Supplementary Information

Application of paper deinking process for silver separation and concentration from a paper-based printed electronics prototype

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Unit operations and their equipment

Figure S1 presents the different equipment used to perform the different unit operations involved in the conventional deinking recycling process.

Pulper

(PE pulping)

Screen

(screening)

Hydrocyclone

(centrifugal cleaning)

Flotation cell

(deinking)

Figure S1. Snapshots of lab equipment running in batch mode used to simulate a conventional recycling process.

Chemicals

Detailed information regarding the different chemicals used in this work is available in Table S1.

Table S1 - Chemical compounds used in this study and their properties. Legend: (-) not available.

Compounds	Chemical Formula	Supplier	CAS number	Mw ($g \cdot mol^{-1}$)	Purity (%)
Sodium Hydroxide	NaOH	Carl Roth, France	1310-73-2	40.00	≥98
Sodium Silicate solution	Na_2SiO_3	Carl Roth, France	1344-09-8	122.06	-
Surfactant (Brij® S100)	$C_{18}H_{37}(OCH_2CH_2)_nOH$ n~100	Sigma Aldrich, France	9005-00-9	~4670	-
Nitric Acid	HNO_3	Carl Roth, France	7697-37-2	63.01	65 (w/w)

Unit operations stream characterization

Detailed information regarding the *h*-index study for non-printed and Grade A pulping trials are presented in Tables S2 and S3, respectively.

Table S2. Non-printed Powercoat™ XD80 sheet formation index results.

Time (min)	Cp = 5%		Cp=10%	
	0 wt% NaOH	0.7 wt% NaOH	0 wt% NaOH	0.7 wt% NaOH
10	360.7 ±9.7	116.4 ±3.3	95.6 ±0.7	56.9 ±5.2
20	253.9 ±8.6	55.9 ±1.7	63.5 ±6.1	44.5 ±1.0
30	193.9 ±4.5	42.8 ±1.0	46.5 ±0.7	47.1 ±1.6
40	175.1 ±4.2	44.0 ±1.5	46.5 ±1.4	45.2 ±2.3

Table S3. Grade A sheet formation index evolution.

Time (min)	Grade A
10	307.4 ±10.8
20	209.8 ±5.1
30	159.4 ±6.1
40	121.7 ±2.6
60	86.8 ±1.8

90	70.9 ±6.2
120	64.1 ±0.9

Furthermore, information on the screening, flotation, and centrifugal cleaning processing streams (Accept and Reject) characterization, including their mass, organic, ash, and Ag fraction, is presented in Tables S3, S4, and S6, respectively. Figure S2 presents the reject fraction deposited on the device screen and the heavy particles, mainly ink, retained at the bottom of the device.

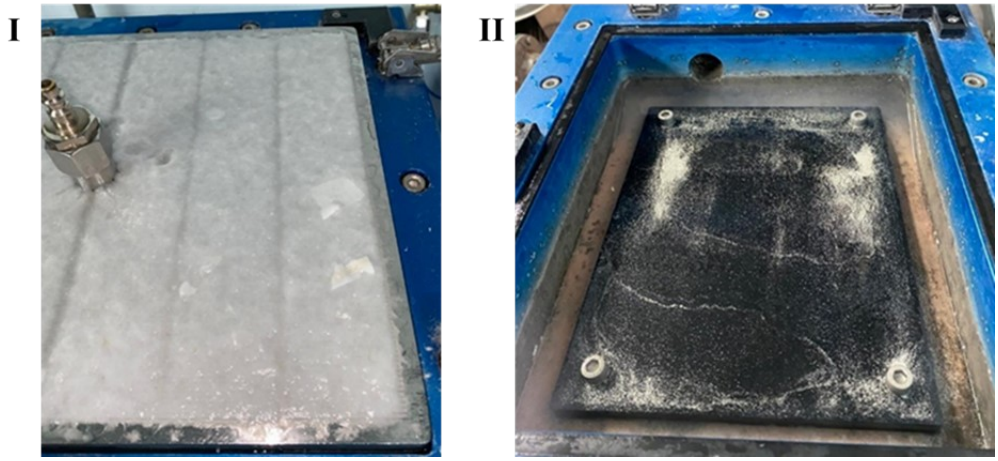

Figure S2. Snapshots of the Mix C screening trial of I – reject fraction collected on the screen; II – Somerville's diaphragm chamber.

Table S4. Mix C screening reject stream characterization. Legend: (-) not measured.

Properties	Mix C	
	Accept	Reject
Cp (%)	-	-
m_{dry} (g)	-	4.4 ±0.2
m_{ash525} (g)	-	0.30 ±0.01
m_{org} (g)	-	4.1 ±0.2
m_{ash900} (g)	-	0.19 ±0.00
m_{Ag} (mg)	-	31.6 ±0.9
SE_{org} (%)	-	-
SE_{Ag} (%)	-	-

Table S5. Flotation trials stream characterization, performed at Cp=1%. Legend: (-) not measured.

