Supporting information

Gram-Scale Synthesis of Carbon-Supported Sub-5 nm PtNi Nanocrystals for Efficient Oxygen Reduction

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Supporting Information

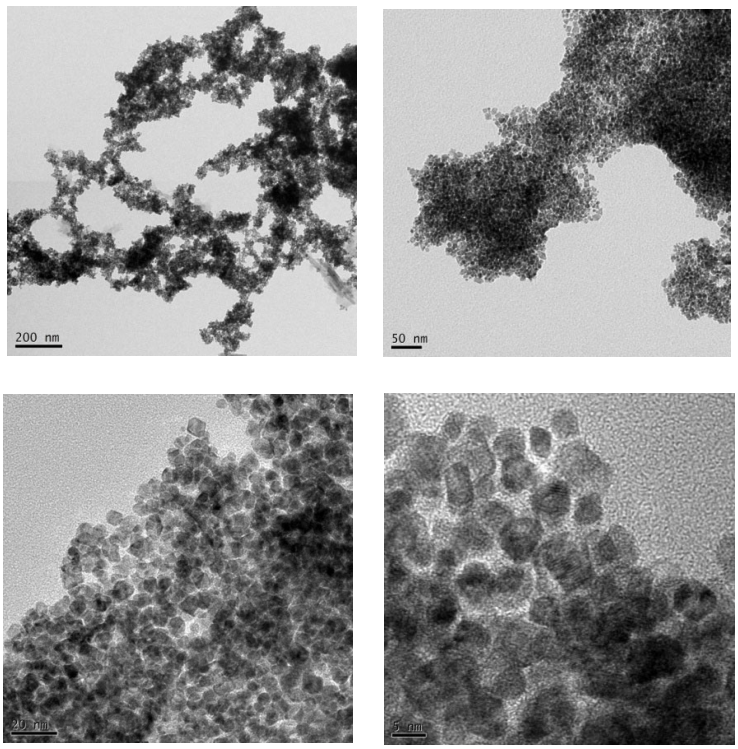


Figure S1. TEM images of PtNi nanocrystals (200ºC, Pt:Ni=1:2).

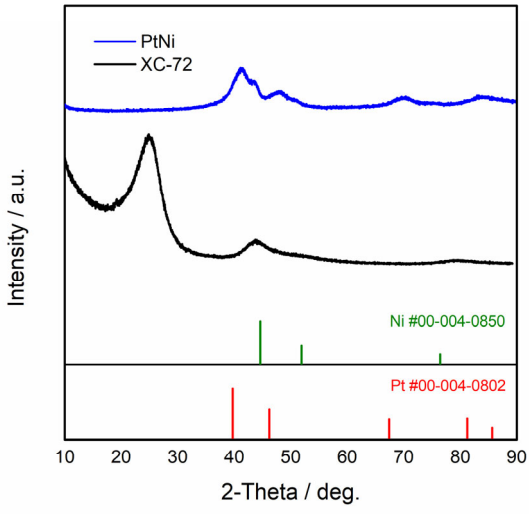


Figure S2. XRD patterns of PtNi nanocrystals (200ºC, Pt:Ni=1:2) and Vulcan XC-72.

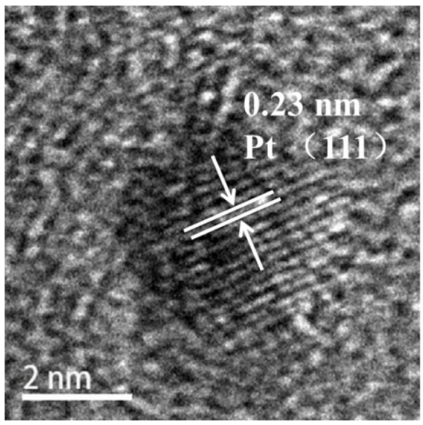


Figure S3. HRTEM image of the initial Pt/C.

