

Adaptive Fabrication of Electrochemical Chips with a Paste-Dispensing 3D Printer

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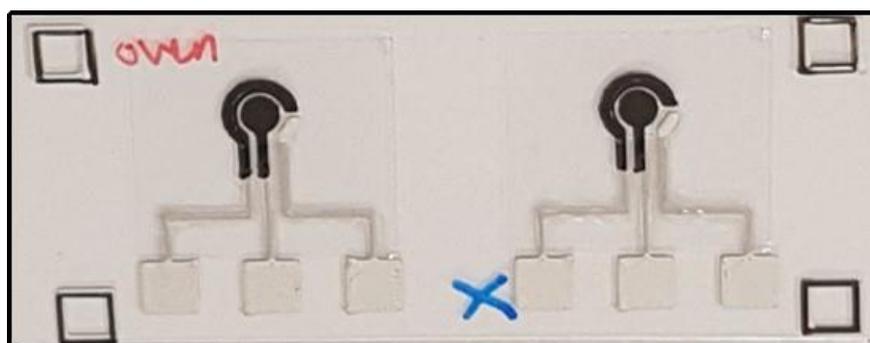
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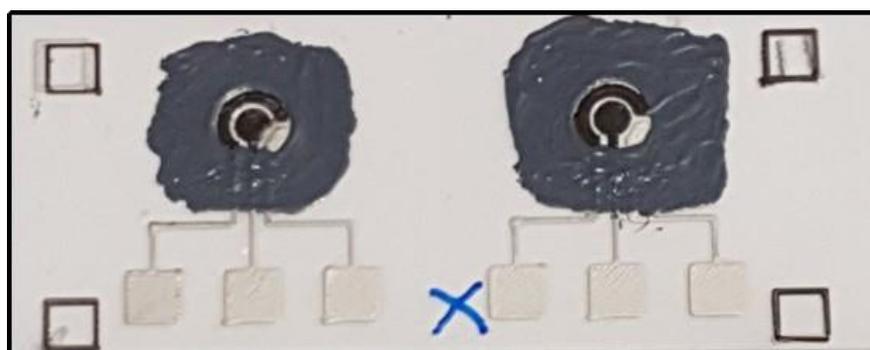
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Figure S1. The filling of carbon paste into the syringe barrel. To avoid bubbles, the paste is squeezed into the syringe barrel through a 2 mm diameter small hole cut on the corner of a zip-lock bag.



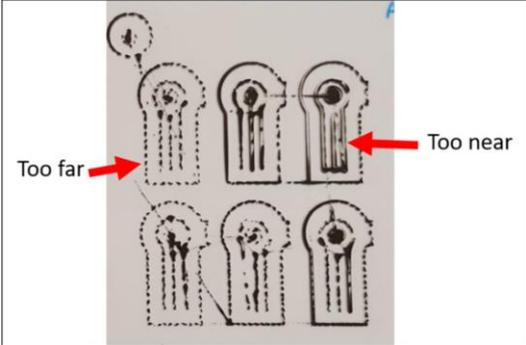
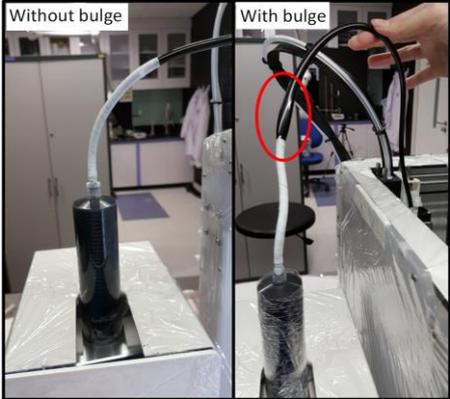
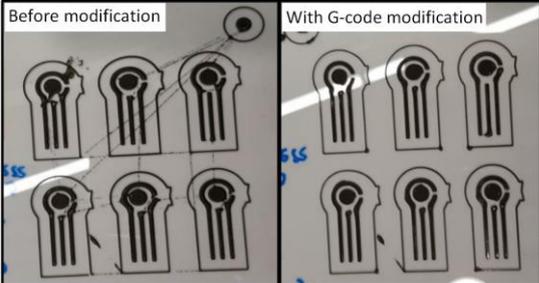
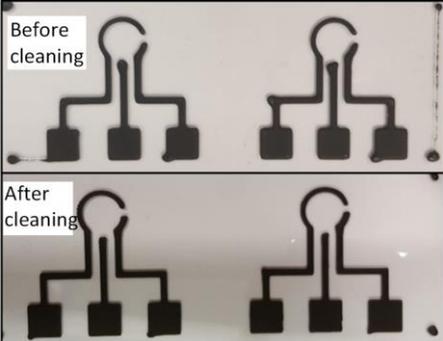
(a)

