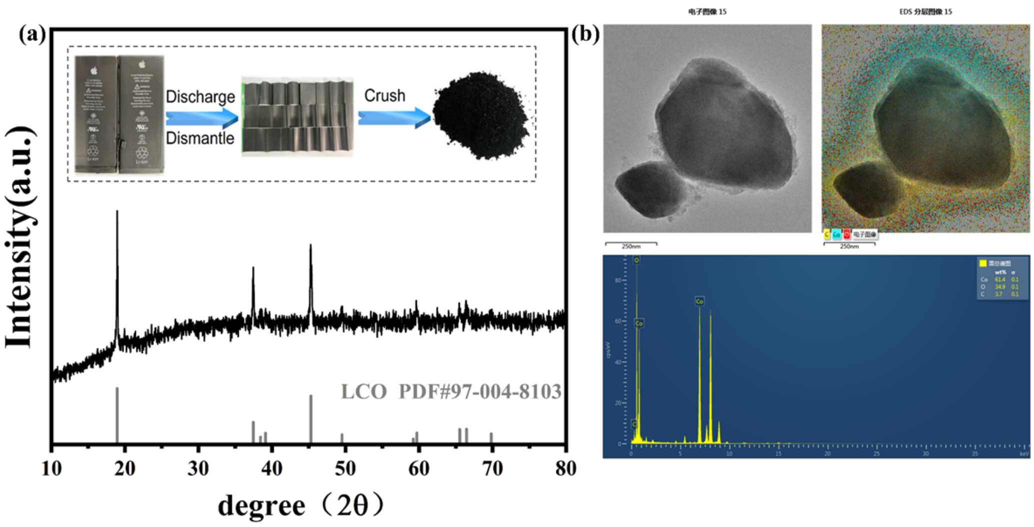

Fig. S1. Composition of $LiCoO_2$ cathode materials after pretreatment

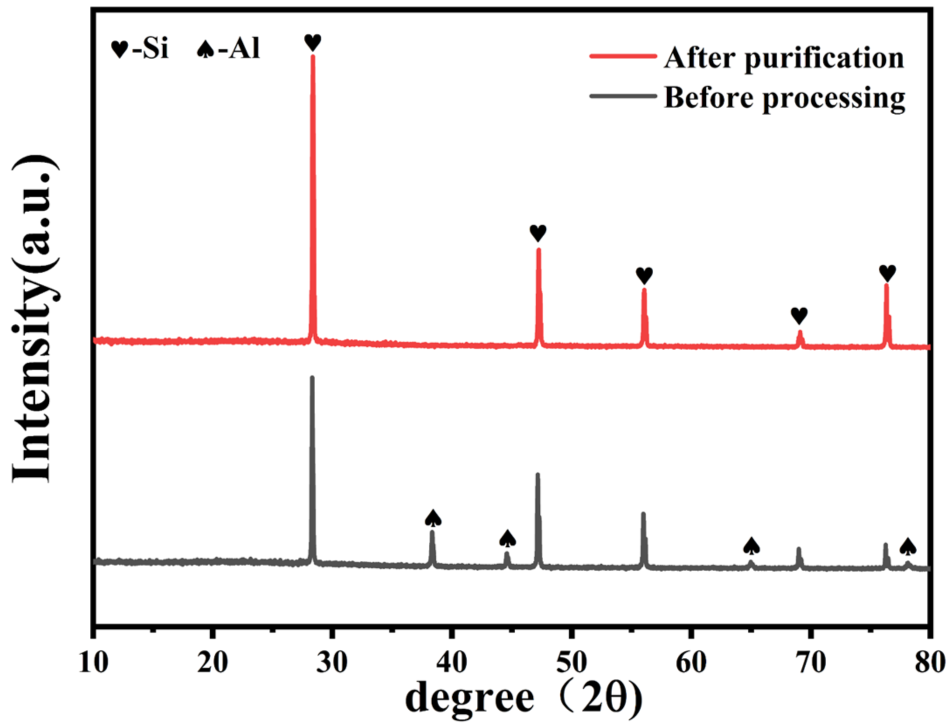

Fig. S2. Silicon powder obtained after simple treatment

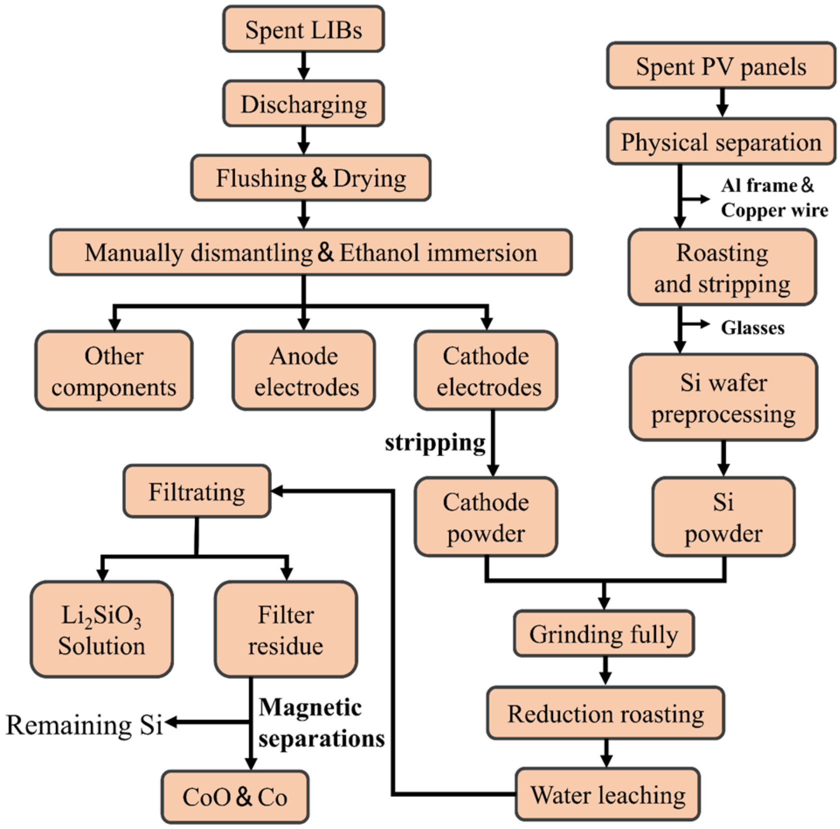

Fig.S3. Schematic diagram of co-processing of spent PV panels to recover valuable elements from waste cathode materials.

