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Supplementary Materials for

Efficient oxygen reduction catalysis by subnanometer Pt alloy nanowires

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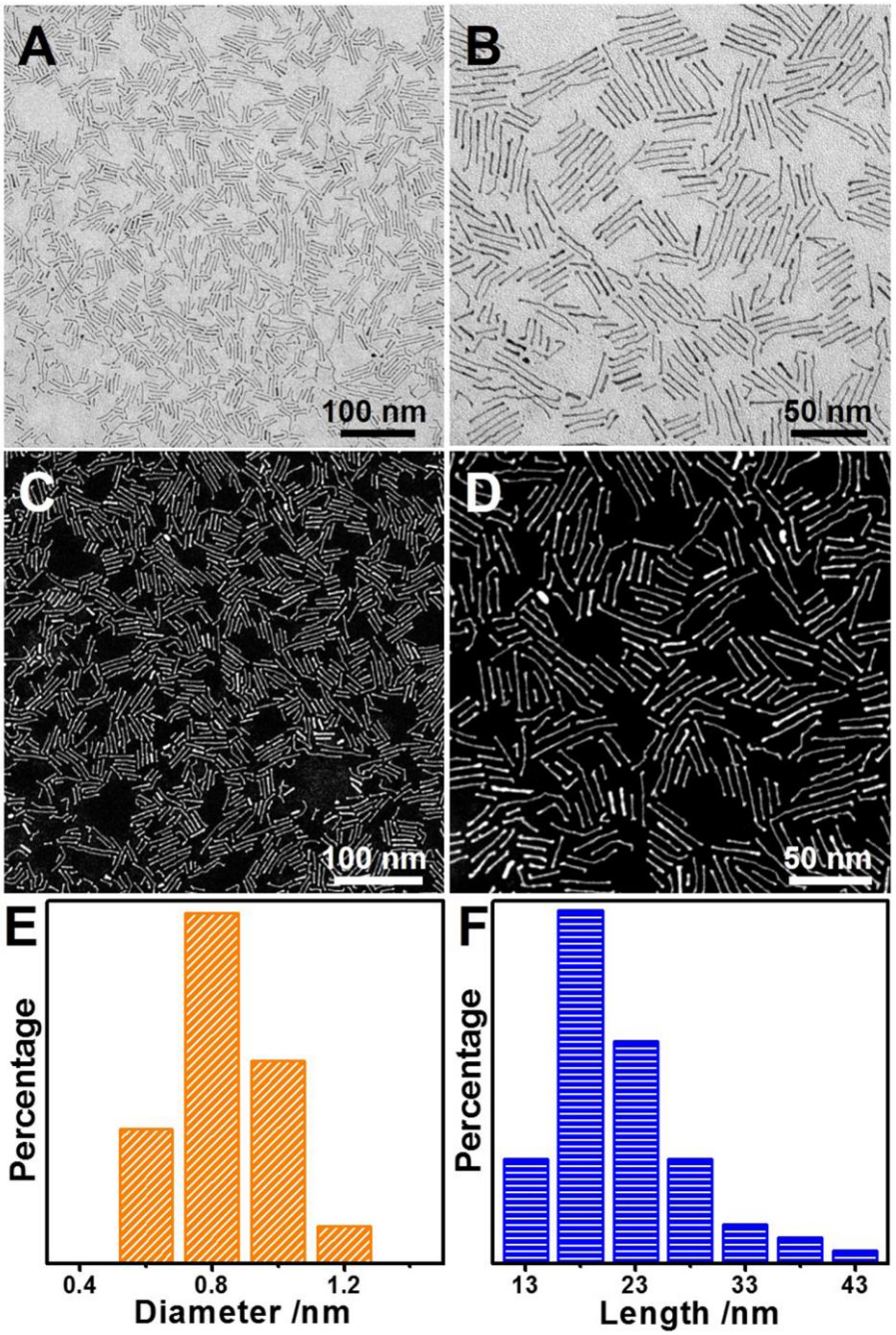

fig. S1. TEM, HAADF-STEM images, and histograms of diameter and length of Pt NWs.

Additional (**A**, **B**) TEM images, (**C**, **D**) HAADF-STEM images, and the histograms of (**E**) diameter and (**F**) length of Pt NWs.

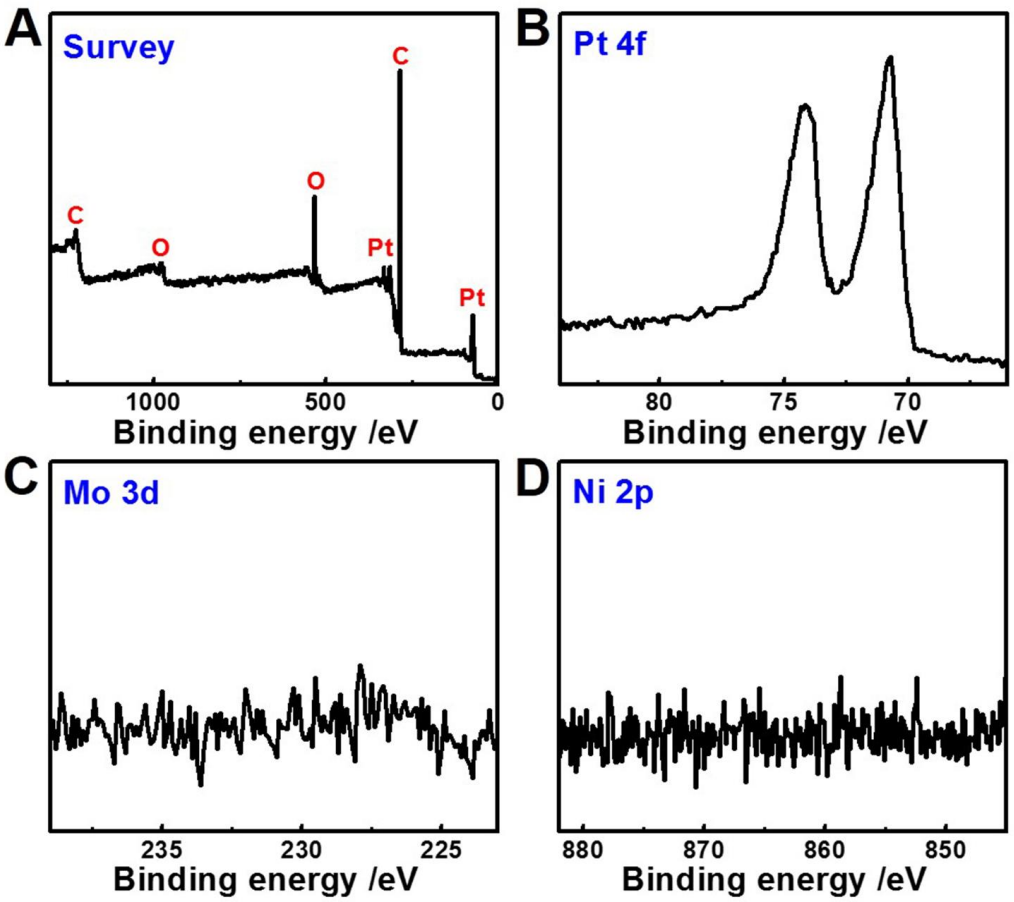

fig. S2. XPS spectra of Pt NWs. XPS spectra of Pt NWs (**A**) survey, (**B**) Pt 4f, (**C**) Mo 3d and (**D**) Ni 2p.

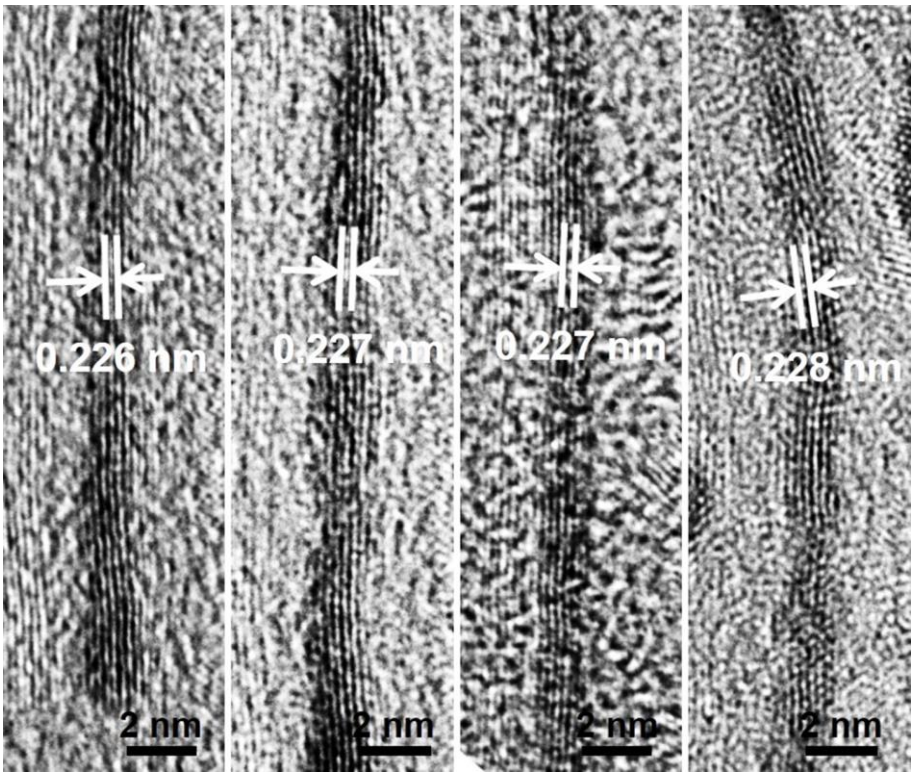

fig. S3. Additional HRTEM images of Pt NWs.