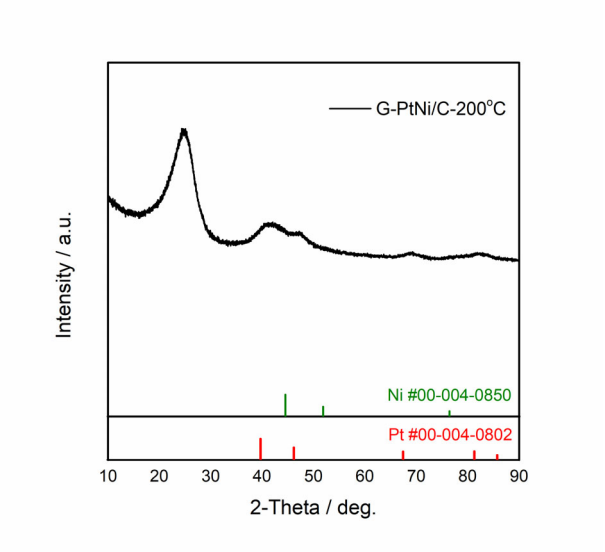


Figure S4. XRD patterns of G-PtNi/C-200ºC nanocrystals.

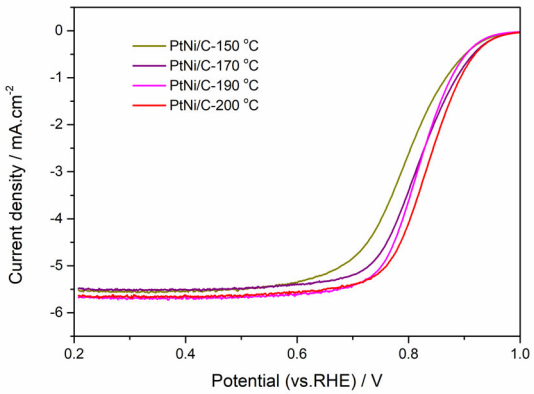


Figure S5. The ORR polarization curves of PtNi/C-150 ºC, PtNi/C-170 ºC, PtNi/C-190 ºC and PtNi/C-200 ºC catalysts were conducted in 0.1 M KOH with saturated oxygen.

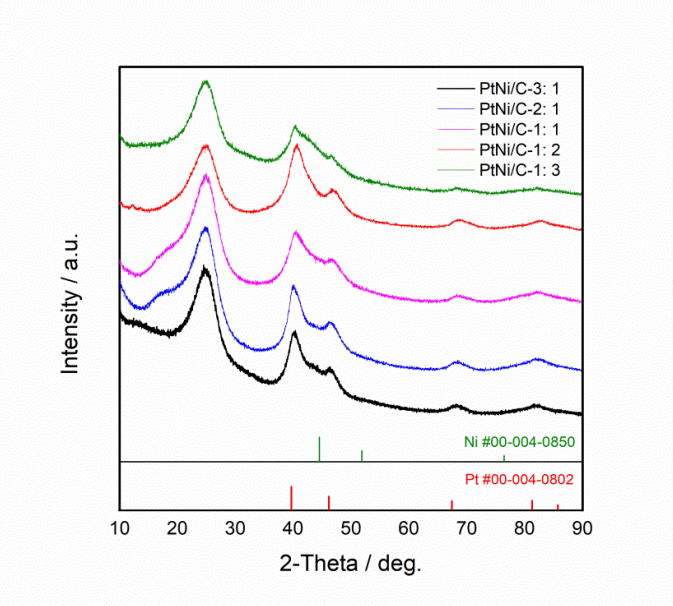


Figure S6. XRD patterns of PtNi/C-3: 1, PtNi/C-2: 1, PtNi/C-1: 1, PtNi/C-1: 2 and PtNi/C-1: 3 nanocrystals.

