Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics

Supporting Information for

Core-Shell Catalysts Consisting of Nanoporous Cores for Oxygen Reduction Reaction

Minhua Shao,[1,] Brandon H. Smith,[1,†] Sandra Guerrero,[1] Lesia Protsailo,[1] Dong Su,[2] Keiichi Kaneko,[3] Jonathan H. Odell,[1] Michael P. Humbert,[1,‡] Kotaro Sasaki,[4] Jesse Marzullo,[1] Robert M. Darling[1,‡]*

[1]UTC Power, 195 Governor's Highway, South Windsor, CT 06074, United States

[2]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY 11973, United States

[3]Toyota Motor Engineering & Manufacturing North America Inc., Ann Arbor, Michigan 48105 United States

[4]Chemistry Department, Brookhaven National Laboratory, Upton, NY 11973, United States

[†]Current address: The Pennsylvania State University, University Park, Pennsylvania, 16802, United States

[‡]Current address: United Technologies Research Center, East Hartford, CT 06108, United States

*Minhua@gmail.com

Tel: (+1) 860-727-7251

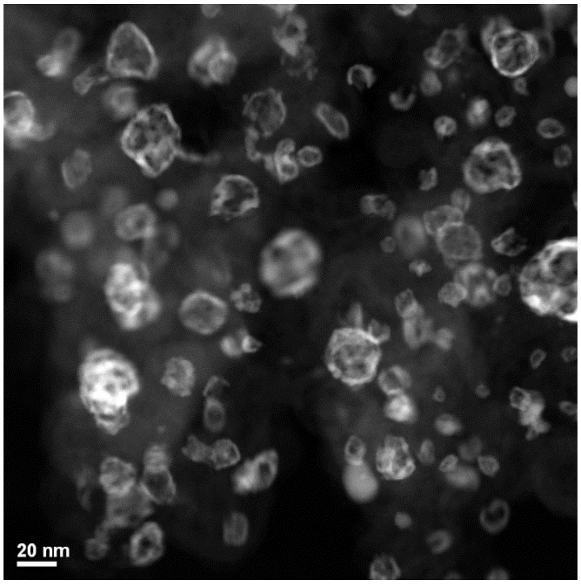

Figure S1. HAADF-STEM images of dealloyed Pd-Ni/C (d-PdNi/C) with a nanoporous structure.

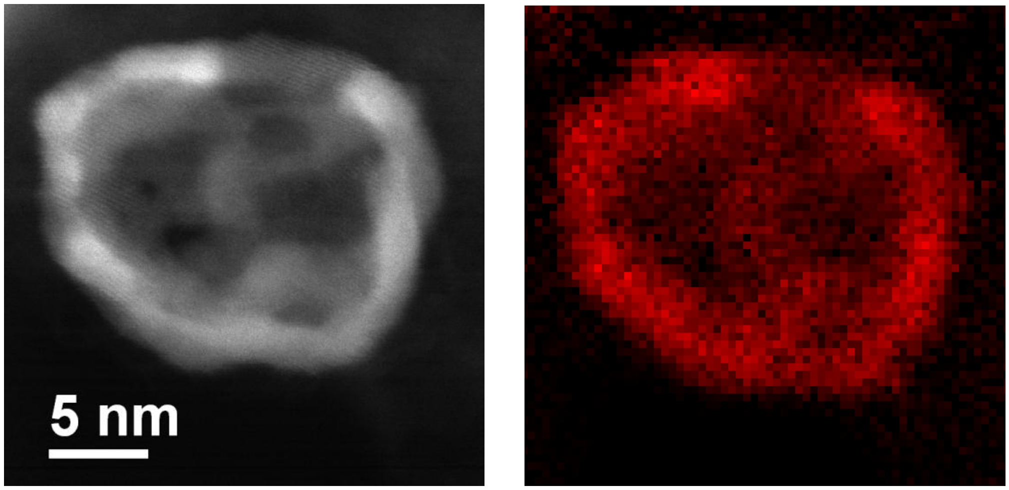

Figure S2. A single d-PdNi particle in sample 3: HAADF-STEM image (A) and 2D EELS mapping (B).

