Electronic Supplementary Material (ESI) for New Journal of Chemistry

Nickel Doped Copper Ferrite $Ni_xCu_{1-x}Fe_2O_4$ as a High Crystalline Anode Material for Lithium Ion Batteries

Adil Saleem,[a,1] Muhammad K. Majeed,[b,1*] Shah-Iram Niaz,[c] M. Iqbal,[c] M. Akhlaq,[c] M. Zeeshan Ishfaq,[a] Yujun Zhang,[a] Hongyu Gong,[a**]

[a] *Key Laboratory for Liquid-Solid Structural Evolution and Processing of Materials, Ministry of Education, School of Material Science and Engineering, Shandong University, Jinan 250061, China. Email: gong_honyu@163.com*

[b] *Key Lab of Colloid & Interface Chemistry, Ministry of Education, School of Chemistry & Chemical Engineering, Shandong University, 250100, Jinan, P. R. China.*

Email: drmkashifmajeed@mail.sdu.edu.cn,

[c] *Institute of Chemical Sciences, Faculty of Pharmacy, Gomal University, D.I.Khan, 29050, Pakistan.*

[1] These authors contributed equally to this work.

Supporting Information

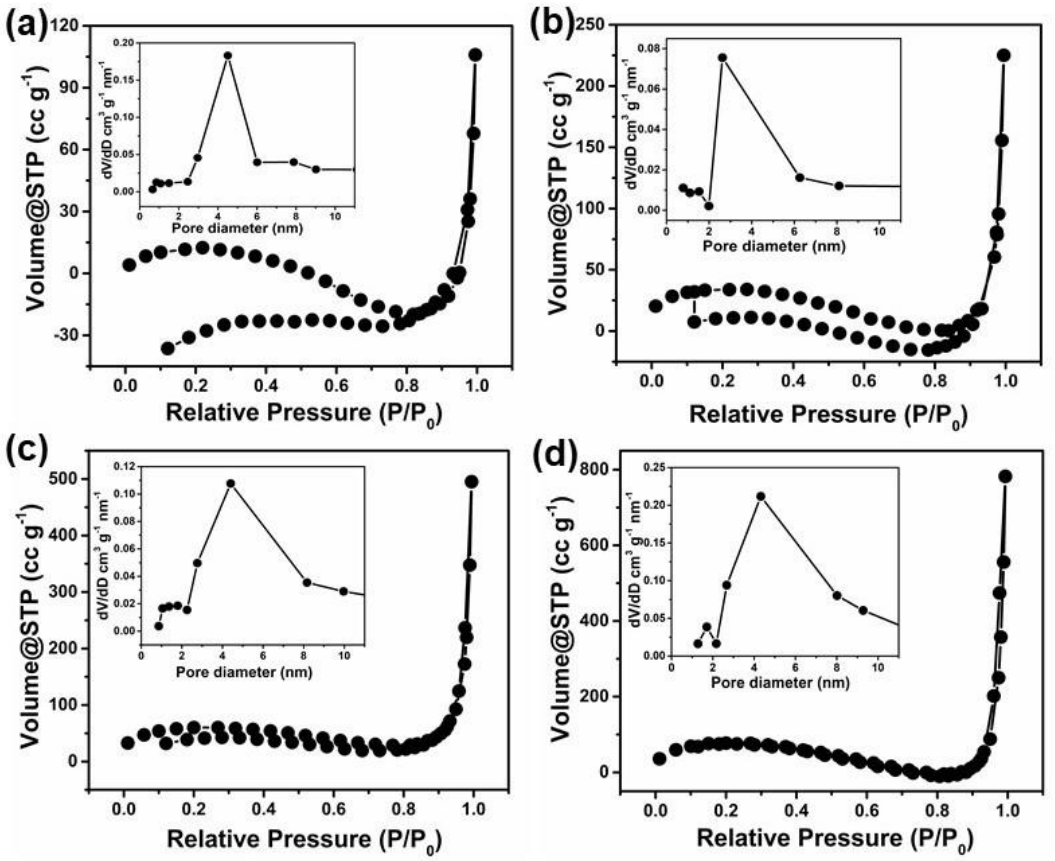

Figure S1: N_2 sorption isotherms (inset: pore size distribution) of $Ni_xCu_{1-x}Fe_2O_4$ **(a)** NCF-1, **(b)** NCF-2, **(c)** NCF-3 and **(d)** NCF-4.