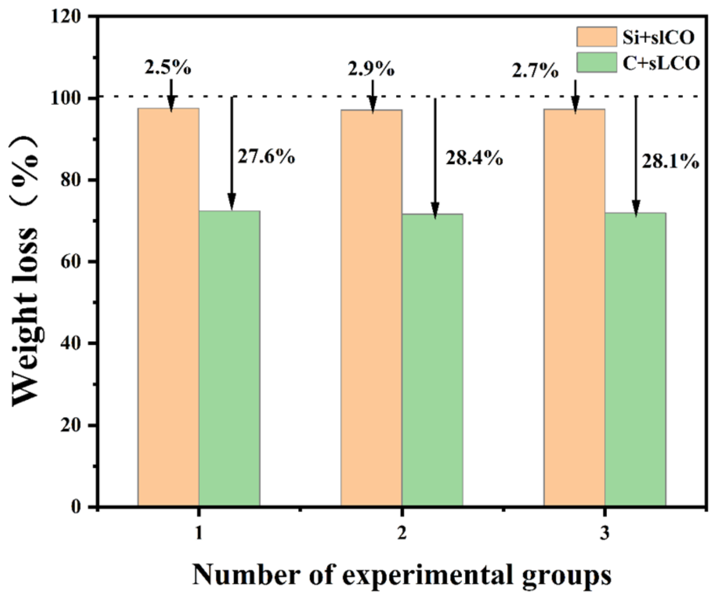

Fig. S4. Total mass loss diagram before and after reaction

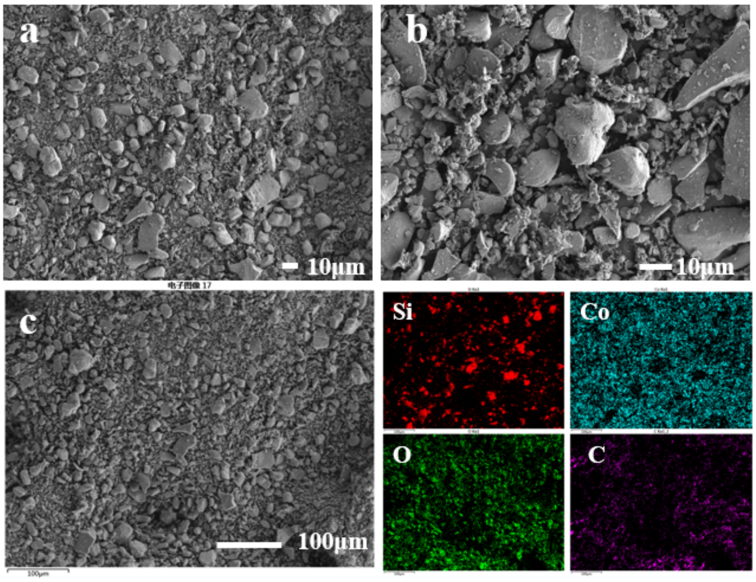

Fig. S5. SEM image of the sample after ball milling

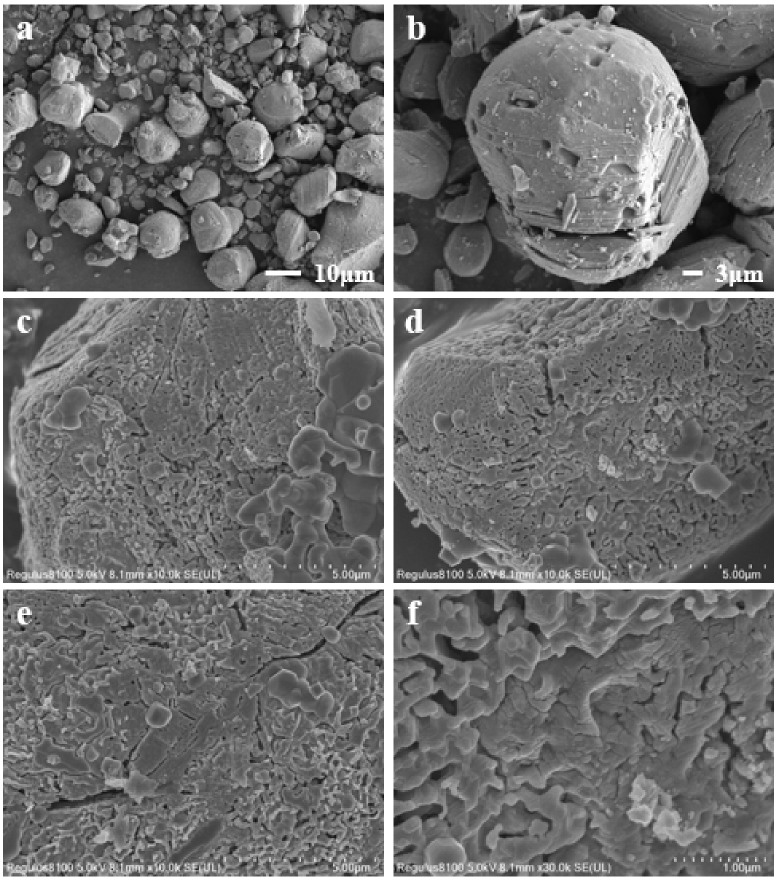

