Supplementary materials

Table S1 Pyrometallurgical technology for RPMs recovery from urban mines

methods	sample	result	principle or reaction	reference
high-temperature incineration method	e-waste scraps	enrichment Au, Ag, Pd	high-temperature incineration enrichment at 1200℃	[1]
	spent auto catalyst	99.99% Pt, Pd Rh	Cu trapping by semi-industrial process	[2]
	spent auto catalyst	90% Au, Pt, Pd	Cu-Sn-Fe trapping process for extracting PMs from waste PCBs and auto catalysts simultaneously	[3]
vacuum carbonthermal reduction method	waste LCD power	In	$In_2O_3 + 3C = 2In (s) + 3CO (g)$	[4]
	coal fly ash	Ge	$GeO_2 (s) + C (s) = Ge (s) + CO_2 (g)$ $GeO_2 (s) + C (s) = GeO (g) + CO_2 (g)$ $GeO_2 (s) + C (s) = GeO (g) + CO (g)$	[5]
	spent LIBs	Co, Li_2CO_3	$4LiCoO_2 + 2C \rightarrow 4Co + 2Li_2CO_3 + O_2(g)$ $2LiCoO_2 + 2C \rightarrow 2Co + Li_2CO_3 + CO(g)$ $4LiCoO_2 + 3C \rightarrow 4Co + 2Li_2CO_3 + CO_2(g)$	[6]
chlorination volatilization method	waste LCD power	$InCl_3$	$In_2O_3 + 6HCl = 2InCl_3 + 3H_2O$	[7]
	alluvial material	$AuCl_3$	$Fe_2O_3 + 3Cl_2(g) \rightarrow Fe_2Cl_6(g) + 3/2O_2$ $Fe_2Cl_6 + Au + 3/2Cl_2(g) \rightarrow AuCl_3 \cdot FeCl_3(g) + FeCl_3$	[8]
	tin slags	$NbCl_5$, $TaCl_5$	chlorination of tin slag by gaseous chlorine in presence of carbon	[9]
	incinerated sewage sludge ash	$AuCl_3$	gold was volatilized by chlorine at high temperature with solid carbon	[10]
	dental metal recycling sludge	$InCl_3$	$In_2O_3 + NH_4Cl \rightarrow InCl_3 + NH_3 + H_2O$	[11]

Table S2 Recent researches for the leaching of RPMs

leaching reagent	sample	conditions	results	reference
cyanide	e-waste	pH > 10	95% Au, 93% Ag, 99% Pd	[12]
	waste PCBs	pH 12.5	60%–70% Au	[13]
	spent auto catalysts	biogenic cyanide, 150℃	92% Pt, 99.5% Pd, 96.5% Rh	[14]
thiosulfate	waste PCB of cell phone	$S_2O_3^{2-}$, Cu^{2+}, NH_3 pH 9.0, 40℃	98% Au, 93% Ag, 90% Pd	[15]
	waste PCB of cell phone	$S_2O_3^{2-}$, Cu, NH_3 pH 10–10.5, 25℃	98% Au	[16]
thiourea	waste PCB of mobile waste	24 $g\cdot L^{-1}$ TU, 0.6% Fe^{3+}	90% Au, 50% Ag	[17]
	waste PCB of mobile waste	0.5 $mol\cdot L^{-1}$ TU in 0.05 $mol\cdot L^{-1}$ H_2SO_4 Au 45℃, Ag 60℃	3.2 $mg\cdot g^{-1}$ Au, 6.8 $mg\cdot g^{-1}$ Ag	[18]
halide	industrial catalysts	60% H_2SO_4, 0.1 $mol\cdot L^{-1}$ NaCl 125℃	99% Pt, Pd, Rh	[19]
	scrapped naphtha reforming catalysts	"active" iodine species (HIO, I_2(aq),andI_3^-), pH 3–4	Pt	[20]
other leaching agent	spent LIBs	1.0 $mol\cdot L^{-1}$ oxalate, H_2O_2, 95℃	98% Li, 97% Co	[21]
	spent LIBs	1 $mol\cdot L^{-1}$ iminodiacetic acid + 0.02 $mol\cdot L^{-1}$ maleic acid and ascorbic acid, 80℃	99% Li, 91% Co	[22]
	LCD panels	$HCl:HNO_3:H_2O$ = 45:5:50, volume ratio	92% In	[23]
	waste HDS catalyst	two stage alkali/acid leaching	98% Mo, 93% Co	[24]
	melting furnace fly ash	water extraction process followed by acidifying with HNO_3 in pH < 2	Ag, Ga, Ge	[25]

Table S3 Summaries of RPMs recovery by bioleaching and biosorption process

biometallurgical technology	Sample	research conditions	results	reference
bioleaching	waste PCBs of cell phone	chromobacterium violaceum 0.004% H_2O_2, pH 8–11	11.3% Au	[26]
	waste PCBs	acidophilic bacterium and Cyanogenic bacterium pH 7.3–8.6	44% Au	[27]
		Pseudomonas Chlororaphis pH 7	8.2% Au, 12.1% Ag	[28]
	spent LIBs	acidithiobacillus ferrooxidans (A.f) 0.75 $g{\cdot}L^{-1}$ Cu^{2+}, pH 3	100% Li, 99.9% Co	[29]
		acidithiobacillus ferrooxidans 3 $g{\cdot}L^{-1}$ Fe^{3+}, pH 2.5–4.0	Li, Co	[30]
		mixed culture of sulfur-oxidizing and iron-oxidizing bacteria pH 1.4–1.69	Li, Co	[31]
	waste petroleum catalyst	acidithiobacillus ferrooxidans and acidithiobacillus thiooxidans pH 1.5–3	V, Mo	[32]
	waste refinery catalyst	sulfur oxidizing bacteria pH 2–3	32.3% V, 58.0% Mo	[33]
	waste hydrocracking catalyst	penicillium simplicissimum pulp density (3% w/v) pH 4–6	100% W, 92.7% Mo	[34]
biosorption		brown alga Fucus vesiculosus pH 7	reduced Au (III) to Au (0)	[35]
	aqueous solutions	chemically modified chitosan resin pH 0.5–2	Au (III) and Ag (I)	[36]
		bayberry tannin immobilized collagen fiber (BTICF) membrane	Pt (IV) and Pd (II)	[37]
		three different species of Desulfovibrio pH 3	Pd and Pt	[38]

Table S4 Summaries of RPMs recovery by Sc-CO_2 extraction technology

RPMs	sample	extraction conditions	chelating agent	reference
In (III)	aqueous solutions	CO_2, 138 bar, 70℃	β-Diketone (AcAcH), fluorinatedß-diketone (TTAH), thiopyridine (PySH), and piperidinyldithiocarb amic acid	[39]
Ga (III)	aqueous solutions	CO_2, 205 bar, 70℃	AcAcH, TTAH and PySH	[40]
Nd(III), Eu (III)	aqueous solutions	CO_2, 200 bar, 50℃	oxa-diamides (TBODA)	[41]
Pd, Pt, Rh	apent auto catalyst	CO_2, 300 bar, 40℃–80℃	tributy1 phenoxo (TBP) ligand	[42]
Ag, Pd	waste PCBs	CO_2,10–40 MPa,40℃–80℃	KI, I_2, acetone	[43]
Li, Co	spent LIBs	CO_2, 75 bar, 75℃	sulfuric acid, H_2O_2	[44]

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