Electronic Supplementary Material (ESI) for Energy & Environmental Science.

Electronic Supplementary Information for:

3D-Printed Plastic Components Tailored for Electrolysis

Jesse R. Hudkins[1], *Danika G. Wheeler*[1], *Bruno Peña*[2], *Curtis P. Berlinguette*[1,2]*

[1]Department of Chemical & Biological Engineering, The University of British Columbia, 2360 East Mall, Vancouver, BC V6T1Z3. [2]Department of Chemistry, The University of British Columbia, 2036 Main Mall, Vancouver, BC V6T1Z1.

Corresponding author: cberling@chem.ubc.ca

Figure S1. Electroplating comparison on 3D-printed electrodes. **Left:** Reprapper Conductive ABS, **Middle**: MatterHackers Conductive ABS, **Right**: Proto-Pasta conductive **PLA**.

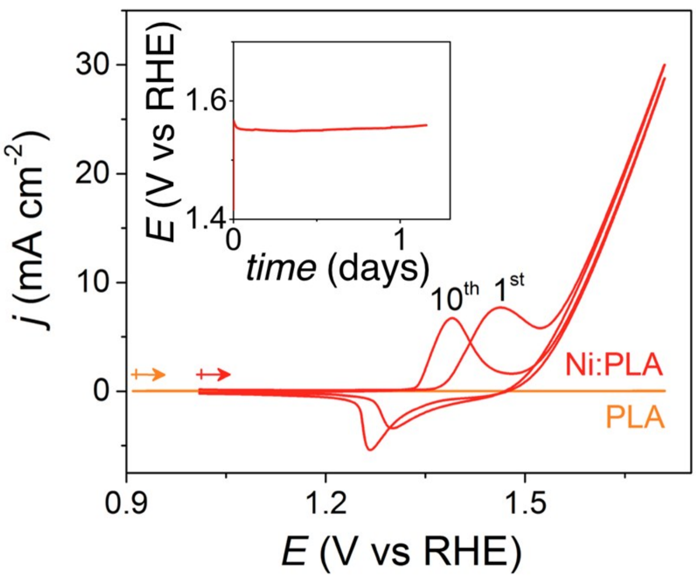

Figure S2. First and tenth cyclic voltammogram cycles recorded (v = 10 mV s^{-1}) on planar Ni:PLA (*red*) and planar PLA (*orange*). Inset: Chronopotentiometry recorded on the planar **Ni:PLA** at a an anodic current density of 4 mA cm^{-2}. Electrochemistry conditions: counter electrode = nickel foam; reference electrode = Ag/AgCl, KCl (sat'd); electrolyte = 1.0 M KOH (aq). Data not corrected for uncompensated resistance.

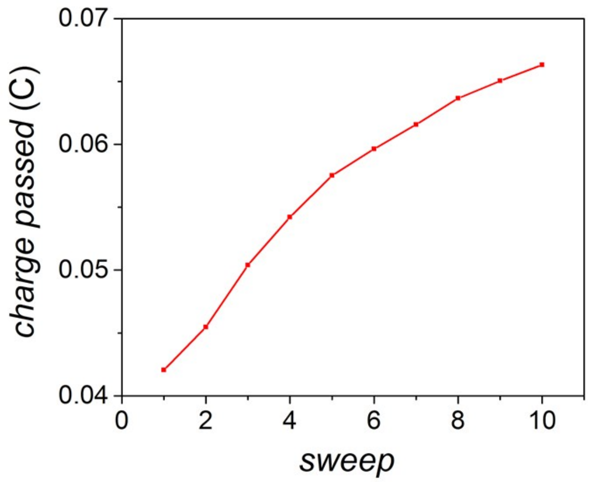

Figure S3. The cathodic charge passed over the first 10 cyclic voltammetry sweeps conducted on a planar **Ni:PLA** electrode. Electrochemistry conditions: counter electrode = nickel foam; reference electrode = Ag/AgCl, KCl (sat'd); electrolyte = 1.0 M KOH (aq); cyclic voltammogram scan rate = 10 mV s^{-1}.

Figure S4. 3D-printed flow-field plates with three different flow-field patterns.

