Optimizing Synergistic Effects: Creating oxygen vacancy in $NiCoWO_4$ via solid-state grinding method for improved energy storage performance.

Anandhavalli Jeevarathinam, Arun Annamalai, Ramya Ravichandran, Kumaresan Annamalai, Sundaravadivel Elumalai *

Department of Chemistry, Faculty of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, 603203, India

*Corresponding author E-mail: sundaravadivelchem@gmail.com

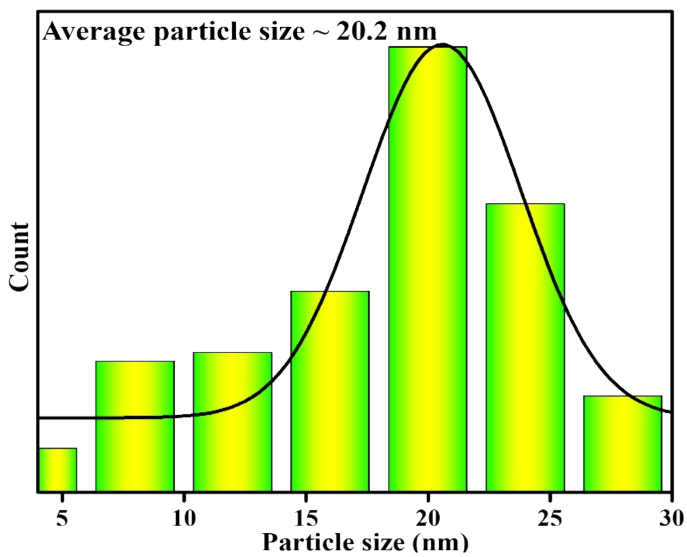
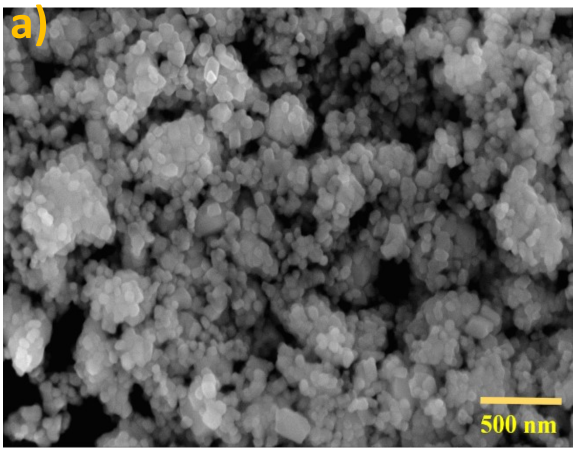