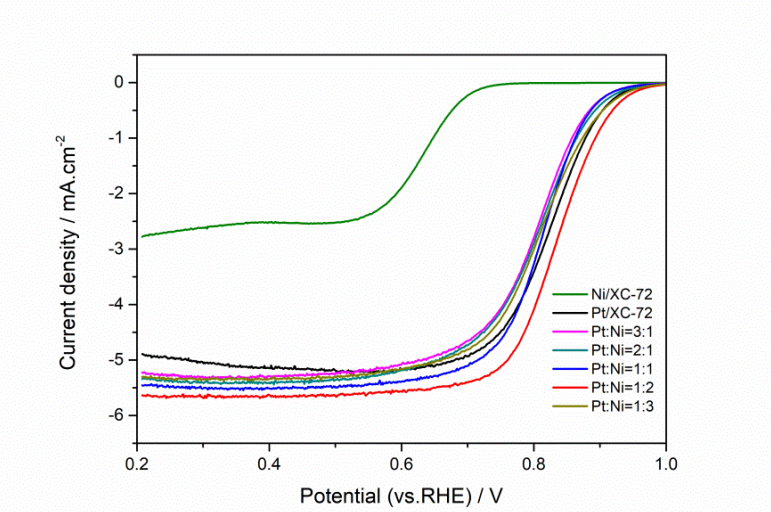


Figure S7. The ORR polarization curves of Ni/XC-72, Pt/XC-72, PtNi/C-3: 1, PtNi/C-2: 1, PtNi/C-1: 1, PtNi/C-1: 2 and PtNi/C-1: 3 catalysts were conducted in 0.1 M KOH with saturated oxygen.

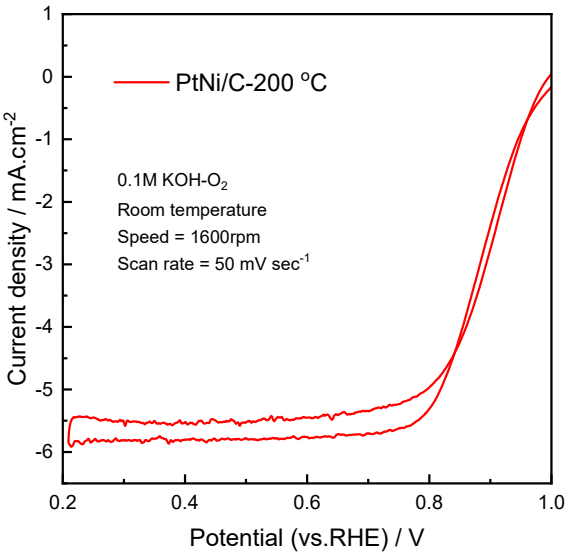


Figure S8. The CV curves of PtNiC-200 catalysts.

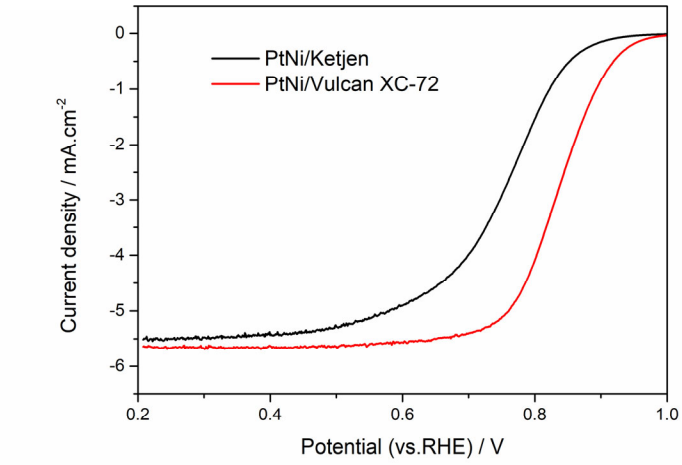


Figure S9. The ORR polarization curves of PtNi/Ketjen Black, PtNi/XC-72 catalysts were conducted in 0.1 M KOH with saturated oxygen.

