Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information

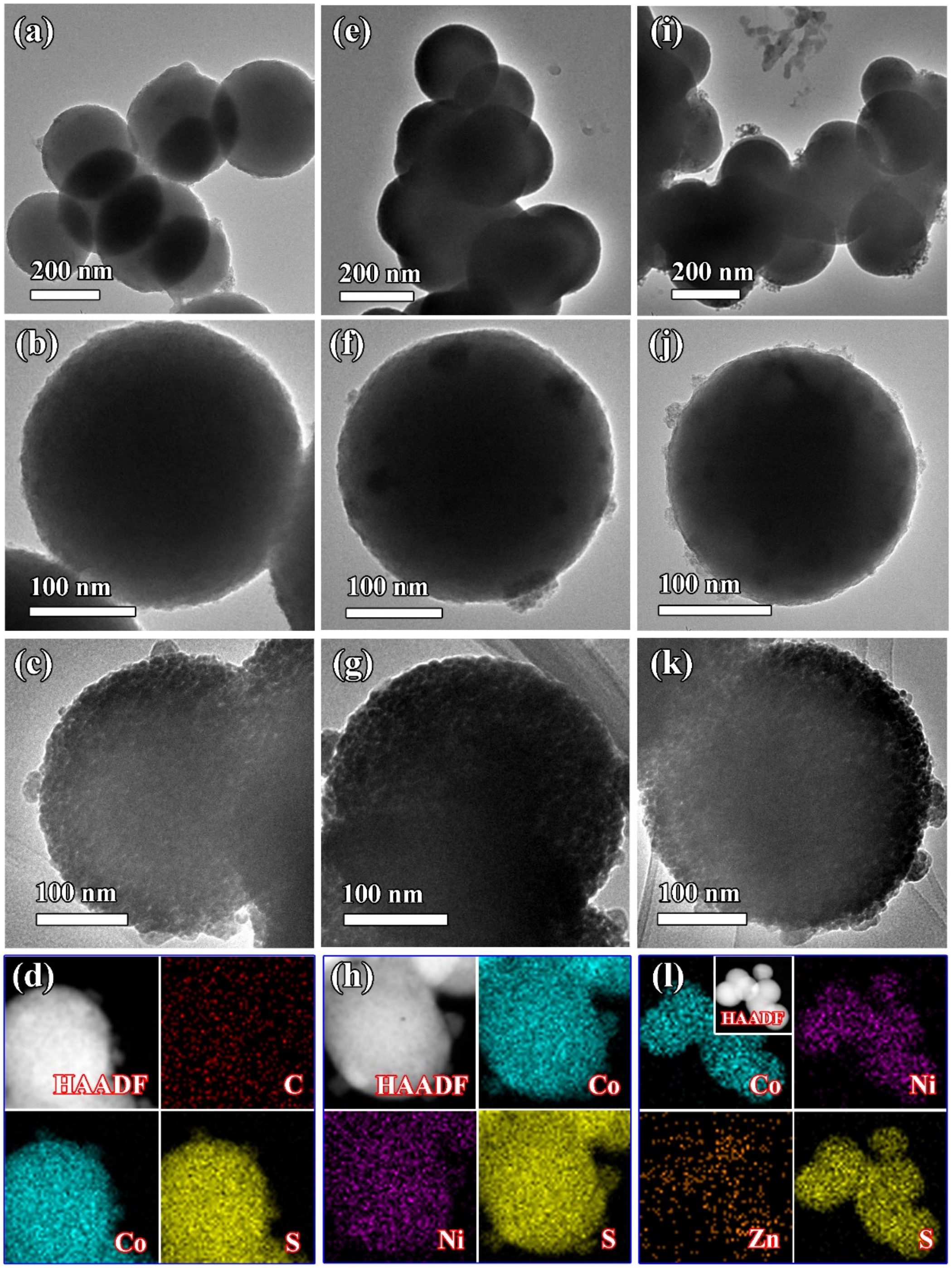


Figure S1 TEM images and corresponding STEM/EDS mapping of (a, b, c, d) CoS_2@C, (e, f, g, h) Ni-CoS_2@C, and (i, j, k) Zn-CoS_2@C spheres. (c, g, k) are TEM images of annealed samples, (l) represent STEM/EDS elemental mapping of Ni/Zn-CoS_2@C spheres confirming low concentration of elemental Zn.

