

NiMoO₄ nanosheets embedded in microflakes-assembled CuCo₂O₄ island-like structure on Ni foam for high-performance asymmetrical solid-state supercapacitors

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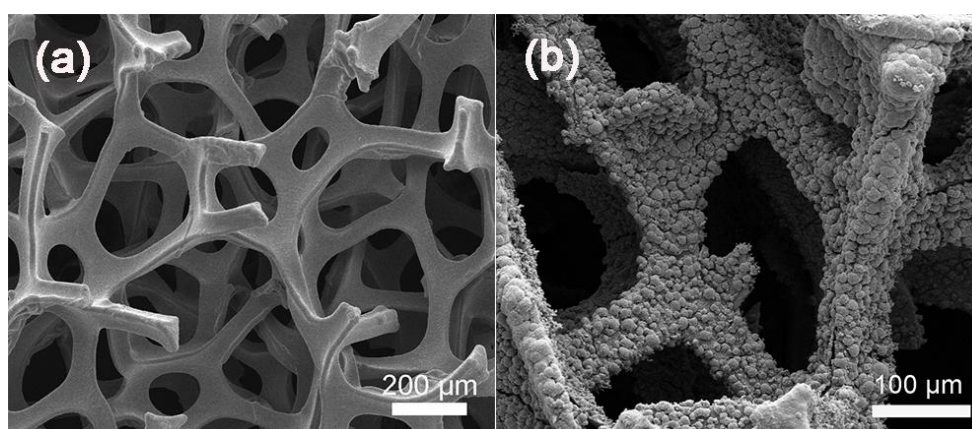


Figure S1. SEM images (a) bare Ni foam (b) Ni/CuCo₂O₄/NiMoO₄.

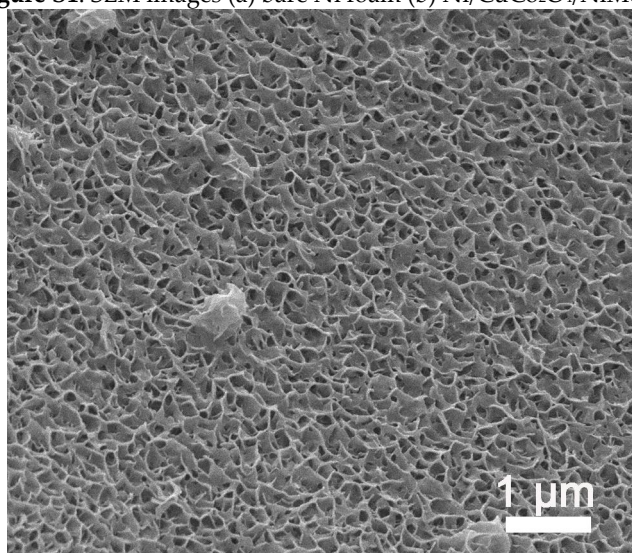


Figure S2. SEM image of NiMoO₄ nanosheet.

