

# Supplementary Material: Synthesis of MnO/C/NiO-Doped Porous Multiphase Composites for Lithium-Ion Batteries by Biomineralized Mn Oxides from Engineered *Pseudomonas putida* Cells

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## Supplementary Tables

**Table S1.** Compositions of surface elements in biogenic MnO<sub>2</sub>/bacteria composites analyzed by line-scan EDS.

Elements	Wt (%)	Atomic (%)
N	19.28	23.62
O	63.99	68.71
Na	2.73	2.04
Mg	0.21	0.07
P	0.2	2.12
K	0.78	0.34
Ca	1.53	0.66
Mn	7.78	2.43

**Table S2.** Near-surface composition of Mn species derived from fittings of Mn (2p<sub>3/2</sub>) spectra.

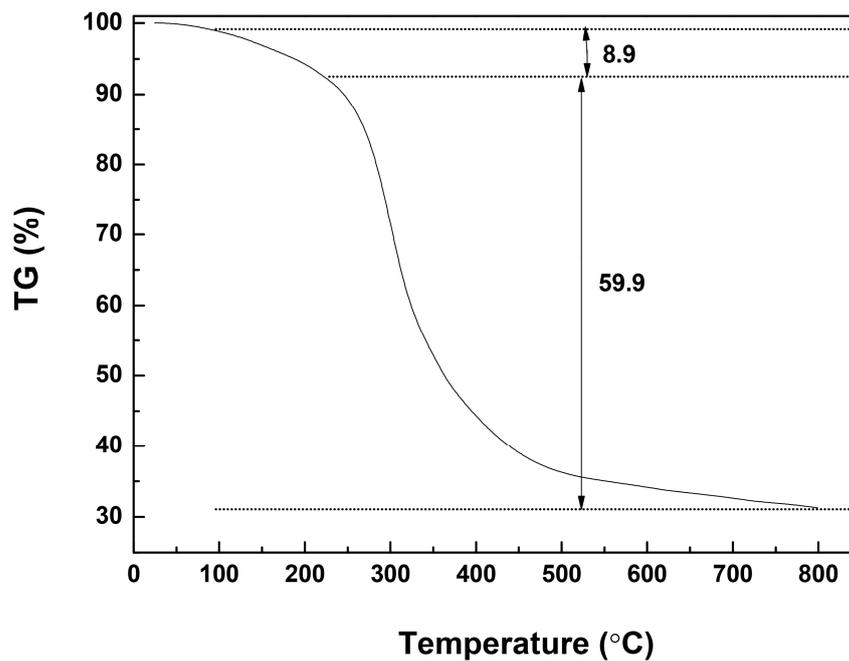
Peak	B.E (eV)	FWHM (eV)	Percent (%)			Surface species & Comments
			BMB	B800	CMB- Ni	
<b>Mn<sup>2+</sup> (2p<sub>3/2</sub>) parameters</b>			Mn <sup>2+</sup> (total) = 30.25 ± 0.1 At. %	Mn <sup>2+</sup> (total) = 81.44 ± 0.3 At. %	Mn <sup>2+</sup> (total) = 75.22 ± 0.3 At. %	
Mn <sup>2+</sup>	639.75	1.25	8.5	11.83	11.62	Mn(II)-O Multiplet #1
Mn <sup>2+</sup>	640.95	1.25	18.75	19.33	21.93	Mn(II)-O Multiplet #2
Mn <sup>2+</sup>	641.75	1.25	0.5	19.72	12.94	Mn(II)-O Multiplet #3
Mn <sup>2+</sup>	642.65	1.25	0	16.56	16.67	Mn(II)-O Multiplet #4
Mn <sup>2+</sup>	644.15	1.25	0	10.06	9.65	Mn(II)-O Multiplet #5
Mn <sup>2+</sup>	646.4	1.25	2.5	3.94	2.41	Mn(II)-O Multiplet #6
<b>Mn<sup>3+</sup> (2p<sub>3/2</sub>) parameters</b>			Mn <sup>3+</sup> (total) = 6 ± 0.3 At. %	Mn <sup>3+</sup> (total) = 9.66 ± 0.1 At. %	Mn <sup>3+</sup> (total) = 12.06 ± 0.1 At. %	
Mn <sup>3+</sup>	640.65	1.25	4.25	0.2	0.22	Mn(III)-O Multiplet #1
Mn <sup>3+</sup>	641.35	1.25	0	0.59	0.22	Mn(III)-O Multiplet #2
Mn <sup>3+</sup>	642.16	1.25	0.5	0.39	2.63	Mn(III)-O Multiplet #3
Mn <sup>3+</sup>	643.18	1.25	0.5	8.28	7.24	Mn(III)-O Multiplet #4
Mn <sup>3+</sup>	644.55	1.25	0.75	0.2	1.75	Mn(III)-O Multiplet #5
<b>Mn<sup>4+</sup> (2p<sub>3/2</sub>) parameters</b>			Mn <sup>4+</sup> (total) = 63.75 ± 0.3 At. %	Mn <sup>4+</sup> (total) = 8.9 ± 0.1 At. %	Mn <sup>4+</sup> (total) = 12.72 ± 0.1 At. %	
Mn <sup>4+</sup>	641.90	1.25	25	0.2	4.17	Mn(IV)-O Multiplet #1
Mn <sup>4+</sup>	642.92	1.25	19.5	0.41	0.22	Mn(IV)-O Multiplet #2
Mn <sup>4+</sup>	643.75	1.25	10	0.2	1.97	Mn(IV)-O Multiplet #3
Mn <sup>4+</sup>	644.78	1.25	6.25	4.34	2.85	Mn(IV)-O Multiplet #4
Mn <sup>4+</sup>	645.80	1.25	3	3.75	3.51	Mn(IV)-O Multiplet #5