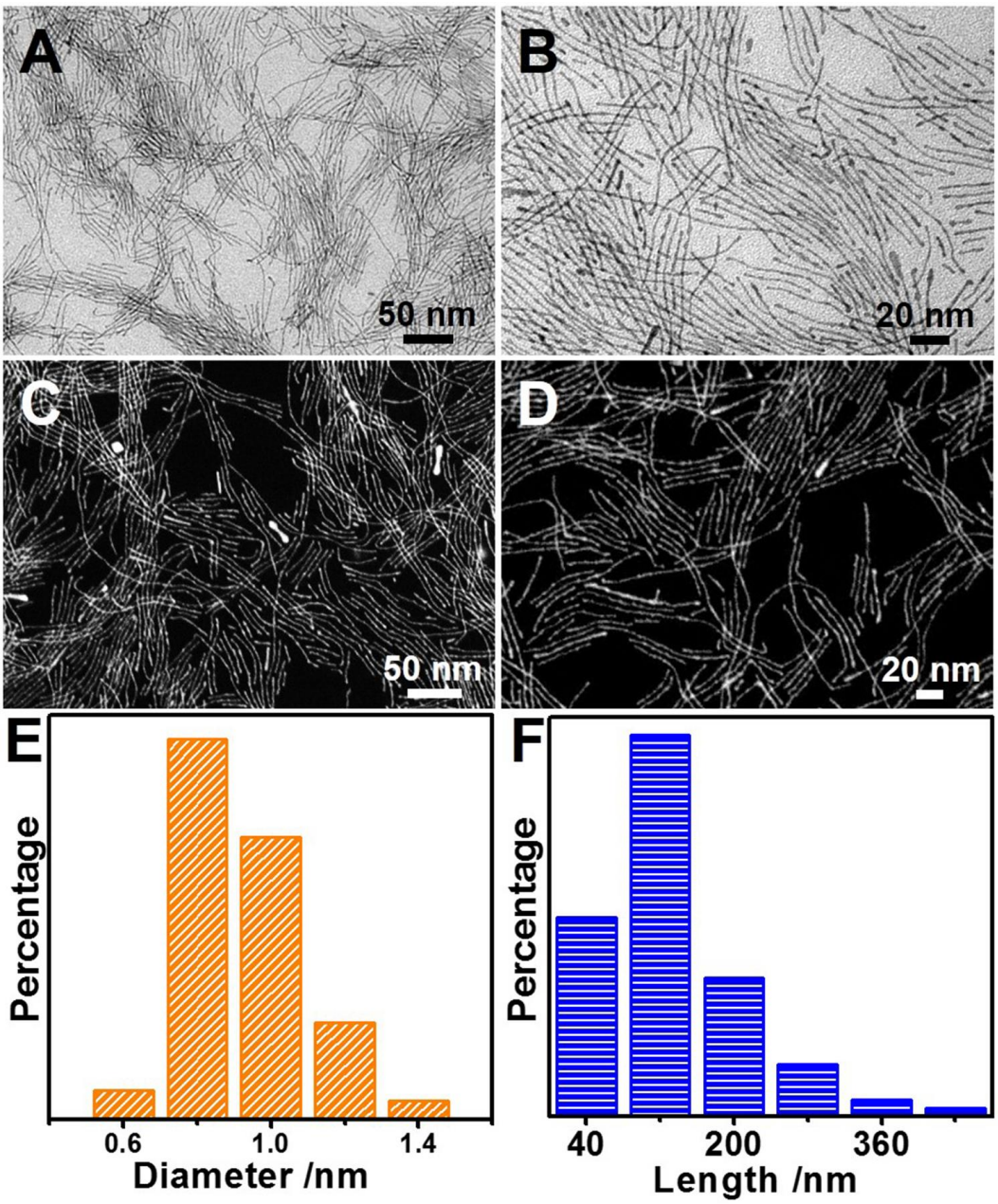

fig. S4. TEM, HAADF-STEM images, and histograms of diameter and length of PtNi NWs.

Additional (**A**, **B**) TEM images, (**C**, **D**) HAADF-STEM images, and histograms of (**E**) diameter and (**F**) length of PtNi NWs.

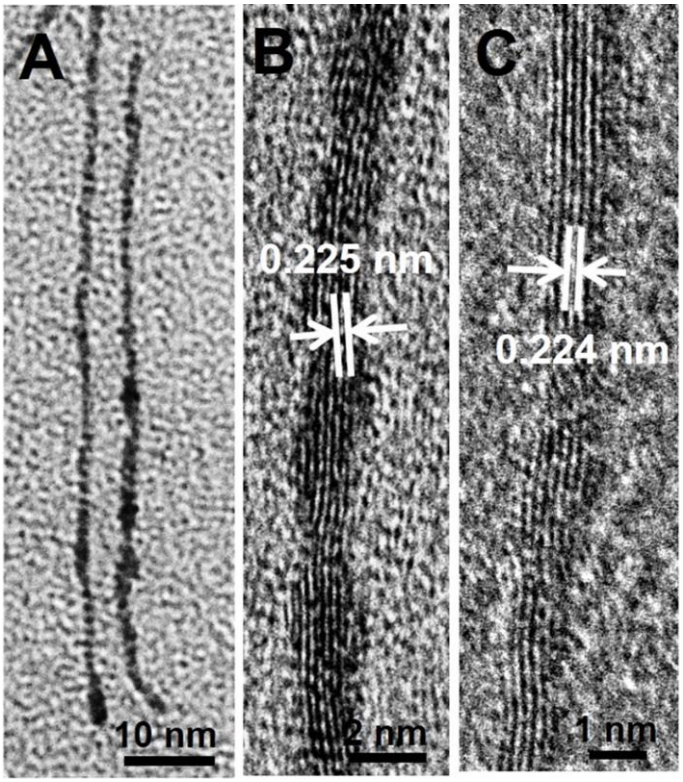

fig. S5. Additional TEM and HRTEM images of PtNi NWs. Additional (**A**) TEM and (**B**, **C**) HRTEM images of PtNi NWs.

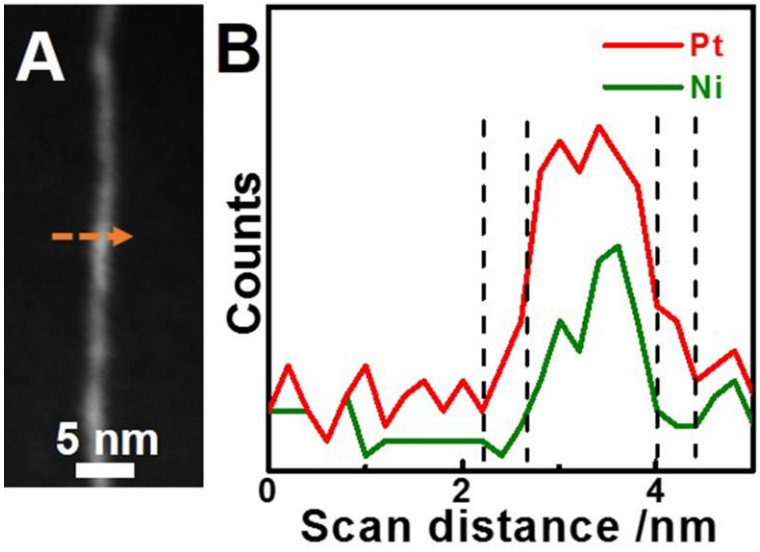

fig. S6. STEM image and EDS line scan of PtNi NWs. (**A**) STEM image and (**B**) EDS line scan of PtNi NWs.

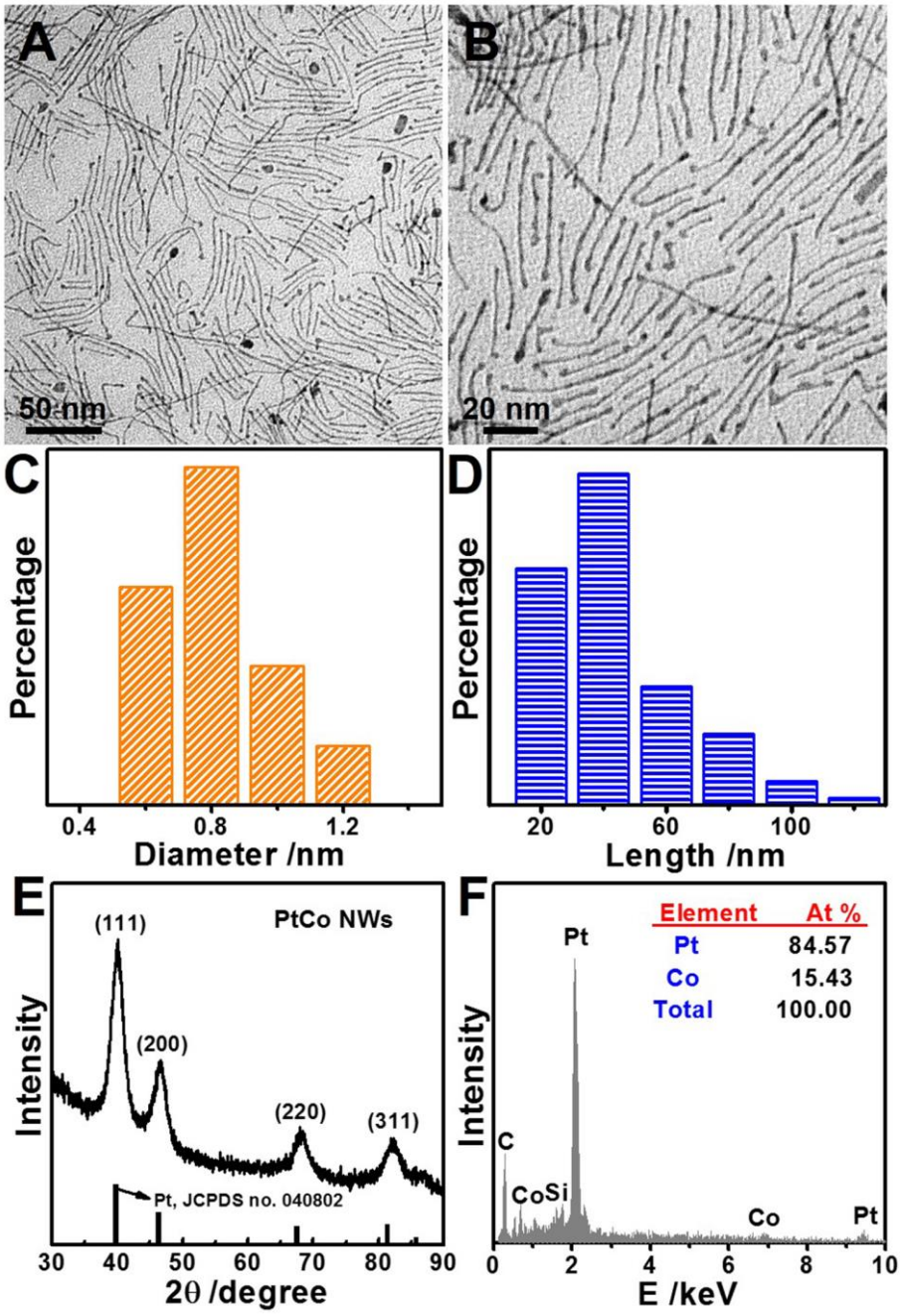

fig. S7. TEM images, histograms of diameter and length, PXRD pattern, and EDS pattern of PtCo NWs. (**A**, **B**) TEM images, the histograms of (**C**) diameter and (**D**) length, (**E**) PXRD pattern and (**F**) EDS pattern of PtCo NWs.