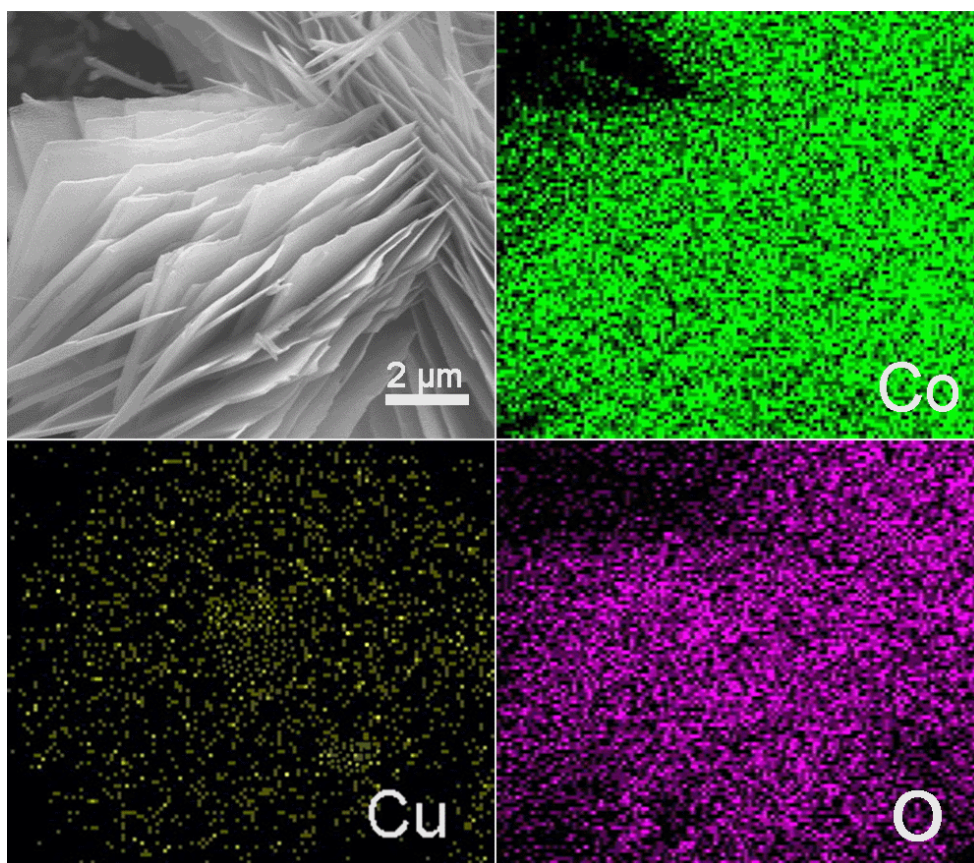


Figure S3. EDS mapping image of CuCo₂O₄ microflakes.

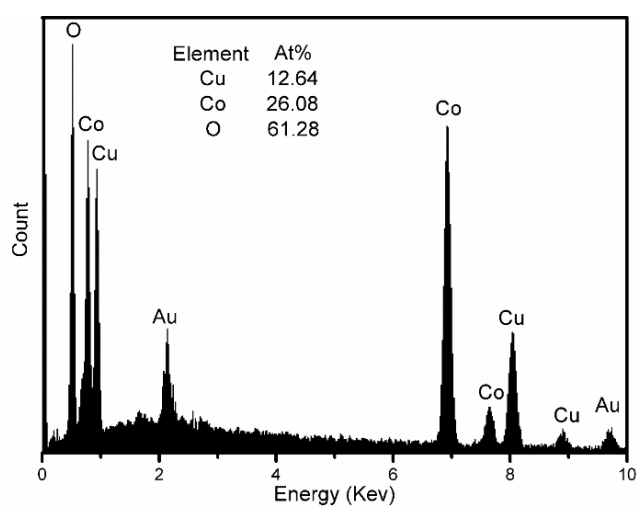


Figure S4. EDS spectrum of the elements Co, Cu and O.

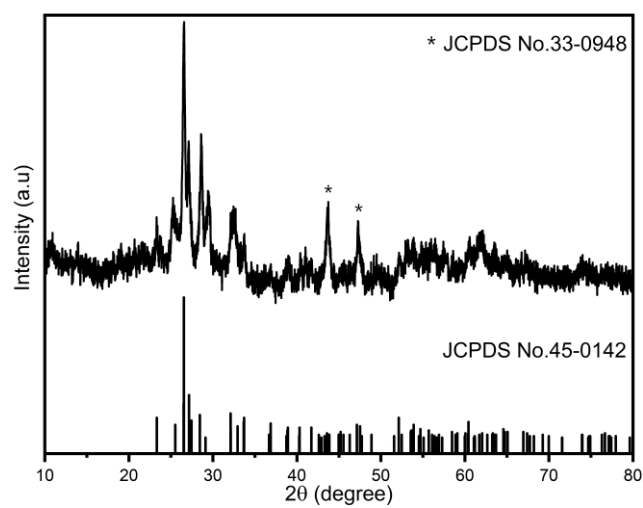


Figure S5. XRD pattern of NiMoO_4 nanosheet.