Note: <sup>a</sup> Abbreviations: BE, binding energy; FWHM, full width at half maximum; At., atoms.

**Table S3.** Composition of surface elements in B800 analyzed by line-scan EDS.

Elements	Wt %	Atomic %
C	9.78	18.52
O	32.20	45.76
F	2.51	3
Na	5.88	5.82
Mg	1.27	1.19
P	15.77	11.58
S	0.32	0.23
K	0.55	0.32
Ca	2.96	1.68
Mn	28.75	11.90

## Supplementary Figures

**Figure S1.** TGA-DSC curves of BMB.

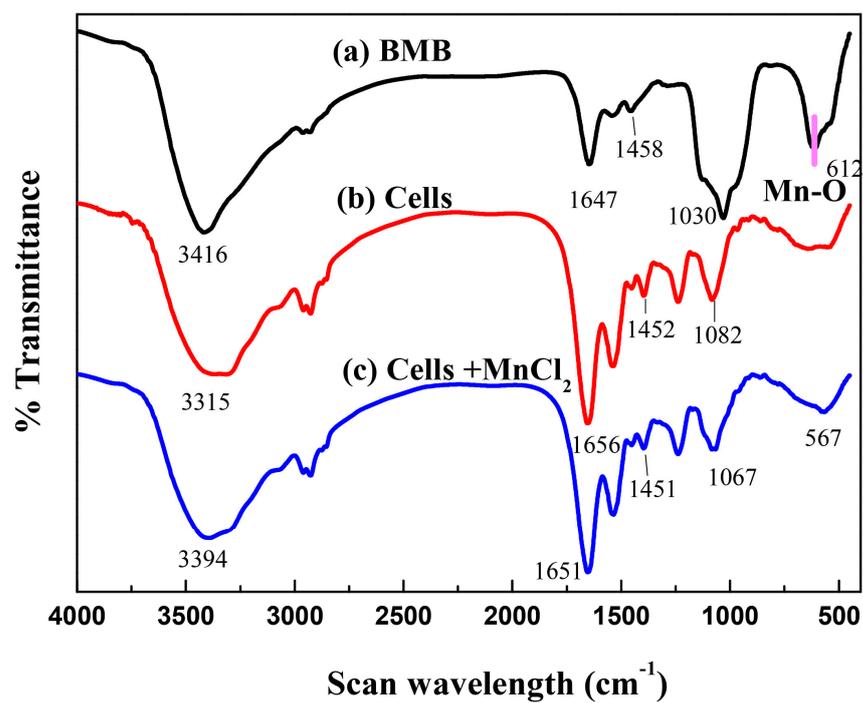


Figure S2. FT-IR spectra of the BMB, pure bacteria cells and pure bacteria cells with  $\text{MnCl}_2$  without cultivation.