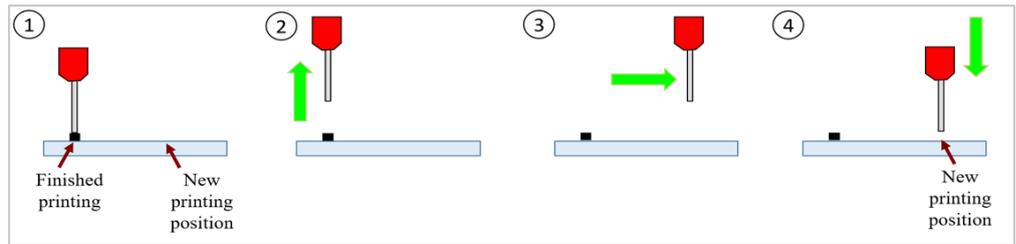


(b)

Figure S2. Photo of the fabricated electrodes with a) double-sided stickers and b) grey di-electric paste as the insulating layer.

Table S1. Engineering problems encountered and solved during the 3D printing of EC chips.

Issues	Solutions	Examples
<p>Poor levelling caused scratching on the substrate or disconnected lines</p>	<p>Carefully aligned, and the gap between the nozzle and the PMMA substrate was set to 0.1 mm</p>	
<p>Bulge of the tube with pressure accumulation</p>	<ol style="list-style-type: none"> 1. Replace the polyethylene tube with a PTFE tube 2. Clean thoroughly and seal tightly for reused needles 	
<p>Whiskers on the printed chip</p>	<p>The nozzle was first moved up, held the paste extrusion, and then pulled down to print (Figure S3)</p>	
<p>Inaccurate printing dimension due to an excessive amount of paste</p>	<p>Moved to a sponge to remove the accumulated paste at the needle tip (Figure S4)</p>	

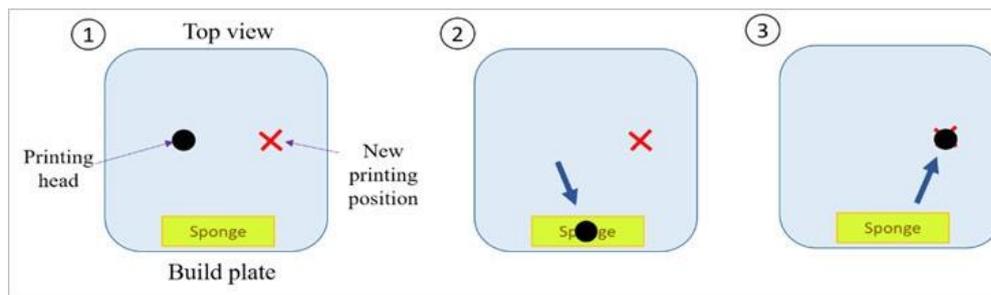


(a)

Before	<pre> G0 F6000 X65.375 Y84.625 G1 F300 X65.375 Y90.375 E0.11183 G1 X59.625 Y90.375 E0.13437 G1 X59.625 Y84.625 E0.15690 G1 X65.375 Y84.625 E0.17943 ;finish printing (original) G1 F10800 E-4.32057 G0 F6000 X80.125 Y103.765 ;move to new printing position (original) G1 F10800 E0.17943 G1 F300 X80.875 Y103.765 E0.18237 ;start printing at new position (original) G1 X80.875 Y108.238 E0.19990 G1 X80.632 Y108.432 E0.20112 G1 X80.369 Y108.707 E0.20261 G1 X80.146 Y109.016 E0.20411 </pre>
After	<pre> G0 F6000 X65.375 Y84.625 G1 F300 X65.375 Y90.375 E0.11183 G1 X59.625 Y90.375 E0.13437 G1 X59.625 Y84.625 E0.15690 G1 X65.375 Y84.625 E0.17943 ;finish printing (original) G0 F6000 Z20.0 ;move up (added) G1 F10800 E-4.32057 G0 F6000 X80.125 Y103.765 ;move to new printing position (original) G1 F10800 E0.17943 G0 F10000 Z1.120 ;move down (added) G1 F300 X80.875 Y103.765 E0.18237 ;start printing at new position (original) G1 X80.875 Y108.238 E0.19990 G1 X80.632 Y108.432 E0.20112 G1 X80.369 Y108.707 E0.20261 G1 X80.146 Y109.016 E0.20411 G1 Y79.967 Y109.351 E0.20559 </pre>

