Electronic Supplementary Information

Pd-Impregnated $NiCo_2O_4$ nanosheets/porous carbon composites as a free-standing and binder-free catalyst for a high energy lithium–oxygen battery

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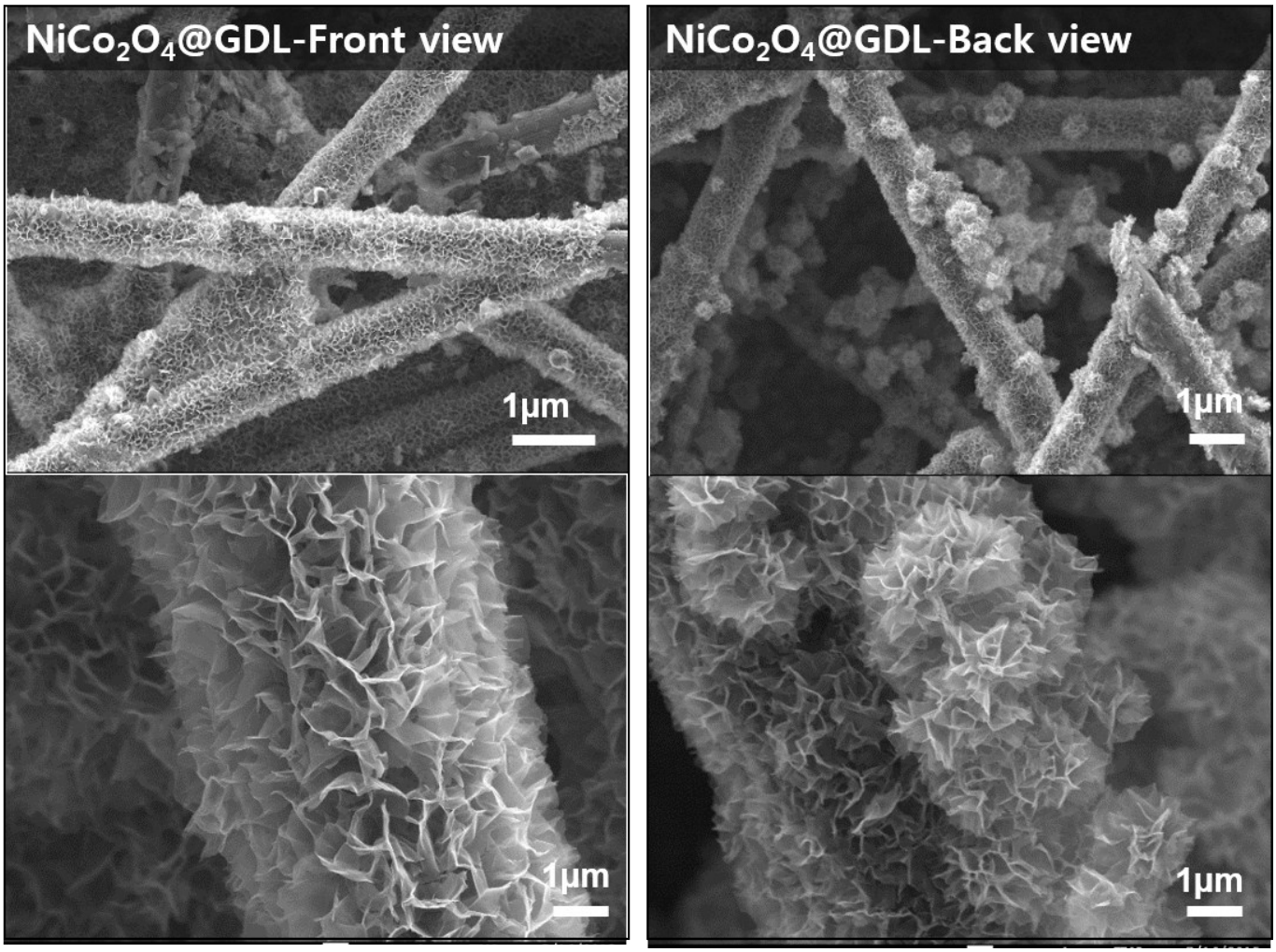

Fig. S1 FESEM images of as-prepared $NiCo_2O_4$ nanosheets directly grown on both sides of GDL as a result of vertically immersion of GDL in reaction solution

