Electronic Supplementary Information

Chloride molten salt-mediated one-step electrochemical recycling of tellurium from copper(I) telluride

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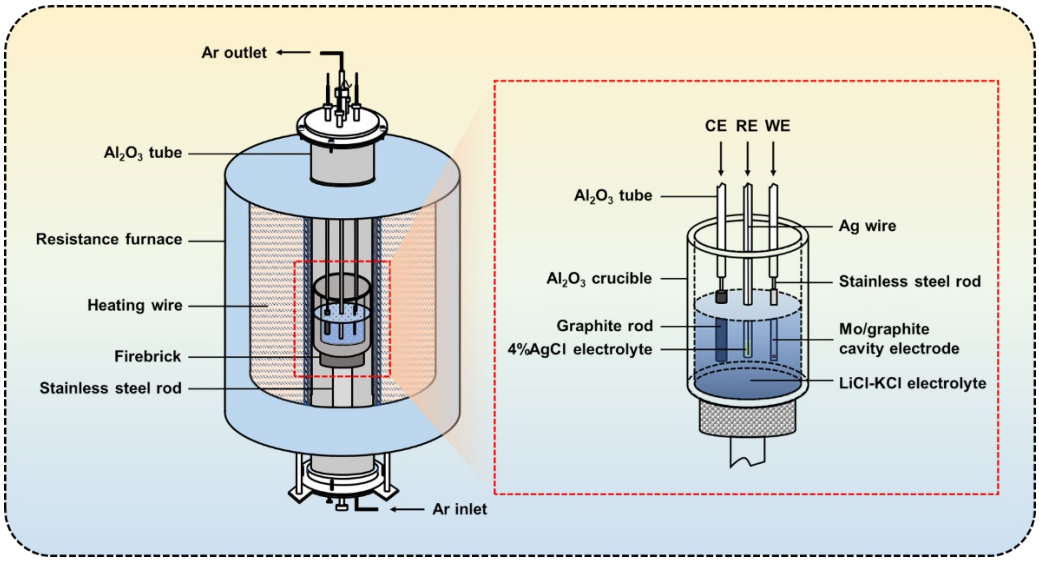

Fig. S1. Schematic diagram of the experimental device.

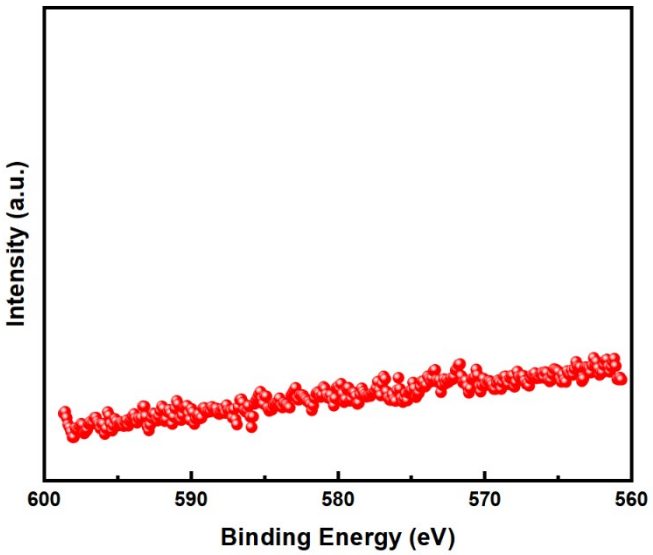

Fig. S2. XPS spectra of Te 3d of the blank LiCl-KCl molten salt.

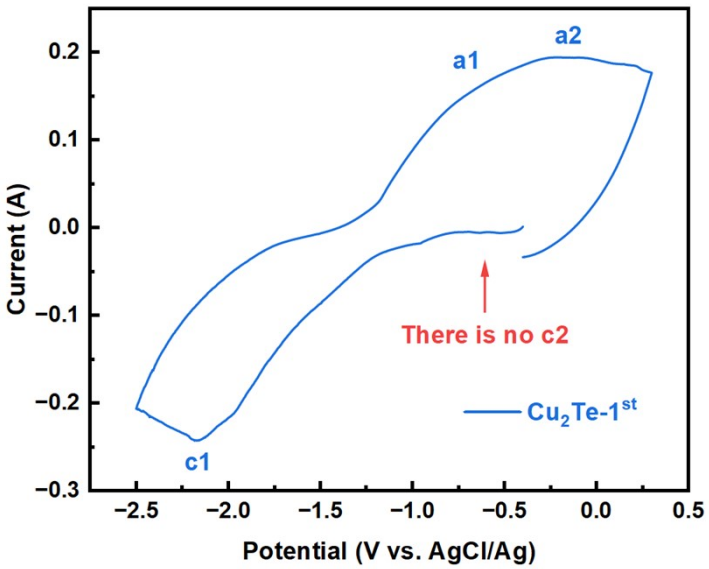

Fig. S3. CV recorded from MCE loaded with Cu_2Te (the first cycle) in molten LiCl-KCl, scan rate: 100 mV/s.

