Electronic Supplementary Information (ESI) for

Copper- and Chloride-Mediated Synthesis and Optoelectronic Trapping of Ultra-High Aspect Ratio Palladium Nanowires

Matthew B. Lim[a], Jennifer L. Hanson[a], Leron Vandsburger[a], Paden B. Roder[a,‡], Xuezhe Zhou[a,§], Bennett E. Smith[b,‡], Fumio S. Ohuchi[†], Peter J. Pauzauskie[*,a,c]

[a] *Department of Materials Science and Engineering and* [b] *Department of Chemistry, University of Washington, Seattle, Washington 98195, USA*

[c] *Physical and Computational Sciences Directorate, Pacific Northwest National Laboratory, Richland, Washington 99352, USA*

* Corresponding author
§ Current address: Apple Inc., Cupertino, California 95014, USA
‡ Current address: Intel Corporation, Hillsboro, Oregon 97124, USA

Experimental Details

Neutron Activation Analysis (NAA). NAA, a quantitative method in which neutron-activated radioactive samples are monitored via gamma decay counts for elemental identification, was performed on the TRIGA Mark II Nuclear Reactor at Kansas State University (Manhattan, Kansas, USA). The samples of approximately 1 mg of dried PdNWs were irradiated for 30 min operating at 100 kW thermal power, $4 \cdot 10^{12}$ neutrons cm^{-2} s^{-1} thermal flux and $4.8 \cdot 10^{12}$ neutrons cm^{-2} s^{-1} fast and epithermal flux. Samples were counted while positioned near the surface of a 25 cm^2, trapezohedral, germanium, lithium-drifted semiconductor detector (Nuclear Diodes), which is constantly cooled by liquid nitrogen (77 K). Dead time between end of irradiation and start of collection was 19 hours, 18 minutes. Copper was monitored via (n, γ) activation of ^{63}Cu to the radioisotope ^{64}Cu, which undergoes β^+ and β^- decay to ^{64}Ni and ^{64}Zn respectively with half-life 12.7 h and characteristic energy 1345 keV. Palladium was monitored via (n, γ) activation of ^{108}Pd to ^{109}Pd, which undergoes β^- decay to the metastable ^{109m}Ag with half-life 13.7 hours and characteristic energy 88 keV. The counts per second (cps) for palladium and copper were $4.567 \cdot 10^5$ and $7.5019 \cdot 10^{-2}$ respectively. After accounting for detector efficiency, these counts correspond to activities of $1.1856 \cdot 10^8$ and 818.3147 μCi, which in turn corresponds to a Pd/Cu ratio of 16000:1 or 0.0062 at% Cu = 62 ppm Cu.

Supporting Data

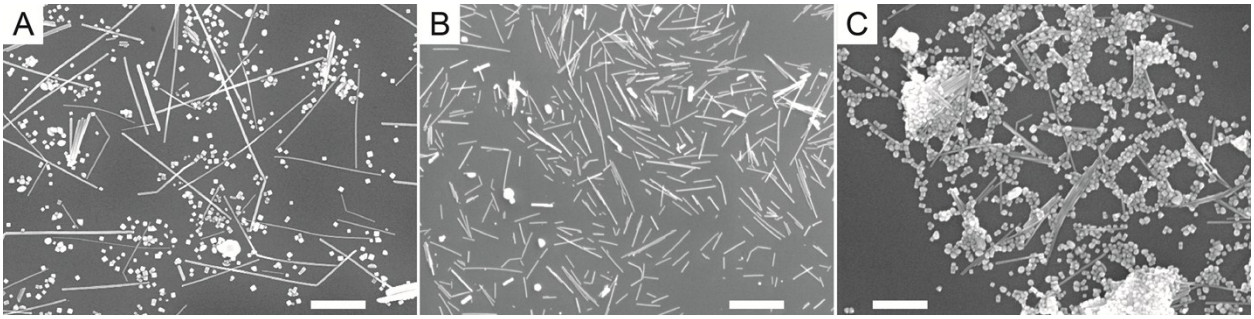

Figure S1. SEM images of hydrothermally synthesized Pd nanoparticles (a) without additives, with MW 29000 PVP, for 6 h; (b) with $CuSO_4$ and MW 29000 PVP for 6 h; (c) with $Cu(OAc)_2$, NaCl, and MW 29000 PVP for 2 h. Scale bar = 1 μm (a, b); 500 nm (c).