Properties	Grade B		Mix C		Mix D		Grade A	
	Accept	Reject	Accept	Reject	Accept	Reject	Accept	Reject
Cp (%)	0.96 ±0.01	-	0.86 ±0.02	-	0.86 ±0.00	-	0.91 ±0.01	-
m_{dry} (g)	205.3 ±1.3	10.7 ±0.3	179.9 ±3.6	30.4 ±0.4	185.1 ±0.1	33.0 ±7.4	197.5 ±1.6	17.3 ±0.4
m_{ash525} (g)	31.5 ±0.3	6.6 ±0.2	25.7 ±0.8	17.4 ±0.3	39.4 ±0.1	22.0 ±5.9	60.8 ±3.2	13.2 ±1.0
m_{org} (g)	173.8 ±1.1	4.1 ±0.1	154.3 ±3.2	13.0 ±0.2	145.7 ±0.1	11.1 ±4.0	136.7 ±3.4	4.1 ±0.9
m_{ash900} (g)	20.6 ±0.2	4.1 ±0.1	16.4 ±0.6	10.7 ±0.2	27.9 ±0.1	16.1 ±5.6	42.6 ±2.5	9.1 ±0.8
m_{Ag} (mg)	4.2 ±0.1	1.27 ±0.03	2.7 ±0.1	1.15 ±0.02	1.90 ±0.01	1.4 ±0.5	3.0 ±0.2	0.2 ±0.0
SE_{org} (%)	97.7 ±0.1	2.3 ±0.1	92.2 ±0.2	7.8 ±0.2	72.9 ±2.4	7.1 ±2.4	97.1 ±0.6	2.9 ±0.6
SE_{Ag} (%)	76.6 ±0.6	23.4 ±0.6	70.3 ±0.2	29.7 ±0.8	57.5 ±8.5	42.5 ±8.5	93.3 ±0.8	6.7 ±0.8

Table S5 lists the centrifugal cleaning results obtained during the Cp effect study.

Table S6. Grade A centrifugal cleaning trials using different pulp consistencies. Legend: (-) not measured.

Properties	0.50%		0.75%		1.0%		2.0%	
	Accept	Reject	Accept	Reject	Accept	Reject	Accept	Reject
Cp (%)	0.50 ±0.01	-	0.68 ±0.01	-	0.98 ±0.00	-	1.80 ±0.02	-
m_{dry} (g)	48.5 ±1.5	1.41 ±0.01	65.9 ±0.2	2.05 ±0.00	83.1 ±0.1	1.90 ±0.00	171.4 ±0.8	3.52 ±0.00
m_{ash525} (g)	16.5 ±0.6	0.83 ±0.00	21.7 ±0.2	1.22 ±0.00	28.4 ±0.1	0.73 ±0.00	57.3 ±0.8	2.01 ±0.00
m_{org} (g)	32.0 ±0.9	0.58 ±0.01	44.2 ±0.2	0.83 ±0.00	54.7 ±0.1	1.17 ±0.00	114.1 ±0.8	1.51 ±0.00
m_{ash900} (g)	11.6 ±0.4	0.76 ±0.00	15.5 ±0.1	1.12 ±0.00	28.4 ±0.2	0.69 ±0.00	39.4 ±0.4	1.73 ±0.00
m_{Ag} (mg)	275 ±44	590 ±21	304 ±103	839	595 ±54	271	2169 ±36	498
SE_{org} (%)	98.2 ±0.4	1.79 ±0.01	98.2 ±0.7	1.83 ±0.01	97.9 ±0.4	2.10 ±0.01	98.7 ±1.0	1.30 ±0.01
SE_{Ag} (%)	31.4 ±2.7	68.6 ±1.7	26.6 ±9.3	73.4 ±6.6	68.7 ±8.3	31.3 ±2.1	81.3 ±1.7	18.7 ±0.3

Table S7. Centrifugal cleaning trials stream characterization, performed at a Cp=0.5%. Legend: (-) not measured.

Properties	Grade B		Mix C		Mix D		Grade A	
	Accept	Reject	Accept	Reject	Accept	Reject	Accept	Reject
Cp (%)	0.55 ±0.00	-	0.53 ±0.01	-	0.53 ±0.01	-	0.51 ±0.01	-
m_{dry} (g)	51.7 ±0.1	1.78 ±0.00	50.2 ±0.4	1.56 ±0.05	50.7 ±0.5	0.96 ±0.00	48.3 ±0.4	1.60 ±0.07
m_{ash525} (g)	9.1 ±0.1	1.13 ±0.00	8.9 ±0.1	0.91 ±0.04	12.9 ±0.2	0.55 ±0.01	16.3 ±0.4	0.94 ±0.03
m_{org} (g)	42.6 ±0.1	0.65 ±0.00	41.3 ±0.1	0.65 ±0.01	37.8 ±0.4	0.41 ±0.02	32.0 ±0.4	0.66 ±0.04
m_{ash900} (g)	5.7 ±0.1	1.1 ±0.00	5.45 ±0.15	0.84 ±0.04	8.78 ±0.02	0.51 ±0.02	11.6 ±0.3	0.87 ±0.02
m_{Ag} (mg)	0.5 ±0.1	763 ±0.1	86 ±31	729 ±60	282 ±17	444 ±22	271 ±28	675 ±0
SE_{org} (%)	98.5 ±0.0	1.5 ±0.0	98.5±0.0	1.5 ±0.0	98.9 ±0.0	1.1 ±0.0	98.0 ±0.0	2.0 ±0.0
SE_{Ag} (%)	0.1 ±0.0	99.9 ±0.0	10.9 ±4.0	89.1 ±4.0	38.9 ±2.0	61.1 ±2.0	28.3 ±1.9	71.7 ±1.9