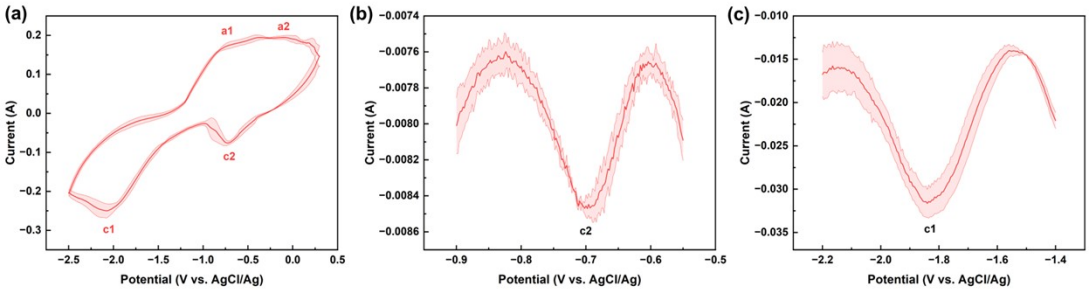

Fig. S4. (a) Three independent replicate CV curves with error bars recorded from the MCE loaded with Cu_2Te in molten LiCl-KCl, scan rate: 100 mV/s. (b) Three independent replicate SWV curves with error bars recorded from the MCE loaded with Cu_2Te and fitting curve under the peak c2. (c) Three independent replicate SWV curves with error bars recorded from the MCE loaded with Cu_2Te and fitting curve under the peak c1.

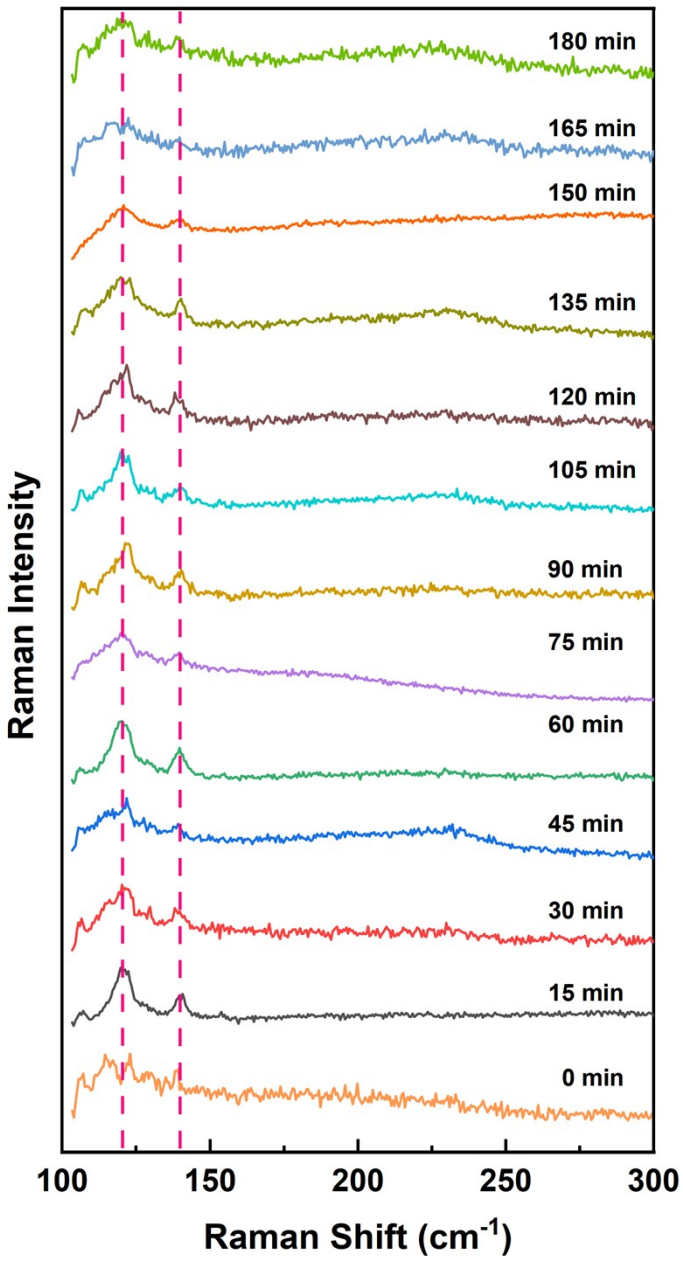

Fig. S5. In-situ time-resolved Raman spectra of molten salt during electrolysis process under 2.4 V for 3 h at 420 ℃.