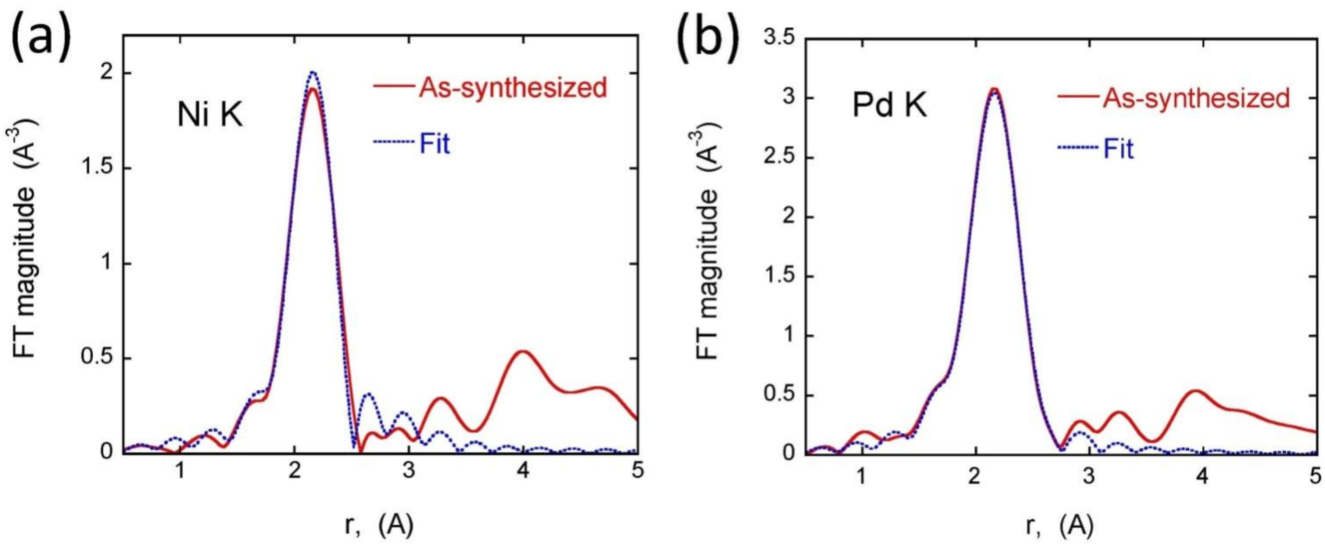

Figure S3. Fourier transformed EXAFS of the data (red) and first-shell fit (dotted blue) of (a) Ni K and (b) Pd K edges from the as-synthesized sample.

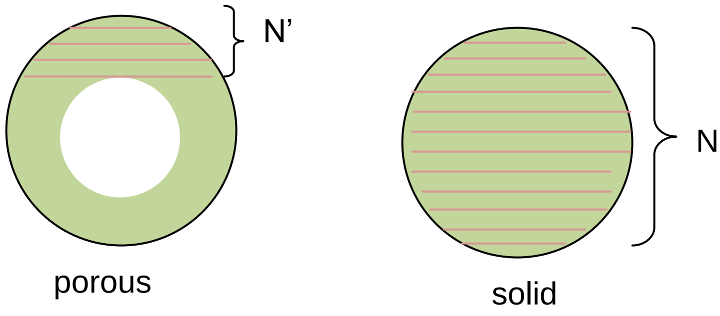

Figure S4. Illustrations of porous and solid particles. The intensity (reverse of broadness) of a XRD peak depends on the number of repeated cell units (N) in one direction (a) in the crystal (p.6 in prism.mit.edu/xray/CrystalSizeAnalysis.ppt):

$$I = I_e F^2 \frac{\sin^2(\pi/\lambda)(s-s_O)\bullet N_1 a_1}{\sin^2(\pi/\lambda)(s-s_O)\bullet a_1} \frac{\sin^2(\pi/\lambda)(s-s_O)\bullet N_2 a_2}{\sin^2(\pi/\lambda)(s-s_O)\bullet a_2} \frac{\sin^2(\pi/\lambda)(s-s_O)\bullet N_3 a_3}{\sin^2(\pi/\lambda)(s-s_O)\bullet a_3}$$

The larger the number N, the higher the intensity (narrower of the XRD peak). For a porous particle, the number of the repeated unit cells (N') is smaller than that a solid particle with a similar overall particle size, resulting in a smaller crystallite size using Scherrer equation.

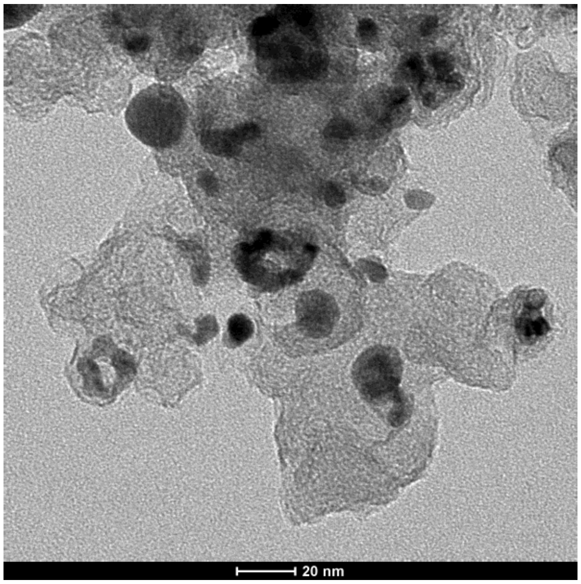

Figure S5. TEM image of sample 3 after first stage of dealloying in 1 M HNO_3 at 60°C for 1 hr. Porous structure was seen in some of the particles.