Platinum-Coated Nickel Nanowires as Oxygen-Reducing Electrocatalysts

Shaun M. Alia,¹ Brian A. Larsen,¹ Svitlana Pylypenko,² David A. Cullen,³ David R. Diercks,² K.C.Neyerlin,¹ Shyam S. Kocha,¹ and Bryan S. Pivovar^{1,*}

¹ Chemical and Materials Science Center, National Renewable Energy Laboratory, Golden, CO 80401

² Department of Metallurgical and Materials Engineering, Colorado School of Mines, Golden, CO 80401

³ Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

* Corresponding Author, Bryan S. Pivovar. Email: bryan.pivovar@nrel.gov

Supporting Information

Figure S.1. Pt content in Pt/NiNWs as a function of the (a) mass of Pt precursor (potassium tetrachloroplatinate) without hydrochloric acid and (b) volume of hydrochloric acid added to 41.4 mg of Pt precursor (potassium tetrachloroplatinate).

Figure S.2. (a) Dark- and (b) bright-field STEM images of cross-sectioned NiNWs. (c) Composite, (d) Ni, and (e) oxygen EDS maps of cross-sectioned NiNWs in STEM.

Figure S.3. Dark- and bright-field high-resolution STEM images of (a,b) NiNWs, (c,d) PtNiNWs (9.6 wt. % Pt), and (e–h) PtNiNWs (96.8 wt. % Pt).

Figure S.4. (a) Dark- and (b) bright-field STEM images of cross-sectioned PtNiNWs (9.6 wt. % Pt). (c) Composite, (d) Pt, (e) Ni, and (f) oxygen EDS maps of cross-sectioned PtNiNWs (9.6 wt. % Pt) in STEM.

Table S.1. XPS of NiNWs and PtNiNWs (9.6 wt. % Pt, 12.2 wt. % Pt, and 96.8 wt. % Pt, by ICP-MS). Compositions are presented in atomic percentage.

	NiNW	PtNi 9.6 %	PtNi 12.2 %	PtNi 96.8 %
C 1s	41.3	44.5	43.4	45.2
O 1s	38.1	28.8	30.8	12.6
Ni 2p	20.6	14.2	14.2	1.4
Pt 4f		12.5	11.6	40.9

Figure S.5. (a) Dark- and (b) bright-field STEM images of cross-sectioned PtNiNWs (96.8 wt. % Pt). (c) Composite, (d) Pt, (e) Ni, and (f) oxygen EDS maps of cross-sectioned PtNiNWs (96.8 wt. % Pt) in STEM.

Figure S.6. (a) Mass and specific ORR activity and (b) ECA and i_d of PtNiNWs (7.4 wt. % Pt) as a function of catalyst loading on the RDE tip. The inks used to prepare the RDE tips contained a Nafion ionomer ($4 \mu\text{L mL}^{-1}$) with and without 60 wt. % graphitized carbon nanofibers (denoted C in Figure subsets). Catalyst loading on the RDE tip was increased by adding multiple aliquots of ink.

Figure S.7. Mass and specific ORR activities of PtNiNWs (7.4 wt. % Pt) varying the amount of (a) Nafion and (b) graphitized carbon nanofibers in the ink used to coat the RDE tip.

Figure S.8. (a) Mass and specific ORR activities and (b) ECAs of PtNiNWs as a function of percent Pt displacement. The inks used to prepare the RDE tips contained a Nafion ionomer ($4 \mu\text{L mL}^{-1}$) and no graphitized carbon nanofibers. ORR activities were corrected for internal resistance and the partial pressure of oxygen at 0.9 V vs. RHE (1600 rpm, 20 mV s^{-1}) in an oxygen-saturated 0.1 M HClO_4 electrolyte.

Figure S.9. (a) Cyclic voltammograms of PtNiNWs (12.2 wt. % Pt), NiNWs, and Pt/HSC in a nitrogen-saturated 0.1 M KOH electrolyte. (b) Oxygen-reduction polarization curves corrected for internal resistance at 1600 rpm, 20 mV s^{-1} in an oxygen-saturated 0.1 M KOH electrolyte.

Figure S.10. ECAs of PtNiNWs as a function of percent Pt displacement. The inks used to prepare the RDE tips contained graphitized carbon nanofibers (60 wt. %) and a Nafion ionomer ($4 \mu\text{L mL}^{-1}$).

Figure S.11. ECAs of PtNiNWs (7.4, 12.2, and 96.8 wt. % Pt) and Pt/HSC as a function of durability cycles. Durability experiments were conducted on PtNiNWs (a,b) with and (c,d) without the addition of graphitized carbon nanofibers to the catalyst ink. Durability testing was completed by potential cyclic (0.6–1.0 V vs. RHE) 30,000 times in a nitrogen-saturated 0.1 M HClO_4 electrolyte.

Figure S.12. (a) Mass and (b) specific ORR activities of PtNiNWs as a function of percent Pt displacement prior to and following durability testing. The inks used to prepare the RDE tips contained a Nafion ionomer ($4 \mu\text{L mL}^{-1}$) and no graphitized carbon nanofibers. Durability testing was completed by potential cyclic ($0.6\text{--}1.0 \text{ V vs. RHE}$) 30,000 times in a nitrogen-saturated 0.1 M HClO_4 electrolyte. ORR activities were corrected for internal resistance and the partial pressure of oxygen at 0.9 V vs. RHE ($1,600 \text{ rpm}$, 20 mV s^{-1}) in an oxygen-saturated 0.1 M HClO_4 electrolyte.