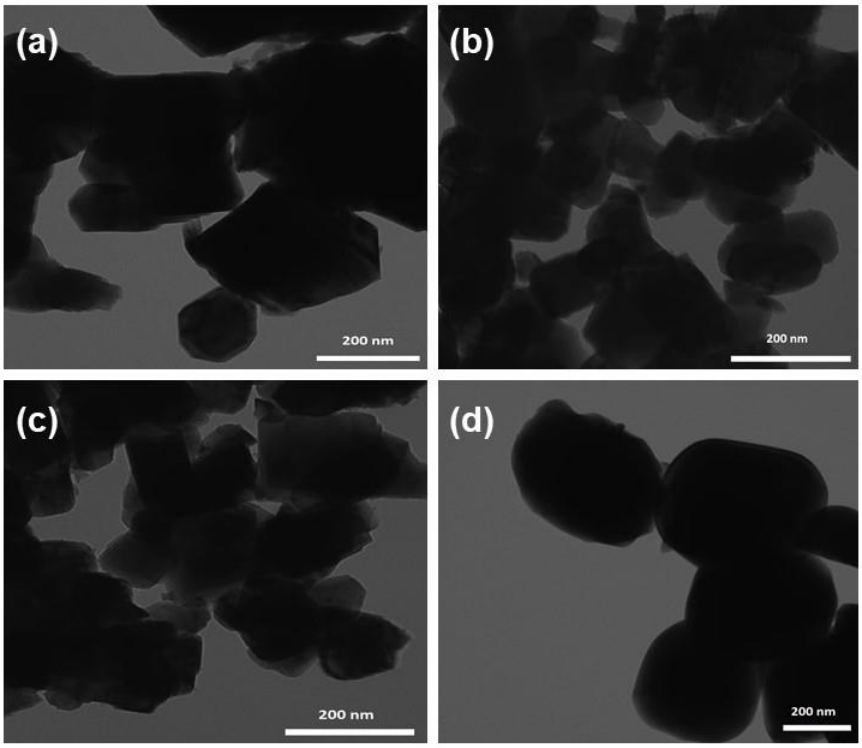

Figure S2.TEM images of $Ni_xCu_{1-x}Fe_2O_4$ **(a)** NCF-1, **(b)** NCF-2, **(c)** NCF-3 and **(d)** NCF-4.

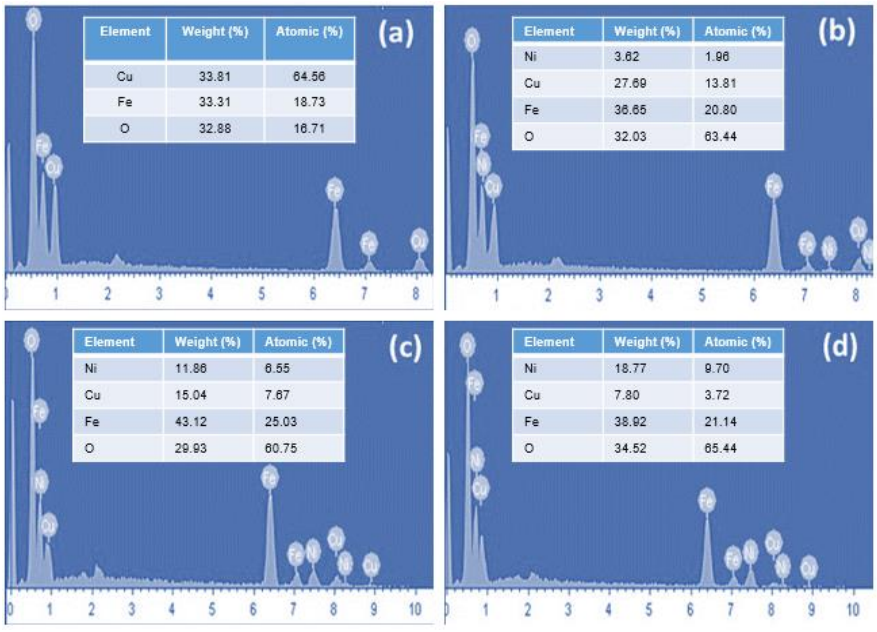

Figure S3. EDS analysis of $Ni_xCu_{1-x}Fe_2O_4$ **(a)** NCF-1, **(b)** NCF-2, **(c)** NCF-3 and **(d)** NCF-4.