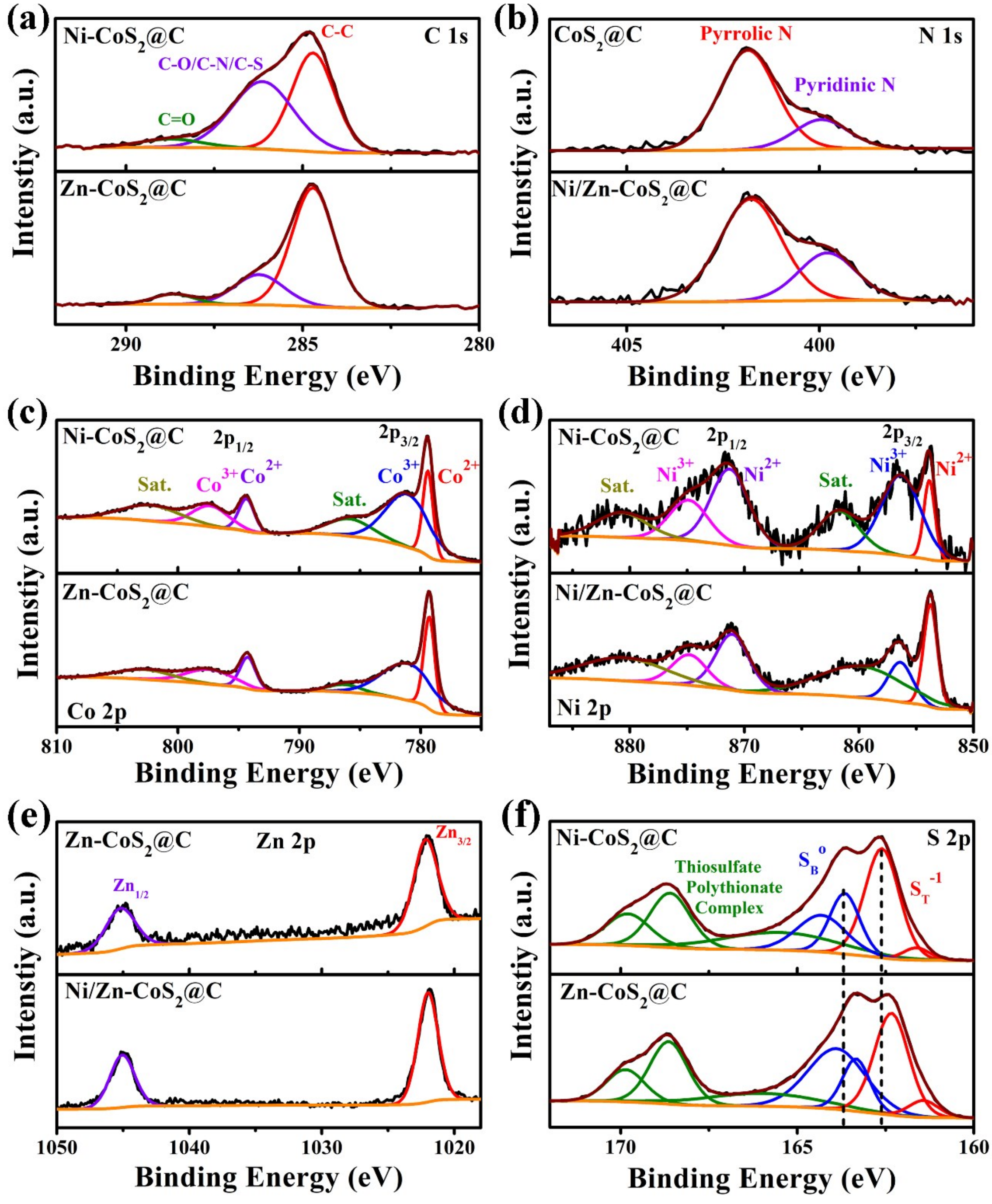


Figure S2 High-resolution XPS spectra of C 1s (a), N 1s (b), Co 2p (c), Ni 2p (d), Zn 2p (e), and S 2p (f) for CoS_2@C, Ni-CoS_2@C, Zn-CoS_2@C, and Ni/Zn-CoS_2@C spheres.

