Supporting Information

Hydrous Nickel Sulphide Nanoparticles Decorated 3D Graphene Foam

Electrodes for Enhanced Supercapacitive Performance of Asymmetric Device

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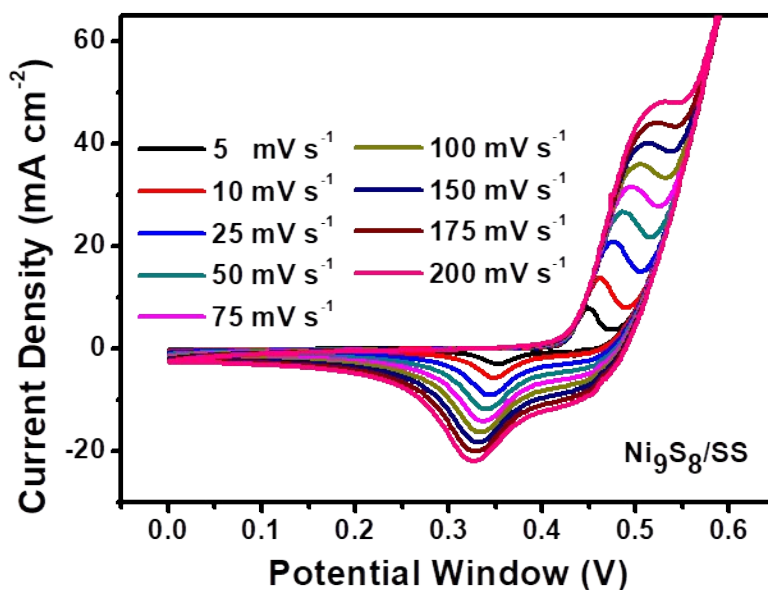

Fig (S1): Cyclic voltammetry (CV) of Ni_9S_8 nanoparticles on stainless steel (SS) at various scan
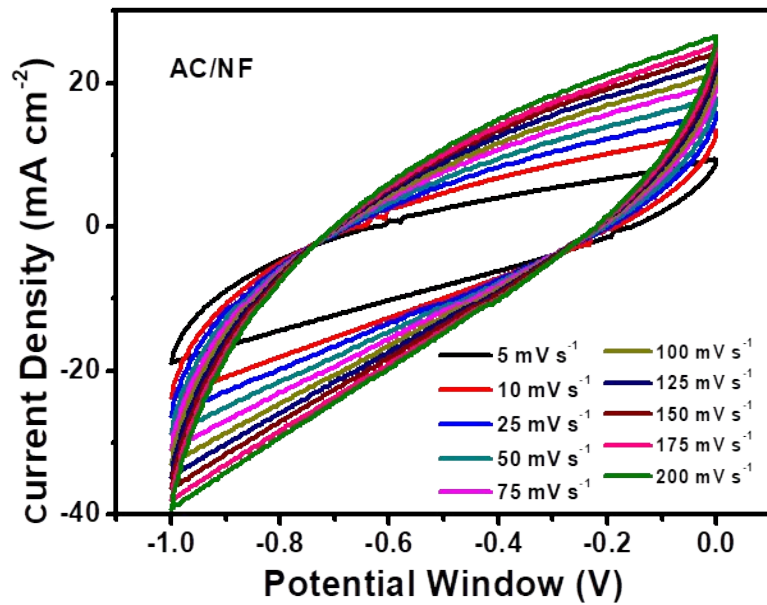
rates (5 to 200 mVs^{-1})

Fig (S2): cyclic voltammetry of activated carbon (AC) on nickel foam (NF) at various scan rates (5 to 200 mVs^{-1})

Table (1): Summary of capacitive performances for Ni_9S_8 composites in supercapacitor.