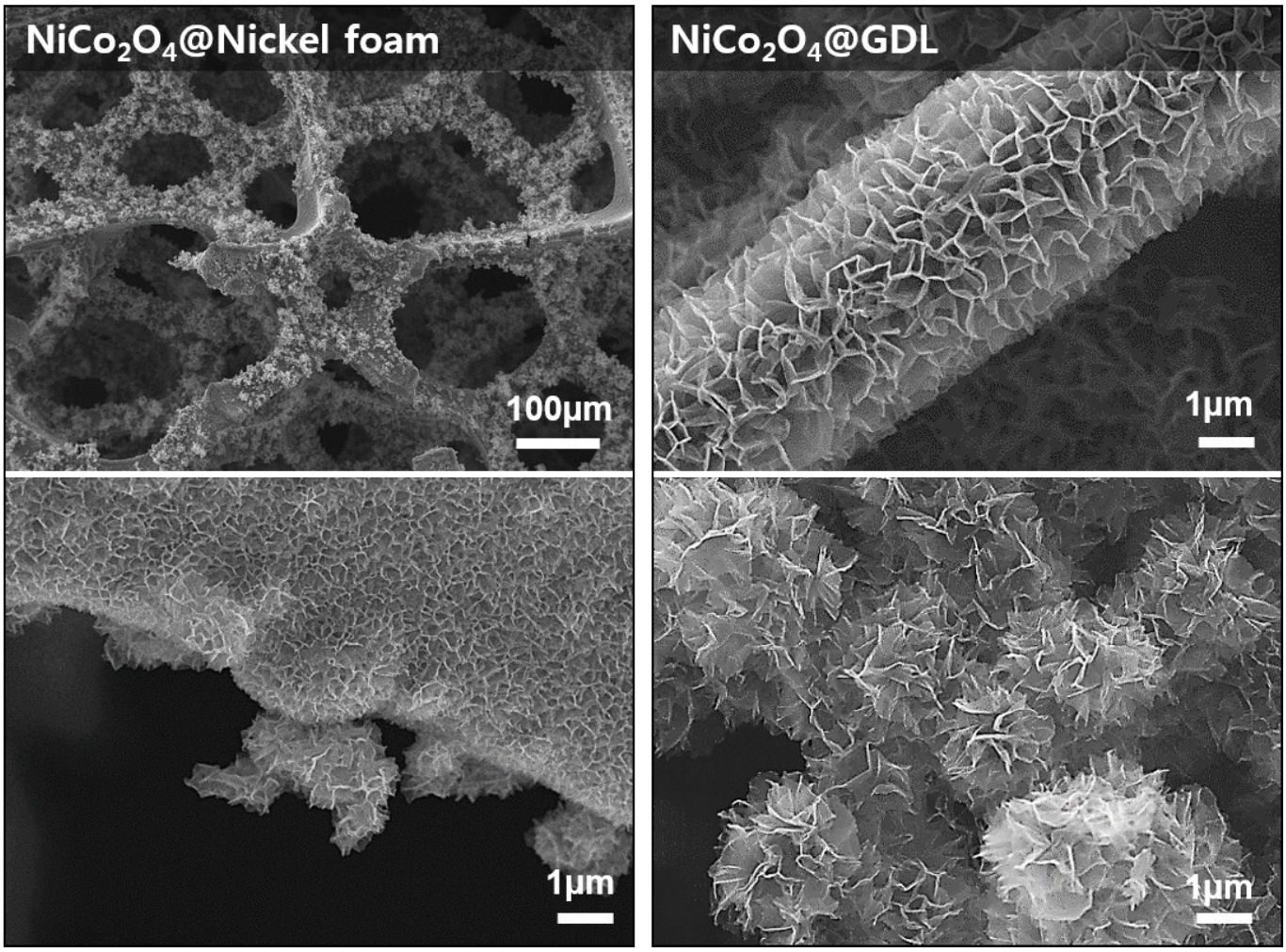

Fig. S2 FESEM images of $NiCo_2O_4$ nanosheets grown on two substrates (i.e. Nickel foam and GDL) illustrating the compatibility of nanosheets on various substrates

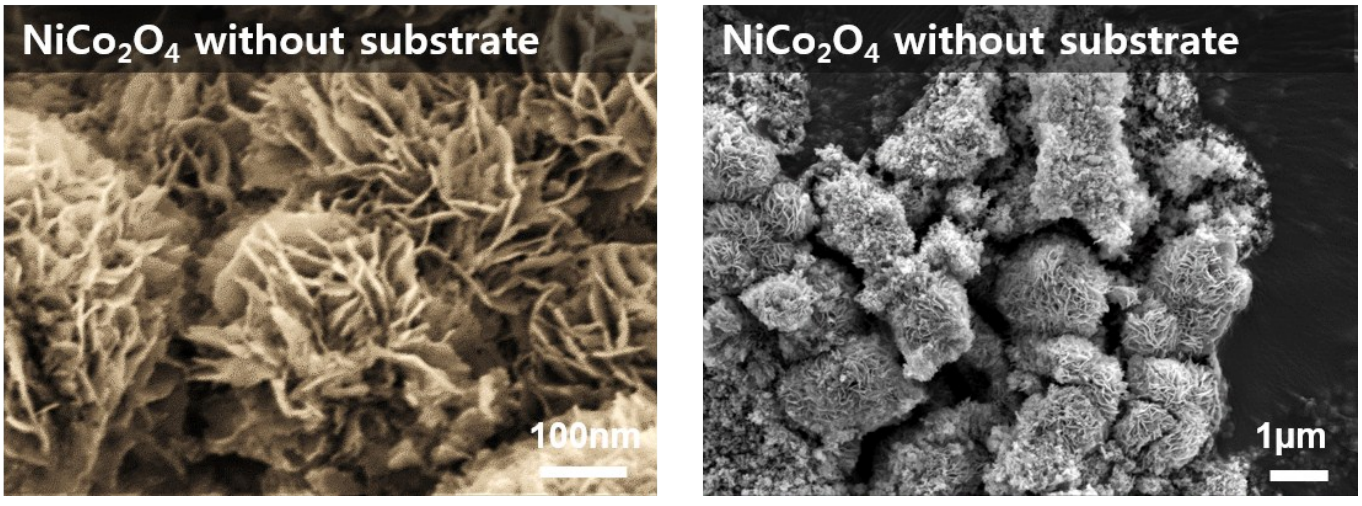

Fig. S3 FESEM images of $NiCo_2O_4$ nanosheets assembled into flower-like morphology, which is grown without substrate