Fig. S6. (a-b) SEM images of cathode materials after direct baking; (c-f) SEM images of added silicon mediated baking

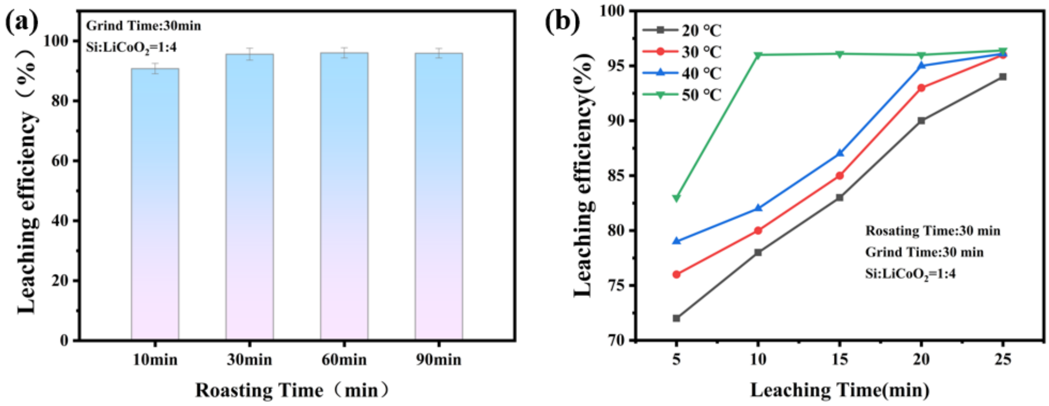

Fig. S7. (a) Lithium leaching rate at different roasting times; (b) Lithium leaching rate under different leaching condition