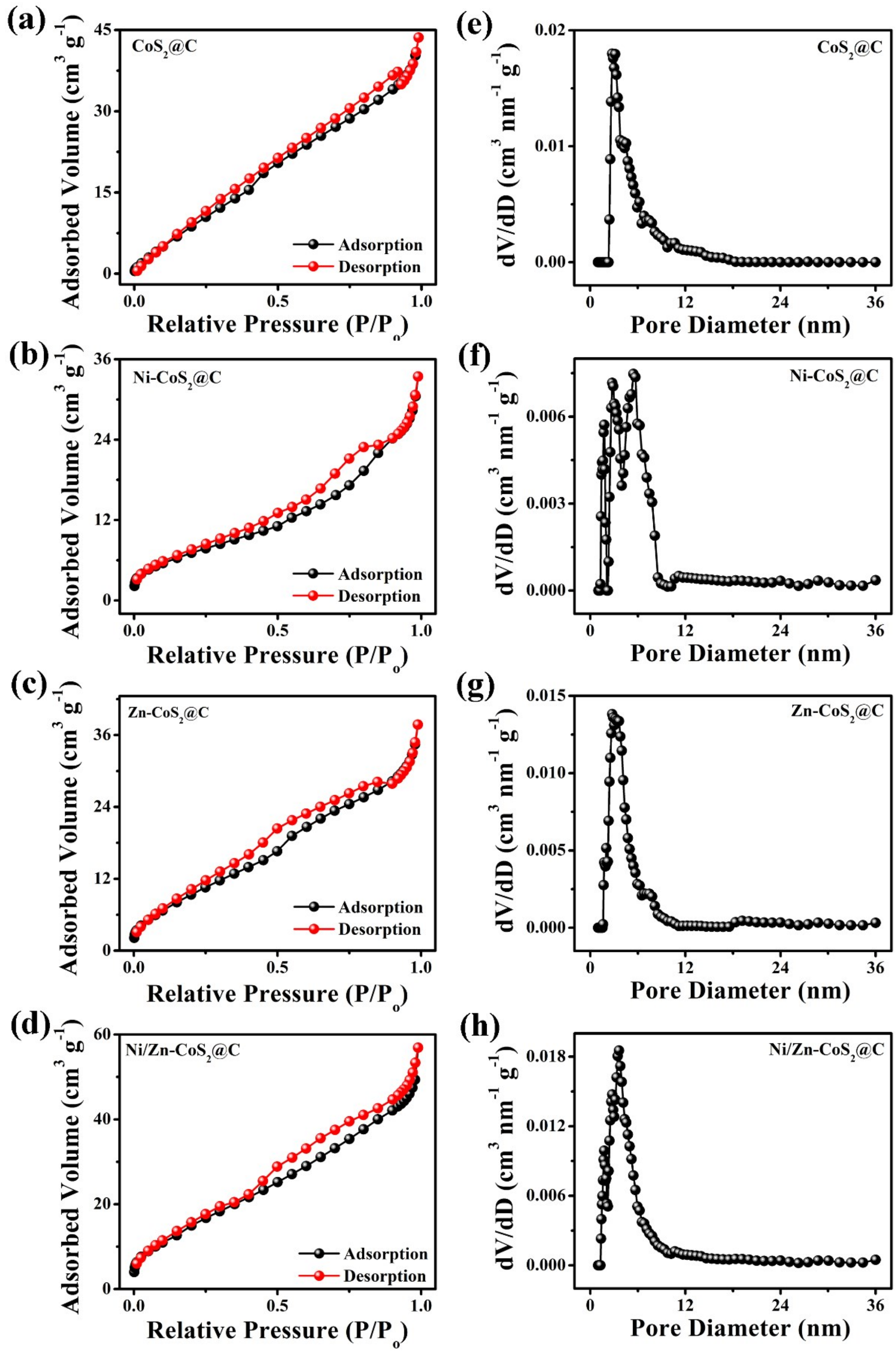


Figure S3 BET nitrogen adsorption-desorption isotherm plots (a, b, c, d) and corresponding pore size distribution (e, f, g, h) of CoS_2@C, Ni-CoS_2@C, Zn-CoS_2@C, and Ni/Zn-CoS_2@C spheres, respectively.

