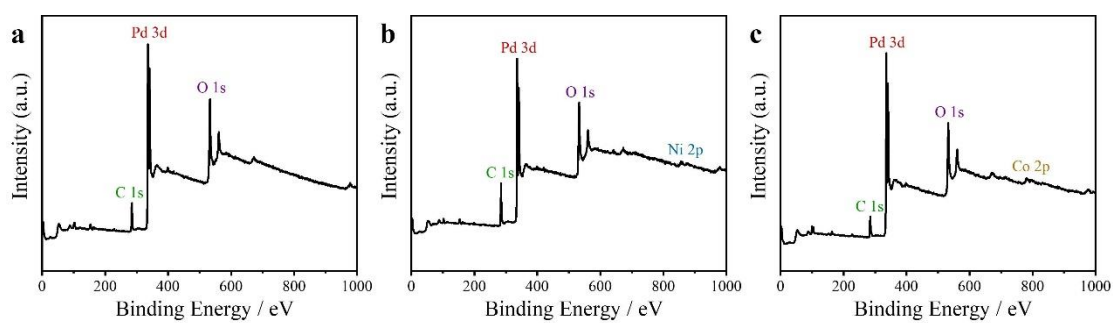
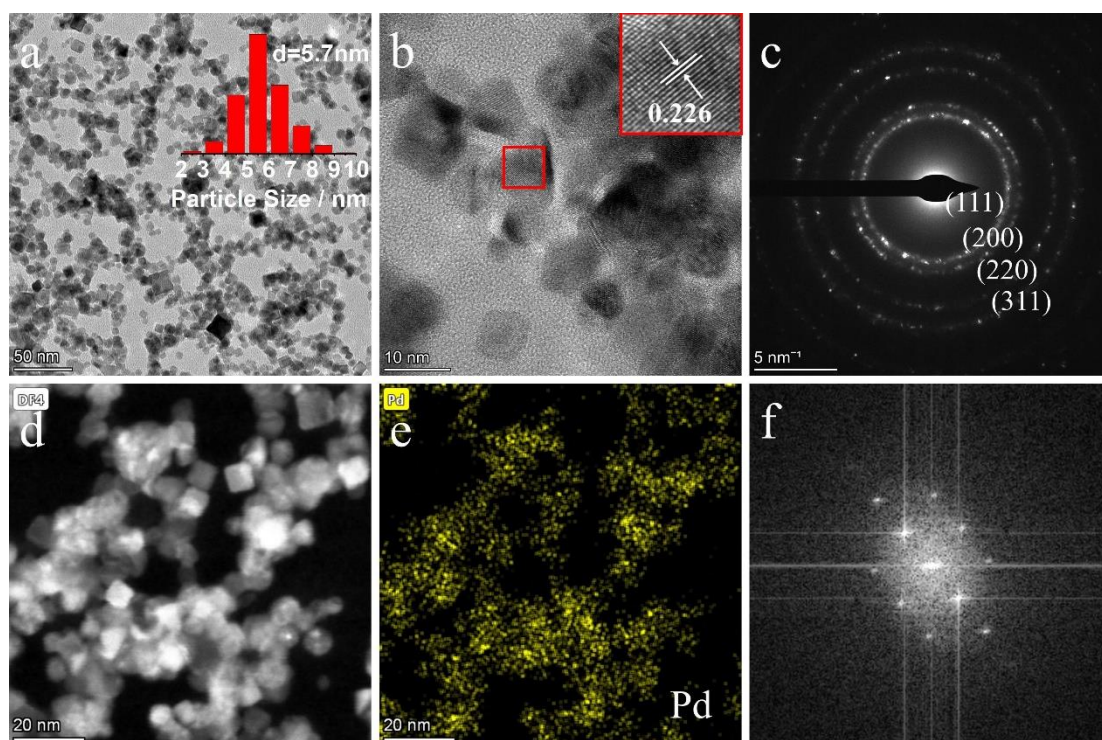