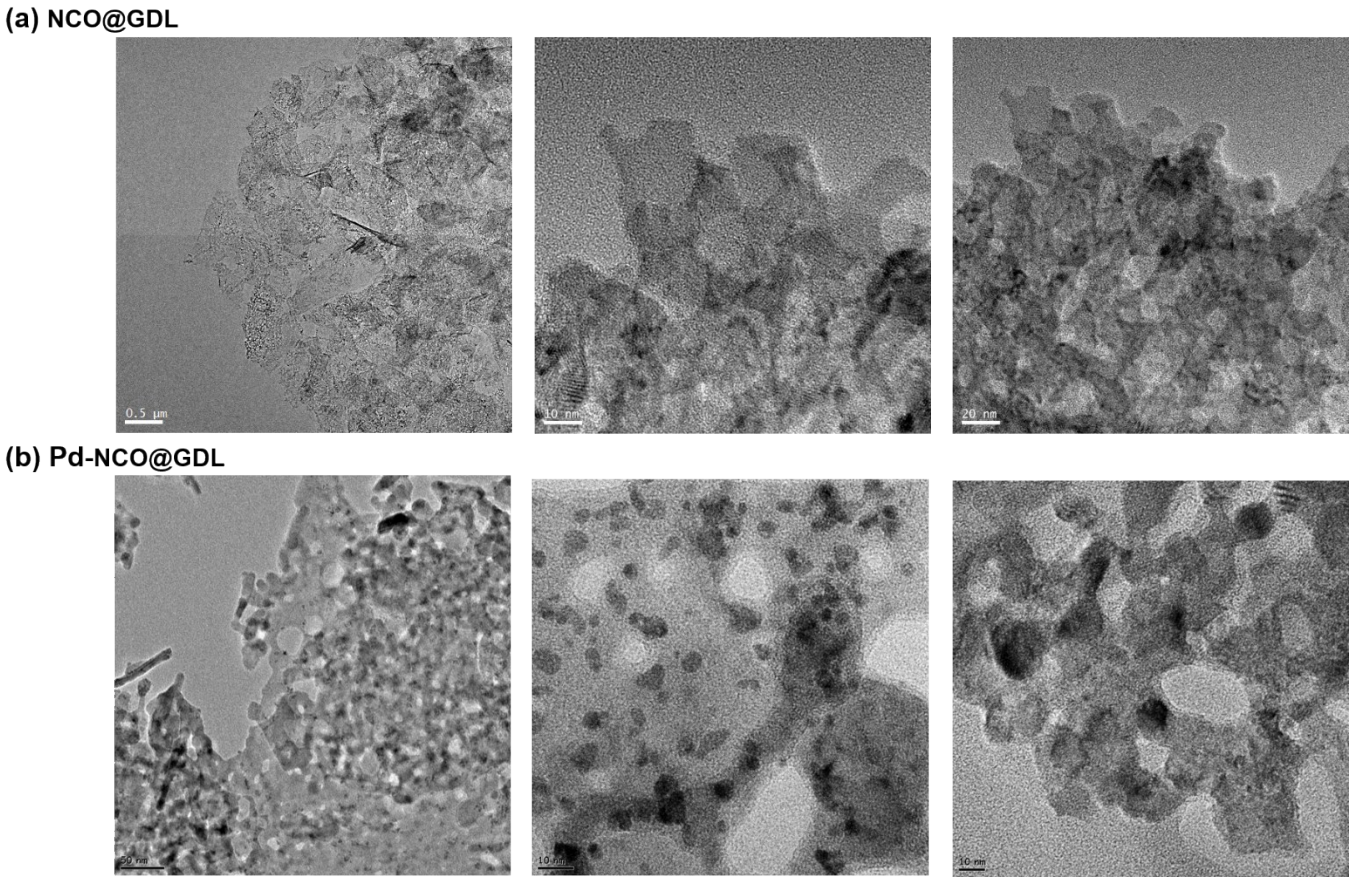

Fig. S4 TEM images of $NiCo_2O_4$ nanosheets before and after Pd deposition

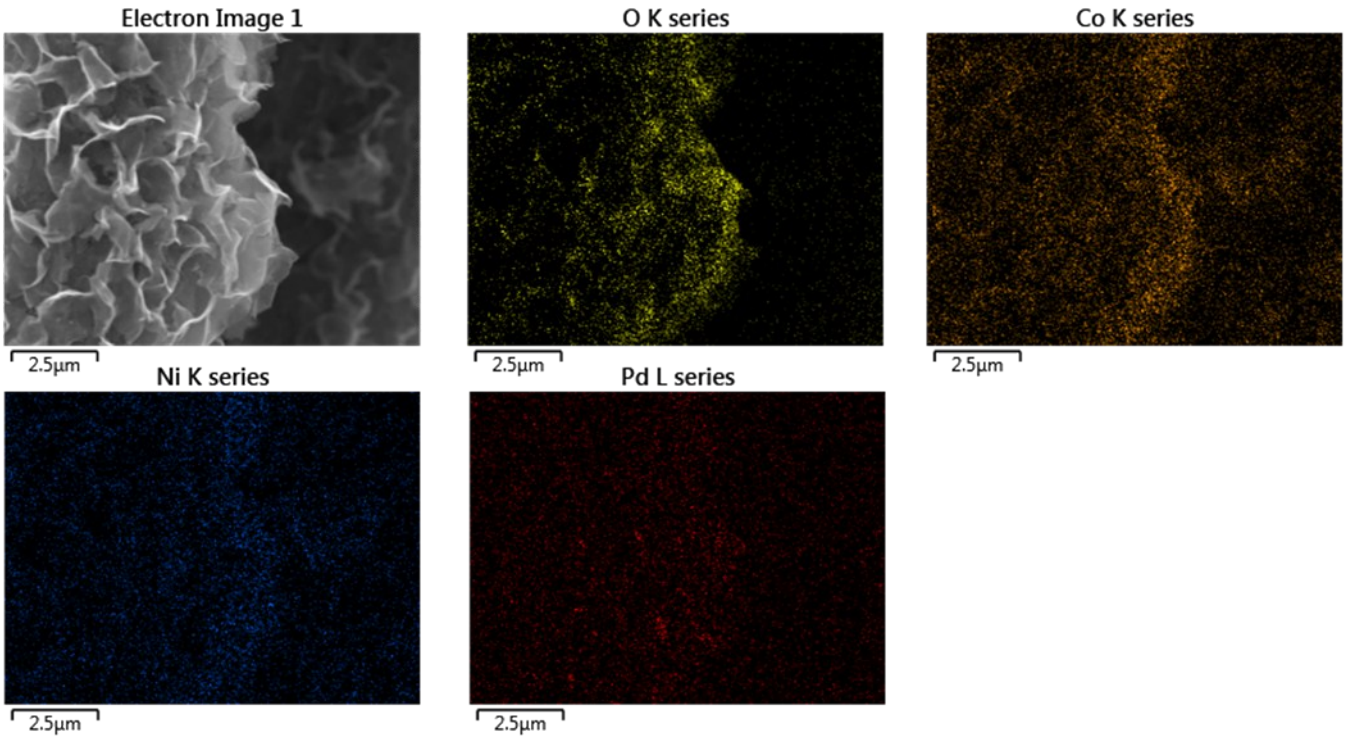

Fig. S5 FESEM-EDS elemental mapping of Pd@$NiCo_2O_4$/GDL showing