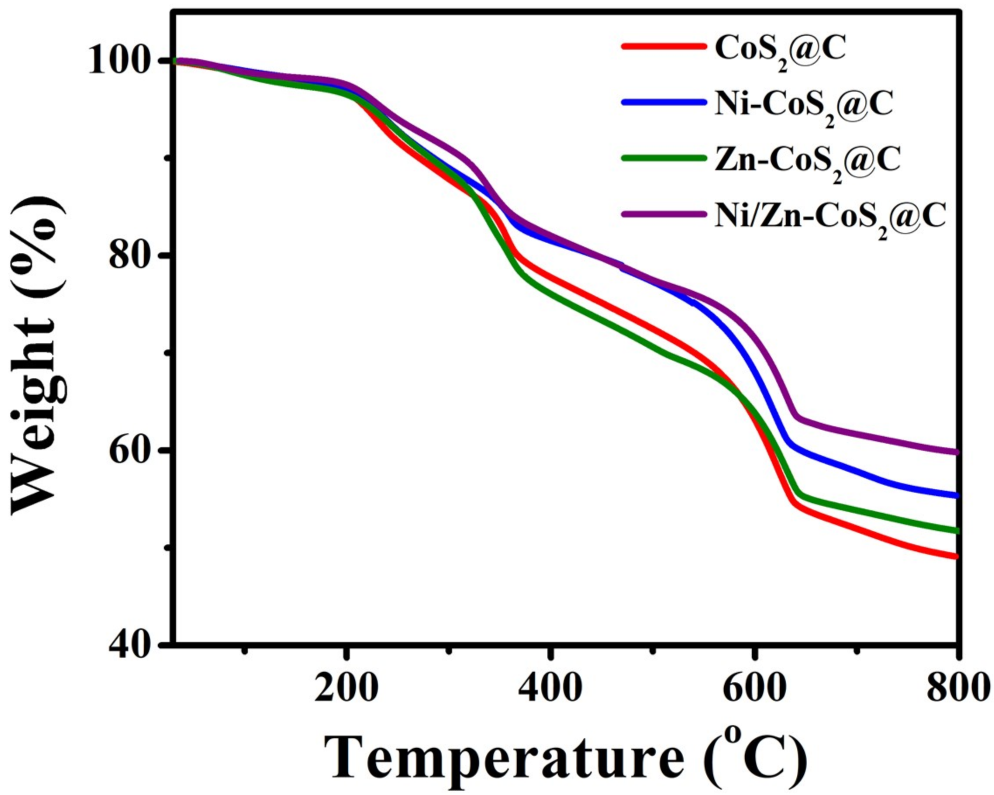
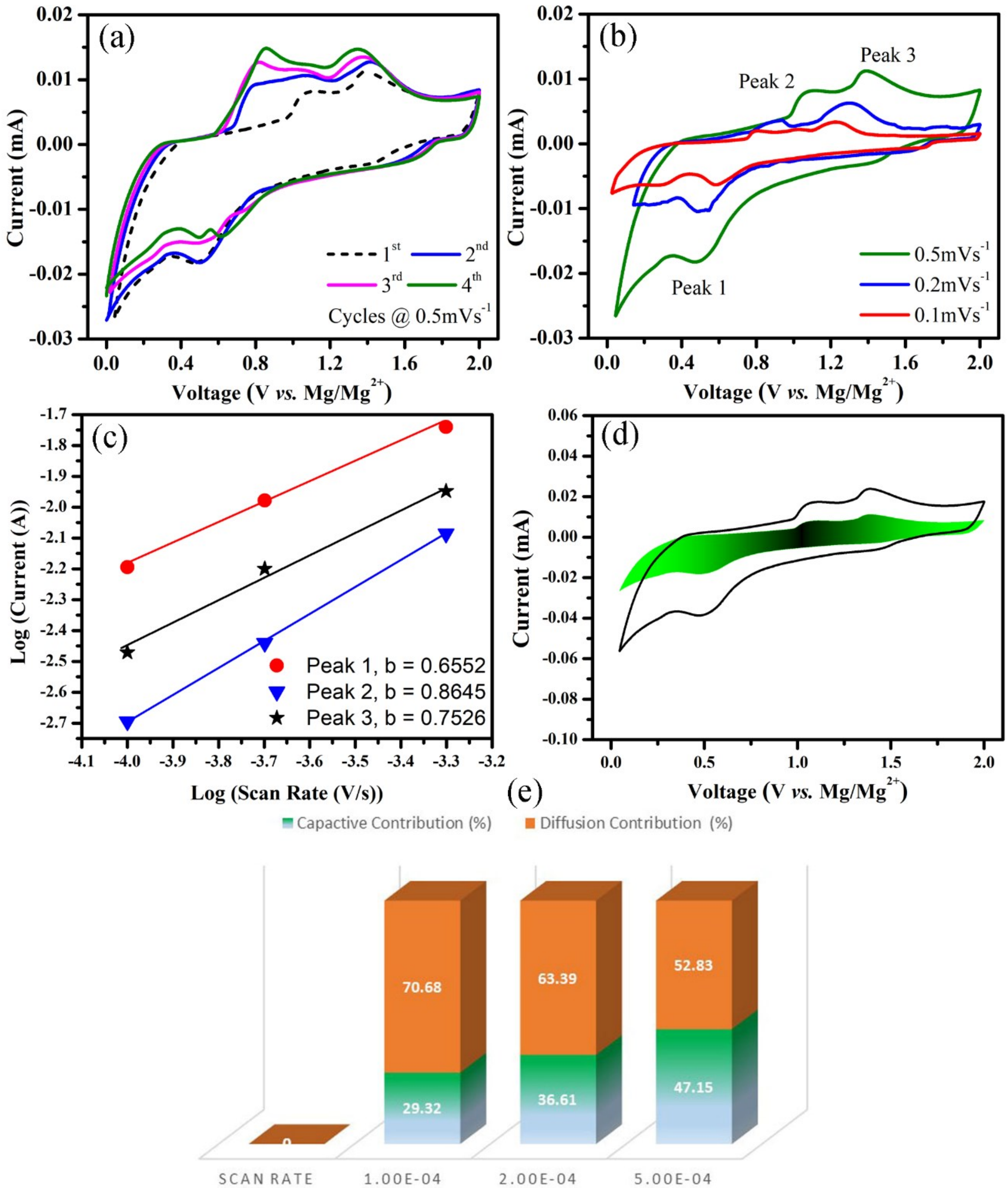


Figure S4 TGA analysis: TGA plot of percentage weight loss with rise in temperature, for CoS_2@C, Ni-CoS_2@C, Zn-CoS_2@C, and Ni/Zn-CoS_2@C spheres.