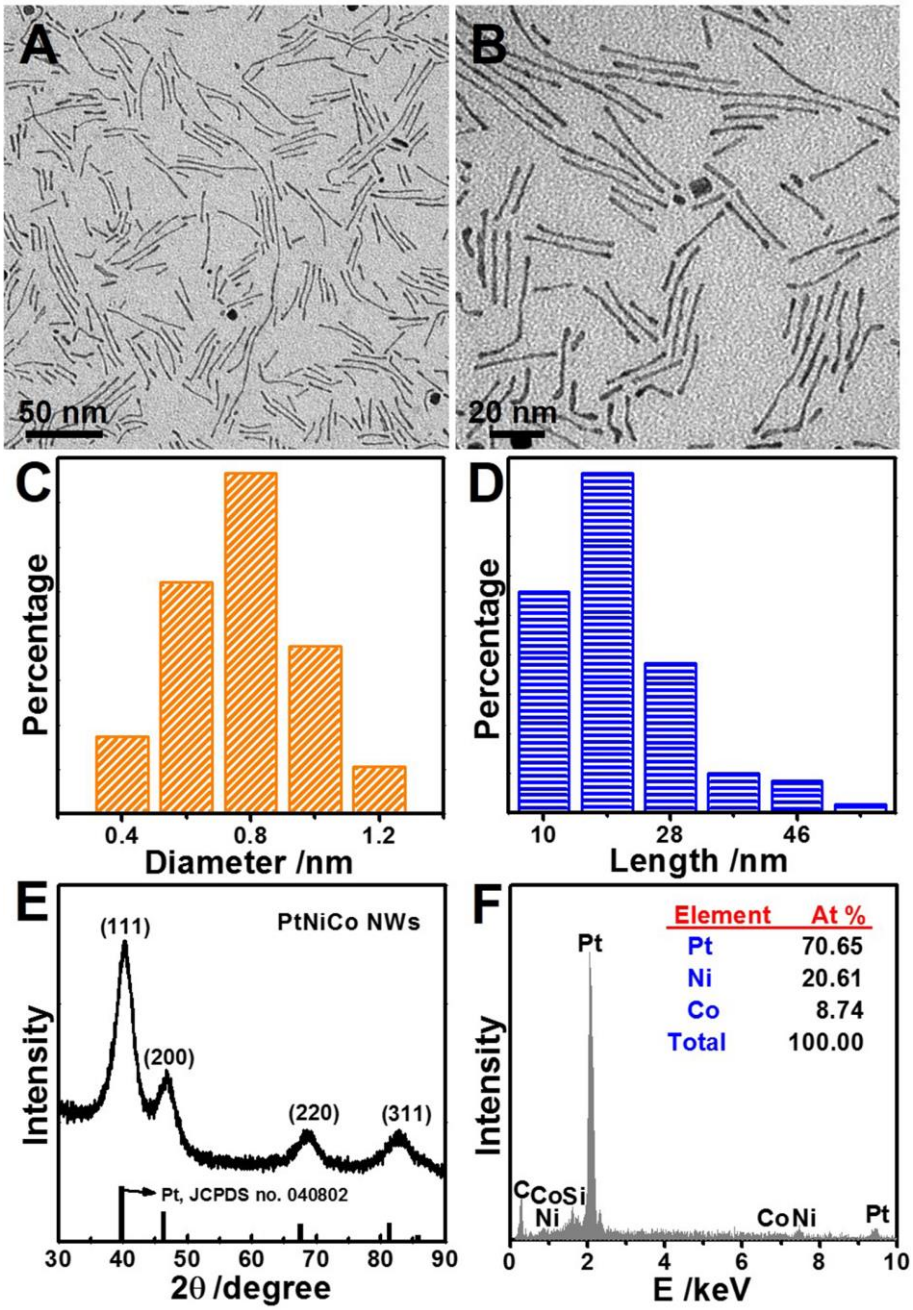

fig. S8. TEM images, histograms of diameter and length, PXRD pattern, and EDS pattern of PtNiCo NWs. (**A**, **B**) TEM images, the histograms of (**C**) diameter and (**D**) length, (**E**) PXRD pattern and (**F**) EDS pattern of PtNiCo NWs.

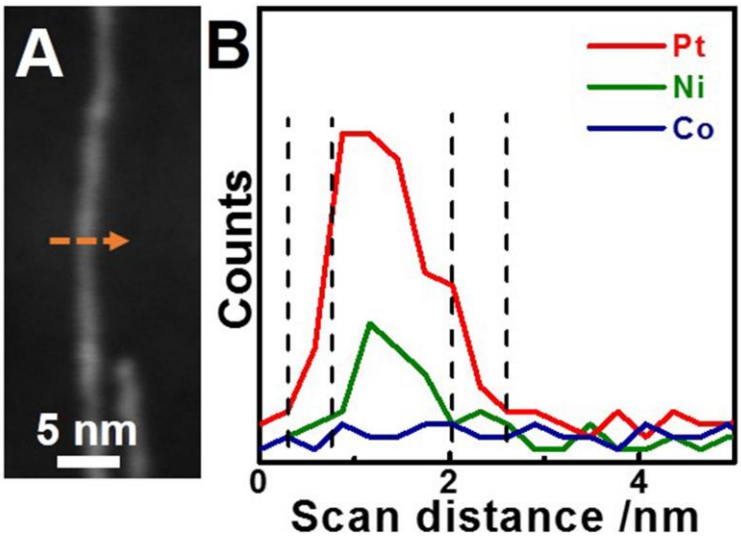

fig. S9. STEM image and EDS line scan of PtNiCo NWs.

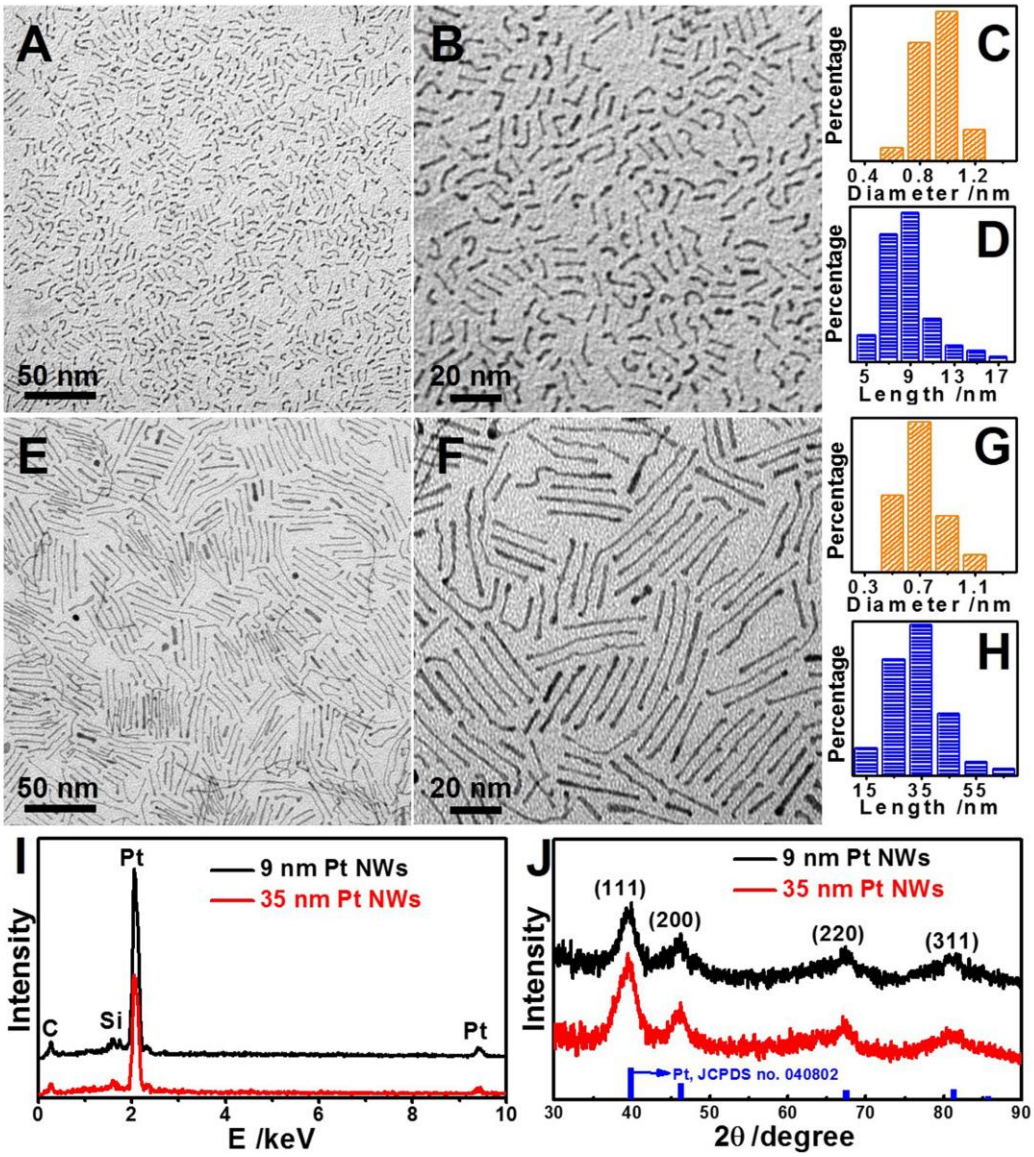

fig. S10. TEM images, histograms of diameter and length, PXRD pattern, and EDS pattern of 9-nm Pt NWs and 35-nm Pt NWs. Additional (**A**) low-magnification and (**B**) high-magnification TEM images, histograms of (**C**) diameter and (**D**) length of 9 nm Pt NWs. Additional (**E**) low-magnification and (**F**) high-magnification TEM images, histograms of (**G**) diameter and (**H**) length of 35 nm Pt NWs. (**I**) PXRD and (**J**) EDS patterns of 9 nm Pt NWs and 35 nm Pt NWs.