Sr. No.	Material and Nano-structure	Method for deposition	Capacitance &current density	Energy density	Power density	Cycles	Stability (%)	Ref.
1.	NiS (Microflowers)	Hydrothermal	1122.7 Fg^{-1} at 1 Ag^{-1}	31 Wh Kg^{-1}	0.9 kW kg^{-1}	1000	97.8	1
2.	NiS (Nanoframes)	Heating treatment	2112 Fg^{-1} at 1 Ag^{-1}	--	--	4000	91.8	2
3.	NiS/CR's (Nanoparticles)	Solvothermal	1092 Fg^{-1} at 1 Ag^{-1}	--	--	2000	100	3
4.	NiS/GO (Nanoparticles)	Hydrothermal	800 Fg^{-1} at 1 Ag^{-1}	111.1 Wh Kg^{-1}	499.5 W kg^{-1}	1000	--	4
5.	rGO/Ni$_3$S$_2$ (Nanoparticles)	Spray technique	1424 Fg^{-1} at 0.75 Ag^{-1}	--	--	3000	67.5	5
6.	NiS/GNS/ CNT (Nanotubes)	Hydrothermal	2377 Fg^{-1} at 2 mVs^{-1}	14 Wh kg^{-1}	16 kWh kg^{-1}	1000	32	6
7.	NiS/rGO (Nanoflakes)	hydrothermal	1312 Fg^{-1} at 5 mVs^{-1}	17.01 Wh kg^{-1}	2285.36 W kg^{-1}	500	86	7
8.	NiS (Nanoflames)	CBD	750 Fg^{-1} at 5 mVs^{-1}	28 Wh kg^{-1}	4.98 kW kg^{-1}	3000	85.3	8
9.	NiS/G (Nanoflakes)	hydrothermal	187.53 Fg^{-1} at 10 mVs^{-1}	--	--	1000	--	9
10.	NiS (Nanoparticles)	Microwave assisted method	845 Fg^{-1} at 1 Ag^{-1}	--	--	1000	81.6	10
11.	NiS/rGO (Nanoparticles)	Hydrothermal	852 Fg^{-1} at 2 Ag^{-1}	--	--	1000	82	11
12.	Ni$_3$S$_2$ (Nanoflakes)	Potentio-dynamic deposition	664 Fg^{-1} at 4 Ag^{-1}	--	--	1000	91	12
13.	NiS/rGO (Nanospheres)	Hydrothermal	1169 Fg^{-1} at % Ag^{-1}	--	--	1000	77.9	13
14.	Ni$_3$S$_2$ (Nanoarray)	Hydrothermal	694 Fg^{-1} at 3.45 Ag^{-1}	1.96 mWhcm^{-3}	0.6 w cm^{-3}	5000	89.3	14
15.	NiS/rGO (Nanorods)	Hydrothermal	579 Fg^{-1} at 5 Ag^{-1}	--	--	2000	90.90	15
16.	Ni$_3$S$_2$-NiS (Nanowires)	Hydrothermal	1077.3 Fg^{-1} at 5 Ag^{-1}	--	--	10000	76.3	16
17.	Ni$_3$S$_2$/CNT (Nanosheets)	CVD	514 Fg^{-1} at 4 Ag^{-1}	--	--	1500	88	17
18.	V$_2$O$_5$ (Flakes)	CBD	735 F g^{-1} at 1 mV s^{-1}	--	--	1000	71	18

Sr. No.	Material	Method for deposition	Capacitance &current density	Energy density	Power density	Cycles	Stability %	Ref.
19.	V_2O_5/MWCNTs (Flakes)	CBD	629 F g^{-1} at 2 A g^{-1}	--	--	4000	93	19
20.	Fe_2O_3/ MWCNTs (Nanoparticles)	SILAR	431 F g^{-1} at 5 mV s^{-1}	38.89 Wh kg^{-1}	800 W kg^{-1}	500	65	20
21.	**Ni_9S_8/GF (Nanoparticles)**	**CBD**	**2055 Fg^{-1} at 2 Ag^{-1}**	**45.66 Wh Kg^{-1}**	**407 W kg^{-1}**	**--**	**--**	**Present work**

Table (2): Summary for Ni_9S_8 and asymmetric device performance in supercapacitor.

Sr. No.	Material	Method for deposition	Capacitance &current density	Energy density	Power density	Cycles	Stability %	Ref.
1.	NiS//AC	Hydrothermal	69.1 Fg^{-1} at 1 Ag^{-1}	31 Wh Kg^{-1}	0.9 kW kg^{-1}	1000	48.8	1
2.	NiS/GNS/CNT//AC	Hydrothermal	--	14 Wh kg^{-1}	16 kWh kg^{-1}	1000	--	6
3.	NiS/rGO//ZIF-8 derived carbon	Hydrothermal	47.85 Fg^{-1} at 2 Ag^{-1}	17.01 Wh kg^{-1}	10 kW kg^{-1}	--	78.91	7
4.	NiS//NiS	CBD	104 Fg^{-1} at 5 mVs^{-1}	28 Wh kg^{-1}	4.98 kW kg^{-1}	3000	85.3	8
5.	NiS/rGO//AC	Hydrothermal	79.7 Fg^{-1} at 0.2 Ag^{-1}	18.7 Wh kg^{-1}	124 W kg^{-1}	1000	--	11
6.	V_2O_5 //V_2O_5	CBD	358 F g^{-1} at 1 mV s^{-1}	43 Wh kg-1	900 W kg-1	1000	88	18
7.	V_2O_5/MWCNT// V_2O_5/MWCNT	CBD	160 F g^{-1} at 1 A g^{-1}	72.07 Wh kg^{-1}	2.3 kW kg^{-1}	4000	96	19
8.	PG-MSCs (Nanosheets)	Filtration	9.8 mF cm^{-2} at 5 mV s^{-1}	11.6 mWh cm^{-3}	--	2000	89.5	21
9.	$Ti_3C_2T_x$ MXene (Nanosheet)	Vacuum-assistant filtration	126 F g^{-1} at100 A g^{-1}	--	--	100,000	92.4	22
10.	NixSy/rGO//G	Hydrothermal	--	46 Wh kg^{-1}	1.8 kW kg^{-1}	5000	80	23
11.	**Ni_9S_8/GF//AC/NF**	**CBD**	**143.7 at 3.0 A g^{-1}**	**51.11 Wh Kg^{-1}**	**2.66 kW kg^{-1}**	**--**	**--**	**Present work**