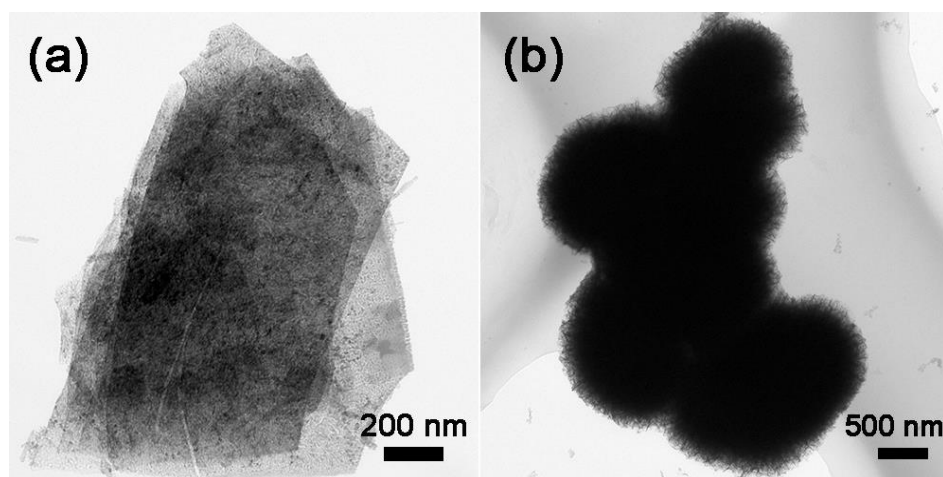


Figure S6. TEM images (a) CuCo_2O_4 microflakes (b) $\text{CuCo}_2\text{O}_4/\text{NiMoO}_4$ micro/nano-heterostructures.