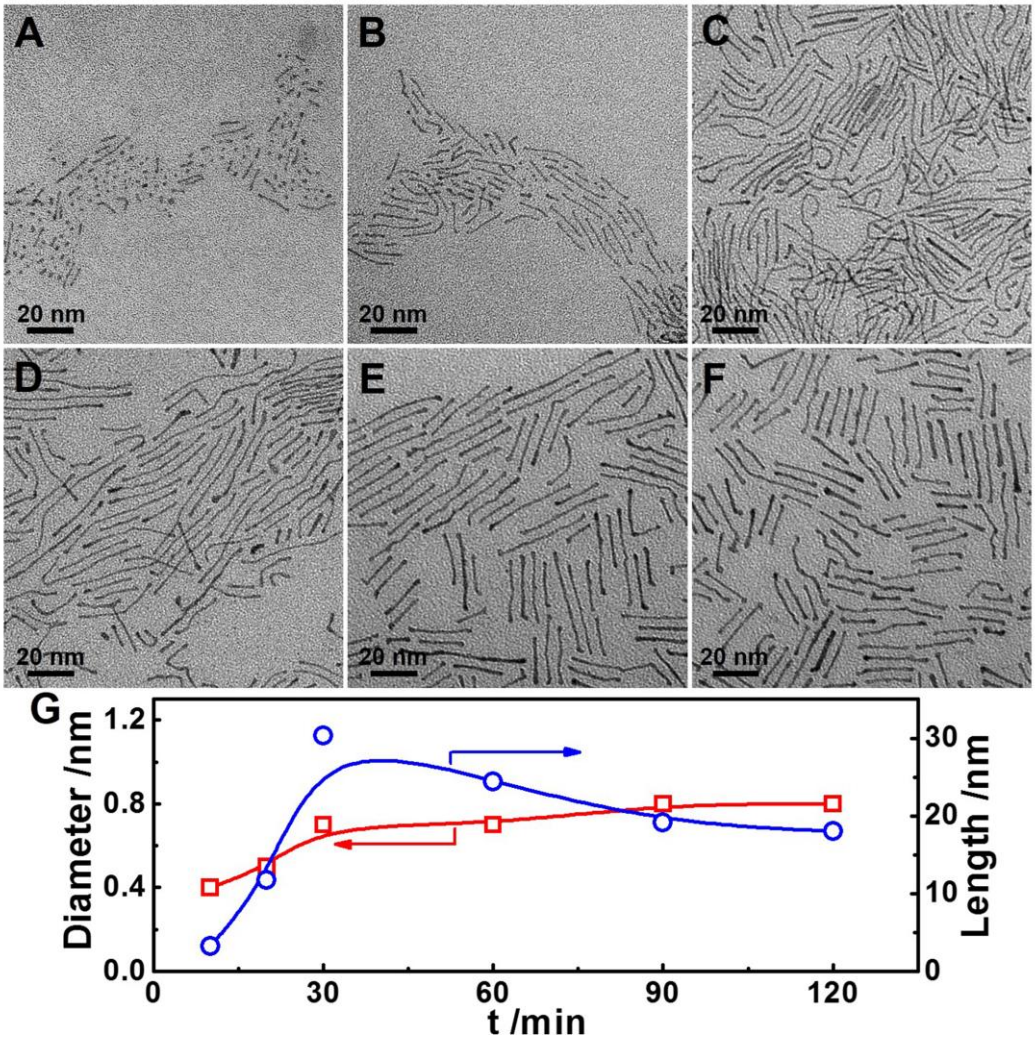

fig. S11. TEM images of diameter and length changes of Pt NW intermediates obtained with different reaction times. TEM images of Pt NWs intermediates obtained with different reaction times: (**A**) 10 min; (**B**) 20 min; (**C**) 30 min; (**D**) 60 min, (**E**) 90 min and (**F**) 120 min. (**G**) The diameter and length changes of Pt NWs with reaction times.

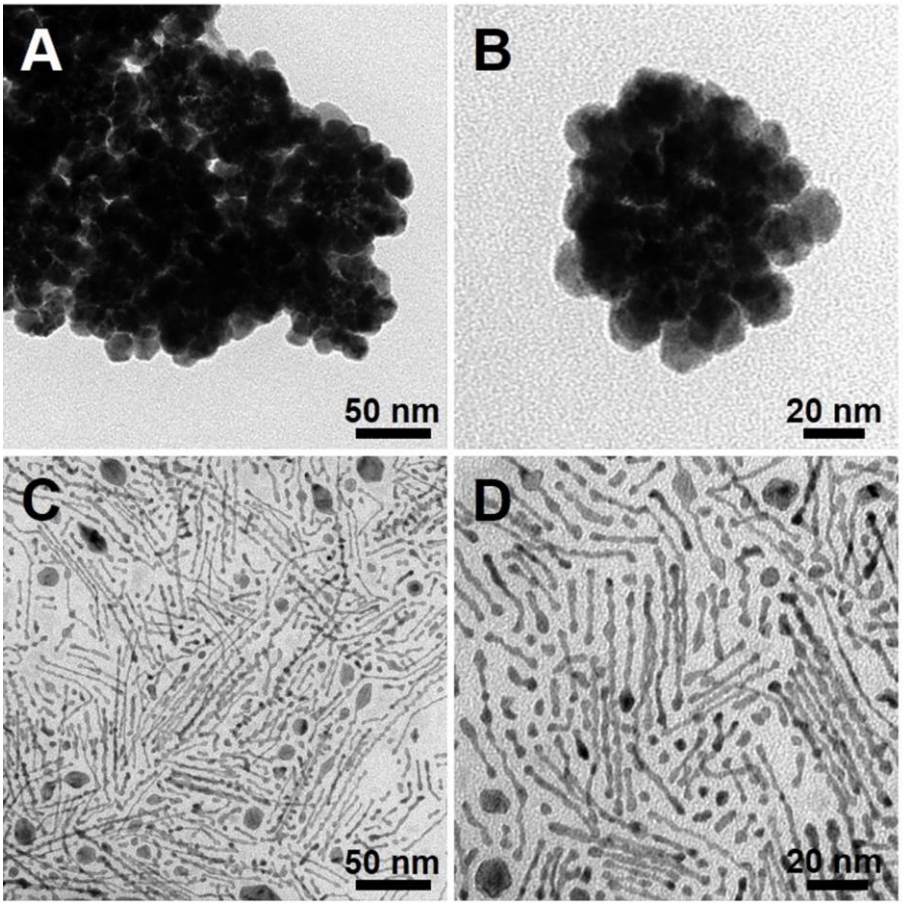

fig. S12. TEM images of the products collected from the reaction with the same condition used in the synthesis of unique Pt NWs but changing $Mo(CO)_6$. TEM images of the products collected from the reaction with the same condition used in the synthesis of Pt NWs but (**A**, **B**) without $Mo(CO)_6$ or (**C**, **D**) by changing $Mo(CO)_6$ with $W(CO)_6$.