(d) at 0.5mV.s^{-1},

Figure S5 Cyclic voltammetry of Zn/Ni-CoS_2@C‖APC ‖Mg at (a) 0.5 mVs^{-1}, (b) 0.1, 0.2, and 0.5 mVs^{-1}; (c) *b*-value analysis from plot of Log (current) *vs.* Log (Scan rate); (d) capacitive (shaded area) current contribution to total charge storage at 0.5 mV.s^{-1}, and (e) capacitive and diffusion contribution ratios at different scan rates.

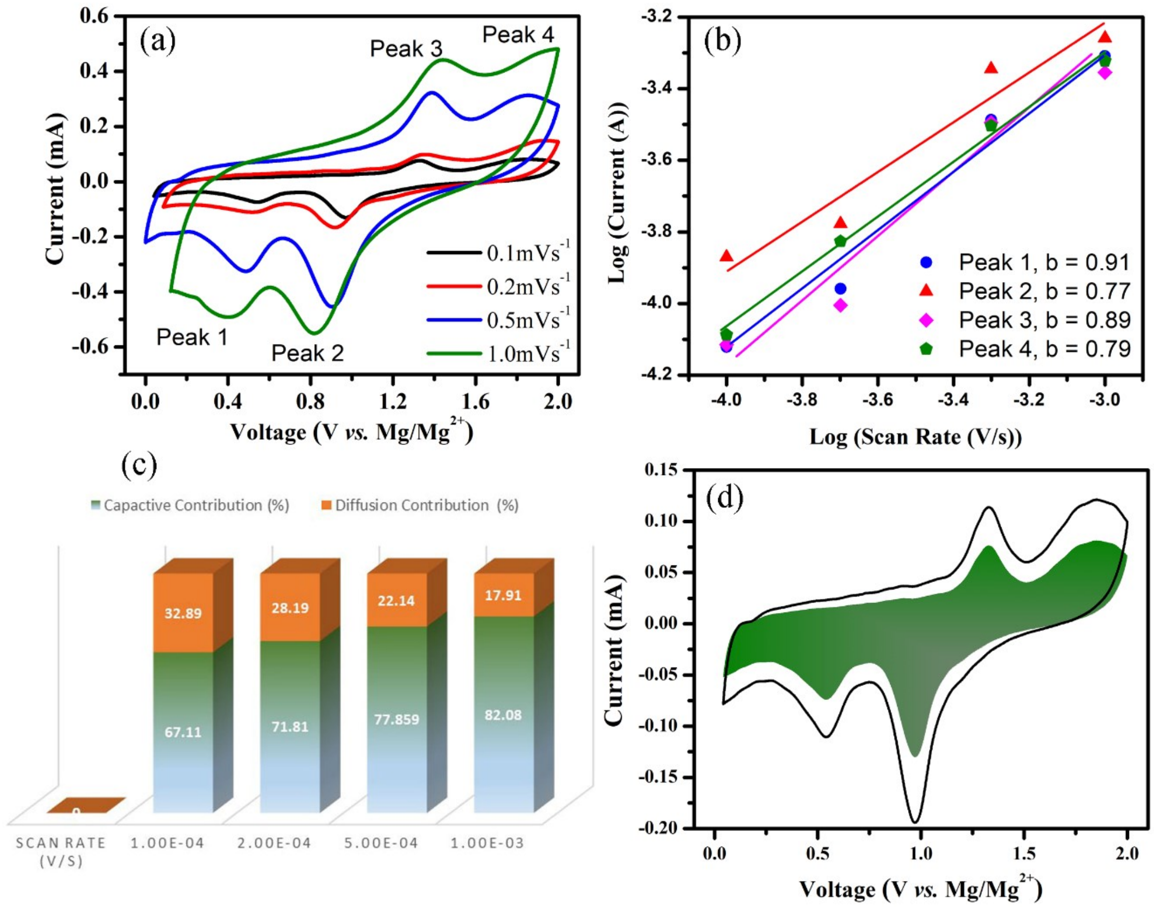


Figure S6 (a) Cyclic voltammetry of Zn/Ni-CoS_2@C‖APC-LiCl‖Mg hybrid cell at 0.1, 0.2, 0.5, and 1.0 mVs^{-1}; (b) *b*-value analysis from plot of Log (current) *vs.* Log (Scan rate); (c) capacitive and diffusion contribution ratios at different scan rates (d) capacitive (shaded area) current contribution to total charge storage at 0.1 $mV.s^{-1}$.