Fig S1 (a) Average particle size of Ov-$NiCoWO_4$



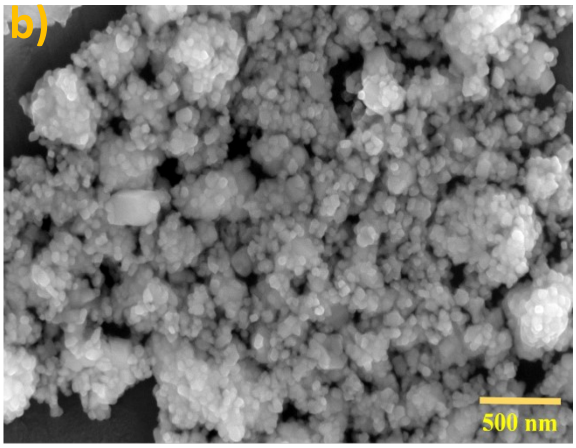


Fig S2 (a,b) SEM images of $NiCoWO_4$ and Ov-$NiCoWO_4$

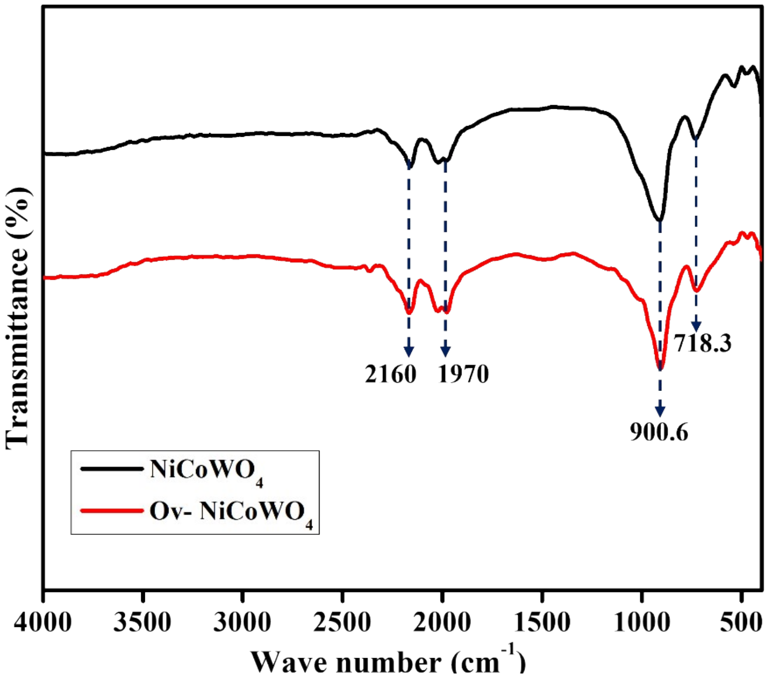


Fig S3 (a) FT-IR spectrum of $NiCoWO_4$ and Ov-$NiCoWO_4$

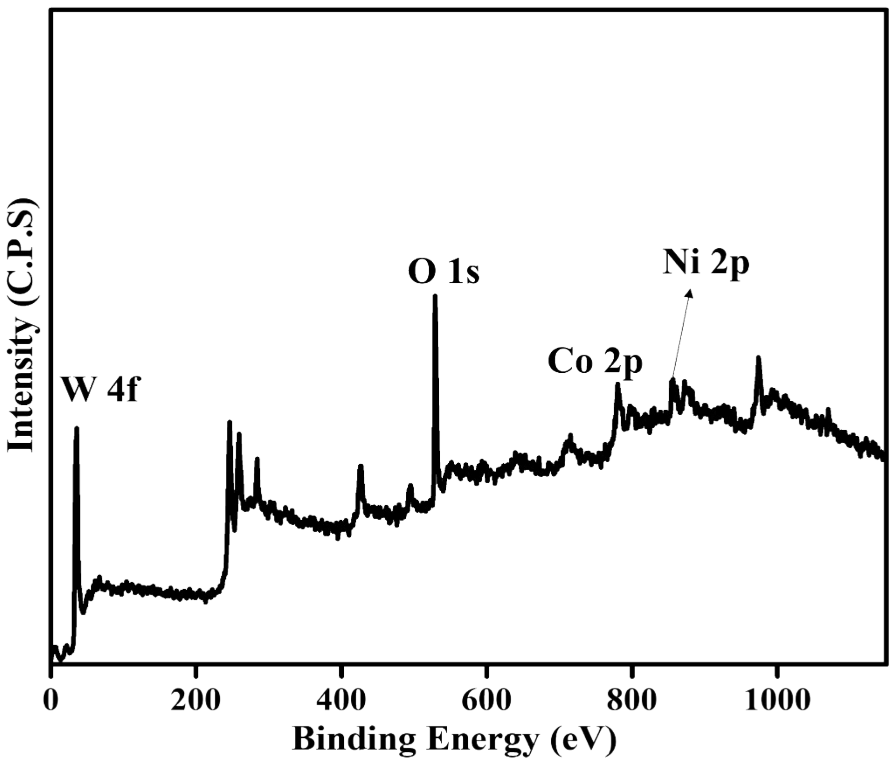