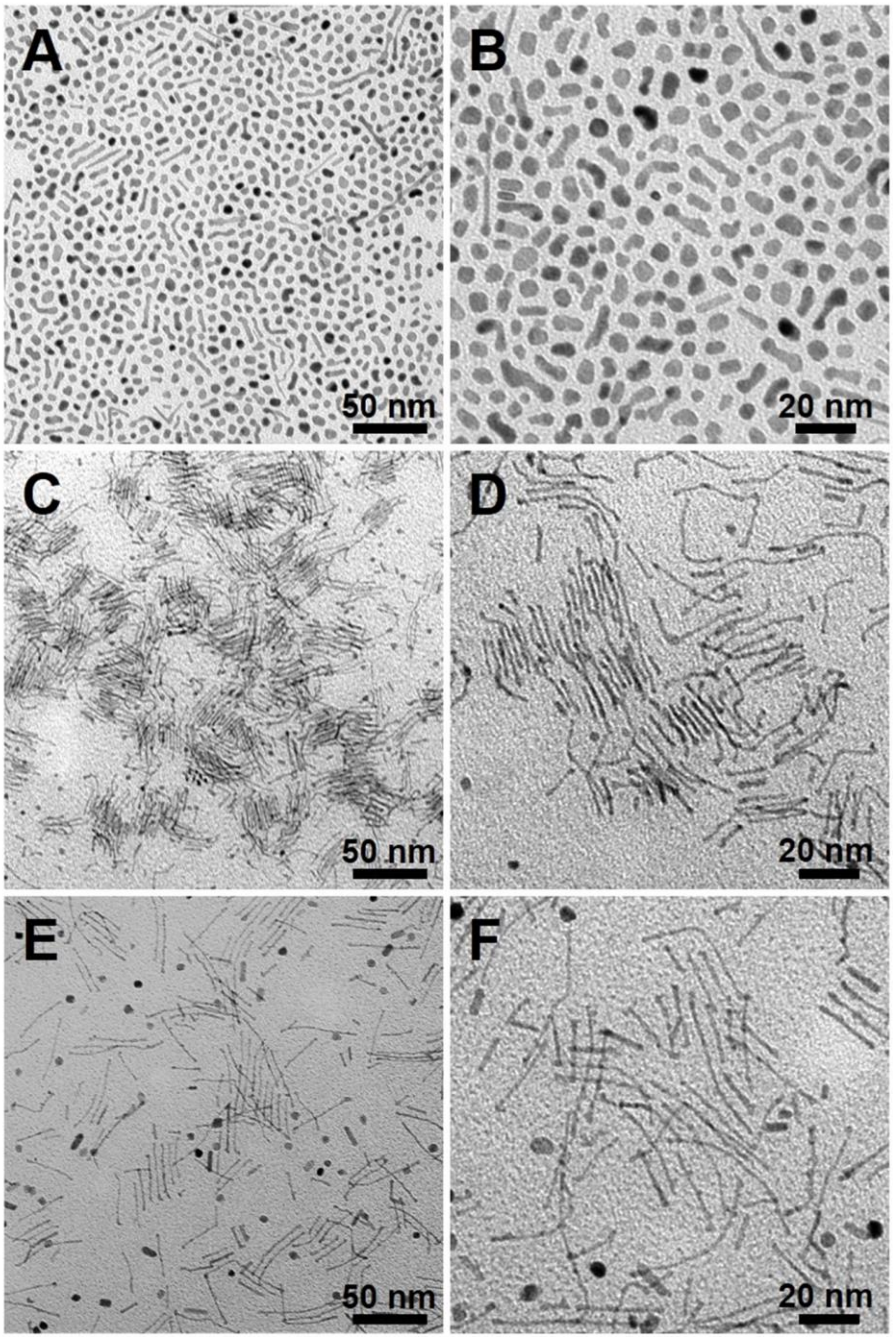

fig. S13. TEM images of the products collected from the reaction with the same condition used in the synthesis of unique Pt NWs but changing $Ni(acac)_2$. TEM images of the products collected from the reaction with the same condition used in the synthesis of Pt NWs but (**A**, **B**) without $Ni(acac)_2$, (**C**, **D**) by changing $Ni(acac)_2$ with $Ni(Ac)_2 \cdot 4H_2O$ and (**E**, **F**) by changing $Ni(acac)_2$ with $NiCl_2 \cdot 6H_2O$.

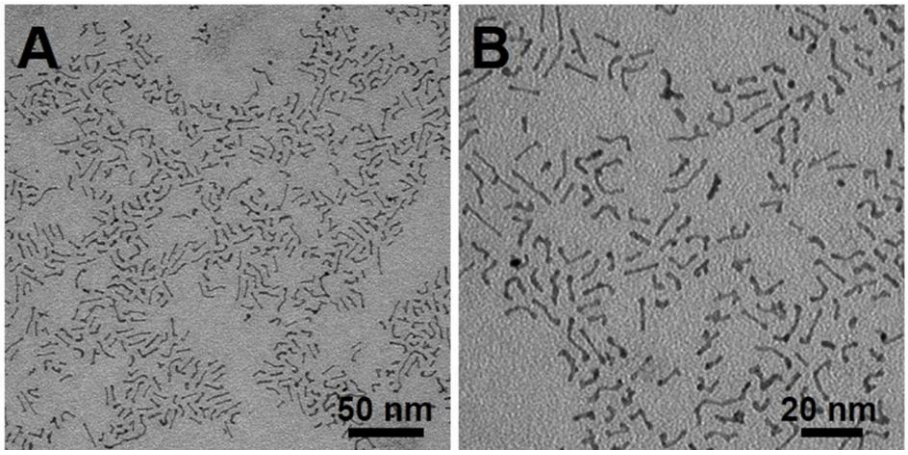

fig. S14. TEM images of the products collected from the reaction with the same condition used in the synthesis of unique Pt NWs but changing $Ni(acac)_2$ with $Fe(acac)_2$. TEM images of the products collected from the reaction with the same condition used in the synthesis of Pt NWs but changing $Ni(acac)_2$ with $Fe(acac)_2$.

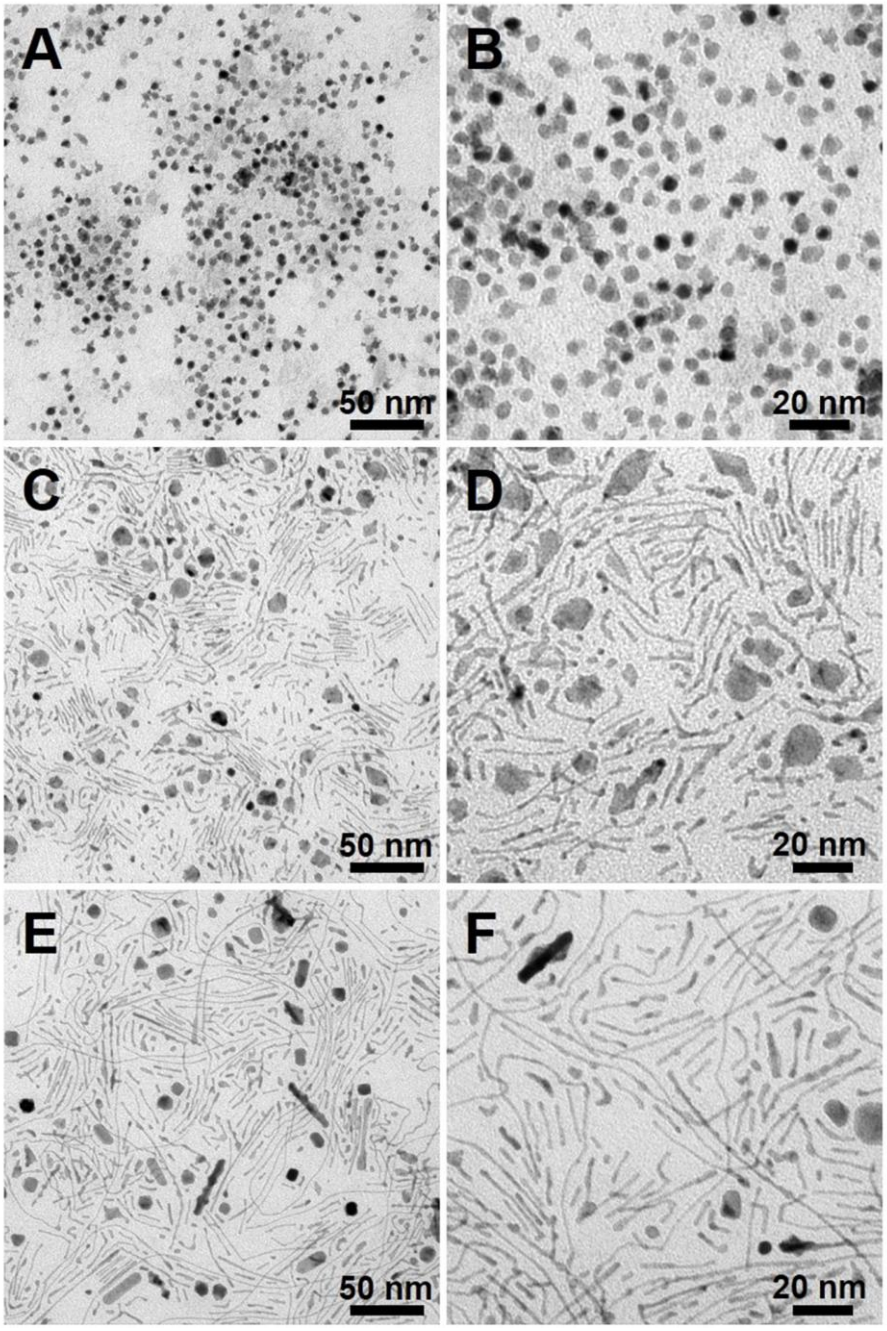

fig. S15. TEM images of the products collected from the reaction with the same condition used in the synthesis of unique Pt NWs but with different amount of CTAC. TEM images of the products collected from the reaction with the same condition used in the synthesis of Pt NWs but with different amount of CTAC: (**A**, **B**) 0 mg, (**C**, **D**) 16 mg and (**E**, **F**) 64 mg.

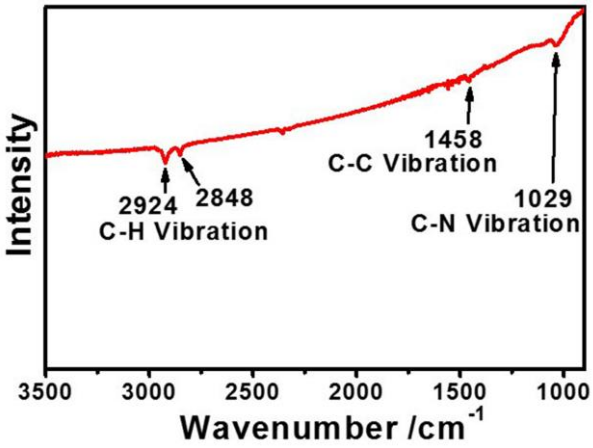

fig. S16. Fourier transform infrared spectroscopy spectrum of PtNi NWs/C.

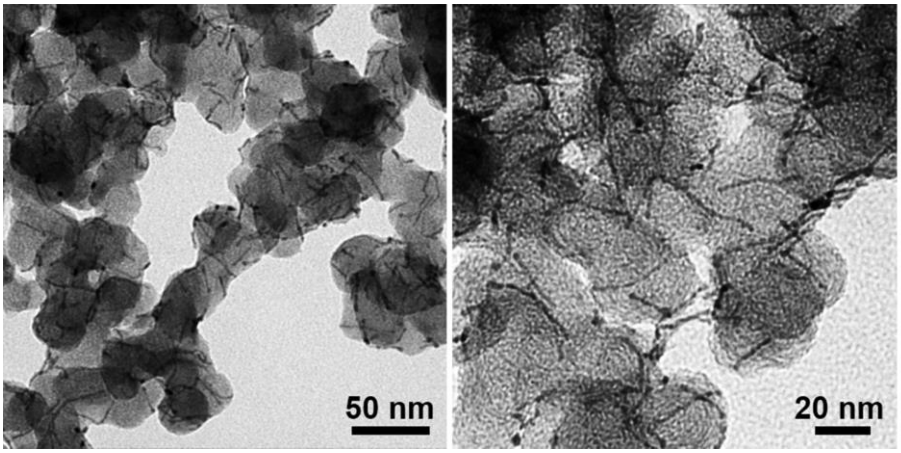

fig. S17. TEM images of Pt NWs on commercial carbon.