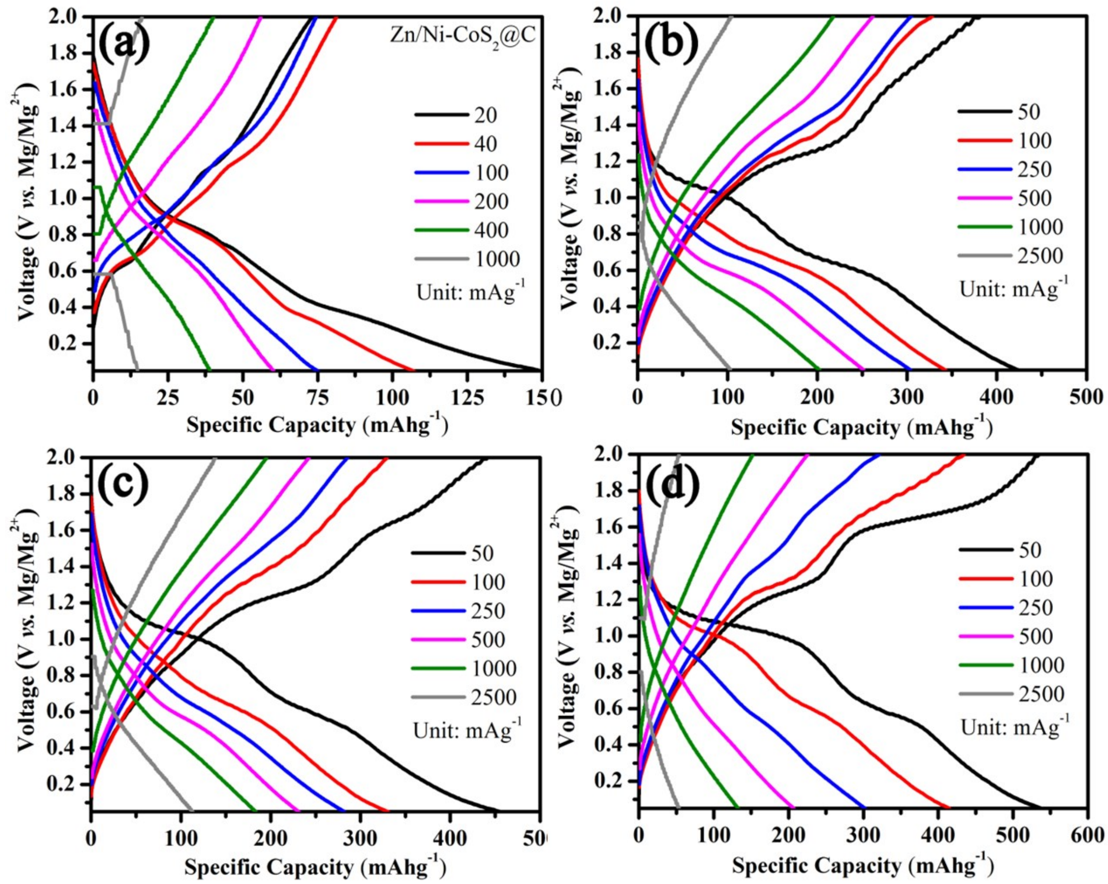


Figure S7 Galvanostatic charging-discharging profiles of (a) Zn/Ni-CoS$_2$@C based MIB; (b) CoS$_2$@C, (c) Ni-CoS$_2$@C, (d) Zn -CoS$_2$@C based MLIB at different current densities.

Table S1 Comparison of present work (MLIBs) with conventional LIBs reported in literature.

Cathodes	**Maximum Capacity ($mA\ g^{-1}$) [Current Density ($mA\ g^{-1}$)]**	**Capacity Retention (%) [Number of Cycles]**	**Reference**
CoS_2-CNTs	805 [100]	56 [50]	[1]
CoS_2-rGO	678 [100]	50 [100]	[1]
CoS_2-fCNTs	801 [50]	99 [200]	[2]
CoS_2	498 [50]	20 [200]	[2]
S/CoS_2-NC	950 [100]	75 [250]	[3]
CoS_2	450 [100]	25 [100]	[4]
CoS_2-CNTs	602 [100]	65 [100]	[4]
CoS_2-GNs	825 [100]	77 [100]	[4]
CoS_2@C	750 [500]	71 [200]	[5]
CoS_2-Carbon	815 [100]	63 [120]	[6]
CoS_2	698 [100]	21 [80]	[7]
$Co_{1-x}S$@C@rGO	601 [100]	99 [500]	[8]
MnS/Co_{1-x} S@C	700 [100]	99 [500]	[8]
C@Co_9S_8	647 [200]	55 [50]	[9]
CoS_2 PH	725 [100]	N.A	[10]
CoS PH	590 [100]	N.A	[10]
CoS-rGO	789 [62.5]	72 [100]	[11]
CoS_2/CNTs/graphene	604 [100]	67 [100]	[12]
CoS_2	325 [100]	12 [100]	[12]
CoS_2/RGO	788 [100]	87 [50]	[13]
Zn/Ni-CoS_2@C	**667 [50]**	**73 [100]**	**Present Work**

