

MATERIAL	USE IN ELECTRONICS	AMOUNT USED	POTENTIAL RECOVERY VALUE (HIGH/LOW)	MATERIAL AVAILABILITY CONSIDERATIONS (Y/N)	ELECTRONICS USE DOMINANT (Y/N)	RESPONSIBLE MATERIAL EXTRACTION (Y/N)	Toxicology issues	REPORTABLE (Y/N)	CIRCULARITY PATHWAY- "4Rs": 1&2 Reuse [product, component], 3 Refurbish, 4 Recycle	SOLUTION/TECHNOLOGY DESCRIPTION TO ACHIEVE 4Rs	4 Rs TRL: TODAY -2023	4 Rs TRL: 3 YEARS -2026	4 Rs TRL: 5 YEARS -2028	4 Rs TRL: 10 YEARS -2033
Epoxy resins	Laminate dielectric material	High	Low	N	N	N	Y	N		Reduce waste through additive processes	7	8	8	9
										Grind & recover metal, burn or repurpose resin	8	8	8	8
										Replace with bio-degradable resin	1	3	5	6
										Solutions to extract and reuse the epoxies	1	3	5	6
Sulphuric acid	Cu plating and micro-etchants (Cu)	High	Low	Y	N	N	Y	N	Reduce	Improved consumption control (e.g. with lower concentrations)	9	9	9	9
									Reuse	Repurposed for other industrial applications	9	9	9	9
										Waste treatment + disposal	9	9	9	9
Hydrochloric acid	Used in etchants (Cu)	High	Low	Y	N	N	Y	N	Reduce	More efficient use (including reuse in-process)	9	9	9	9
									Reuse	Repurposed for other industrial applications	8	8	9	9
										Waste treatment + disposal	9	9	9	9
Hydrogen peroxide	Used in micro-etchants or etchants (Cu)	Medium	Low	Y	N	N	Y	N	Reuse	Reused & recycled in-process	9	9	9	9
										Waste treatment + disposal	9	9	9	9
Sodium persulphate	Used in micro-etchants (Cu)	Medium	Low	Y	N	N	Y	N	Reduce	Waste treatment + disposal	9	9	9	9
									Eliminate	Phase out use, with the aid of substitutes (e.g. alternative sulphates, blended cleaners)	7	7	8	9
Formaldehyde	Reducing agent for electroless Cu	Low	Low	Y	N	N	Y	N	Reduce	Waste treatment + disposal	9	9	9	9
									Eliminate	Phase out use, with the aid of alternative processes (e.g. direct metalization, sputtering)	7	7	8	9
Boric acid	Used in nickel plating baths	Medium	Low	Y	N	N	Y	N		Waste treatment + disposal	9	9	9	9
Cyanides	Electroplating Au and Ag	Medium	Low	Y	N	N	Y	N	Reduce	Waste treatment + disposal	9	9	9	9
									Eliminate	Replacement of Au and Ag	6	7	8	9
Amines	Resist stripping solutions and substrates conditioners	Medium	Low	Y	N	N	Y	N		Reused & recycled in-process	9	9	9	9
										Waste treatment + disposal	9	9	9	9
Ammonium solution	Etchant and for plating electroless Ni	Medium	Low	Y	N	N	Y	N		Reused & recycled in-process	9	9	9	9
										Waste treatment + disposal	9	9	9	9
										Replacement by ferric chloride or similar, removal of the tin layers	5	7	9	9

[1] Ron Shinn, "Extracting Polymers from Electronics", *Plastics Recycling*, Summer 2021.

(Table Key on page 2.)

Table Key

In-table color key	Range of Technology Readiness Levels	Description
2	TRL: 1 to 4	Levels involving research
6	TRL: 5 to 7	Levels involving development
9	TRL: 8 to 9	Levels involving deployment

Spreadsheet column category	Explanation
Use in electronics	Applications of the named material
Amount used	Is the quantity of material used significant in absolute terms?
Potential recovery value (high/low)	If extracted through processes like recycling, does the quantity of material have significant commercial value?
Material availability considerations (y/n)	Is the primary extraction of the material confined to a limited number of regions globally?
Electronics use dominant (y/n)	Is the electronics industry the major user of the material or do other industries have a bigger share?
Responsible material extraction (y/n)	Are there issues around the primary extraction (e.g. mining, refining, etc.) of the material?
Reportable (y/n)	Are there legal requirements to report the use of the materials, for toxicological/environmental reasons?