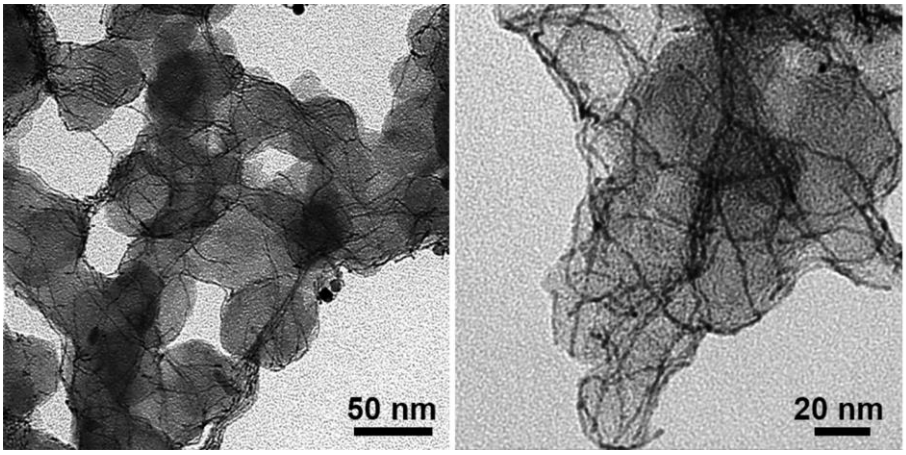

fig. S18. TEM images of PtNi NWs on commercial carbon.

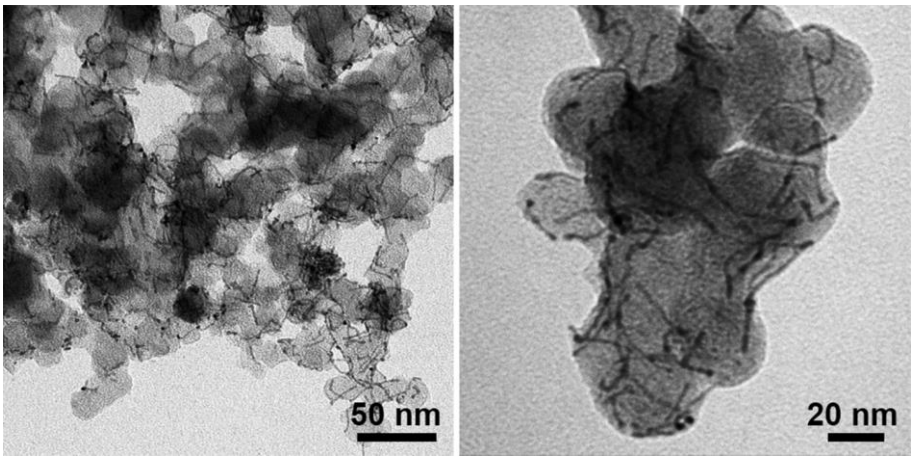

fig. S19. TEM images of PtNiCo NWs on commercial carbon.

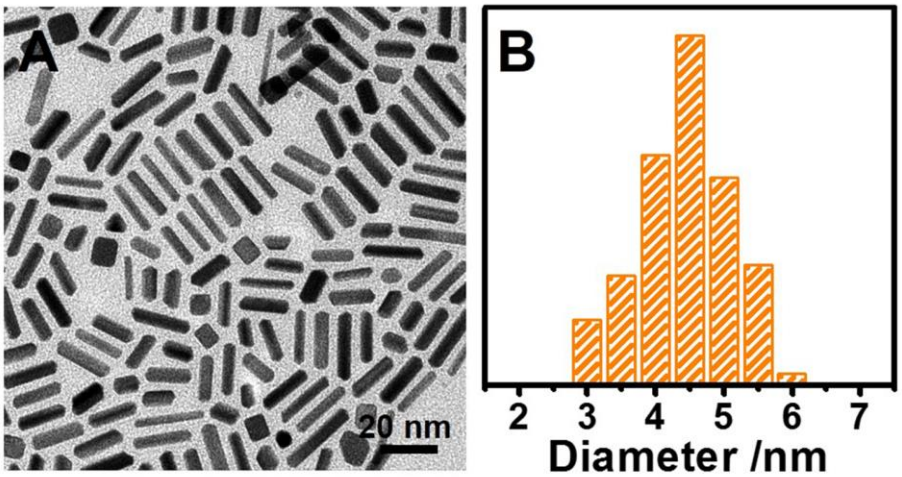

fig. S20. TEM image and diameter histogram of Pt NWs with the diameter of 4.5 nm. (**A**) TEM image and (**B**) diameter histogram of Pt NWs with the diameter of 4.5 nm.

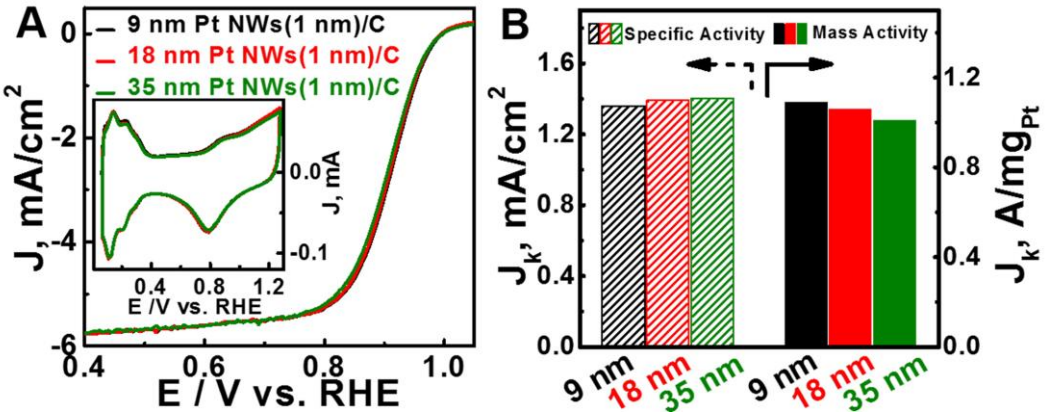

fig. S21. ORR polarization curves, CVs, mass, and specific activities of Pt NWs with different lengths. (**A**) ORR polarization curves and CVs (inset) of Pt NWs with different lengths. (**B**) Mass and specific activities of Pt NWs with different lengths.

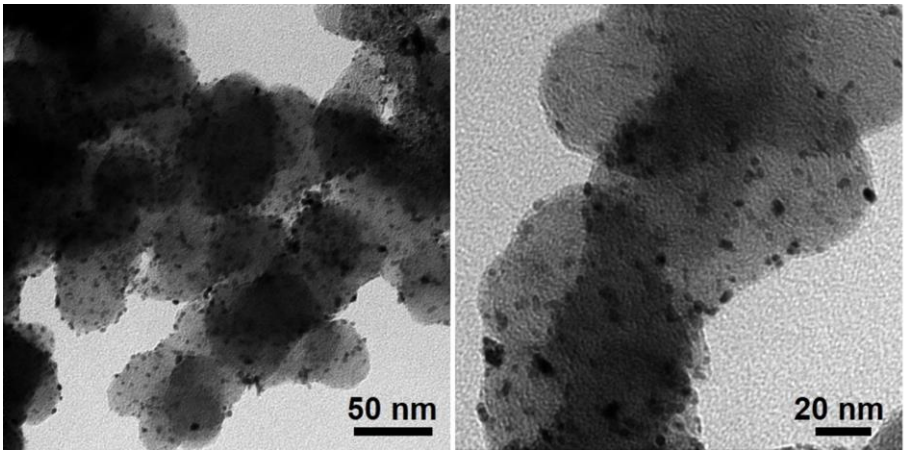

fig. S22. TEM images of commercial Pt/C.

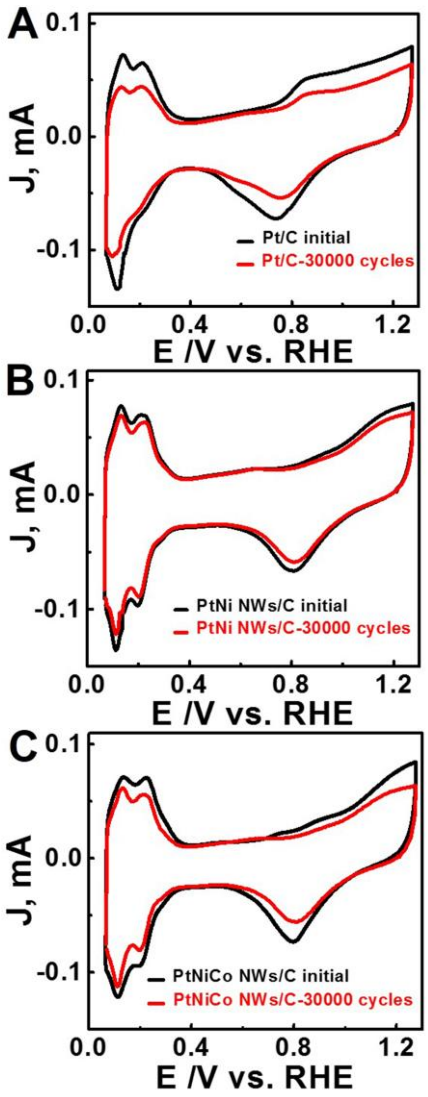

fig. S23. CVs of Pt/C, PtNi NWs/C, and PtNiCo NWs/C before and after 30,000 cycles. CVs of (**A**) Pt/C, (**B**) PtNi NWs/C and (**C**) PtNiCo NWs/C before and after 30000 cycles.