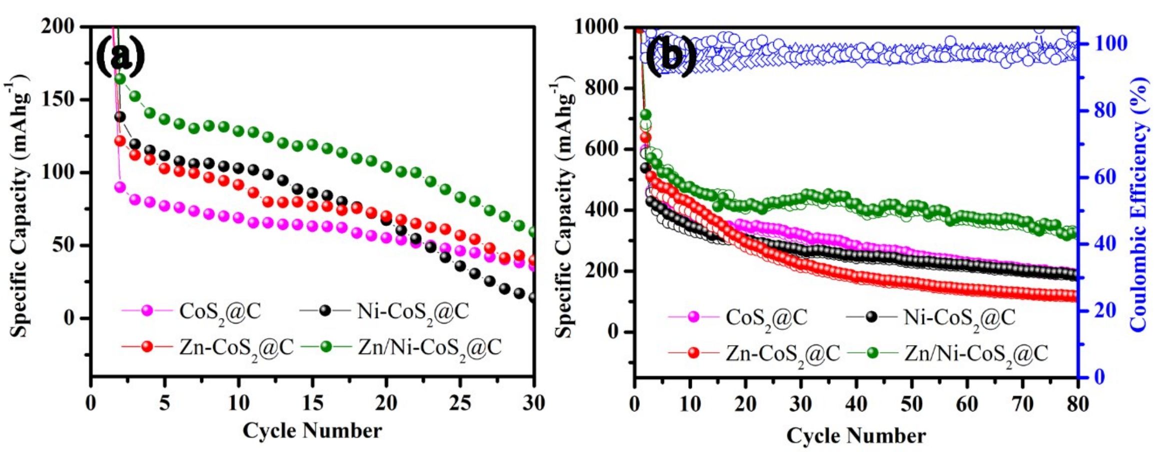


Figure S8 Cycle stabilities of (a) MIBs at 20 mA g^{-1} and (b) MLIBs at 100 mA g^{-1}.

Table S2 Atomic percentage of different elements in charged (2V), discharged (0.0V), and blank electrodes.

Electrode Status	Elements				
	Co (%)	**S (%)**	**Zn (%)**	**Ni (%)**	**Mg (%)**
Blank	3.81	10.08	0.84	1.01	0.00
D 0.0V	2.60	2.83	0.65	0.70	5.91
C 2.0V	3.04	4.80	0.53	0.79	1.37