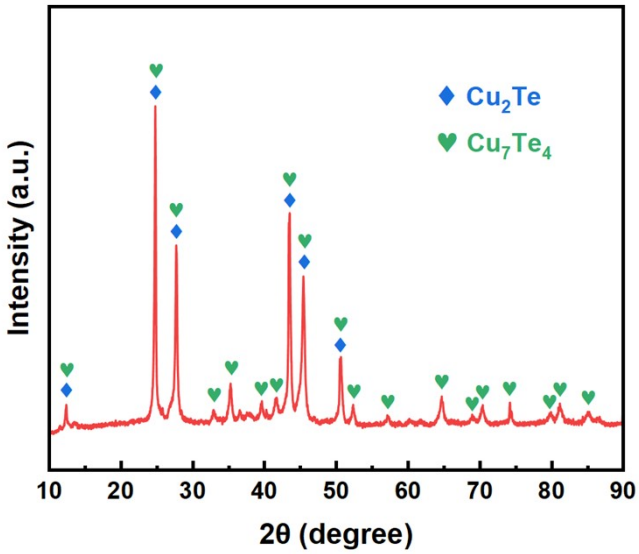

Fig. S6. XRD pattern of electrolytic product of Cu_2Te obtained under -1.2 V for 3 h at 420 ℃.

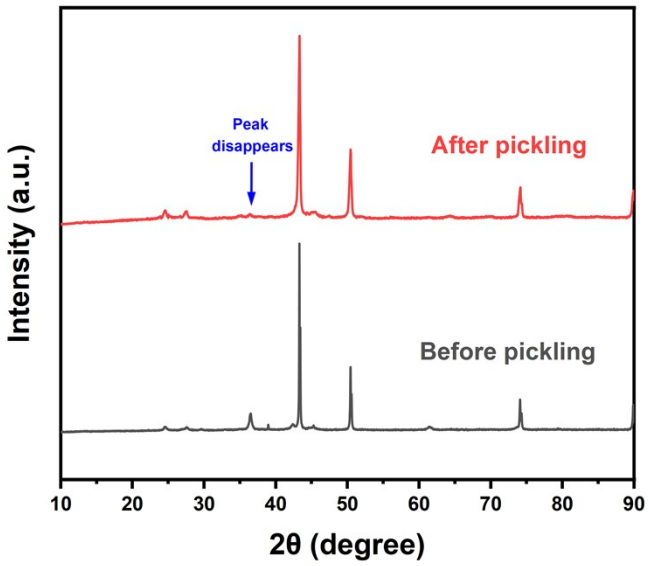

Fig. S7. XRD patterns of electrolytic product Cu before and after pickling.

Fig. S8. Tellurium deposited on the furnace cover after volatilization during electrolysis at 500 ℃.

Fig. S9. The optical photograph of Te product collected from the anode.