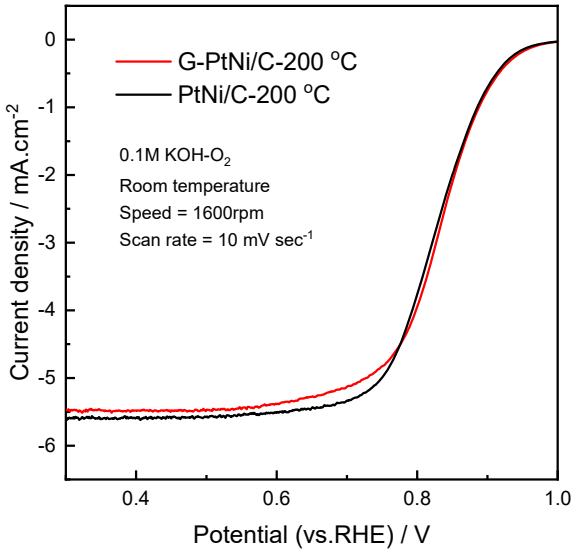


Figure S10. The ORR polarization curves of G-PtNi/C-200 °C, PtNi/C-200 °C in O_2-saturated 0.1 M KOH.

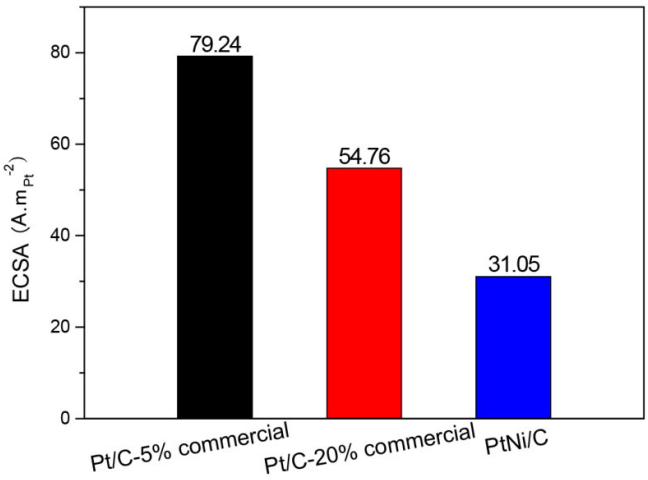


Figure S11. ECSA of commercial Pt/C (platinum content is 5% and 20%) and PtNi/C at 0.9 V (vs. RHE).

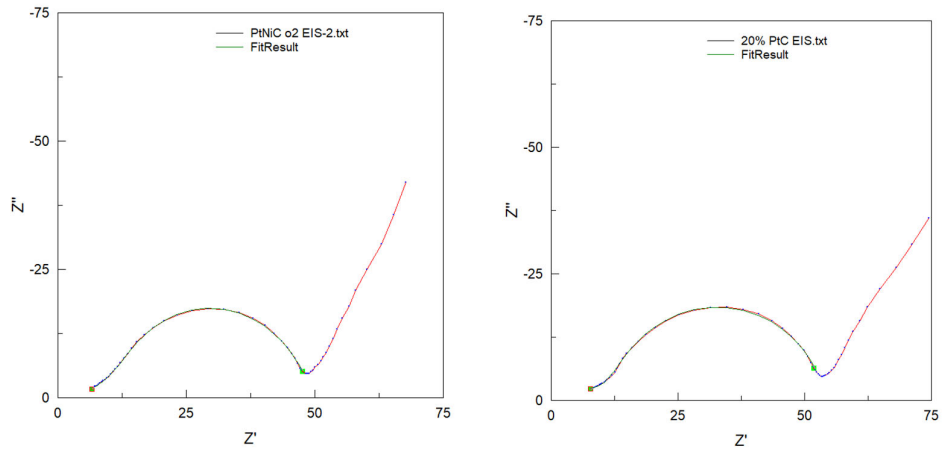


Figure S12. Nyquist plots of PtNi/C-200 and commercial Pt/C-20%.