the various elements present in the composition

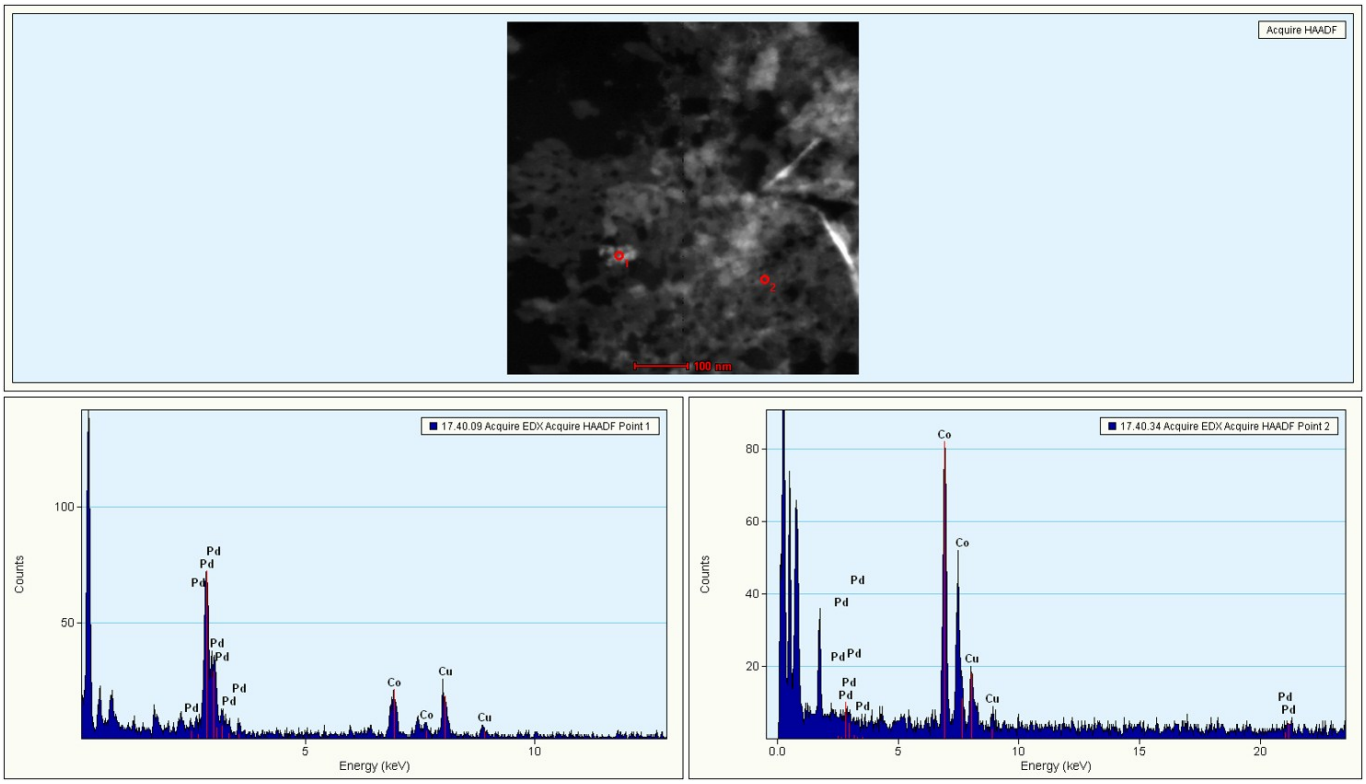

Fig. S6 HAADF-STEM image and point EDX spectra showing the existence of Pd nanoparticles adsorbed onto the $NiCo_2O_4$ nanosheets