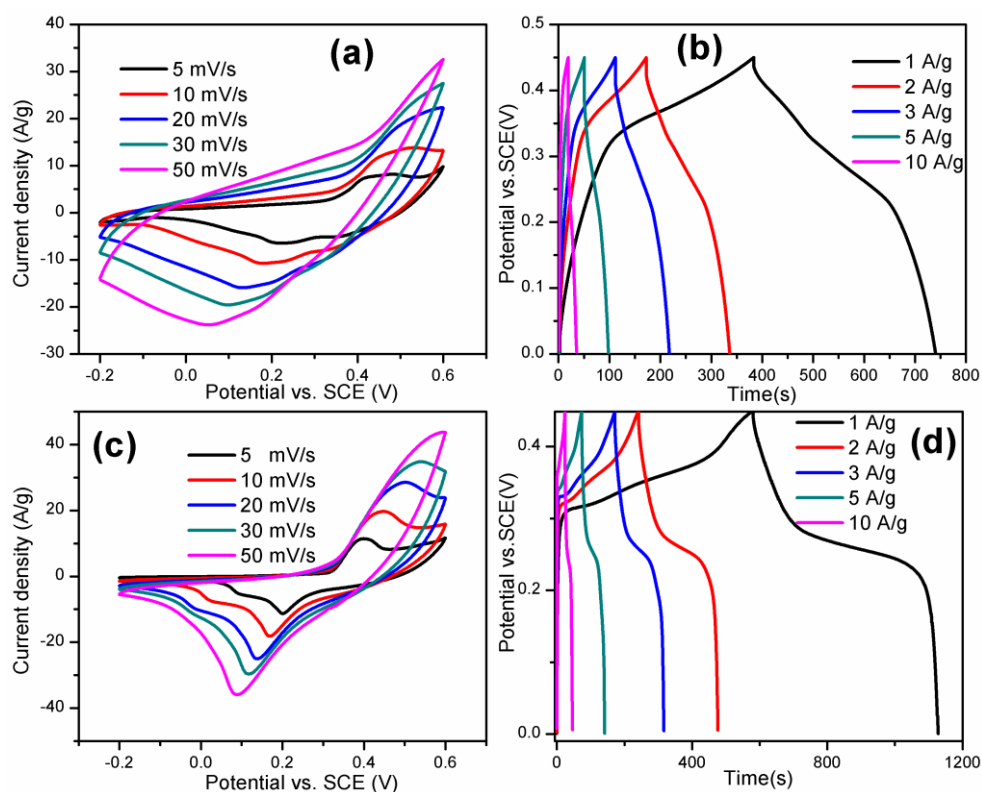


Figure S7. CV curves of (a) CuCo_2O_4 (c) NiMoO_4 at various scan rates. GCD curves of (b) CuCo_2O_4 (d) NiMoO_4 at different current densities.

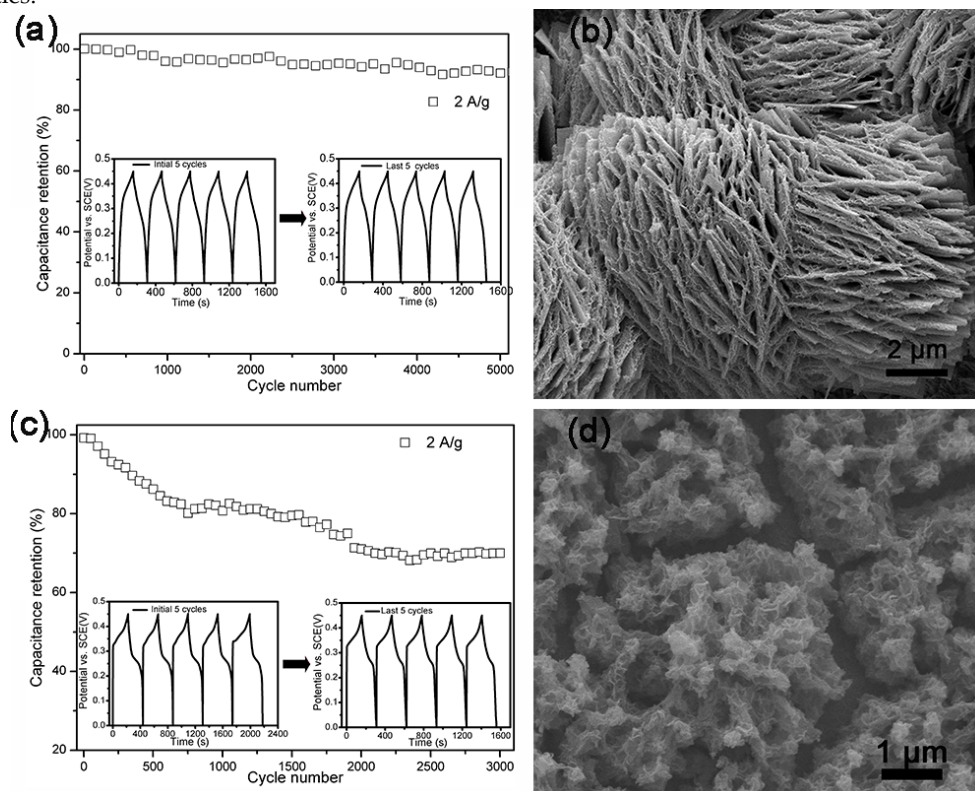


Figure S8. Cycling performance of (a) CuCo_2O_4 electrode (c) NiMoO_4 electrode at 2 A/g. (inset: GCD curves of the first 5 cycles and the last 5 cycles). SEM images of (b) CuCo_2O_4 electrode after 5000 cycles (d) NiMoO_4 electrode after 3000 cycles.