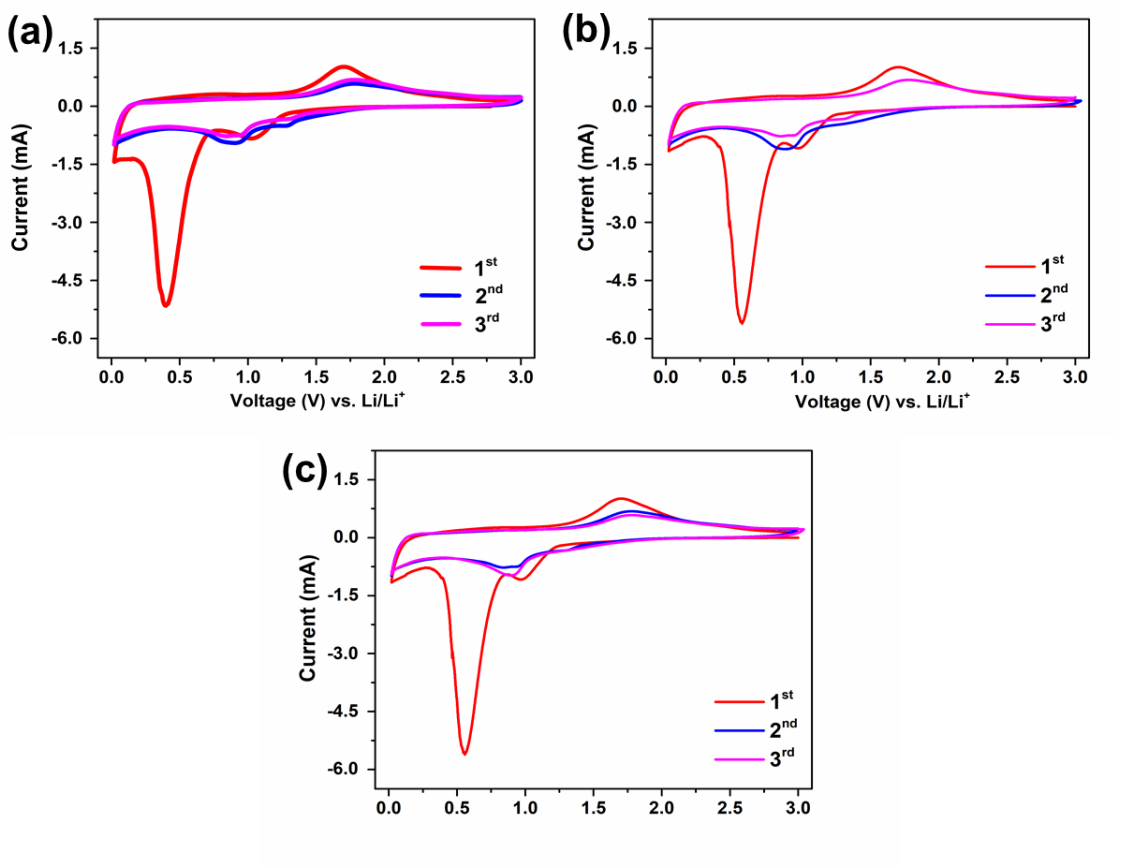

Figure S4: CV curves of $Ni_xCu_{1-x}Fe_2O_4$ **(a)** NCF-1, **(b)** NCF-2 and **(c)** NCF-3.

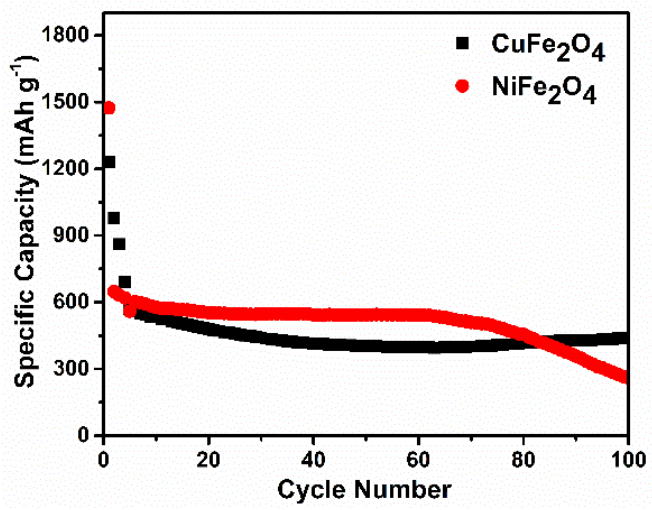

Figure S5: Cycling performance of $CuFe_2O_4$ and $NiFe_2O_4$.