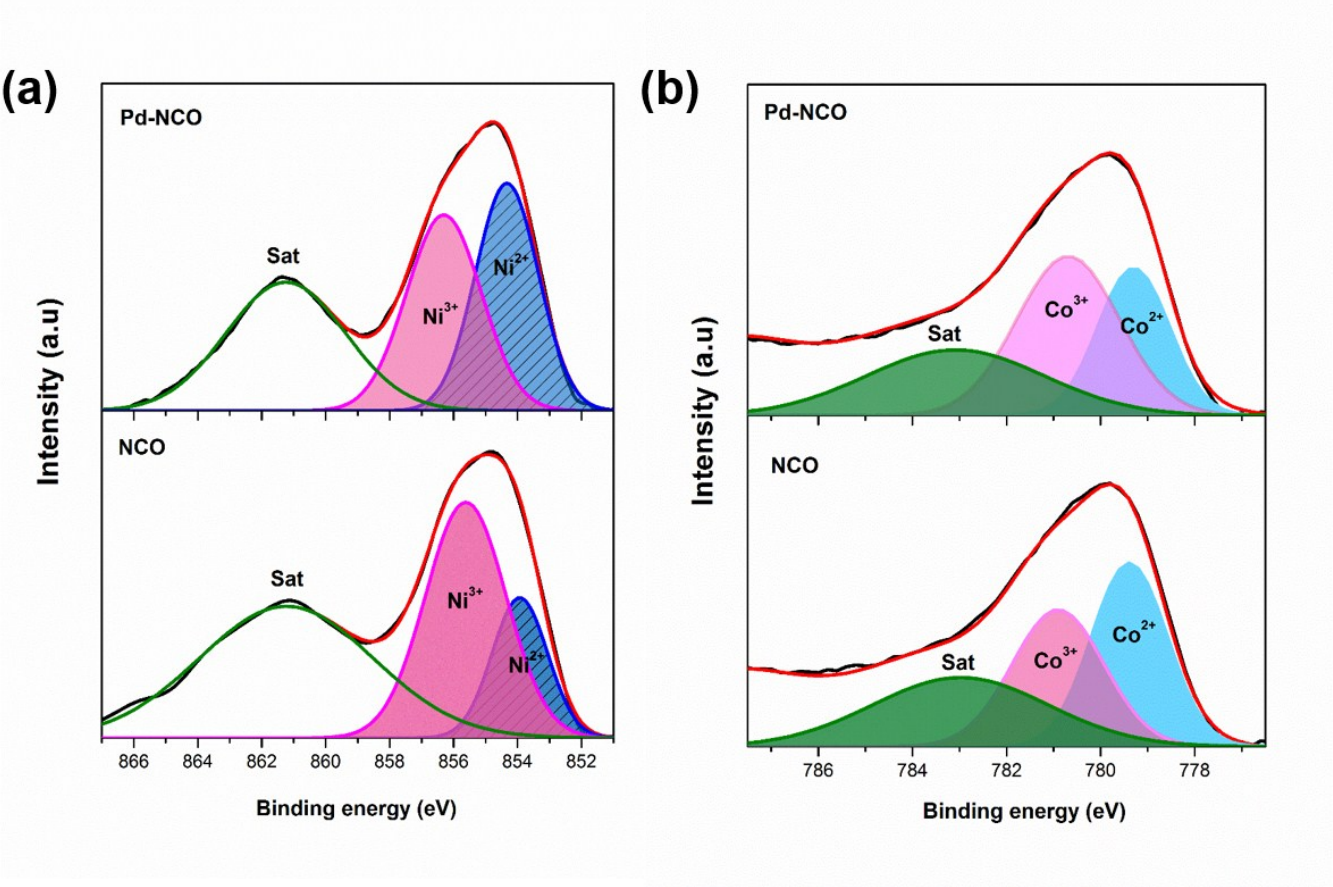

Fig. S7 XPS analysis of (a) Ni 1s and (b) Co 2p spectra demonstrating the change of oxidation states before and after Pd introduction