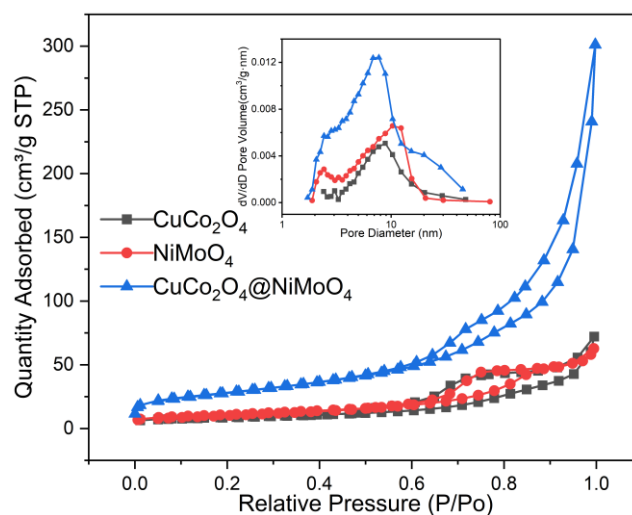


Figure S9. Nitrogen adsorption-desorption isotherms and pore size distribution (inset) of CuCo_2O_4 , NiMoO_4 and $\text{CuCo}_2\text{O}_4/\text{NiMoO}_4$ (powder from the Ni foam substrate).

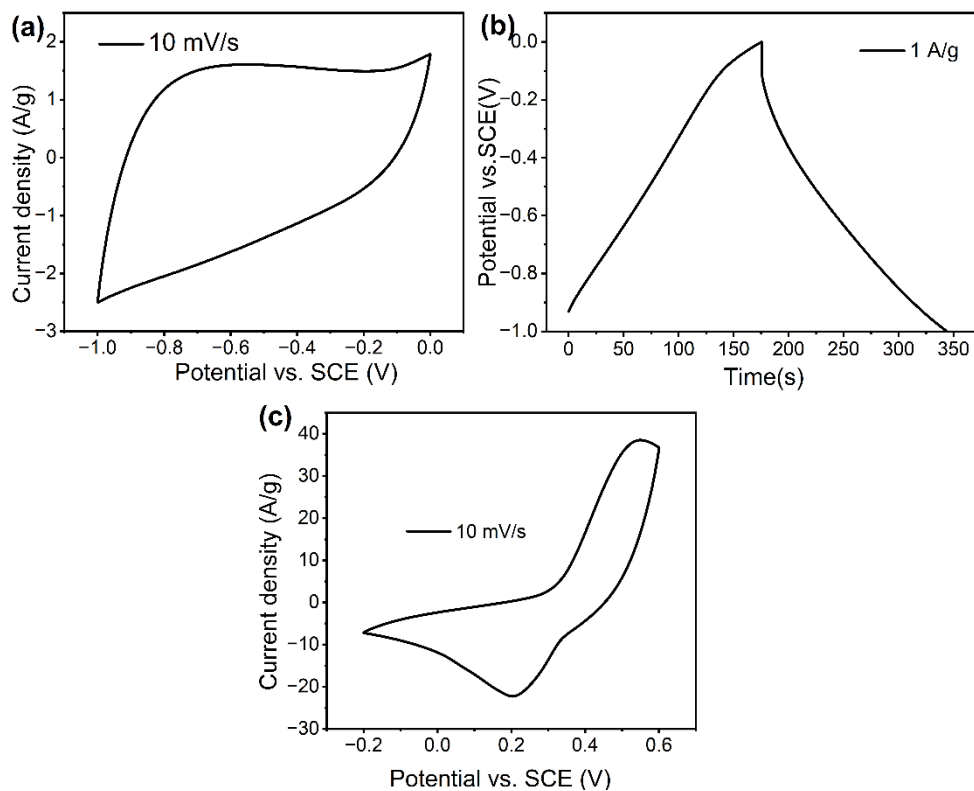


Figure S10. CV (a) and GCD curves (b) of AC electrode. CV curve (c) of $\text{CuCo}_2\text{O}_4/\text{NiMoO}_4$ electrode.

Table S1: The fitted parameters of three electrodes.

Sample	$R_s (\Omega)$	$R_{ct} (\Omega)$	$W (\Omega)$
CuCo_2O_4 microflakes	1.27	8.27	9.28
NiMoO_4 nanosheets	1.36	0.38	5.53
$\text{CuCo}_2\text{O}_4/\text{NiMoO}_4$ heterostructures	0.93	1.14	7.54

Table S2: Various pseudocapacitive electrodes in supercapacitors.