Reference:

1) B. Guan, Y. Li, B. Yin, K. Liu, D. Wang, H. Zhang, C. Cheng, Chem. Eng. J., 2017, **308**, 1165-1173.

2) X. Y. Yu, L. Yu, H. B. Wu, X. W. (David) Lou, Angew. Chem., 2015, **127**, 1-6.

3) C. Sun, M. Ma, J. Yang, Y. Zhang, P. Chen, W. Huang, X. Dong, Sci. Rep., 2014, **4**, 1-6.

4) A. Wang, H. Wang, S. Zhang, C. Mao, J. Song, H. Niu, B. Jin, Y. Tian, Appl. Surf. Sci., 2013, **282**, 704-708.

5) H. Zhang, X. Yu, D. Guo, B. Qu, M. Zhang, Q. Li, T. Wang, ACS Appl. Mater. Interfaces, 2013, **5**, 7335-7340.

6) H. Chen, J. Li, C. Long, T. Wei, G. Ning, J. Yan, Z. Fan, J. Marine Sci. Appl., 2014**, 13**, 462-466.

7) P. R. Jothi, R. R. Salunkhe, M. Pramanik, S. Kannan, Y. Yamauchi, RSC Adv., 2016, **6**, 21246-21253.

8) A. M. Patil, V. C. Lokhande, A. C. Lokhande, N. R. Chodankar, T. Ji, J. H. Kim, C. D. Lokhande, RSC Adv., 2016, **6**, 68388-68401.

9) C. A. Pandey, S. Ravuri, R. Ramachandran, R. Santhosh, S. Ghosh, S. R. Sitaraman, A. N. Grace, Int. J. Nanosci., 2017**, 16**, 1-7.

10) L. Peng, X. Ji, H. Wan, Y. Ruan, K. Xu, C. Chen, L. Miao, J. Jiang, Electrochim. Acta, 2015**, 182**, 361–367.

11) F. Cai, R. Sun, Y. Kang, H. Chen, M. Chen, Q. Li, RSC Adv., 2015, **5**, 23073-23079.

12) S. W. Chou, J. Y. Lin, J. Electrochem. Soc., 2013, **160**, D178-D182.

13) Z. Xing, Q. Chu, X. Ren, J. Tian , A. M. Asiri, K. A. Alamry, A. O. Al-Youbi, X. Sun, Electrochem. Commun., 2013**, 32**, 9-13.

14) X. Xiong, B. Zhao, D. Ding, D. Chen, C. Yang, Y. Lei, M. Liu, NPG Asia Mater., 2016**, 8**, 1-7.

15) J. Yang, X. Duan, W. Guo, D. Li, H. Zhang, W. Zhengn, Nano Energy, 2014**, 5**, 74-81.

16) X. Zang, Z. Dai, J. Yang, Y. Z. Zhang, W. Huang, X. C. Dong, ACS Appl. Mater. Interfaces, 2016**, 8**, 24645-24651.

17) T. Zhu , H. B. Wu , Y. Wang , R. Xu, X. W. (David) Lou, Adv. Energy Mater., 2012, **2**, 1497-1502.

18) B. Pandit, D. P. Dubal, B. R. Sankapal, Electrochim. Acta, 2017, **242**, 382-389.

19) B. Pandit, D. P. Dubal, P. G. Romero, B. B. Kale, B. R. Sankapal, Sci. Rep., 2017, **7**, 1-12.

20) S. S. Raut, B. R. Sankapal, New J. Chem., 2016, **40**, 2619-2627.

21) H. Xiao, Z. S. Wu, L. Chen, F. Zhou, S. Zheng, W. Ren, H. M. Cheng, X. Bao, ACS Nano, 2017, **11**, 7284-7292.

22) L. Yu, L. Hu, B. Anasori, Y. T. Liu, Q. Zhu, P. Zhang, Y. Gogotsi, B. Xu, ACS Energy Lett., 2018, **3**, 1597-1603.

23) S. Dai, B. Zhao, C. Qu, D. Chen, D. Dang, B. Song, B. M. deGlee, J. Fu, C. Hu, C. P. Wong, M. Liu, Nano Energy, 2017, **33**, 522-531.