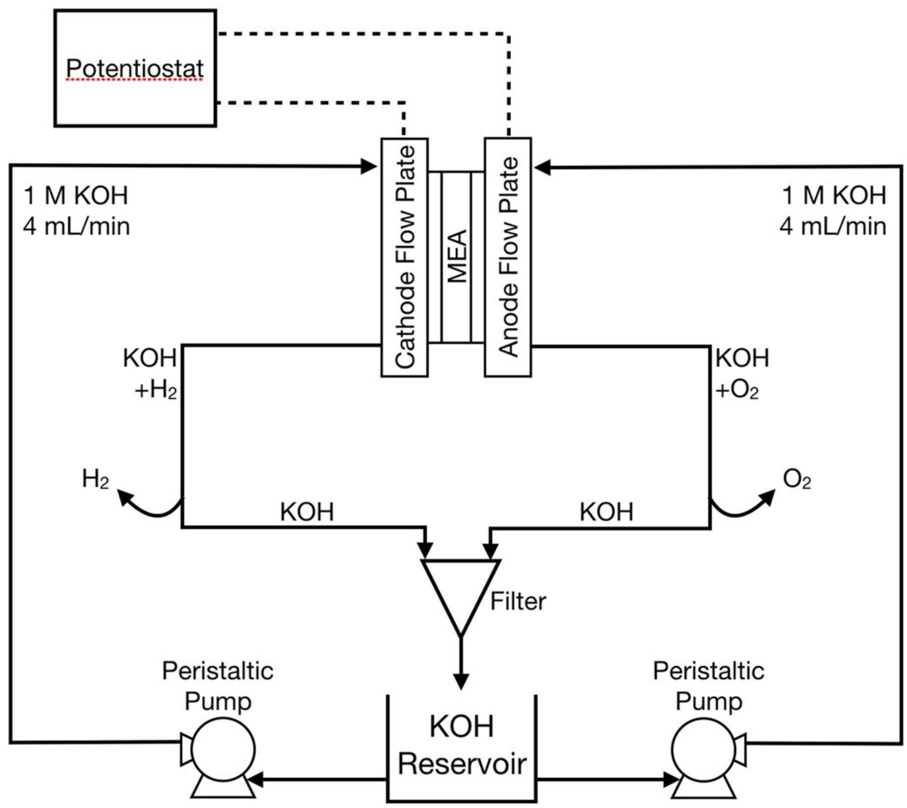

Figure S5. Process flow diagram of electrolyzer testing experimental setup. The membrane electrode assembly (MEA) consists of Ni foam gas diffusion layers hot pressed onto a Zirfon™ Perl UTP separator membrane.

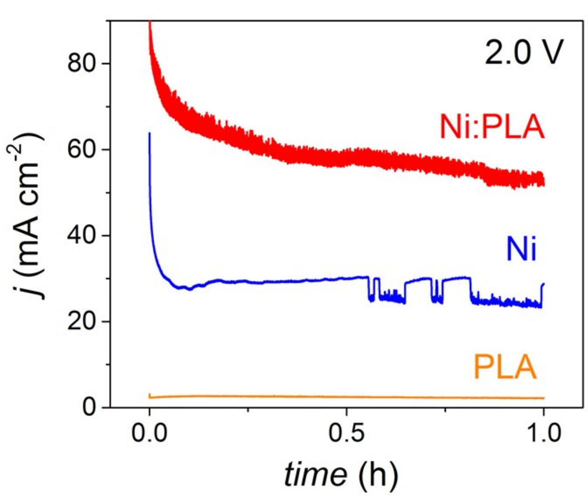

Figure S6. Chronoamperometry recorded on electrolyzer cells with flow-field plates made of bulk Nickel 200 (*blue*), carbon PLA (*orange*), and nickel electroplated PLA (*red*). Electrochemistry conditions: applied potential = 2.0 V; electrolyte = 1.0 M $KOH_{(aq)}$.