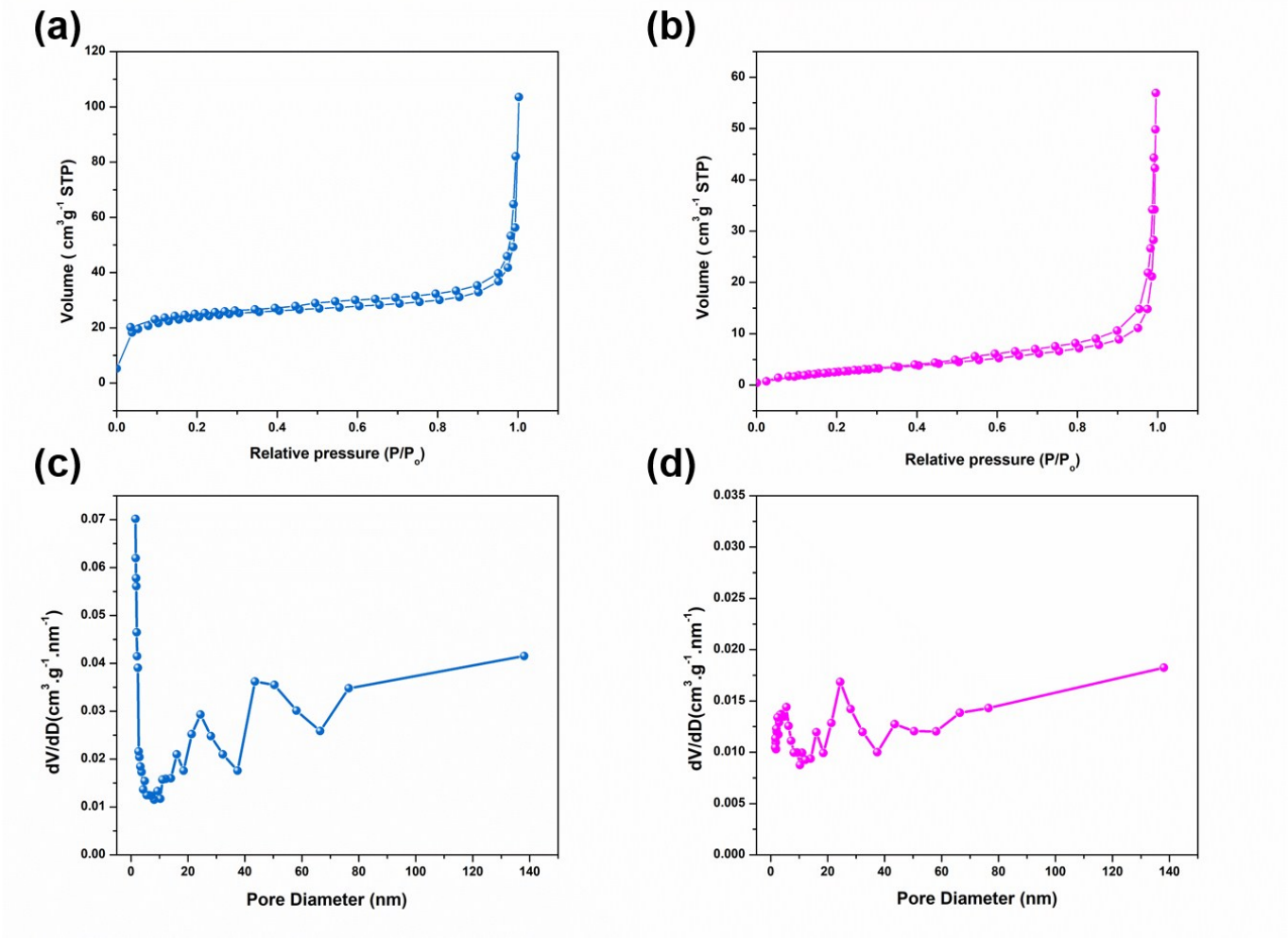

Fig. S8. Nitrogen adsorption-desorption isotherms and Pore size distributions of (a & c) Pd@$NiCo_2O_4$/GDL and (b & d) $NiCo_2O_4$/GDL