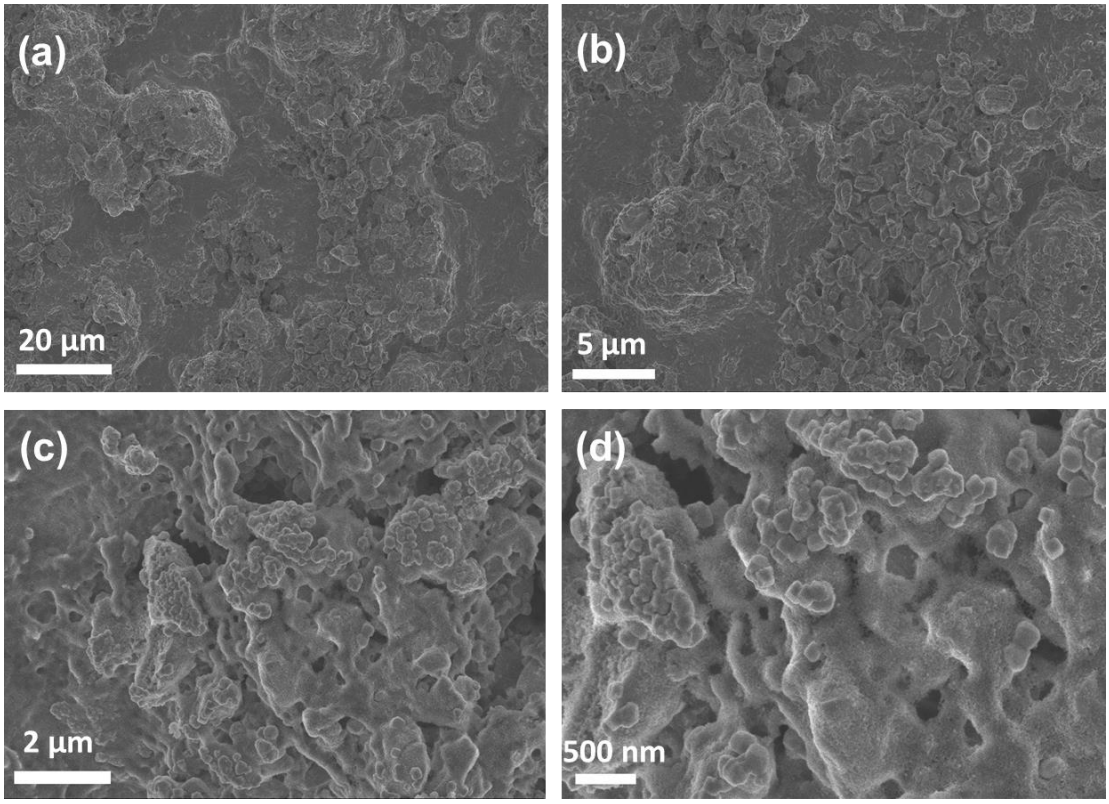

Figure S6: SEM images of the cycled electrode of $Ni_xCu_{1-x}Fe_2O_4$.

Table.S1: Crystalline size, lattice constant, X-ray density, volume, hopping length d_B and d_A for pure $Ni_xCu_{1-x}Fe_2O_4$.

Samples	**Crystallite size (nm)**	**Lattice constant (Å)**	**X-ray density (g/cm^3)**	**Volume (m^3)**	**d_B (nm)**	**d_A (nm)**
NCF-1	46.68	8.353	5.455	582.81	0.295	0.362
NCF-2	41.59	8.338	5.473	579.68	0.295	0.361
NCF-3	30.5	8.367	5.394	585.75	0.296	0.362
NCF-4	28.55	8.343	5.419	580.72	0.295	0.361

Table S2. Parameters of EIS equivalent circuit of $Ni_xCu_{1-x}Fe_2O_4$ anode at a potential of 1.0 V.