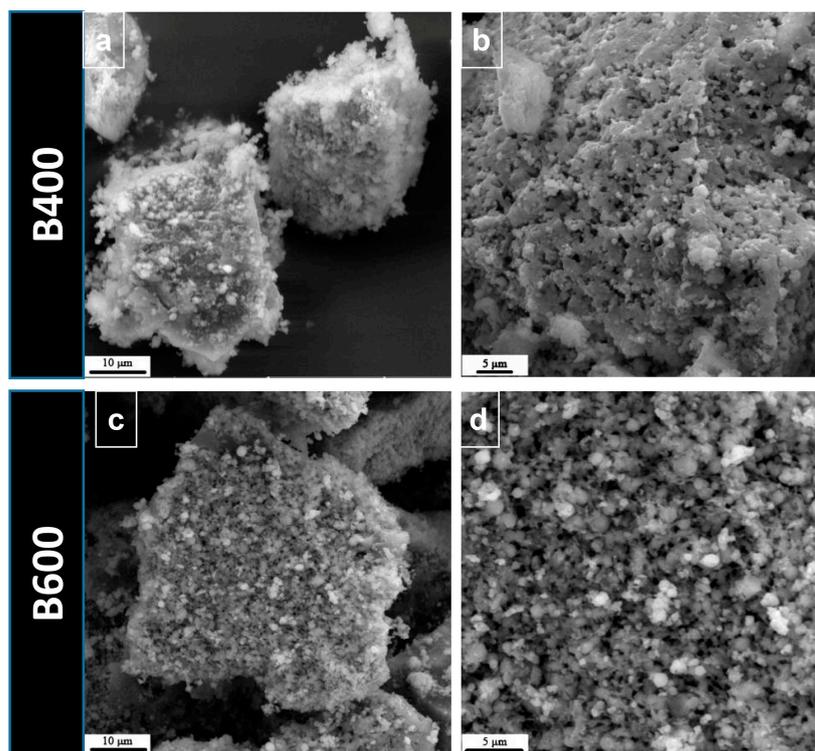
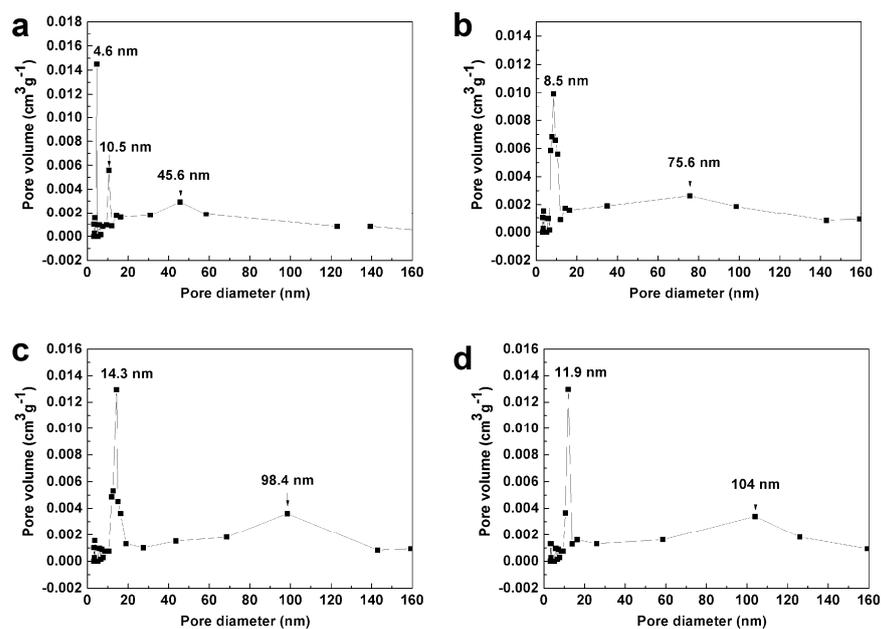
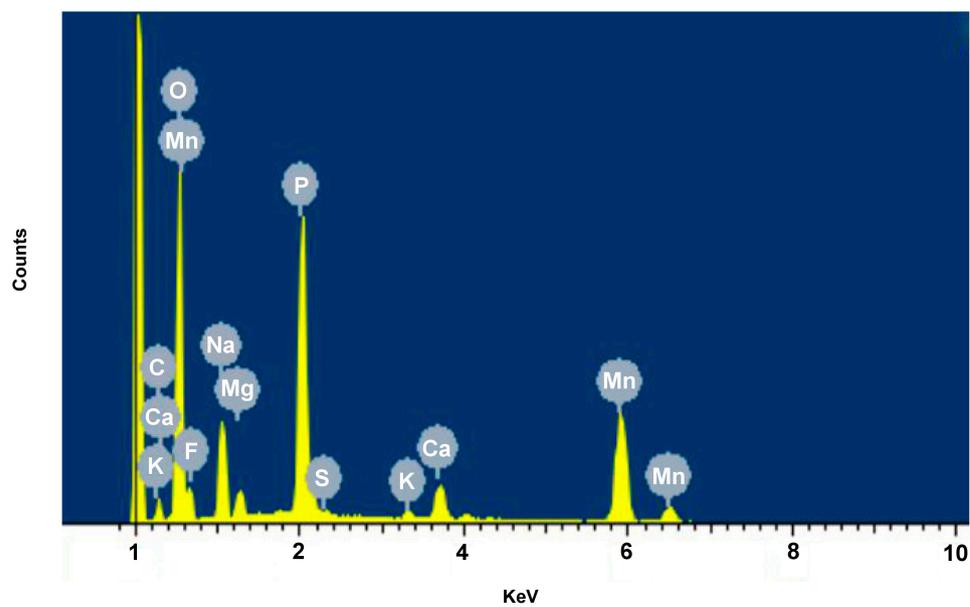