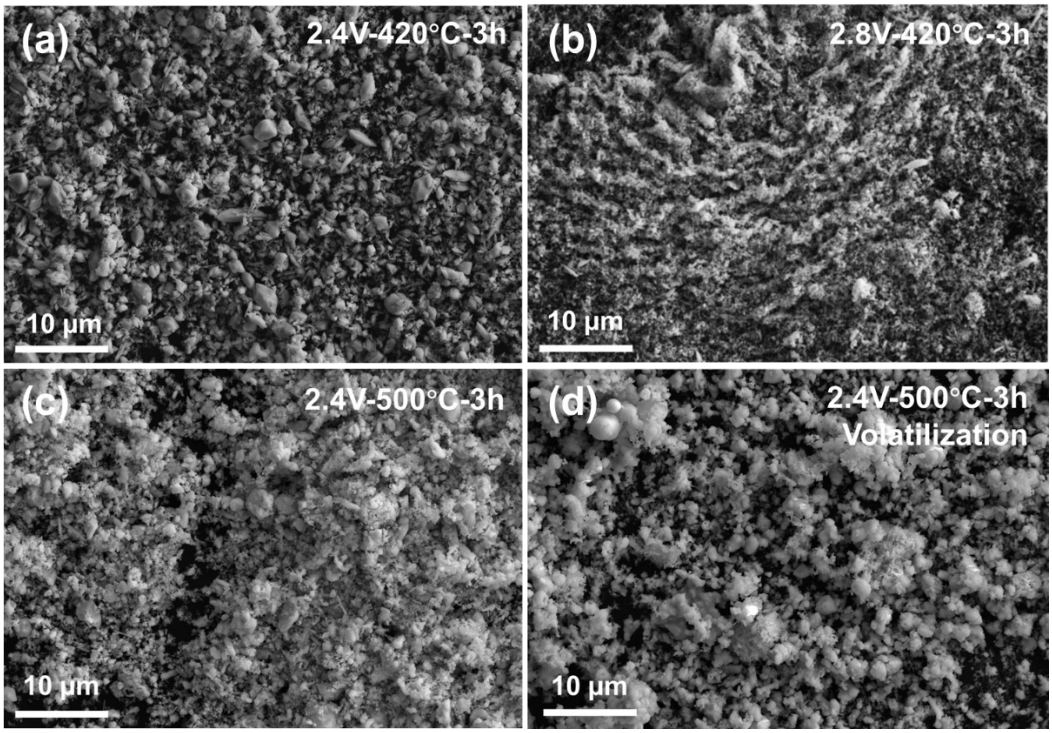

Fig. S10. SEM images of the electrolytic products Te collected from the anode under 2.4 V for 3 h at 420 ℃ (c), under 2.8 V for 3 h at 420 ℃ (d), under 2.4 V for 3 h at 500 ℃ (e), and under 2.4 V for 3 h at 500 ℃ collected from the furnace cover (f). (Magnification: 2000×)