Parameters	Rs	Rct	CPE_{dl}	W	T
NCF-1	1.71	409	17.0	7.70	13.1
NCF-2	3.55	186	16.5	13.3	31.9
NCF-3	3.15	137	28.8	17.3	56.4
NCF-4	4.60	129	20.2	15.1	17.3

Table S3. Comparison of various anode materials in terms of their preparations and electrochemical performances.

Anode	Preparation techniques	Cycling Stability				Ref
		Initial Discharge capacity [mAh g^{-1}]	Capacity after n^{th} cycles	Cycle Numbers	Current rate [mA g^{-1}]	
$NiFe_2O_4$	electrospinning	1450	550	50	100	1
$NiFe_2O_4$	Hydrothermal	1148	501	25	183	2
$NiFe_2O_4$	Arc-discharge	1198	200	100	91.5	3
$NiFe_2O_4$	Hydrothermal	1209	257	50	100	4
$NiFe_2O_4$	Sol-gel	1401	600	80	1000	5
$CuFe_2O_4$	electrospinning	1399	489	50	200	6
$CuFe_2O_4$	polymer-pyrolysis	1375	551	100	112	7
$NiFe_2O_4$	Hydrothermal	1239	470	20	100	8
Transition metal ferrite	Electrodeposition	452	339	100	100	9
$CuFe_2O_4$	Hydrothermal	1571	117	100	141	10
$Ni_xCu_{1-x}Fe_2O_4$	Co-precipitation	1646	677	250	200	Our Work

References:

1. Cherian C T, Sundaramurthy J, Reddy M V, Kumar P S, Mani K, Pliszka D, Sow C H, Ramakrishna S and Chowdari B V R, Morphologically robust $NiFe_2O_4$ nanofibers as high capacity Li-ion battery anode material, *ACS Appl. Mater. Interfaces*, 2013, **5**, 9957.
2. Mujahid M, Khan R U, Mumtaz M, Mubasher, Soomro S A, Ullah S, $NiFe_2O_4$ nanoparticles/MWCNTs nanohybrid as anode material for lithium-ion battery, *Ceram, Intl*., 2019, **45**, 8486.
3. Han D, Song G, Liu B and Yan H, Core-shell-structured nickel ferrite/onion-like carbon nanocapsules: an anode material with enhanced electrochemical performance for lithium-ion batteries, *RSC Adv*., 2015, **5**, 42875.
4. Liu L, Sun L, Liu J, Xiao X, Hu Z, Cao X, Wang B and Liu X, Enhancing the electrochemical properties of $NiFe_2O_4$ anode for lithium ion battery through a simple hydrogenation modification, *Intl. J. Hydrogen Energy*, 2014, **39**, 11258.
5. Wang N, Xu H, Chen L, Gu X, Yang J, Qian Y, A general approach for MFe_2O_4 (M ¼ Zn, Co, Ni) nanorods and their high performance as anode materials for lithium ion batteries, *J. Power Sources*, 2014, **247**, 163.
6. Penga S, Lia L, Srinivasan M, Electrospun $CuFe_2O_4$ nanotubes as anodes for high-performance lithium-ion batteries, *J. Energy Chemistry*, 2014, **23**, 301.
7. Ding Y, Yang Y and Shao H, Synthesis and characterization of nanostructured $CuFe_2O_4$ anode material for lithium ion battery, *Solid State Ionics*, 2012, 217 27.
8. Li X D, Yang W S, Li F, Evans D G, Duan X, Stoichiometric synthesis of pure $NiFe_2O_4$ spinel from layered double hydroxide precursors for use as the anode material in lithium-ion batteries, *J. Physics Chem. Solids*, 2006, 67, 1286.
9. NuLi Y N, Qin Q Z, Nanocrystalline transition metal ferrite thin films prepared by an electrochemical route for Li-ion batteries, *J. Power Sources*, 2005, **142**, 292.
10. Dong Y, Cao C, Chui Y S and Zapien J A, Facile hydrothermal synthesis of $CuFeO_2$ hexagonal platelets/rings and graphene composites as anode materials for lithium ion batteries, *Chem. Commun.*, 2014, **50**, 10151.