Figure S3. SEM images of the products prepared at (a, b) 400 °C (B400) and (c, d) 600 °C (B600).



**Figure S4.** Pore size distribution curve of the samples under calcination conditions of (a) 400 °C (B400), (b) 600 °C (B600) and 800 °C (c: B800; d: CMB-Ni).



**Figure S5.** Line-scan SEM-EDS analysis of B800.

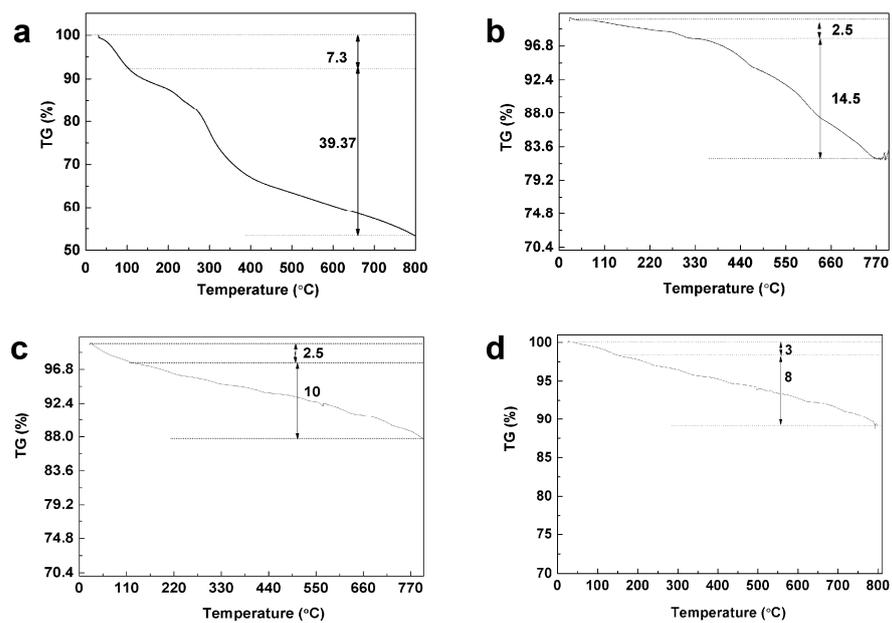


Figure S6. TGA-DSC curves of (a) B400, (b) B600, (c) B800 and (d) CMB-Ni.

