Supplementary Materials

1. Qualitative test of TBBPA

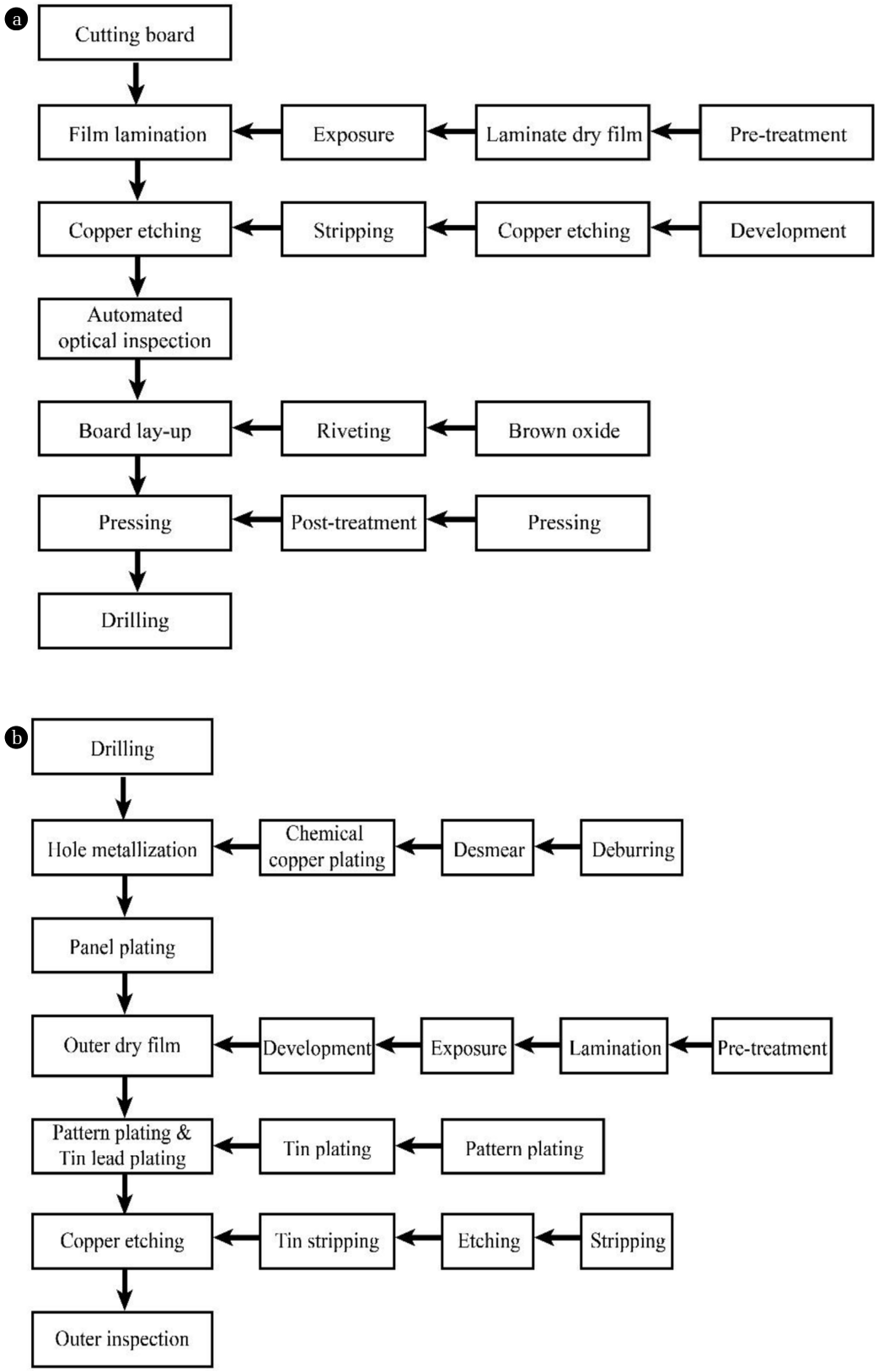
Gas chromatograph-mass spectrometer (GC-MS, Agilent7890A/GC-5975C MS) was used in TBBPA qualitative test. In the gas chromatograph part, HP-5 quartz capillary column was used with column length of 30 m, film thickness of 250 μm, inner diameter of 0.25 μm. The initial column temperature was set at 80℃. After 1 min, the temperature increased to 300℃, with a rate of 15 ℃/min. The temperature was constant at 300℃ for 10min before injection. The injector temperature was 260℃. The sample load was 1 μL, and the injection mode was split inlet with a split ratio of 10:1. Helium was the carrier gas with a flow rate of 1 mL/min. In the mass spectrometer part, the electron impact source was adopted with electron energy of 70 eV. The temperature of ion source was 230℃, of quadrupole was 150℃. The solvent delay time was 4 min, single ion monitor model and full scan models were adopted simultaneously. The scan range was 50~560 (m/z), the mass-to-charge ratio of qualitative ions was 529, 527, 531 (m/z). Dichloromethane solution of TBBPA (50 mg/L) was injected to obtain the total ion chromatography.