Fig S4 (a) Survey spectrum of Ov-$NiCoWO_4$

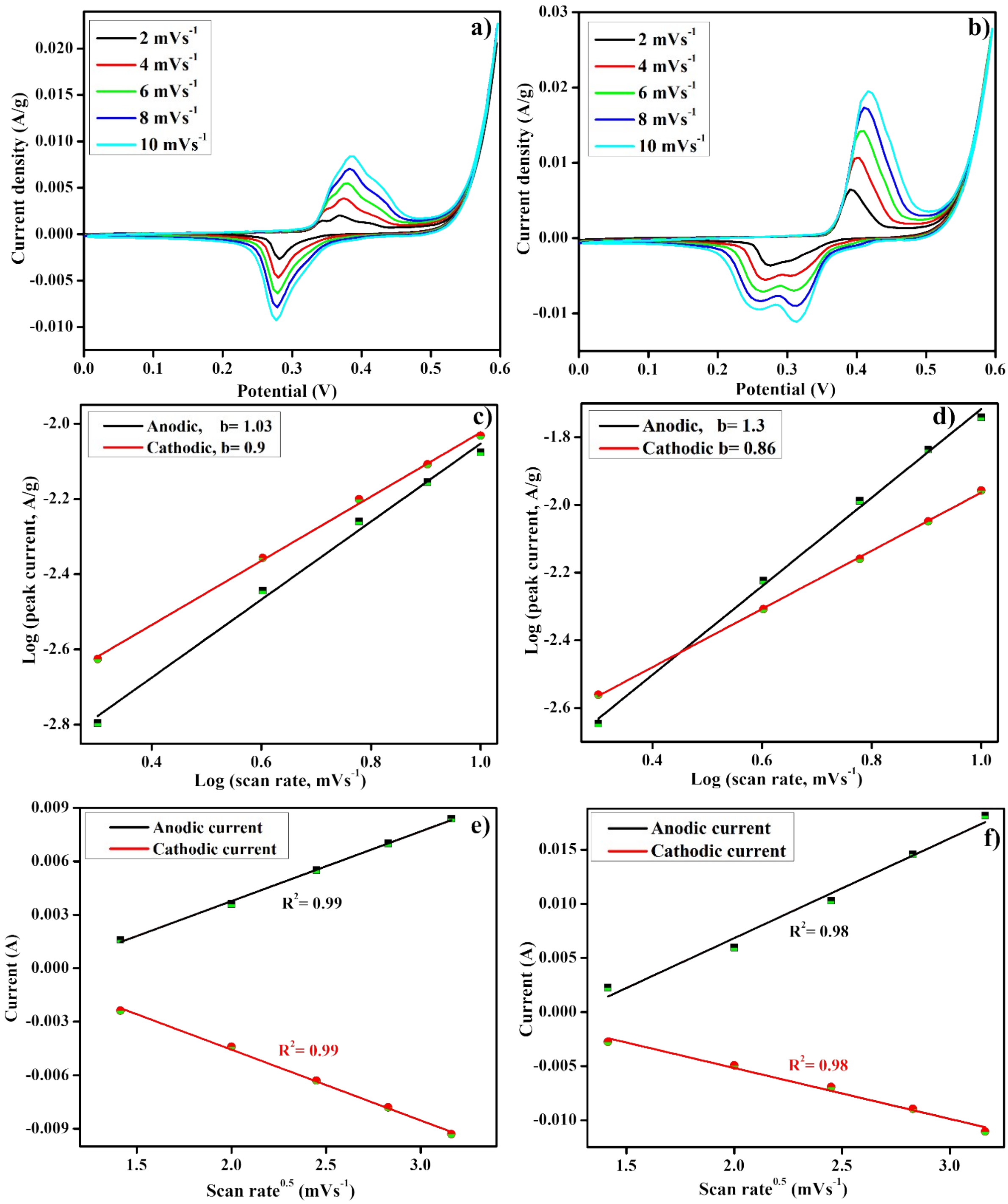


Fig S5 (a,b) CV plots of $NiCoWO_4$ and Ov-$NiCoWO_4$ at scan rate of 2-10 mV/s, (c,d) b value of $NiCoWO_4$ and Ov-$NiCoWO_4$. (e,f) linear plot of anodic and cathodic peak current.