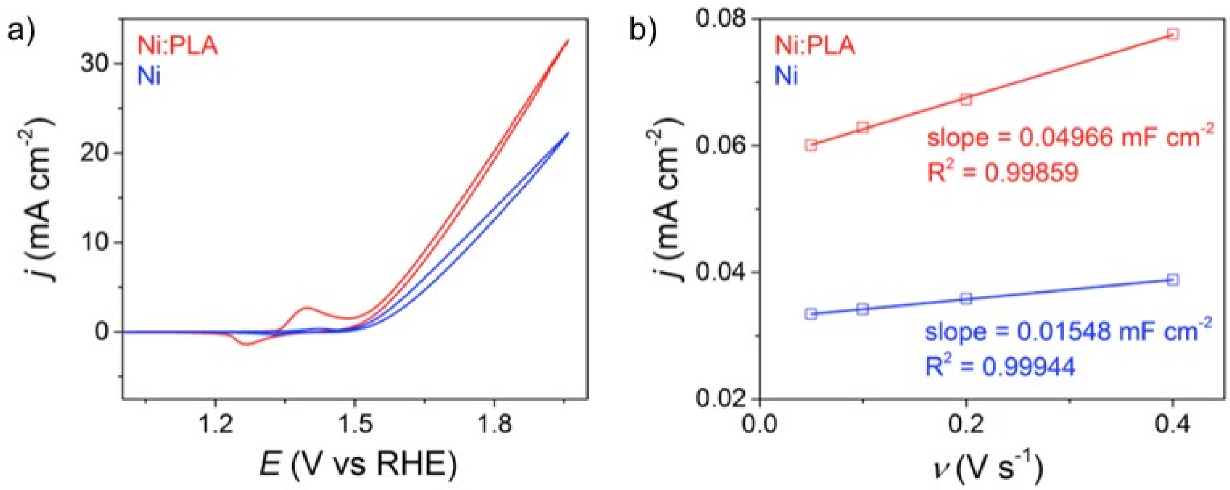

Figure S7. (a) First cyclic voltammogram cycle recorded on a **Ni:PLA** flow-field plate (red) and a **Ni** flow-field plate (blue) in a 3-electrode cell. (b) Cyclic voltammograms were measured in a non-Faradaic region of the voltammogram at the following scan rate: 0.05, 0.1, 0.2, and 0.4V/s. The working electrode was held at each potential vertex for >30 s before the beginning the next sweep. All current is assumed to be due to capacitive charging. Electrochemistry conditions: counter electrode = nickel foam; reference electrode = Ag/AgCl, KCl (sat'd); electrolyte = 1.0 M KOH (aq); cyclic voltammogram scan rate = 10 mV s^{-1}. Data not corrected for uncompensated resistance.