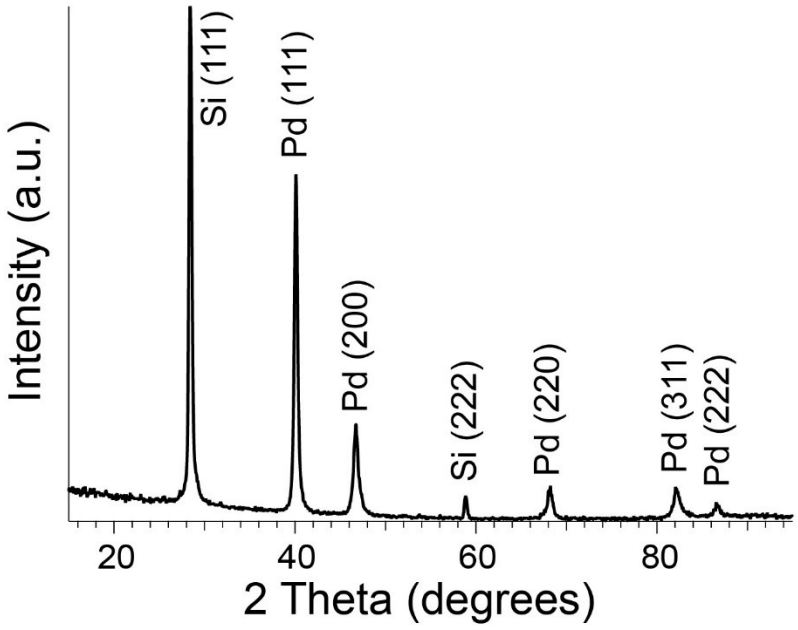

Figure S2. Cu Kα XRD pattern of PdNWs synthesized with $Cu(OAc)_2$ and MW 29000 PVP for 6 h.

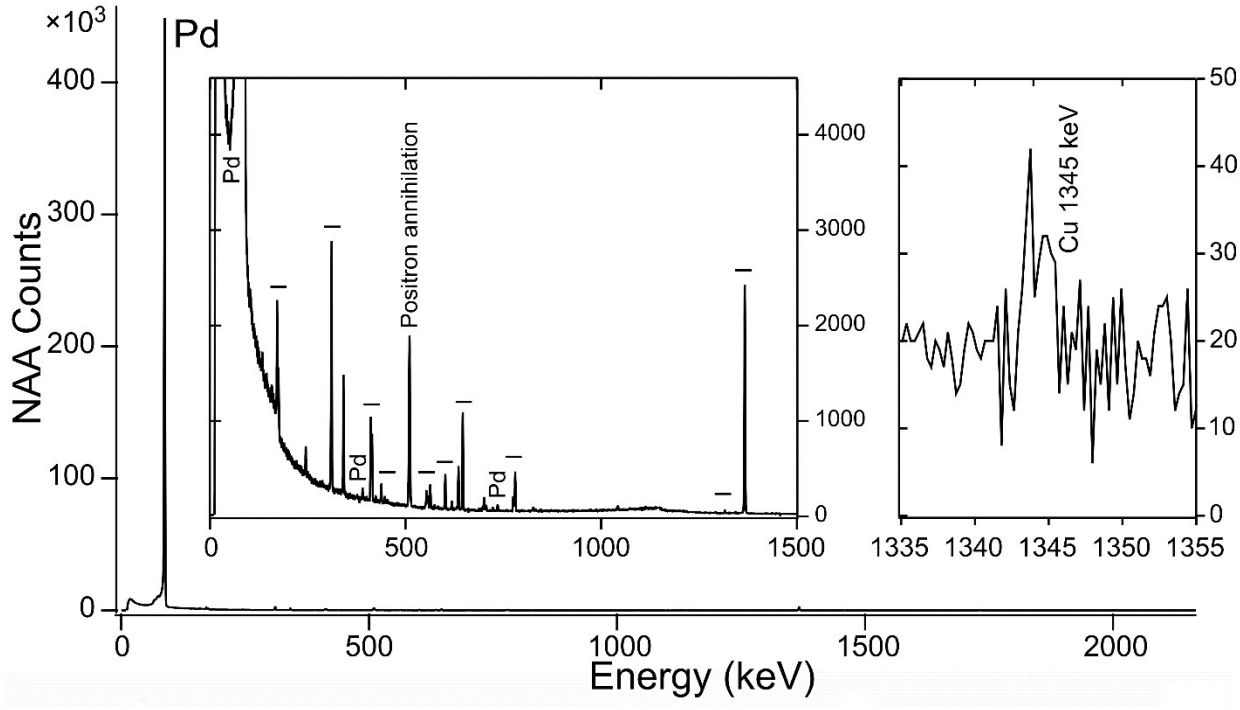

Figure S3. Neutron activation analysis (NAA) plots of PdNWs synthesized with 0.67 μM Cu(II) solution, showing a prominent Pd peak at 88 keV and Cu peak at 1345 keV (inset).