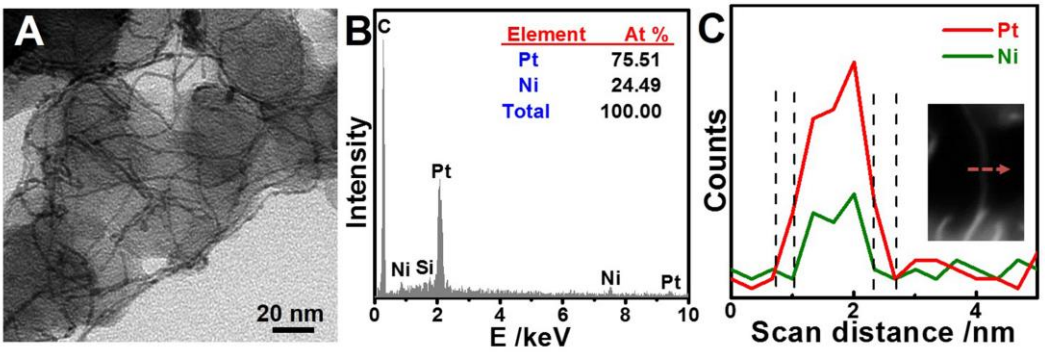

fig. S24. TEM image, EDS pattern, and EDS line scan of PtNi NWs/C after 30,000 cycles. (**A**) TEM image, (**B**) EDS pattern, (**C**) EDS line scan of PtNi NWs/C after 30000 cycles. Inset of (**C**) is the STEM image of PtNi NWs/C.

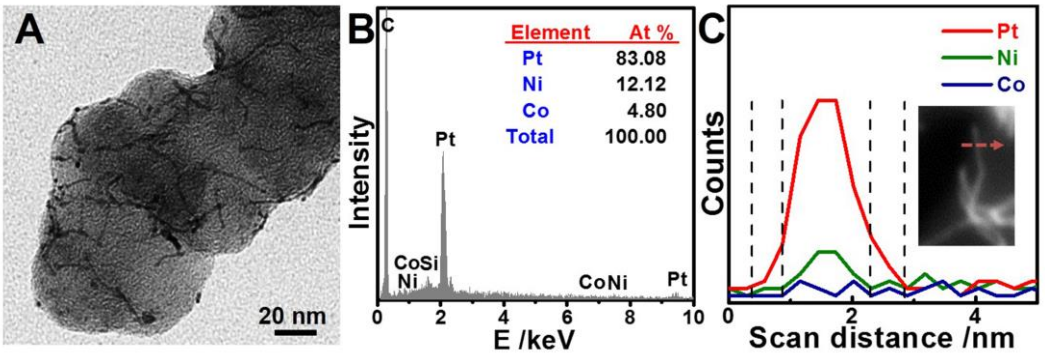

fig. S25. TEM image, EDS pattern, and EDS line scan of PtNiCo NWs/C after 30,000 cycles. (**A**) TEM image, (**B**) EDS pattern, (**C**) EDS line scan of PtNiCo NWs/C after 30,000 cycles. Inset of (C) is the STEM image of PtNiCo NWs/C.

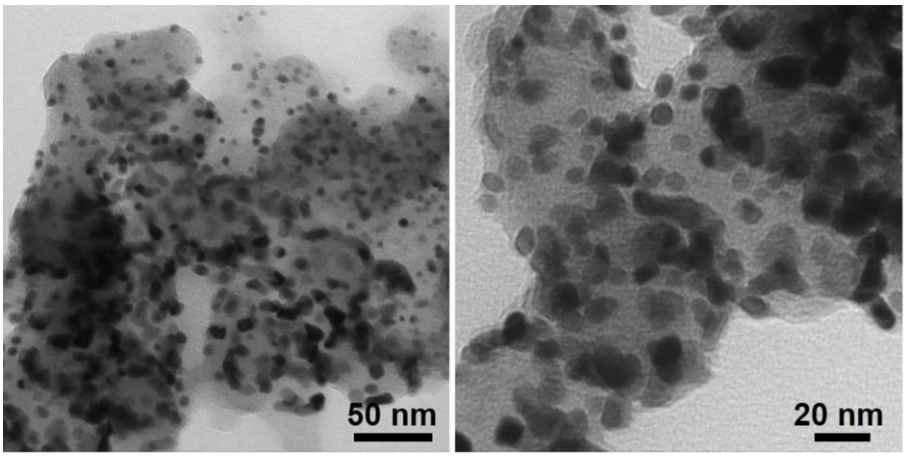

fig. S26. TEM images of commercial Pt/C catalyst after 30,000 cycles.

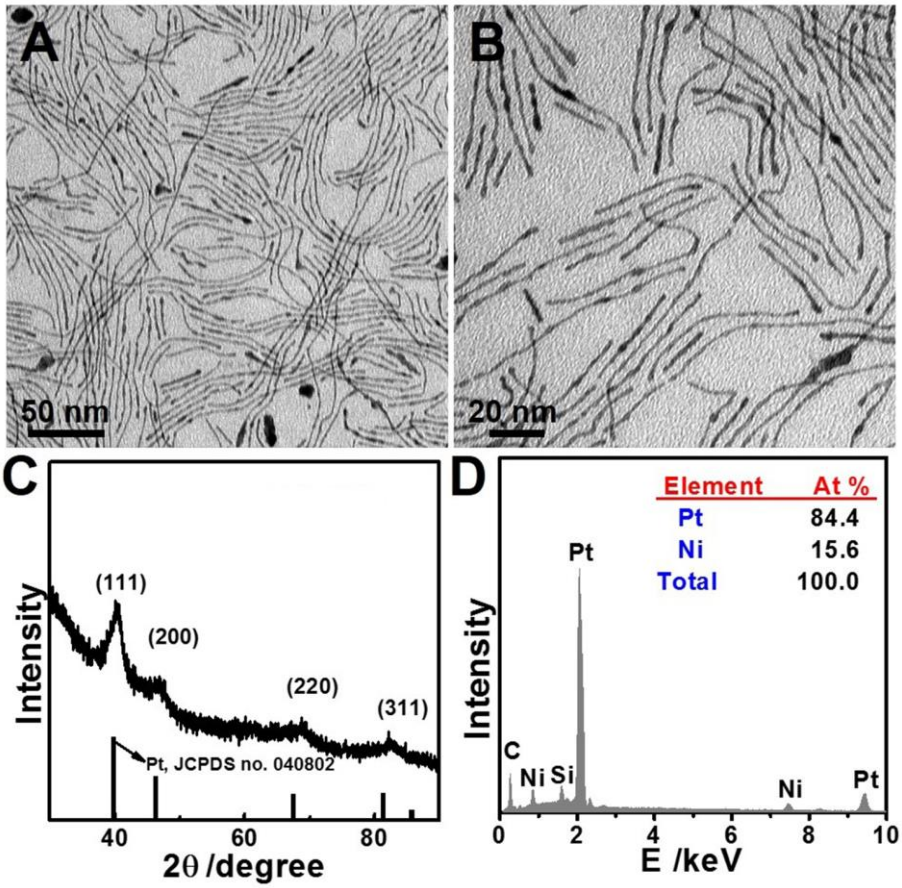

fig. S27. TEM, PXRD pattern, and EDS pattern of $Pt_{84.4}Ni_{15.6}$ NWs. (**A**, **B**) TEM images, (**C**) PXRD pattern and (**D**) EDS pattern of $Pt_{84.4}Ni_{15.6}$ NWs.

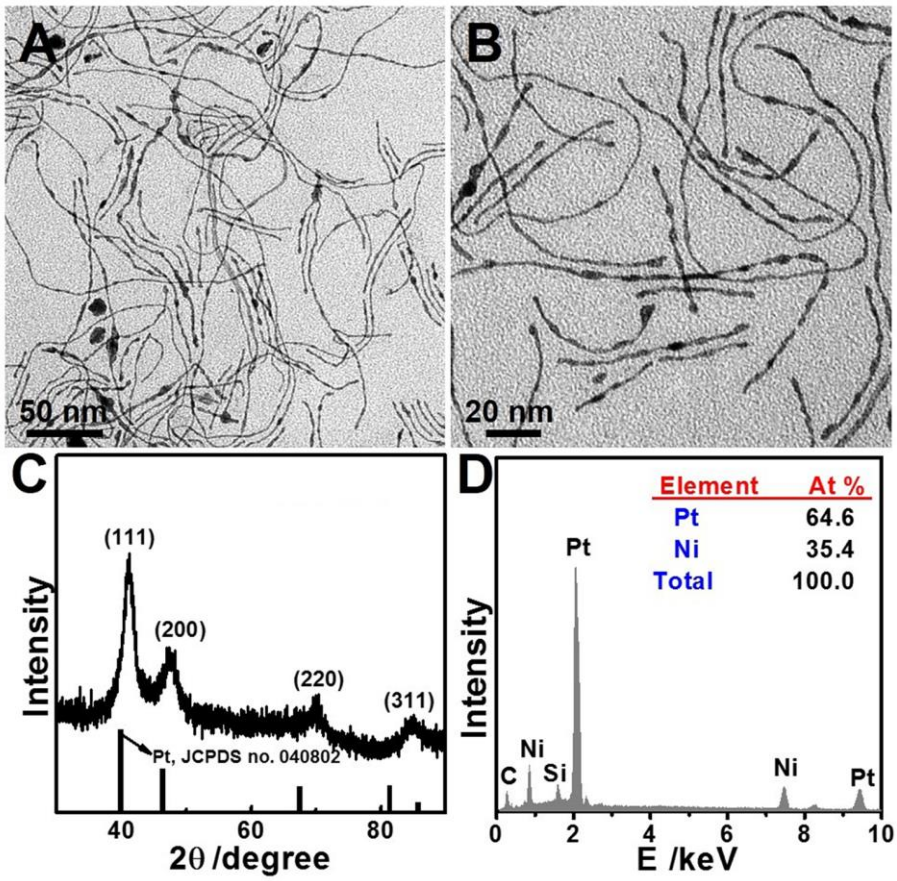

fig. S28. TEM, PXRD pattern, and EDS pattern of $Pt_{64.6}Ni_{35.4}$ NWs. (**A**, **B**) TEM images, (**C**) PXRD pattern and (**D**) EDS pattern of $Pt_{64.6}Ni_{35.4}$ NWs.