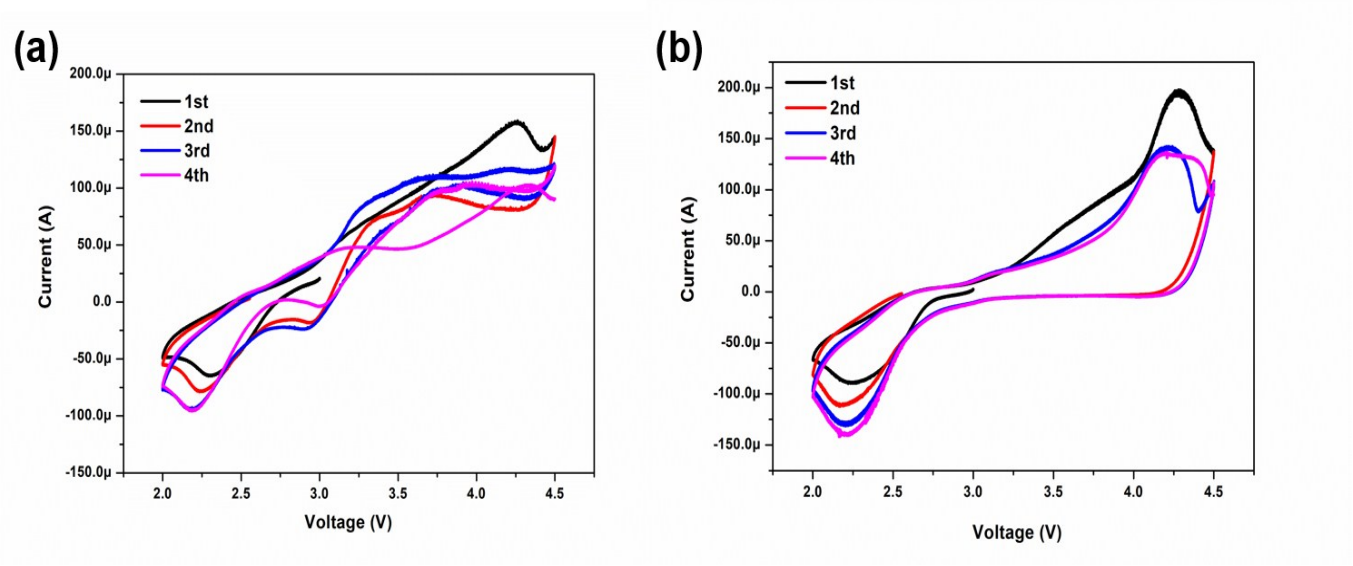

Fig. S9 Cyclic Voltammetry (CV) curves of Li-O_2 cells with (a) Pd@$NiCo_2O_4$/GDL and (b) $NiCo_2O_4$/GDL at the scan rate of 0.2mVs^{-1}