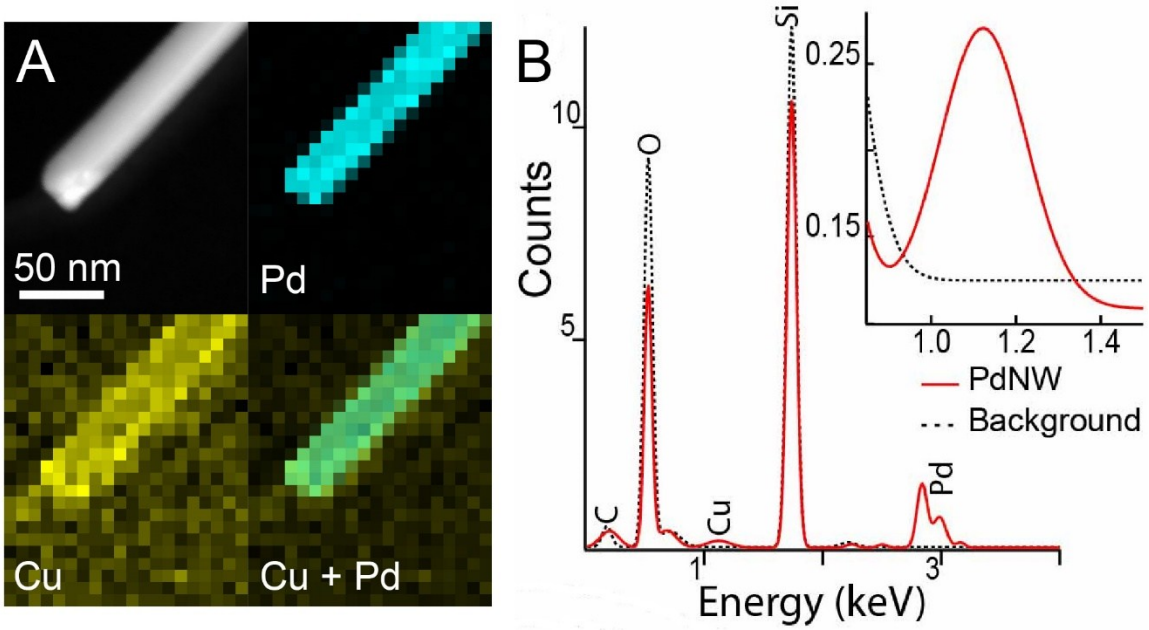

Figure S4. Energy-dispersive X-ray spectroscopy (EDS) of a PdNW obtained on the TEM. (a) High-angle annular dark-field (HAADF) image of a PdNW with accompanying EDS elemental map showing copper enrichment along the wire. (b) EDS spectra of a PdNW (red) and background SiO_2 support film (black).

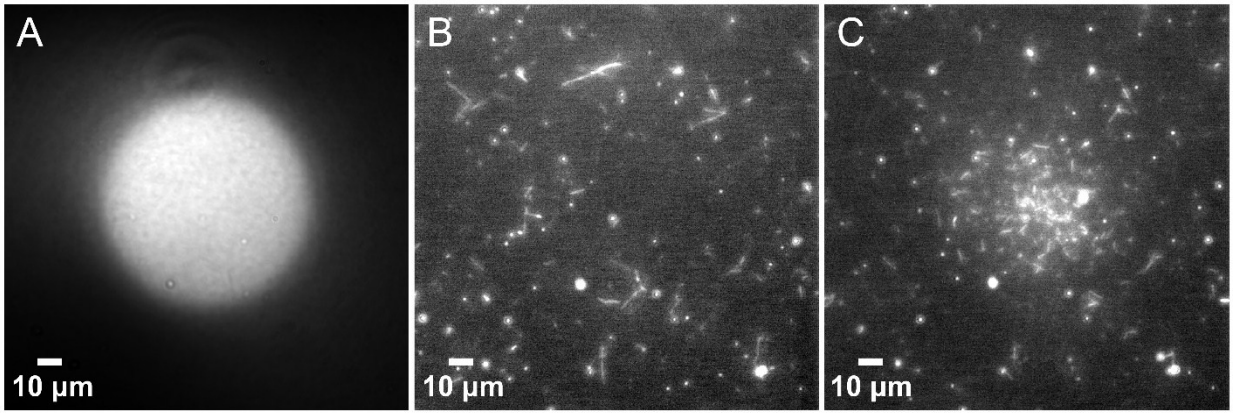

Figure S5. Aggregation of PdNWs in water with OET. (a) An illuminated circle ~86 µm in diameter is projected onto the OET device using an ordinary digital projector. (b) PdNW suspension before illumination and biasing. (c) PdNW suspension after illumination and application of 20 V peak-to-peak, 500 kHz for 5 min (bias off and projected image removed).

Supporting Video

Video 1 shows the manipulation of a single PdNW in water with optoelectronic tweezers (OET), using a 633-nm HeNe laser to actuate the trap (depicted in Figure 4 of the main text). With no applied voltage, the nanowire of interest initially moves about randomly. However, when a bias of 5 V peak-to-peak and 500 kHz is applied across the OET device, the nanowire aligns with the electric field and falls into the laser spot. As the laser spot is moved within the field of view, the nanowire moves along with it. Afterwards, the bias is turned off and the nanowire reverts back to Brownian motion.