(b)

Figure S3. (a) Schematic diagram of additional movement added into the G-code for removing the whiskers. (b) G-code before and after the addition of extra movements.



(a)

Before	G1 X59.625 Y90.375 E0.13437	
	G1 Y59.625 Y84.625 E0.15690	
	G1 X65.375 Y84.625 E0.17943	;finish printing (original)
	G0 F6000 Z20.0	;move up (added)
	G1 F10800 E-4.32057	
	G0 F6000 X80.125 Y103.765	;move to new printing position (original)
After	G1 F10800 E0.17943	
	G0 F10000 Z1.120	;move down (added)
	G1 F300 X80.875 Y103.765 E0.18237	;start printing at new position (original)
	G1 X80.675 Y108.238 E0.19990	
	G1 X80.632 Y108.432 E0.20112	
	G1 X59.625 Y84.625 E0.15690	
	G1 X65.375 Y84.625 E0.17943	;finish printing (original)
	G0 F6000 Z20.0	;move up (added)
	G1 F10800 E-4.32057	
	G0 F6000 Y60	;move to the side (cleaning)
	G1 F10800 E0.17943	
	G0 F6000 Z14.9	;move down and touch the sponge (cleaning)
G0 F6000 X75.0	;move right (cleaning)	
G0 F6000 X60.0	;move left (cleaning)	
G0 F6000 X75.0	;move right (cleaning)	
G0 F6000 X80.125 Y103.765	;move to new printing position (original)	
G0 F10000 Z1.120	;move down (added)	
G1 F300 X80.875 Y103.765 E0.18237	;start printing at new position (original)	
G1 X80.675 Y108.238 E0.19990		
G1 X80.632 Y108.432 E0.20112		

(b)

Figure S4. The cleaning step added to remove the excessive paste accumulated on the print head: (a) the cleaning step added and (b) the modification of the G-code.