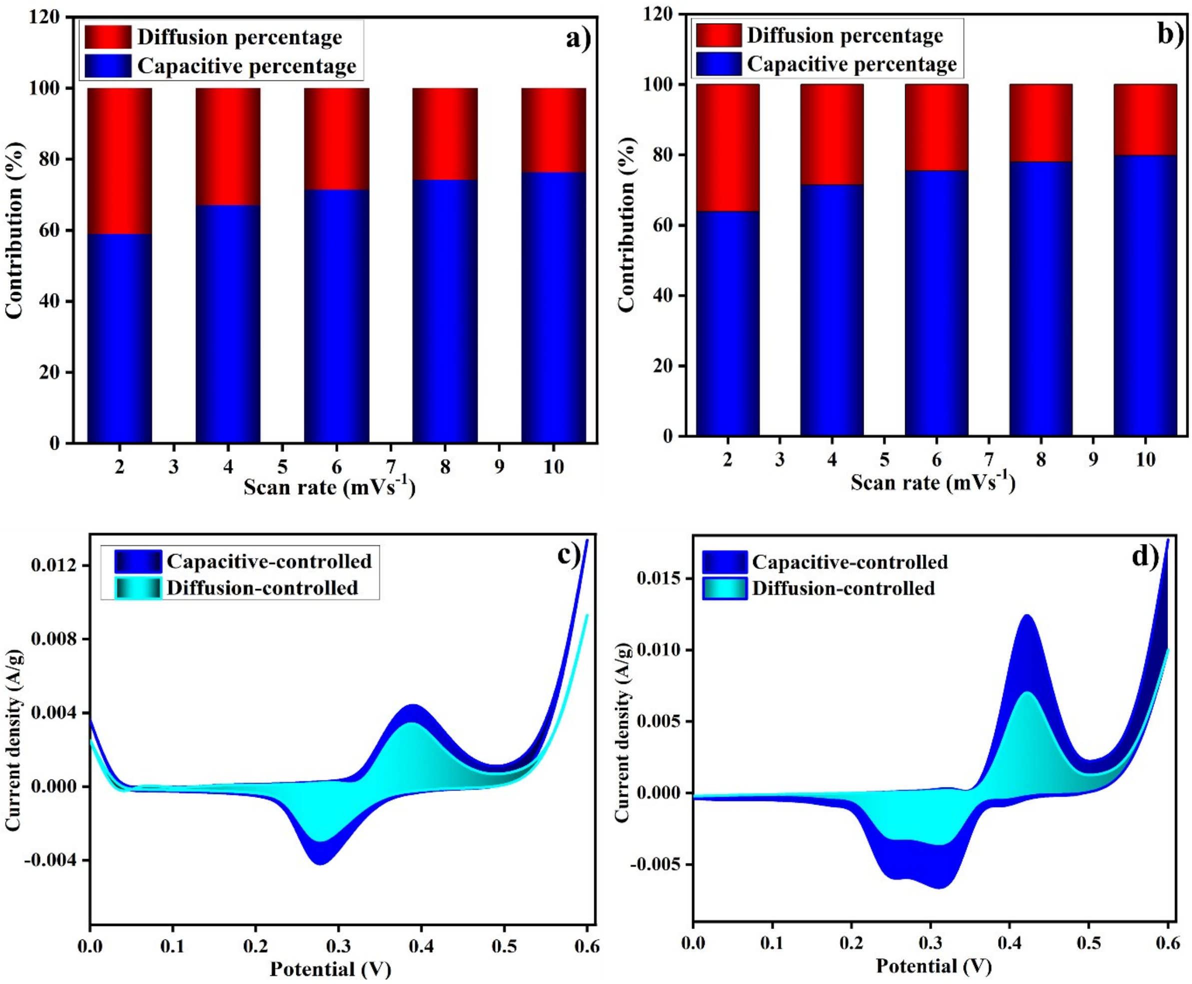


Fig S6 (a,b) Contribution percentage of $NiCoWO_4$ and Ov-$NiCoWO_4$. (c,d) Dunn real plot of $NiCoWO_4$ and Ov-$NiCoWO_4$ at scan rate of 10 mV/s.

Table S1

Comparison of specific capacitance of metal oxide-based materials:

Material	Preparation method	Surface area	Electrolyte	Current density	Specific capacitance	References
$NiCoWO_4$	*Wet chemical*	-	*PVA/H_3PO_4*	0.8 mA	862.26 mF	[1]
$NiWO_4$	Hydrothermal	101.48 m^2/g	3M KOH	0.5 A/g	1524 F/g	[2]
$CoNiWO_4$-P-S-GNS	Hydrothermal	94.45 m^2/g	6M KOH	0.5 A/g	1298.6 F/g	[3]
$NiCoWO_4$	Hydrothermal	51.926 m^2/g	3M KOH	1 A/g	634.55 C/g	[4]
$FeWO_4$	Hydrothermal	18.059 m^2/g	1M Na_2SO_4	0.5 A/g	875 F/g	[5]
$CoNiWO_4$	Hydrothermal	76.2 m^2/g	*2M KOH*	1 A/g	626.4 C/g	[6]
$CuZnWO_4$	Hydrothermal	-	6M KOH	4 A/g	480 F/g	[7]
$NiWO_4$-$CoWO_4$	Co-precipitation	150.7 m^2/g	2M KOH	0.5 A/g	1967 C/g	[8]
$NiCoWO_4$	**Solid-state Grinding**	**48.464 m^2/g**	**3M KOH**	**1 A/g**	**590 F/g**	**This work**
Ov-$NiCoWO_4$	**Solid-state Grinding**	**53.173 m^2/g**	**3M KOH**	**1 A/g**	**703.66 F/g**	**This work**

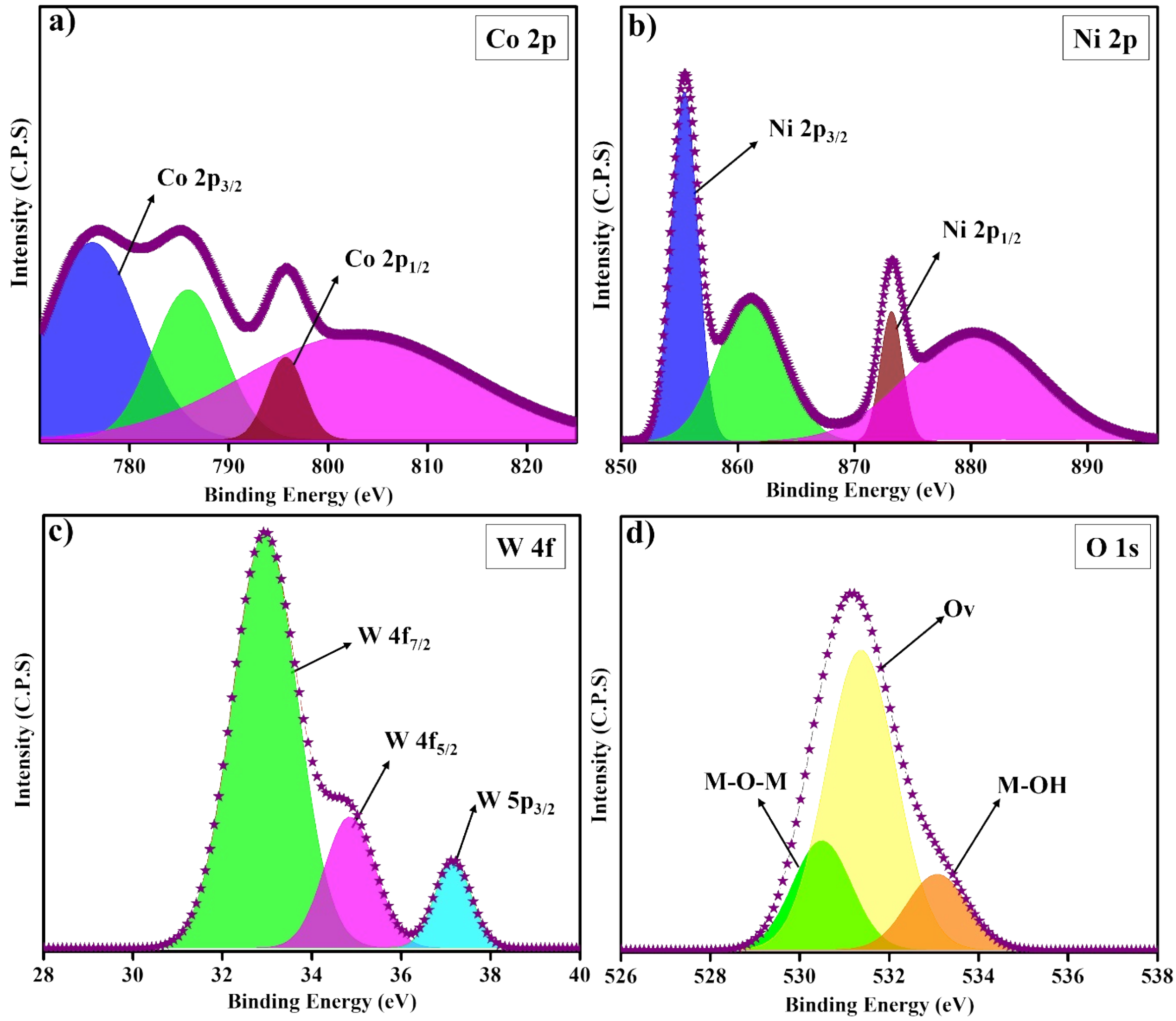


Figure S7 (a,b,c,d) XPS spectrum of Ni 2p, Co 2p, W 4f and O 1s of Ov-NiCoWO$_4$ of cycled samples