2. Quantitative test of TBBPA

Ultra-performance liquid chromatography (UPLC, Waters H-Class) was used to quantitatively analyze the TBBPA. Isocratic elution was adopted, and the mobile phase with flow rate of 0.5 mL/min consisted of acetonitrile/water solution (volume ratio: 7:3). Column temperature was 40℃. Injection volume was 1 μL. The TUV detector (Acquity UPLC TUV) was set to detect the wavelength at 210 nm. The samples were centrifuged at 8000 r/min for 15 minutes before injection, and then, 1 mL of the supernatant was added to the UPLC injection bottle for testing. The detection limit of TBBPA was 10 μg/L. External standard method (Concentration gradient: 0.1, 0.2, 0.4, 0.6, 0.8, 1.0 mg/L) was carried out to measure the TBBPA concentration and the R^2 was control over 0.995. Matrix spike/recovery tests were conducted in duplicate for quality control, and the TBBPA recovery rate was averaged at 92.3%. TBBPA removal efficiency was calculated according to Eq. S1.

$$R_{TBBPA} = 1 - c_{effluent}/c_{influent} \quad \text{(S1)}$$

Where R_{TBBPA} is TBBPA removal efficiency, $c_{effluent}$ is TBBPA concentration in effluent, $c_{effluent}$ is TBBPA concentration in influent.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Cutting board
Film lamination
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Pre-treatment
Copper etching
Stripping
Copper etching
Development
Automated optical inspection
Board lay-up
Riveting
Brown oxide
Pressing
Post-treatment
Pressing
Drilling
b
Drilling
Hole metallization
Chemical copper plating
Desmear
Deburring
Panel plating
Outer dry film
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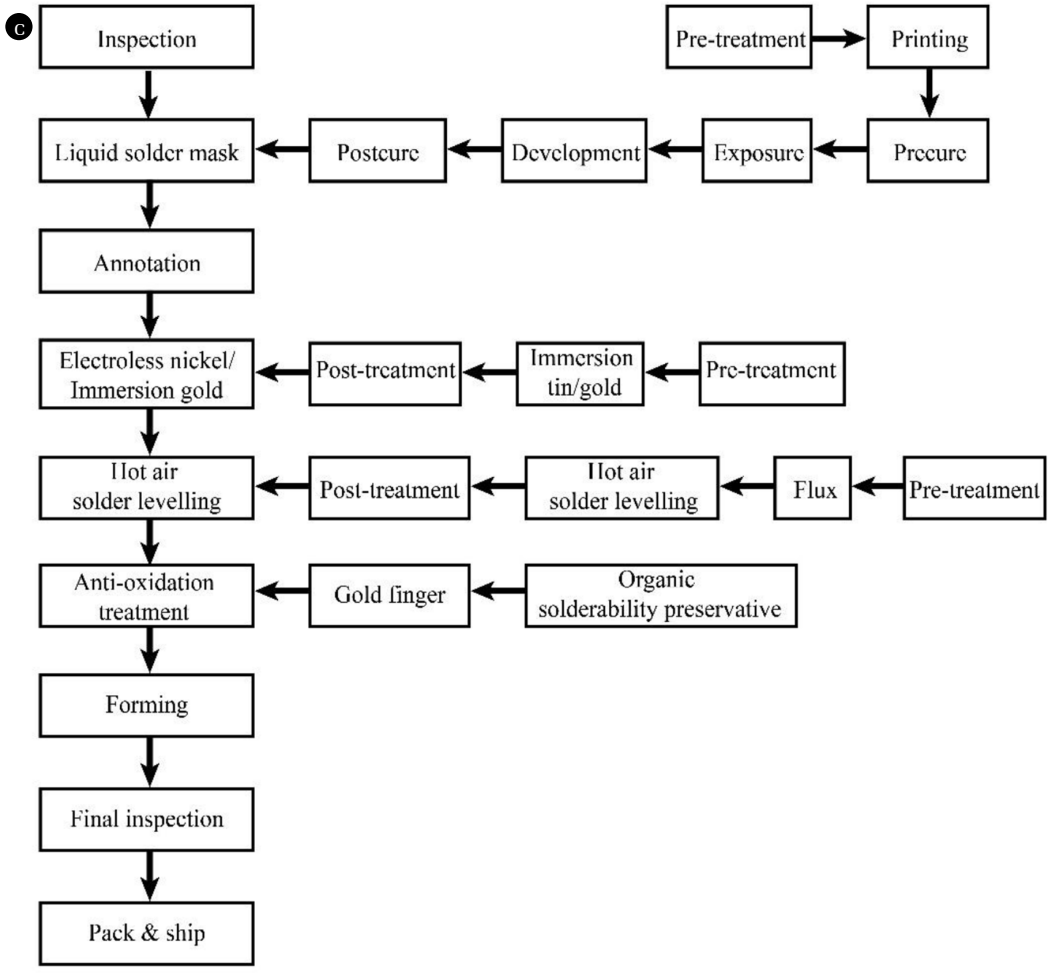