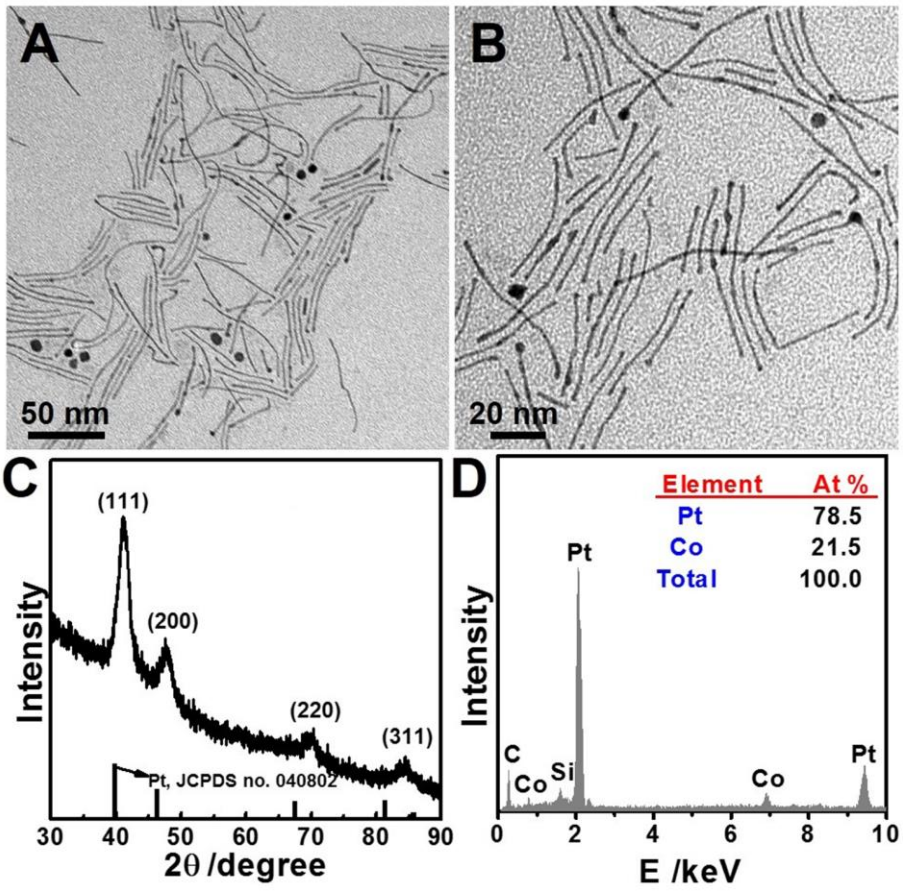

fig. S29. TEM, PXRD pattern, and EDS pattern of $Pt_{78.5}Co_{21.5}$ NWs. (**A**, **B**) TEM images, (**C**) PXRD pattern and (**D**) EDS pattern of $Pt_{78.5}Co_{21.5}$ NWs.

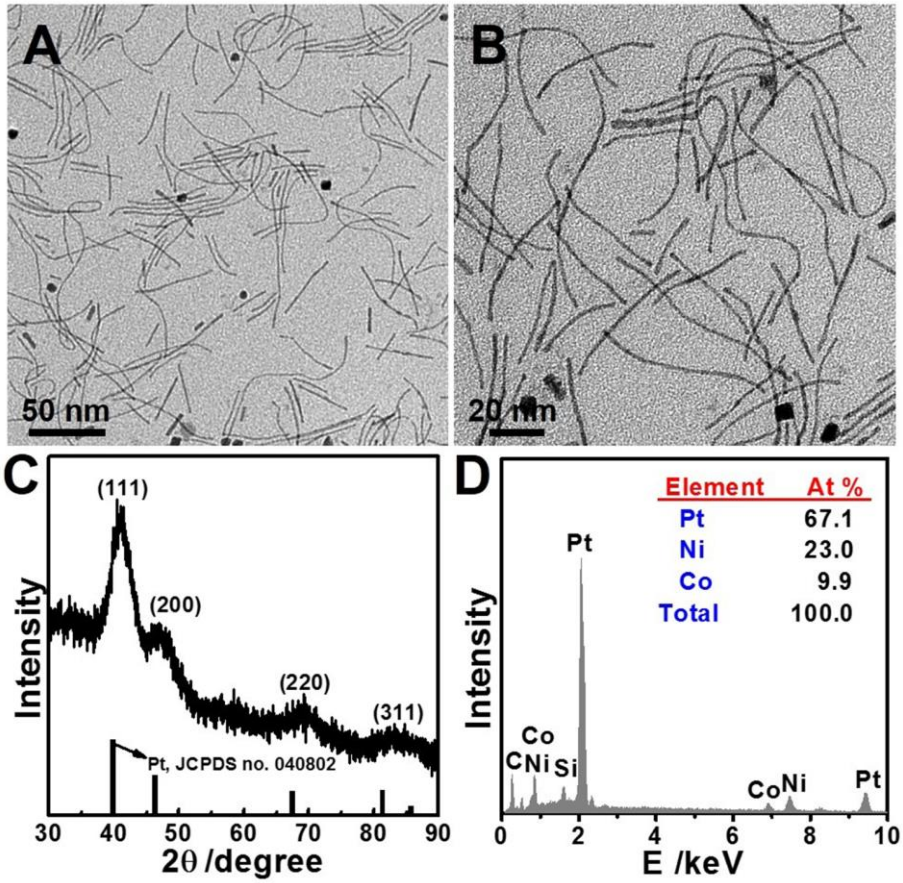

fig. S30. TEM, PXRD pattern, and EDS pattern of $Pt_{67.1}Ni_{23.0}Co_{9.9}$ NWs. (**A**, **B**) TEM images, (**C**) PXRD pattern and (**D**) EDS pattern of $Pt_{67.1}Ni_{23.0}Co_{9.9}$ NWs.

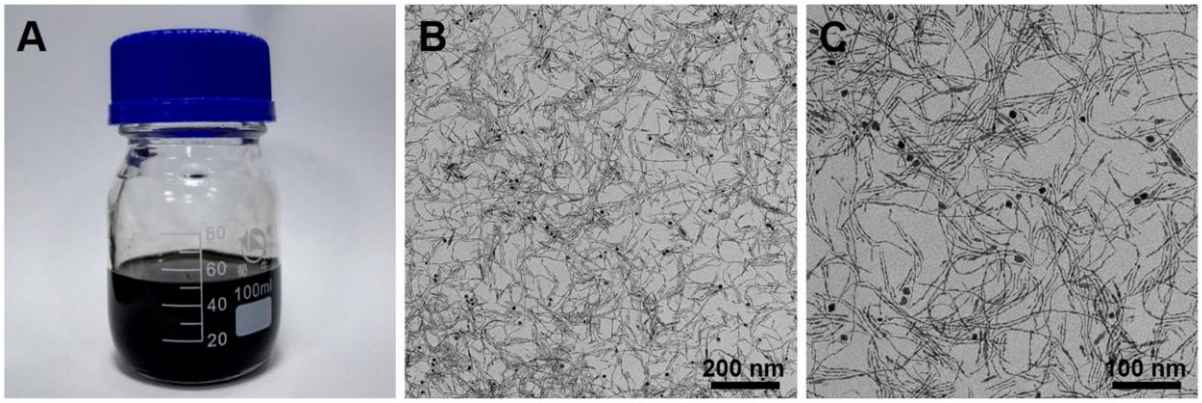

fig. S31. Image of ~50-ml PtNi NW colloidal solution and TEM images of PtNi NWs. (**A**) Picture of ~50 mL PtNi NWs collodial solution and (**B**, **C**) TEM images of PtNi NWs.

table S1. Atomic ratios of PtNi NWs and PtNiCo NWs characterized by ICP, EDS, and XPS.

Sample	ICP	EDS	XPS
PtNi NWs (Pt:Ni)	75.5:24.5	74.8:25.2	79.7:20.3
PtNiCo NWs (Pt:Ni:Co)	71.3:19.7:9.0	70.7:20.6:8.7	79.3:14.1:6.6

table S2. Performance comparisons of various Pt-based NWs and this work.

Sample	Diameter (nm)	Mass activity @ 0.9 V (A/mg)	Specific activity @ 0.9 V (mA/cm^2)	Stability	Ref.
PtNi NWs	0.8	2.97	3.68	Mass activity loss 6% after 30000 cycles	This work
PtNiCo NWs	0.8	4.20	5.11	Mass activity loss 21.4% after 30000 cycles	This work
Pt NWs	3-25	0.167	0.675	Mass activity loss 33% after 3000 cycles	*50*
Pt NWs	2	0.144	0.139	ECSA loss 14.6% after 6000 cycles	*51*
Pt NWs[a]	4-15	0.135	0.611	ECSA loss 40% after 4000 cycles	*52*
Pt NWs[a]	5-10	0.0124 (@ 0.85V)	N/A	ECSA loss 27.5 % after 1000 cycles	*53*
Pd@Pt NWs	2	1.83	0.77	ECSA loss 37% after 30000 cycles	*54*
Pd@Pt NWs	7-9	1.56	0.98	Mass activity loss ~23.1% after 20000 cycles	*41*
FePtCu NWs	~2	1.034 (@0.512 V vs. Ag/AgCl)	1.369 (@0.512 V vs. Ag/AgCl)	Mass activity nearly overlap after 5000 cycles	*55*
FePtAu/FePt NWs	~3.3	1.59 (@0.5 V vs. Ag/AgCl)	1.69 (@0.5 V vs. Ag/AgCl)	Mass activity without degradation after 5000 cycles	*42*
FePtPd/FePt NWs	~3.3	1.68 (@0.5 V vs. Ag/AgCl)	3.47 (@0.5 V vs. Ag/AgCl)	Mass activity without degradation after 5000 cycles	*42*

[a] The electrochemical property was collected in O_2-saturated 0.5 M H_2SO_4 solution.