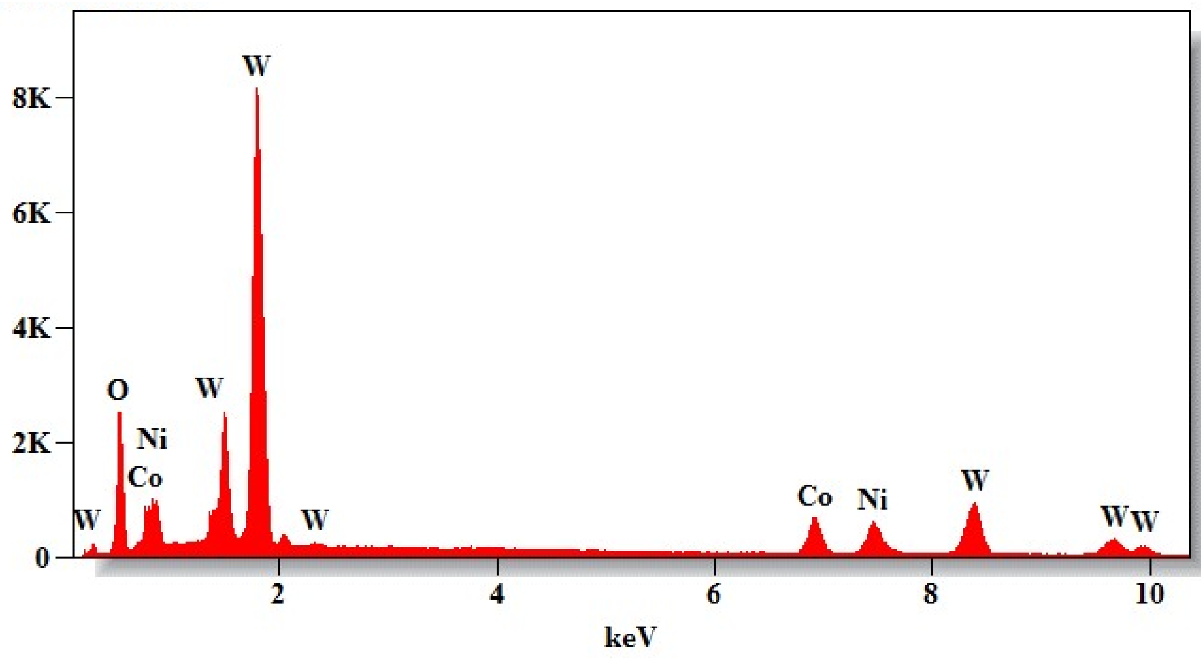


Figure S8 EDS Spectrum of Ov-$NiCoWO_4$

Element	*Net Counts*	*Weight %*	*Atom %*	*Atom % Error*	*Formula*
O	16615	24.25	71.62	± 0.75	O
Co	10077	8.17	6.55	± 0.20	Co
Ni	9233	8.16	6.57	± 0.22	Ni
W	26806	59.41	15.27	± 0.31	W
Total		100.00	100.00		