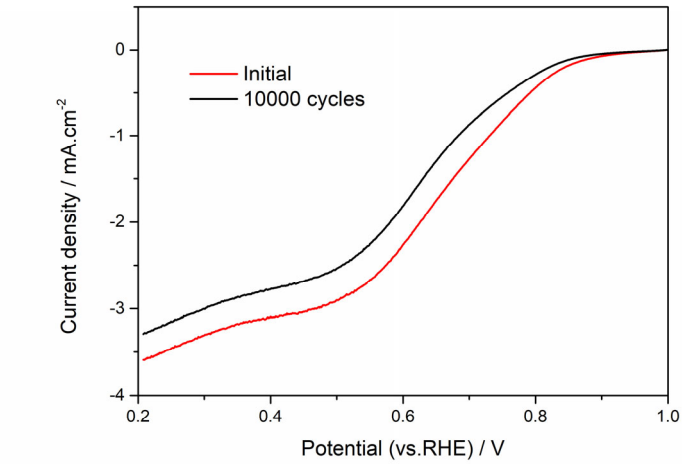


Figure S13. Long-term stability of commercial Pt/C (5 wt.%) catalyst. The ORR polarization curves were conducted in 0.1 M KOH with saturated oxygen.

Table S1. ICP-OES results for various PtNi/C samples.

	Pt (mg/kg)	Ni (mg/kg)	Pt wt%	Ni wt%	Pt:Ni (atomic ratio)
PtNi/C-3:1	33605.4	3683.43	3.36%	0.37%	1:0.36
PtNi/C-2:1	32279.7	4869.51	3.23%	0.49%	1:0.50
PtNi/C-1:1	36902.2	7870.31	3.69%	0.79%	1:0.71
PtNi/C-1:2	30393.6	7870.31	3.04%	1.29%	1:1.41
PtNi/C-1:3	30047.2	15411.8	3.00%	1.54%	1:1.71
Pt/XC-72	31806.3	--	3.18%	--	--
Ni/XC-72	--	3831.75	--	0.38%	--

Table S2. Fitting data of EIS results of Pt/C-20% commercial and PtNi/C in 0.1 M KOH.

Catalyst	R_1 (Ω)	R_2(Ω)	R_3(Ω)
Pt/C-20% commercial	2.365	14.27	38.13
PtNi/C	4.06	23.12	25.79

R_1 is the resistance of the solution, R_2 is the resistance of the corrosion layer and R_3 is the charge transfer resistance on the electrode surface.

Table S3. Comparison of the alkaline ORR activity of different Pt-based catalysts

Catalysts	E_{onset} (V vs.RHE)	$E_{1/2}$ (Vvs.RHE)	Tafel slope ($mv.dec^{-1}$)	Electron transfer numbers (n)	Durability test $\Delta E_{1/2}$ (mV)	Pt (wt%)	Reference
$PtP_{1.4}$@Pt/C	--	0.88	--	--	27 (30 k cycles)	32.3	[1]
Pt/MnO	--	0.78	--	4.0	--	--	[2]
$Pt_{67}Ni_{33}$ NCs	0.92	0.82	61.8	3.7	7.1 (2.5 k cycles)	--	[3]
Pt_L@Ni_L	--	0.68	--	--	--	4.71	[4]
P-PtNi/C	--	0.9	--	4.08	~50 (2.5 k cycles)	17.7	[5]
$Pt_{3.5\%}$Ni PF	0.92	0.80	--	3.90	--	--	[6]
$Pt_{75}Ni_{25}$	0.95	0.86	--	3.90	~5mV (1 k cycles)	--	[7]
PtNi/C	--	0.88	98	4.0	15mV (1 k cycles)	22.75	[8]
PtNi/C-200	0.98	0.84	77.08	4.0	5mV (10 k cycles)	3.04	This work

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