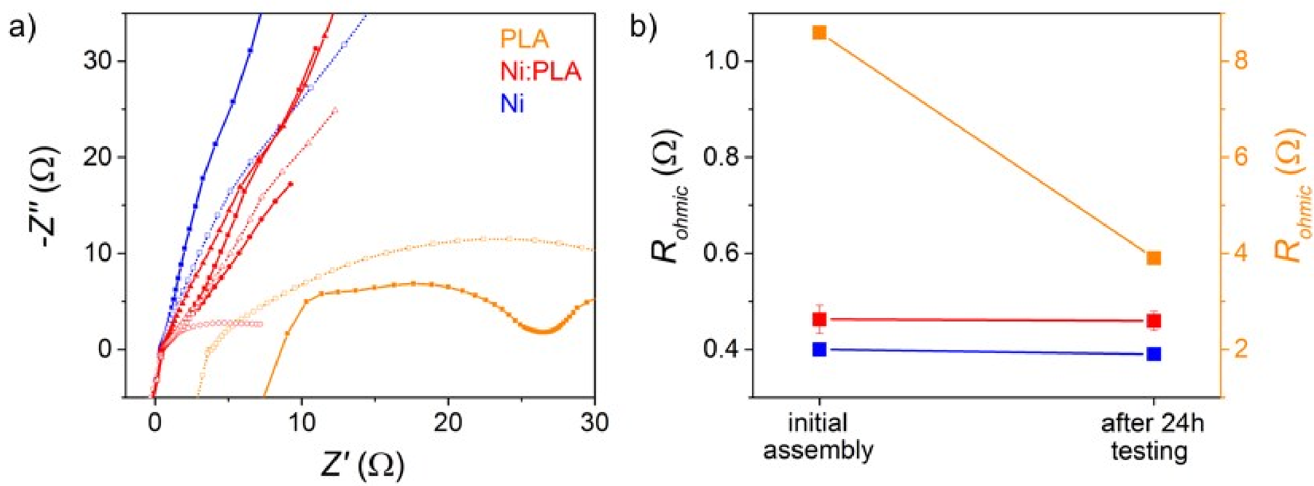

Figure S8. Alternating current electrochemical impedance spectroscopy (EIS) recorded on electrolyzers with different flow-field materials. (a) Nyquist plots of EIS recorded on electrolyzer cells with flow-field plates made of bulk Nickel 200 alloy (*blue*), conductive PLA (*orange*), nickel electroplated PLA (*red*). Solid lines indicate data recorded before electrolysis experiments, dashed lines indicate data recorded after 24 h testing. Three different examples of data recorded on Ni:PLA are shown. All EIS was recorded at open cell potential (OCP). (b) Ohmic cell resistances extrapolated from electrochemical impedance spectra recorded on electrolyzer cells with flow-field plates made of bulk Nickel 200 alloy (*blue*), conductive PLA (*orange*), nickel electroplated PLA (*red*).

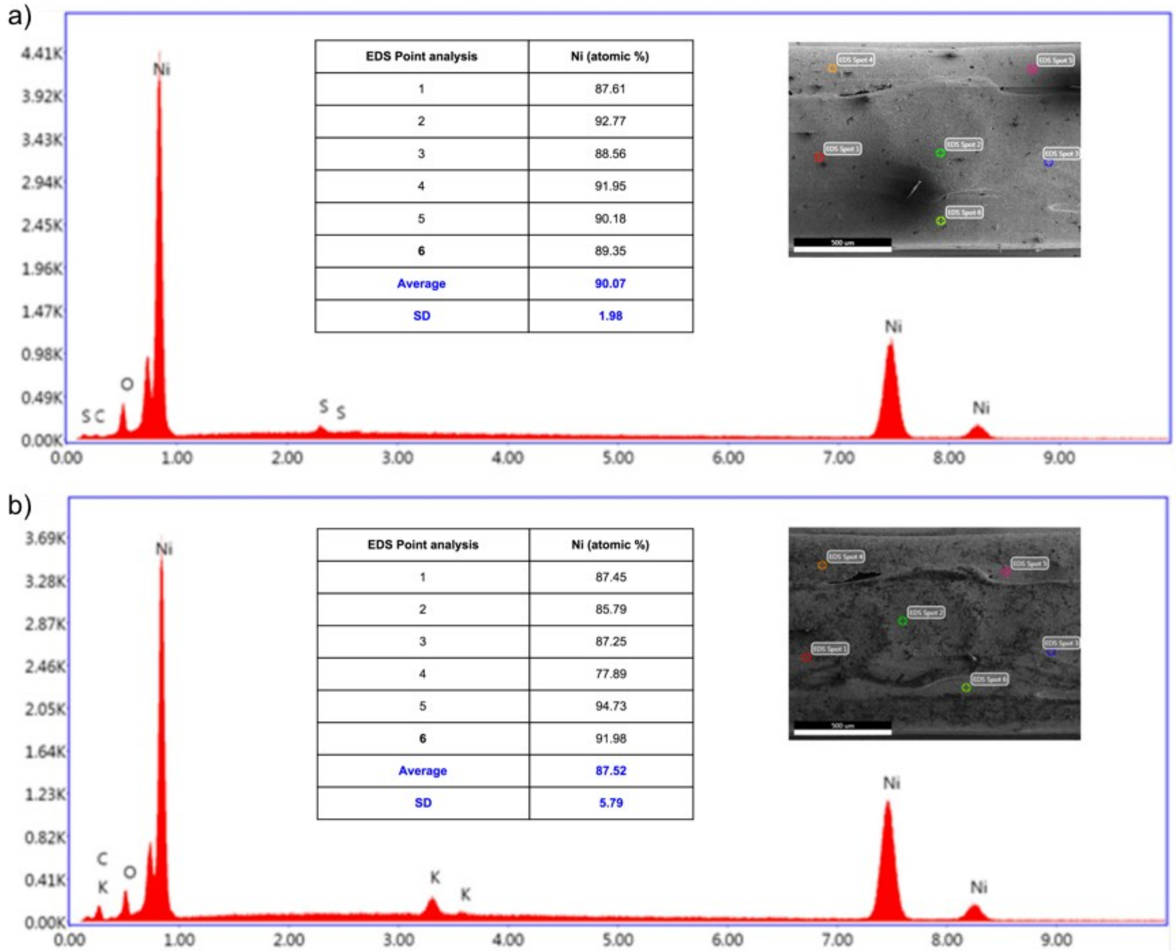

Figure S9. Elemental analysis of six different points on the central flow-field rib (fifth rib from top) using Energy-dispersive X-ray spectroscopy. Representative EDS spectrum: X axes = energy (keV); Y axes = intensity (counts). **a**, Before electrolysis. **b**, After 24 h chronoamperometry and 24 h chronopotentiometry.