Table S2 Weight percentage of Ov-$NiCoWO_4$

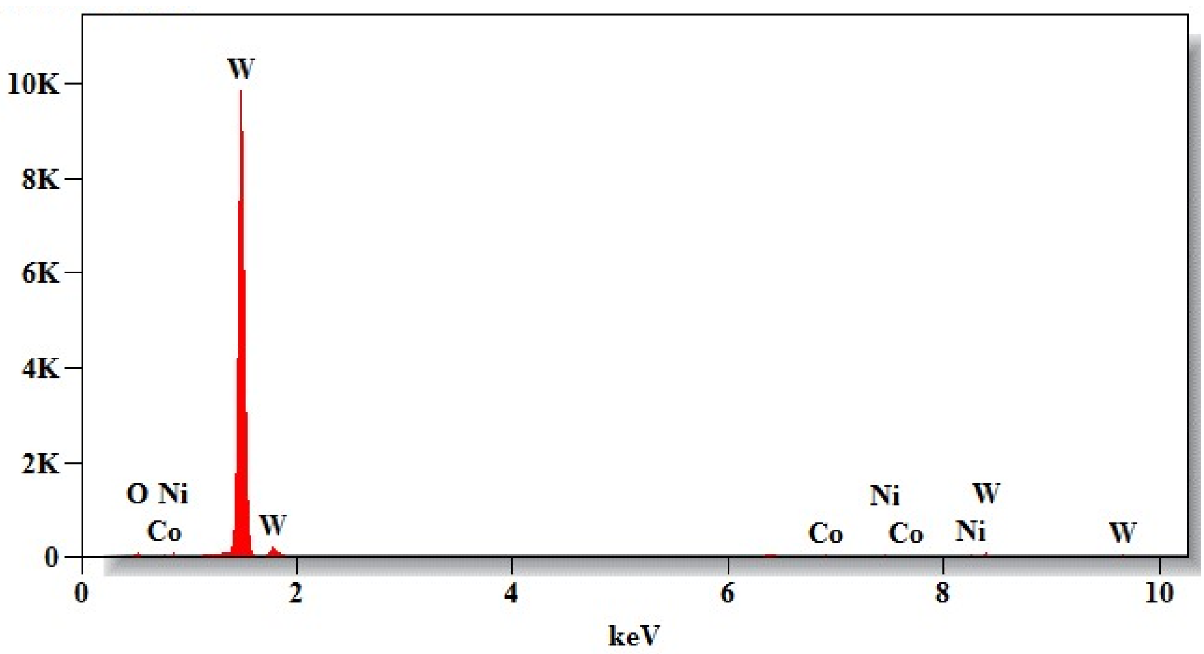


Figure S9 EDS Spectrum of $NiCoWO_4$

Element	*Net Counts*	*Weight %*	*Atom %*	*Atom % Error*	*Formula*
O	595	41.85	84.33	± 4.39	O
Co	466	7.10	3.89	± 0.71	Co
Ni	484	7.59	4.17	± 0.41	Ni
W	1296	43.46	7.62	± 0.85	W
Total		100.00	100.00		

Table S3 Weight percentage of $NiCoWO_4$

References

1 S. Jha, S. Mehta, E. Chen, S. S. Sankar, S. Kundu and H. Liang, *Mater Adv*, 2020, **1**, 2124–2135.

2 M. Ikram, Y. Javed, N. A. Shad, M. M. Sajid, M. Irfan, A. Munawar, T. Hussain, M. Imran and D. Hussain, *J Alloys Compd*, , DOI:10.1016/j.jallcom.2021.160314.

3 A. S. Rajpurohit, N. S. Punde, C. R. Rawool and A. K. Srivastava, *Chemical Engineering Journal*, 2019, **371**, 679–692.

4 S. Prabhu, C. Balaji, M. Navaneethan, M. Selvaraj, N. Anandhan, D. Sivaganesh, S. Saravanakumar, P. Sivakumar and R. Ramesh, *J Alloys Compd*, , DOI:10.1016/j.jallcom.2021.160066.

5 P. Sathish Kumar, P. Prakash, A. Srinivasan and C. Karuppiah, *J Power Sources*, , DOI:10.1016/j.jpowsour.2020.228892.

6 B. Huang, H. Wang, S. Liang, H. Qin, Y. Li, Z. Luo, C. Zhao, L. Xie and L. Chen, *Energy Storage Mater*, 2020, **32**, 105–114.

7 E. Dhandapani, S. Prabhu, N. Duraisamy and R. Ramesh, *Journal of Materials Science: Materials in Electronics*, 2022, **33**, 8446–8459.

8 Y. Wang, C. Shen, L. Niu, Z. Sun, F. Ruan, M. Xu, S. Shan, C. Li, X. Liu and Y. Gong, *Mater Chem Phys*, 2016, **182**, 394–401.