Fig. S1. Main PCB manufacturing processes: (a) inner layer manufacturing; (b) outer layer manufacturing; (c) forming and surface treatment.

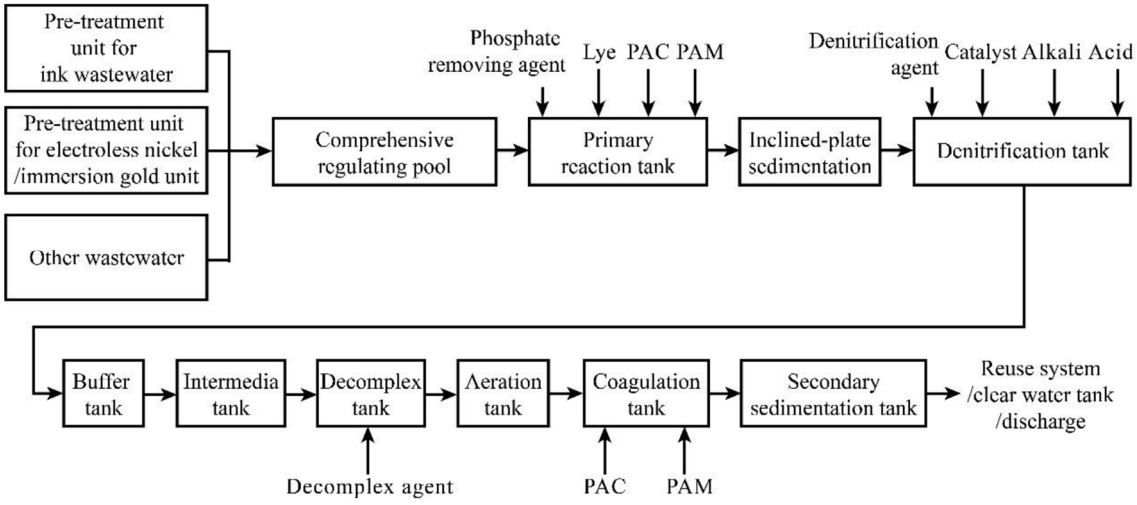

Fig. S2. Current wastewater treatment facilities in the PCB factory.

Table S1. The real wastewater qualities of the PCB manufacturing processes

Item	pH	COD (mg/L)	NO_2^--N (mg/L)	NH_4^+-N (mg/L)	NO_3^--N (mg/L)	TP (mg/L)
(Inner layer) Development	9.7±1.3	1421±142	2.92±1.84	15.72±1.42	31.00±6.41	0.91±0.53
Etching solution	0.2±0.1	33035±3 276	0.52±0.43	4.61±1.35	Non-Detected	29.90±2.55
Stripping	12.5±1.5	16482±3004	0.14±0.11	17.06±2.33	100.76±15.08	3.52±1.71
Pattern plating	6.5±1.3	619±100	0.03±0.03	Non-Detected	Non-Detected	Non-Detected
Tin-plating	1.7±1.5	1953±194	0.10±0.09	17.35±2.09	9.66±2.06	0.38±0.49
(Surface treatment) Development	11.7±1.0	15452±2864	0.32±0.21	15.16±1.98	105.23±18.17	4.55±2.32
Electroless nickel/Immersion gold	2.2±1.6	676±60	0.03±0.02	0.95±0.24	146.00±20.43	0.33±0.22