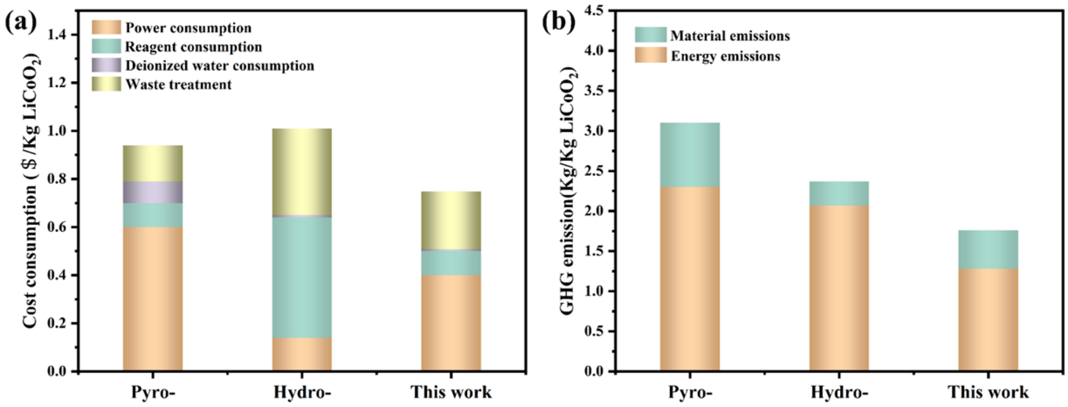

Fig. S8. (a) Cost analysis of processing 1kg of spent $LiCoO_2$ cathode powder, (b) Carbon emission analysis

Table S1. Percentage of O before and after roasting

O	Lattice oxygen	Adsorbed oxygen	Other oxygen
Cathode	29.58%	68.24%	11.33%
Cathode-700 ℃	50.88%	15.53%	39.59%
Cathode+Si-700 ℃	19.54%	16.23%	49.07%

Table S2. Percentage of Co before and after roasting

Co	Co^{2+}	Co^{3+}
Cathode	35.89%	64.11%
Cathode-700 ℃	40.79%	59.21%
Cathode+Si-700 ℃	100%	0%

Table S3. Recovery of valuable metals by combined thermal and wet processes

Recovery	Leaching rate/%		Ref.
	Li	Co	
Biochar-assisted carbon reduction with water leaching	98	98.5	[2]
Microwave-assisted hydrogen reduction plus leaching	98.17	98.52	[3]
Diaphragm roasting plus leaching	93.2	-	[4]
Urea-assisted ammonium sulphate roasting plus leaching	94.94	95.47	[5]

Table S4. Economic cost comparison ($/kg capacity)

Type of cost	Pyrometallurgy	Hydrometallurgy	This work
Power consumption	Electricity consumption: 2.5 kWh × 0.12 = 0.30 Fuel consumption: 15 MJ × 0.02 = 0.30	Electricity consumption: 1.2 kWh × 0.12 = 0.14	Electricity consumption: 1.5 kWh×0.12 = 0.18 Fuel consumption: 10 MJ × 0.02 = 0.20
Reagent consumption	Acid consumption 0.2 kg × 0.5 = 0.10	Acid consumption 1.0 kg × 0.5 = 0.50	Recycled silicon 0.2 kg × 0.5 = 0.10
Deionized water consumption	9 L × 0.001 = 0.09	10 L × 0.001 = 0.01	8 L×0.001 = 0.008
Waste treatment	0.5 kg × 0.3 = 0.15	1.2 kg × 0.3 = 0.36	0.8 kg × 0.3 = 0.24
Total cost ($/kg)	0.94	1.01	0.73

Table S5. Comparison of carbon emissions (kg CO_2/kg treatment)

Sources of emissions	Pyrometallurgy	Hydrometallurgy	This work
Energy emissions	High temperature consumption 2.5 kWh × 0.475 = 1.19 Fuel consumption 15 MJ × 0.074 = 1.11	Stirring, extraction 1.2 kWh × 0.475 = 0.57 Acid consumption (H_2SO_4 + H_2O_2) 1.5 kg × 1 = 1.5	Medium temperature consumption 1.5 kWh × 0.475 = 0.71 Fuel consumption 10 MJ ×0.057 = 0.57
Material emissions	Direct process emissions (CO_2) 0.8	Chemical precipitation & extractant emissions 0.3	Silicon recovery process 0.48
Total carbon emissions (kg CO_2/kg)	3.1	2.37	1.76

References：

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