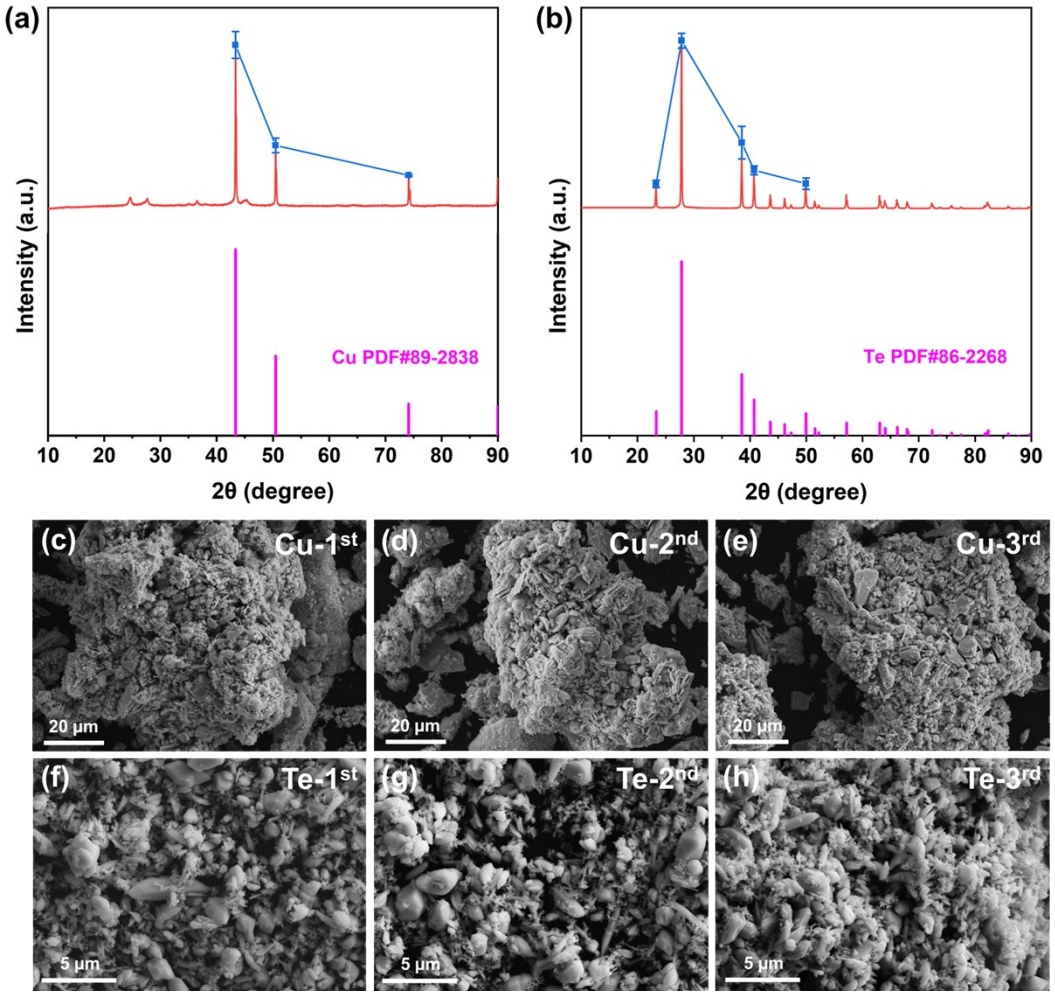

Fig. S11. (a) XRD patterns with error bars of three independent replicate electrolytic products Cu from a two-electrode electrolysis under 2.4 V for 3 h at 420 ℃. (b) XRD patterns with error bars of three independent replicate electrolytic products Te from a two-electrode electrolysis under 2.4 V for 3 h at 420 ℃. (c-e) SEM images of three independent replicate electrolytic products Cu from a two-electrode electrolysis under 2.4 V for 3 h at 420 ℃. (f-h) SEM images of three independent replicate electrolytic products Te from a two-electrode electrolysis under 2.4 V for 3 h at 420 ℃.

Table S1. Equations used for calculating standard potentials and the corresponding Gibbs free energy changes (all the data are obtained from HSC Chemistry 6 software, T = 420 ℃).

Equation	ΔG (kJ/mol)	Equation Number
$2LiCl = 2Li + Cl_2(g)$	702.813	(S1)
$2KCl = 2K + Cl_2(g)$	740.552	(S2)
$2NaCl = 2Na + Cl_2(g)$	693.584	(S3)
$CaCl_2 = Ca + Cl_2(g)$	689.523	(S4)
$MgCl_2 = Mg + Cl_2(g)$	531.886	(S5)
$2AlCl_3 = 2Al + 3Cl_2(g)$	1103.962	(S6)
$Cu_2Te + 2LiCl = 2Cu + Li_2Te + Cl_2(g)$	430.016	(S7)
$Cu_2Te + Cl_2(g) = 2CuCl + Te$	-142.209	(S8)
$Li_2Te + Cl_2(g) = 2LiCl + Te$	-372.196	(S9)
$Cu_2Te + Cl_2(g) = CuCl_2 + CuTe$	-89.721	(S10)

Table S2. Chemical composition of product Te and Cu obtained by molten salt electrolysis.

Element / Product	Te	Cu	Li	K
Te	99.98%	0.0159%	0.0023%	0%
Cu	10.3%	89.53%	0.0158%	0.1525%

Table S3. Chemical composition of molten salt after different cycles of electrolysis.

Element / Cycle	Te	Cu
1st	0.0447%	0.0006%
2nd	0.0484%	0.0043%
3rd	0.0588%	0.0096%

Techno-economic evaluation

The most widely used hydrometallurgical treatment process methods for Te recovery from Cu_2Te involves the use of a large number of chemicals. Therefore, the cost of hydrometallurgy methods mainly comes from the consumption of chemicals (the electric energy consumed by electrowinning in hydrometallurgy is not considered here). According to the calculations for the chemicals required to treat 1 t of copper telluride slag, the total cost of the chemicals is \$287/t.[1] The comprehensive recovery rate of hydrometallurgy process is 83.15%. Therefore, the production cost of the Te by hydrometallurgy method is ~689.0 \$/t.

In the process of Te recovery from Cu_2Te in this work, LiCl-KCl molten salt is only used as a medium for the transport of Te^{2-} ions and graphite anode can be recycled for a long time as an inert anode. Both of them do not participate in the electrolysis reaction and will not be consumed. Therefore, the molten salt electrolysis method does not involve the consumption of reagents, and its actual cost mainly comes from the energy consumption of electrolysis. According to UK's statistical data as of January 7, 2026, the price of electricity is 0.11 \$/kWh (the data are searched from tradingeconomics.com/commodities). In this study, the electrolysis energy consumption calculated is ~1.24 kWh per kg Te. Therefore, the production cost of Te by molten-salt electrolysis method is 136.4 \$/t. Compared with the hydrometallurgy method, the cost of the molten salt electrolysis method is reduced by 552.6 \$/t.

References

1 Z. Li, J. Deng, D. Liu, W. Jiang, G. Zha, D. Huang, P. Deng and B. Li, *Journal of Cleaner Production*, 2022, **335**, 130356.