Cyclic Voltammogram of Commercial chip

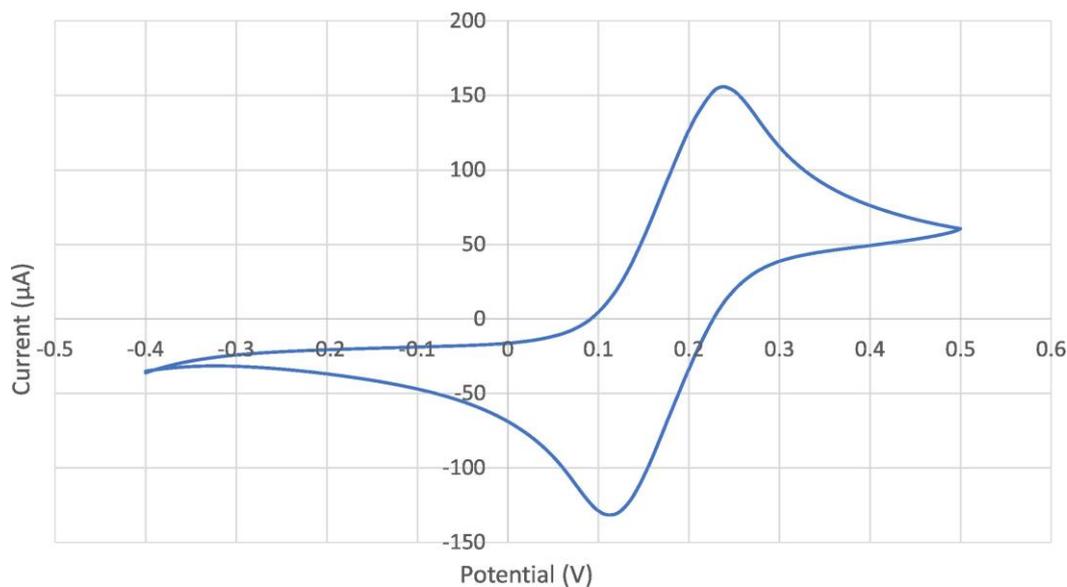
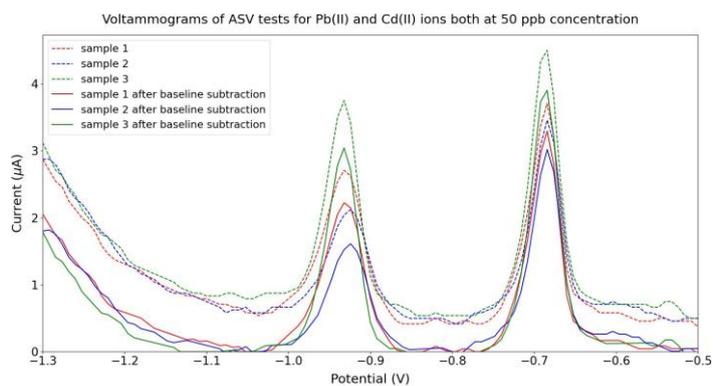
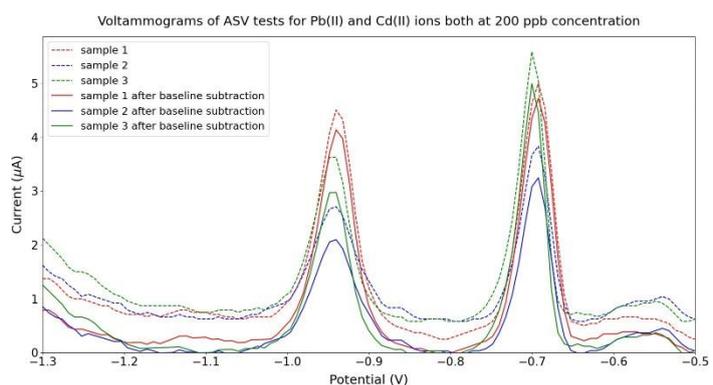


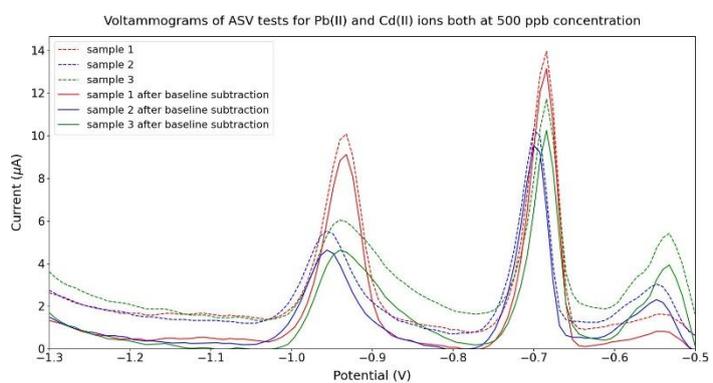
Figure S5. Recorded cyclic voltammogram of a commercial carbon chip using 10 mM $K_3Fe(CN)_6$ in 1.0 MKCl solution.



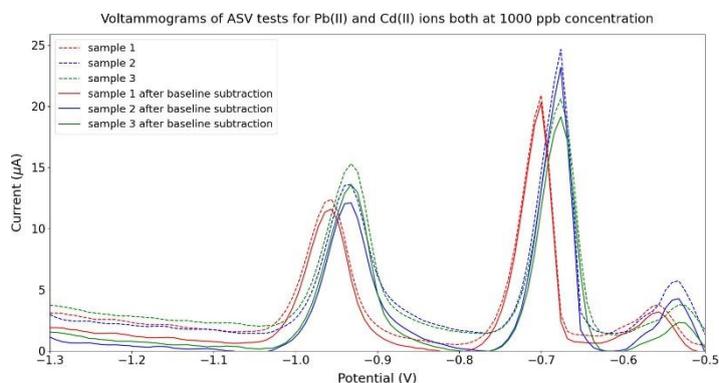
(a)



(b)



(c)



(d)

Figure S6. Voltammograms of ASV tests with the baseline deducted for Pb(II) and Cd(II) in 0.1 M acetate buffer solution with pH = 4.5, at the concentrations of (a) 50 ppb, (b) 200 ppb, (c) 500 ppb, and (d) 1000 ppb for both ions.