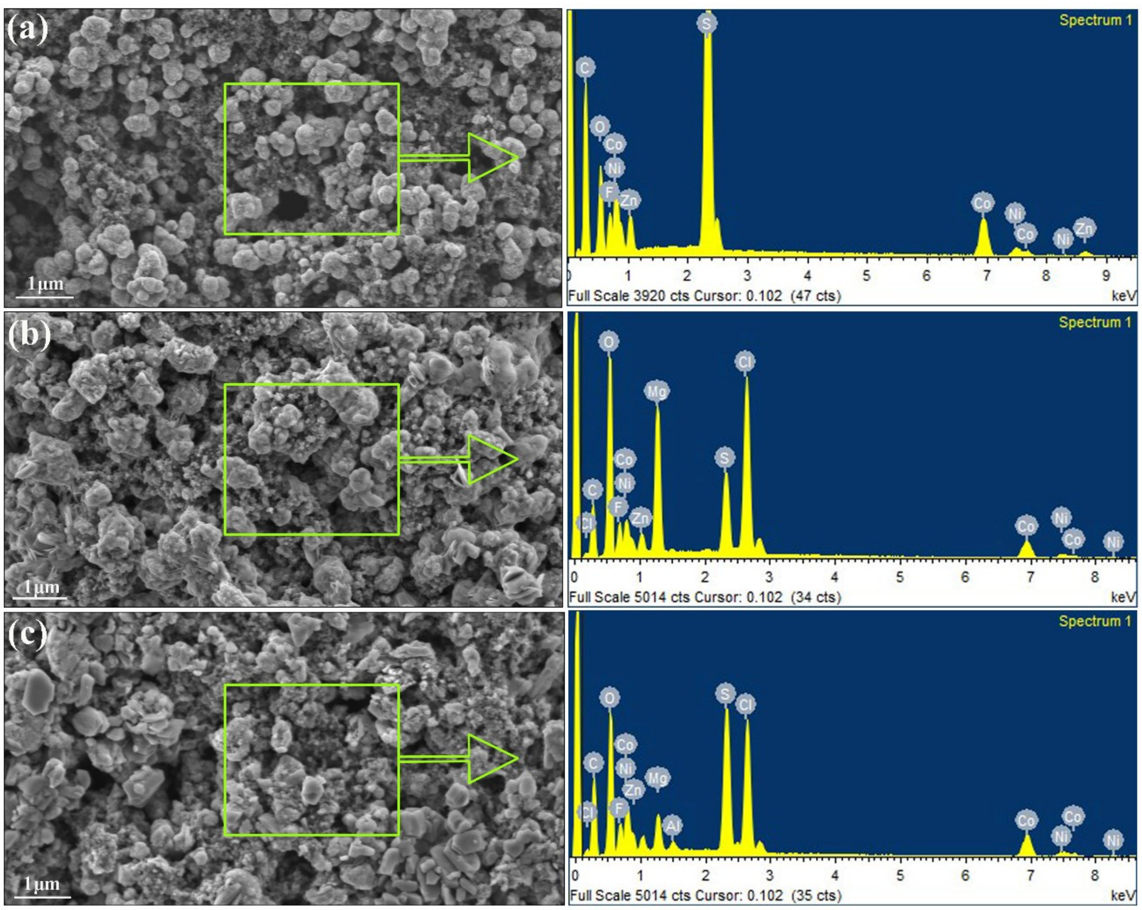


Figure S9 Surface morphology and elemental analysis of Zn/Ni-CoS_2@C cathodes (a) blank, (b) discharged 0.0V, and (c) fully charged 2.0V states.

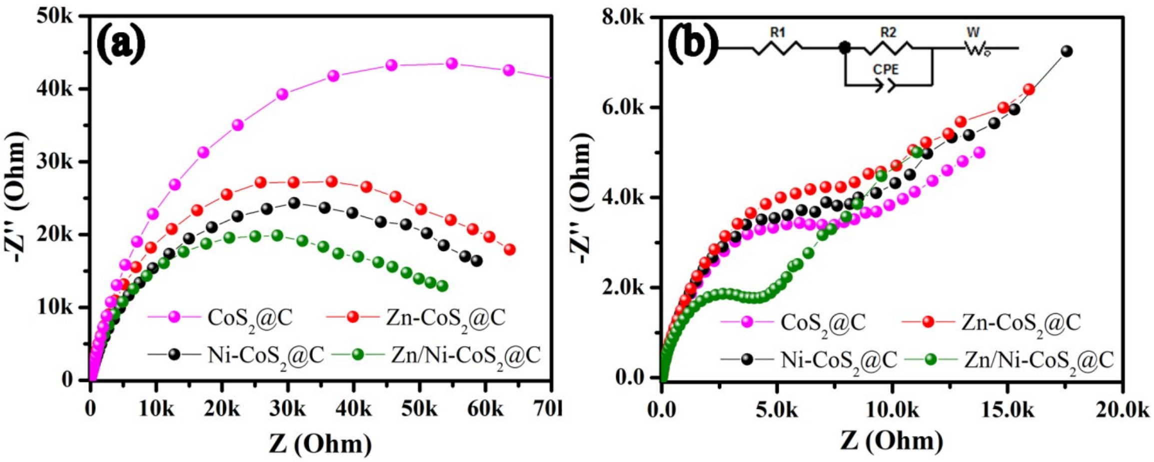


Figure S10 Electrochemical impedance curves of different electrodes at the open circuit potential (a) MIBs; and (b) MLIBs. (Inset in (b) represents the equivalent circuit).

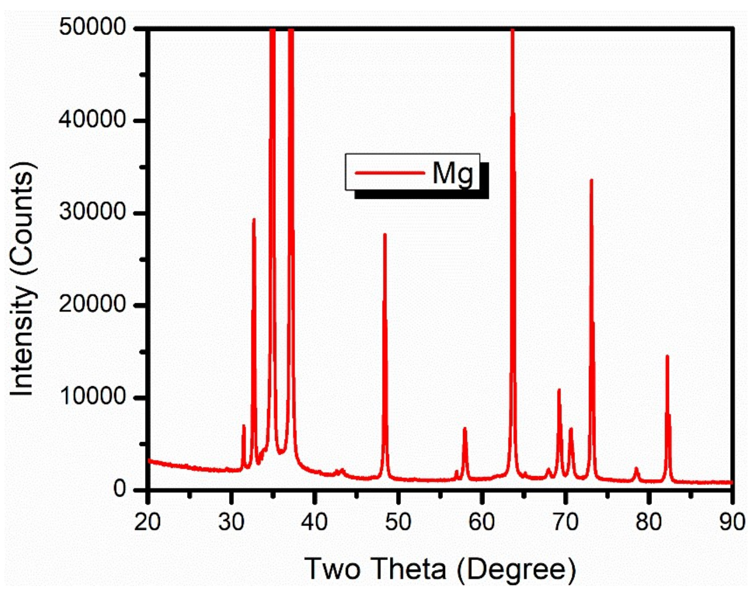


Figure S11 XRD profile of Mg anode after cycling in hybrid electrolytes.

Calculation of Energy and Power Densities:

The power density (***P***) was calculated using Equation 1 given below.

$$P = U * I \qquad (1)$$

Where ***U*** is average working voltage of battery and ***I*** is applied current. Whereas, energy density ***E*** was calculated using average working voltage (***U***), specific capacity (***C***) based on the total mass of the active materials (***m***) using Equation 2 given below.

$$E = {U * C}/{m} \qquad (2)$$

References

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