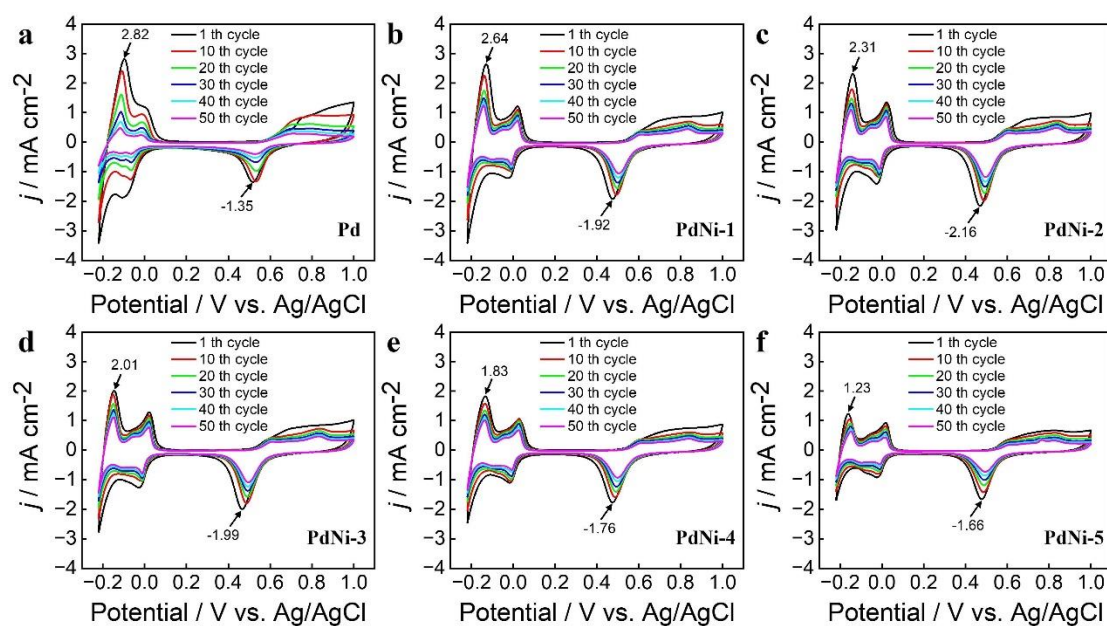
**Figure S1.** Schematic diagram of the nanoparticle beam composite deposition system.



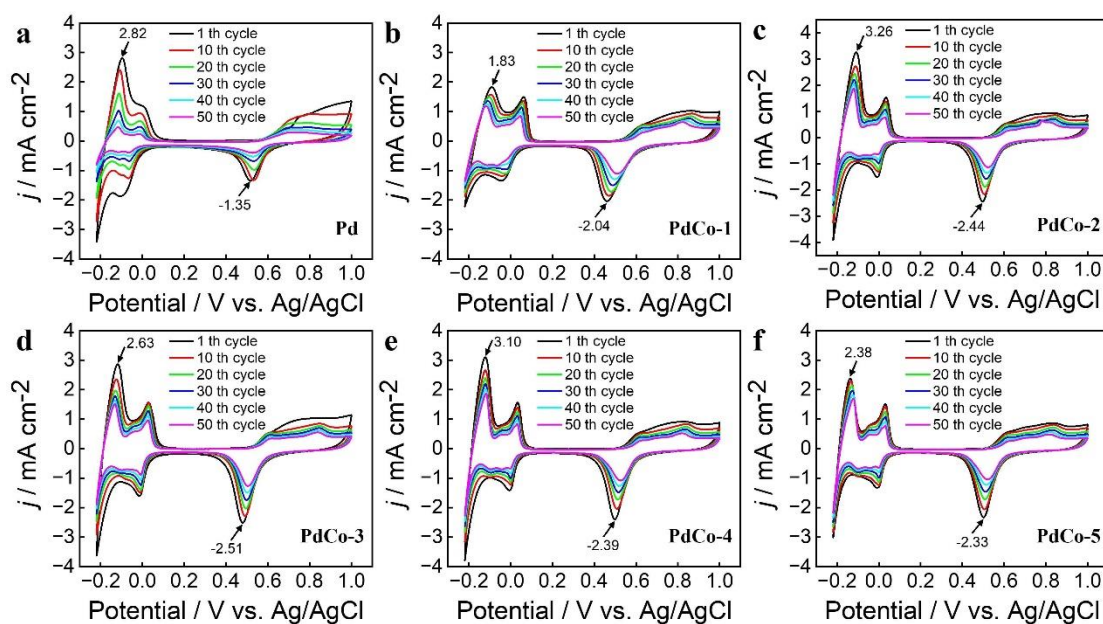
**Figure S2.** XPS survey spectra of (a) Pd, (b) PdNi-2 and (c) PdCo-3 catalysts.



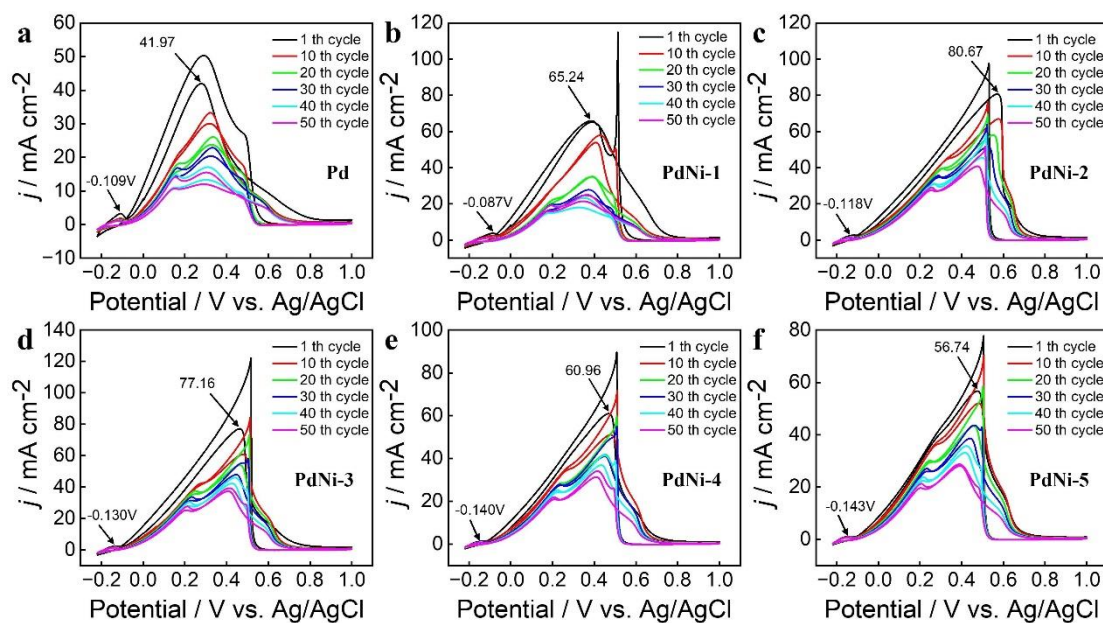
**Figure S3.** (a) TEM analysis and particle size histogram, (b) HRTEM analysis and local magnification, (c) SAED analysis, (d) HAADF-STEM analysis, (e) elemental mapping image, (f) FFT analysis of Pd catalyst.