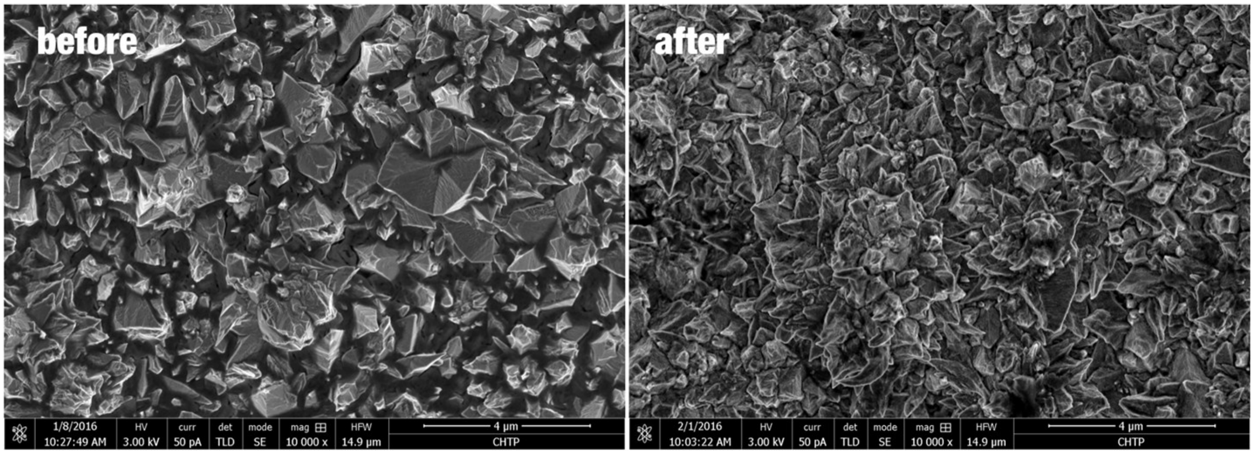

Figure S10. SEM image of an electroplated nickel layer on a PLA flow-field plate before and after 48 h of electrolysis.

Table S1. Volumetric resistivity of conductive 3D-printing filaments

plastic filament[1]	resistivity[2] (Ω cm)		electroplated film thickness
	parallel	orthogonal	
ABS A[3]	6000	30000	–[6]
ABS B[4]	500	3000	–[6]
PLA[5]	20	40	13 µm

[1]ABS = acrylonitrile butadiene styrene; PLA = polylactic acid. [2]With respect to printing plane. [3]Reprapper Conductive ABS. [4]MatterHackers Conductive ABS [5]Proto-Pasta Conductive PLA. [6]Electroplating could not be achieved.

Table S2. Relative prices and densities of flow-field plate materials

material	volumetric pricing (US$ cm^{-3})	density (g cm^{-3})	source
titanium (grade 2)	0.316	4.51	McMaster-Carr
graphite (high conductivity)	0.155	1.70[a]	McMaster-Carr
stainless steel (corrosion resistant)	0.260	7.75	McMaster-Carr
nickel (corrosion resistant)	0.196	8.86	McMaster-Carr
conductive PLA (filament)	0.101	1.15	Proto-pasta
ABS (filament)	0.031	1.01	MatterHackers

[a]Measured

Table S3. Techno-economic analysis of electrolyzer bipolar plates

	zero-gap				conventional			
	actual		relative		actual		relative	
material	mass (g)	cost ($)	mass	cost	mass (kg)	cost ($)	mass	cost
Nickel	44.3	0.98	5.5	1.8	6.6	147.0	6.8	1.9
Stainless Steel	38.8	1.30	4.8	2.3	5.8	195.0	6.0	2.5
Titanium	22.6	1.58	2.8	2.8	3.4	237.0	3.5	3.0
Conductive PLA	5.75	0.51	-	-	0.86	75.8	-	-
Ni:PLA[a]	8.10	0.56	1.0	1.0	0.97	78.2	1.0	1.0

[a]Electrodeposited nickel was assumed to have the same volumetric cost and density as bulk nickel.