Electrode materials	(A/g or mA cm ⁻²)	Capacitance F g ⁻¹ (Current density)	Retention (Cycles)	Ref
NiMoO ₄ wires	1.2 A g ⁻¹	1517	76.9 % (4000)	[S1]
NiMoO ₄ /N-doping of graphene	1 A g ⁻¹	1913	94.2 % (5000)	[S2]
NiMoO ₄ /rGo composites	1 A g ⁻¹	1274	81.1 % (1000)	[S3]
carbon nanofibers embedded with NiMoO ₄ nanoparticles	1 A g ⁻¹	1438	88 %/(3000)	[S4]
CuCo ₂ O ₄ @MoNi-LDH	1 A g ⁻¹	1286	88 % (6000)	[S5]
CuCo ₂ O ₄ /MnCo ₂ O ₄ heterostructures	0.5 A g ⁻¹	1434	81.4 % (5000)	[S6]
CuCo ₂ O ₄ @MgMoO ₄ composites	1 A g ⁻¹	1153	76.6 % (2000)	[S7]
NiMoO ₄ @MoS ₂ nanorods	1 A g ⁻¹	2246.7	88.4 % (5000)	[S8]
CuCo ₂ O ₄ /NiMoO ₄ heterostructures	1 A g ⁻¹	2350	91.5 % (5000)	This work

References

- Guo, D.; Luo, Y.; Yu, X.; Li, Q.; Wang, T. High performance NiMoO₄ nanowires supported on carbon cloth as advanced electrodes for symmetric supercapacitors. *Nano Energy* **2014**, *8*, 174-182.
- Feng, X.; Wang, J.; N. D.; Zhang, J.; Xia, M.; Wang, Y.; Hao, Y. Heterostructure arrays of NiMoO₄ nanoflakes on N-doping of graphene for high-performance asymmetric supercapacitors. *J. Alloys Compd.* **2020**, *816*, 152625.
- Liu, T.; Chai, H.; Jia, D.Z.; Su, Y.; Wang, T.; Zhou, W.Y. Three-dimensional Co₃O₄@NiMoO₄ core/shell nanowire arrays on Ni Foam for electrochemical energy storage. *Electrochim. Acta* **2015**, *180*, 998-1006.
- Budhiraju, V.S.; Kumar, R.; Sharma, A.; Sivakumar, S. Structurally stable hollow mesoporous graphitized carbon nanofibers embedded with NiMoO₄ nanoparticles for high performance asymmetric supercapacitors. *Electrochim. Acta* **2017**, *238*, 337-348.
- Zhang, C.; Sui, Q.; Lu, L.; Zou, Y.; Xu, F.; Sun, L.; Cai, D.; Xiang, C. Hollow core-shell CuCo₂O₄@MoNi-layered double hydroxides as an electrode material for supercapacitors. *J. Energy Storage* **2023**, *61*, 106691.
- Liu, S.; Hui, K.S.; Hui, K.N.; Yun, J.M.; Kim, K.H. Vertically stacked bilayer CuCo₂O₄/MnCo₂O₄ heterostructures on functionalized graphite paper for high-performance electrochemical capacitors. *J. Mater. Chem. A* **2016**, *4*, 8061-8071.
- Hao, C.; Guo, Y.N.; Xian, S.L.; Zheng, W.H.; Gao, H.W.; Wang, X.H. Fabrication of flower-shaped CuCo₂O₄@MgMoO₄ nanocomposite for high-performance supercapacitors. *J. Energy Storage* **2021**, *41*, 102972.
- Wan, L.; Liu, J.; Li, X.; Zhang, Y.; Chen, J.; Du, C.; Xie, M. Fabrication of core-shell NiMoO₄@MoS₂ nanorods for high-performance asymmetric hybrid supercapacitors. *Int. J. Hydrogen Energy*. **2020**, *45*, 4521-4533.