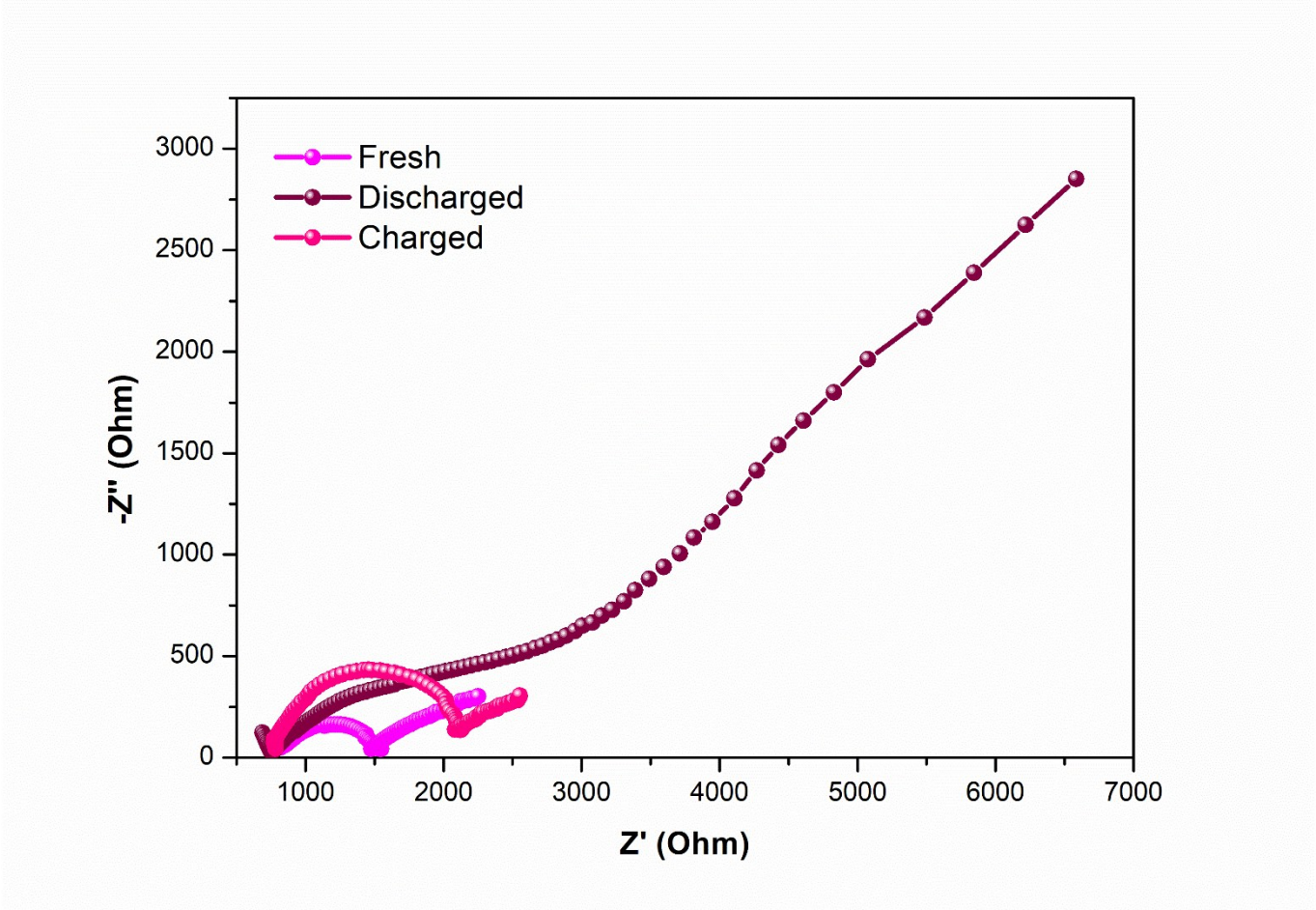

Fig. S10 Nyquist plots of the Li-O_2 cells containing $NiCo_2O_4$/GDL cathode

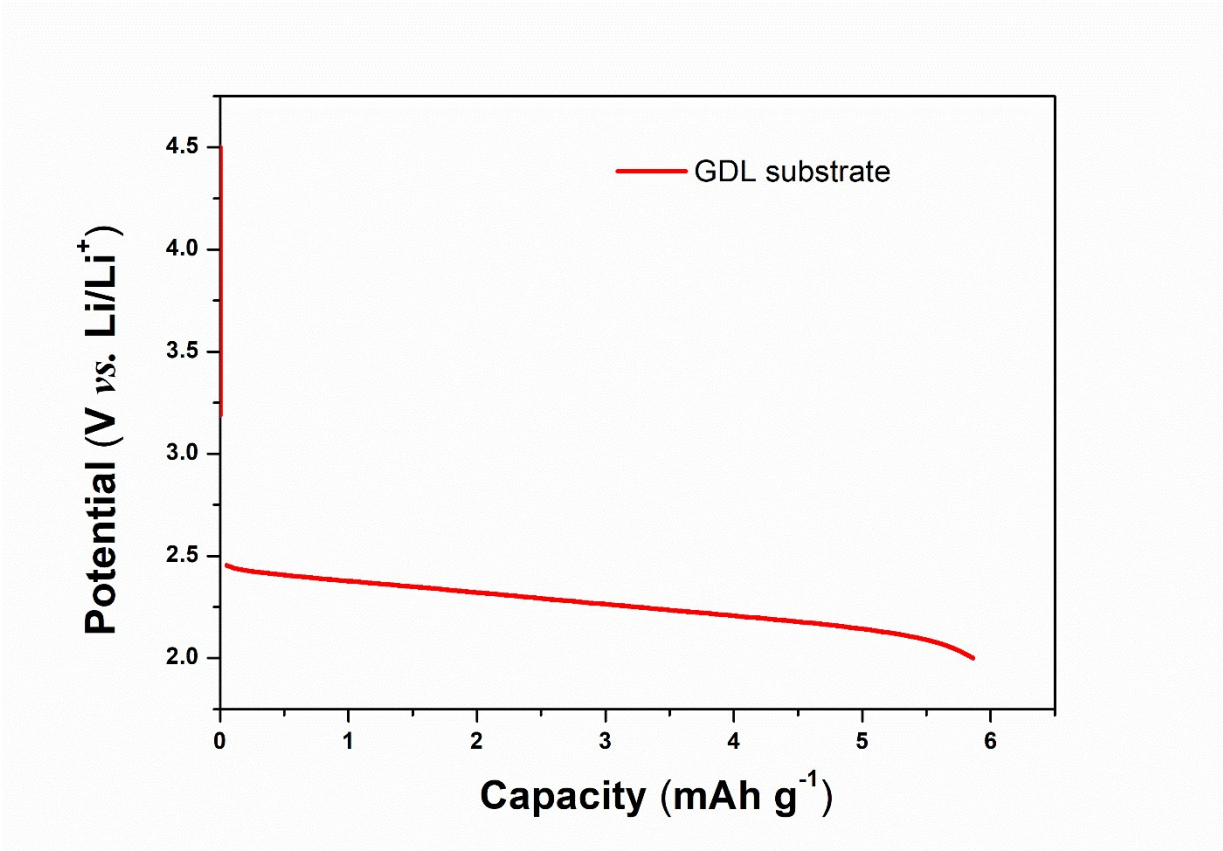

Fig. S11 Discharge curve of bare GDL substrate

Sample Name	Discharge capacity(mAhg-	Cut-Off capacity (mAhg^{-1})/ Cycling	Discharge product	Reference

	[1)]/current density	stability	morphology	
Au@$NiCo_2O_4$/3D-G	1275 / 42.5mAg^{-1}	500 / 40	Flakes	23
Flower-like $NiCo_2O_4$ microsphere	3163 / 0.08mAcm^{-1}	500 / 60	Thin film	22
Mesoporous spinel $NiCo_2O_4$	7309 / 0.2mAcm^{-1}	1000 / 35	precipitate	14
3D Foam-like $NiCo_2O_4$	10137 / 200mAg^{-1}	1000 / 80	precipitate	13
Porous $NiCo_2O_4$ nanotube	6000 / 100mAg^{-1}	1000 / 110	toroidal	44
Macroporous/mesoporous $NiCo_2O_4$ nanosheets	11860 / 200mAg^{-1}	500 / 50	plates	45
Pd@$NiCo_2O_4$/GDL	4000 / 200mAg^{-1}	1000 / 100	Flower-like	This work

Table S1 Comparison between the electrochemical properties of various $NiCo_2O_4$ based electrodes for Li-O_2 batteries

References

13. F. Deng, L. Yu, G. Cheng, T. Lin, M. Sun, F. Ye and Y. Li, J. Power Sources, 2014, **251**, 202–207.

14. H. Guo, L. Liu, T. Li, W. Chen, J. Liu, Y. Guo and Y. Guo, Nanoscale, 2014, **6**, 5491–5497.

22. Z. Li, X. Li, L. Xiang, X. Xie, X. Li, D.-R. Xiao, J. Shen, W. Lu, L. Lu and S. Liu, J. Mater. Chem. A, 2016, **4**, 18335–18341.

23. H.-Q. Wang, J. Chen, S.-J. Hu, X.-H. Zhang, X.-P. Fan, J. Du, Y.-G. Huang and Q.-Y. Li, RSC Adv., 2015, **5**, 72495–72499.

44. L. Li, L. Shen, P. Nie, G. Pang, J. Wang, H. Li, S. Dong and X. Zhang, J. Mater. Chem. A, 2015, **3**, 224309–224314.

45. B. Sun, X. Huang, S. Chen, Y. Zhao, J. Zhang, P. Munroe and G. Wang, J. Mater. Chem. A, 2014, 2, 12053–12059