Table S2. The simulated wastewater qualities according to the PCB manufacturing processes

Item	pH	COD (mg/L)	NO_2^--N (mg/L)	NH_4^+-N (mg/L)	NO_3^--N (mg/L)	TP (mg/L)
(Inner layer) Development	9.55	1507.57	4.02	16.18	36.14	1.27
Etching solution	0.24	36211.76	0.18	3.99	0	28.40
Stripping	12.17	19397.34	0.21	16.06	88.28	3.79
Pattern plating	6.45	540.59	0.05	0	0	0
Tin-plating	1.88	1767.47	0.13	16.54	10.88	0.64
(Surface treatment) Development	12.19	18228.38	0.33	15.88	104.50	3.87
Electroless nickel/Immersion gold	2.32	721.14	0.04	0.83	146.70	0.24

Table S3. Soaking time of raw material combinations in corresponding simulated processes

Simulated process	Raw material	Soaking time (min)
Development (inner layer manufacturing)	PCB substrate (3 g), dry film (1 g)	30 min
Etching	PCB substrate (3 g), dry film (1 g)	10 min
Stripping	PCB substrate (3 g), dry film (1 g)	30 min
Pattern plating	PCB substrate (3 g), dry film (1 g)	120 min
Tin-plating	PCB substrate (3 g), dry film (1 g)	30 min
Development (forming and surface treatment)	PCB substrate (3 g), solder mask ink (1 g)	10 min
Electroless nickel/Immersion gold	PCB substrate (3 g), solder mask ink (1 g), character ink (1 g)	30 min

Table S4. Raw materials for PCB manufacturing in the factory

No.	Raw material	No.	Raw material	No.	Raw material
1	PCB copper-clad laminate (contains formaldehyde substrate)	11	Character ink	21	Alkaline etching agent
2	Copper sulfate	12	Solder mask ink (liquid photosensitive ink)	22	Brown oxide solution
3	Copper anode	13	Dry film	23	98% industrial sulfuric acid
4	Reducing agent copper (contains formaldehyde)	14	Developer	24	Industrial nitric acid
5	Immersion copper solution	15	Film	25	Stripping solution
6	Solder balls	16	Hydrogen peroxide	26	Copper foil
7	Tin additives	17	Industrial hydrochloric acid	27	Prepreg
8	Flux	18	Sodium persulfate	28	Epoxy copperplate
9	Potassium gold(III) cyanide	19	Etching solution	29	Copper ball
10	Nickel sulfate solution	20	Ammonia		

Table S5. Experimental test conditions for the analysis of TBBPA fate in the traditional wastewater treatment facilities

Flocculation-sedimentation process		Activated sludge process (ASP)	
Influence factors	**Fixed conditions**	**Influence factors**	**Fixed conditions**
PAM dosage method	pH=7.5~8.0, 300 mg/L PAC, 3 mg/L PAM, 1 mg/L TBBPA, 25°C	Microbial activity	400±50 mg/L sludge, natural pH, 25°C, no NH_4^+, no Cu^{2+}, 4 mg/L dissolved oxygen
pH	300 mg/L PAC, 0 mg/L PAM, 1 mg/L TBBPA, 25°C	Sludge loading	Activated sludge, natural pH, 25°C, no NH_4^+, no Cu^{2+}, 4 mg/L dissolved oxygen
PAC dosage	pH=7.5~8.0, 0 mg/L PAM, 1 mg/L TBBPA, 25°C	pH	Activated sludge, 400±50 mg/L sludge, 25°C, no NH_4^+, no Cu^{2+}, 4 mg/L dissolved oxygen
PAM dosage	pH=7.5~8.0, 300 mg/L PAC, 1 mg/L TBBPA, 25°C	Temperature	Activated sludge, natural pH, 400±50 mg/L sludge, no NH_4^+, no Cu^{2+}, 4 mg/L dissolved oxygen
		NH_4^+ dosage	Activated sludge, natural pH, 400±50 mg/L sludge, 25°C, no Cu^{2+}, 4 mg/L dissolved oxygen
		Cu^{2+} dosage	Activated sludge, natural pH, 400±50 mg/L sludge, 25°C, no NH_4^+, 4 mg/L dissolved oxygen