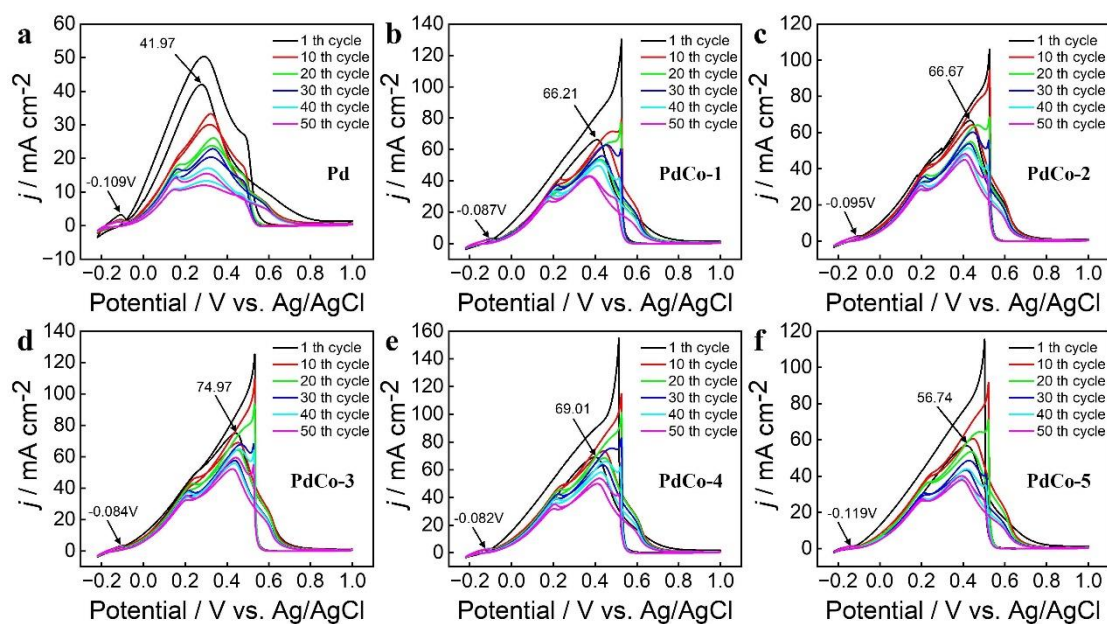
**Figure S4.** Repeated 50 cycles CV curves of (a) Pd, (b) PdNi-1, (c) PdNi-2, (d) PdNi-3, (e) PdNi-4 and (f) PdNi-5 electrocatalysts tested in 0.5 M  $\text{H}_2\text{SO}_4$  solution (scan rate =  $50 \text{ mV s}^{-1}$ ).



**Figure S5.** Repeated 50 cycles CV curves of (a) Pd, (b) PdCo-1, (c) PdCo-2, (d) PdCo-3, (e) PdCo-4 and (f) PdCo-5 electrocatalysts tested in 0.5 M  $\text{H}_2\text{SO}_4$  solution (scan rate = 50  $\text{mV s}^{-1}$ ).



**Figure S6.** Repeated 50 cycles CV curves of (a) Pd, (b) PdNi-1, (c) PdNi-2, (d) PdNi-3, (e) PdNi-4 and (f) PdNi-5 electrocatalysts tested in 0.5 M  $\text{H}_2\text{SO}_4$  + 0.5 M  $\text{HCOOH}$  solution (scan rate = 50  $\text{mV s}^{-1}$ ).



**Figure S7.** Repeated 50 cycles CV curves of (a) Pd, (b) PdCo-1, (c) PdCo-2, (d) PdCo-3, (e) PdCo-4 and (f) PdCo-5 electrocatalysts tested in 0.5 M  $\text{H}_2\text{SO}_4$  + 0.5 M  $\text{HCOOH}$  solution (scan rate = 50  $\text{mV s}^{-1}$ ).