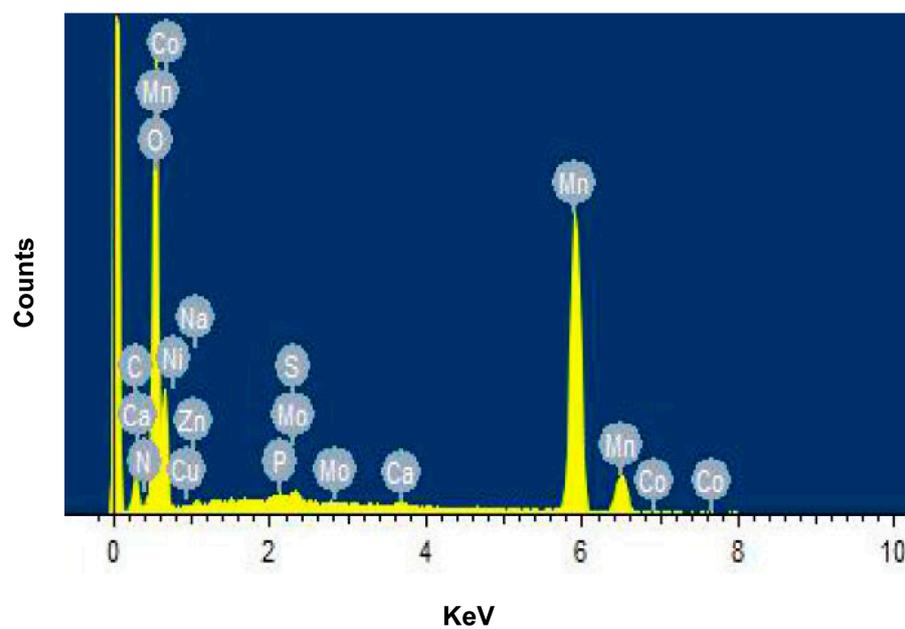


Figure S7. Line-scan SEM-EDS analysis of CMB-Ni.

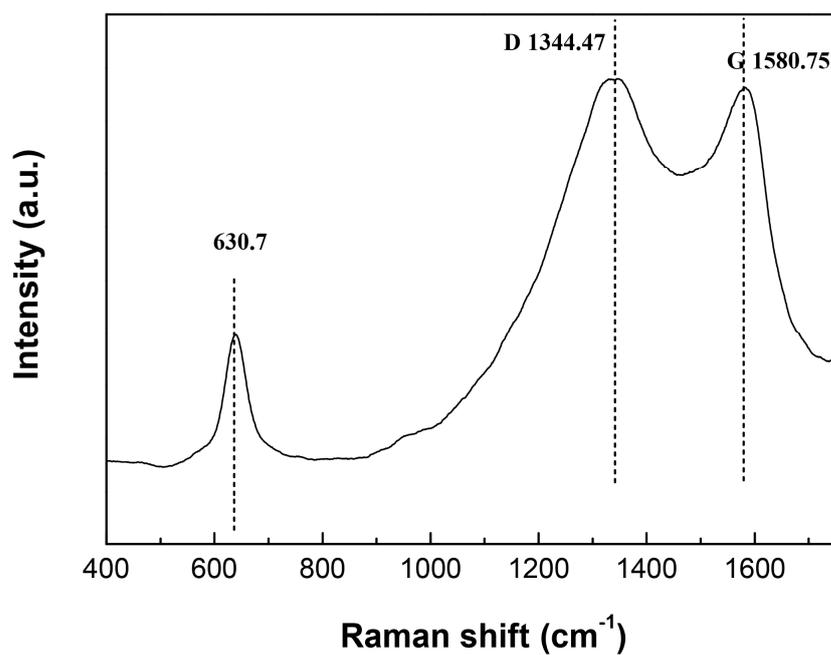


Figure S8. Raman spectra of B800 annealed under Ar atmospheres.

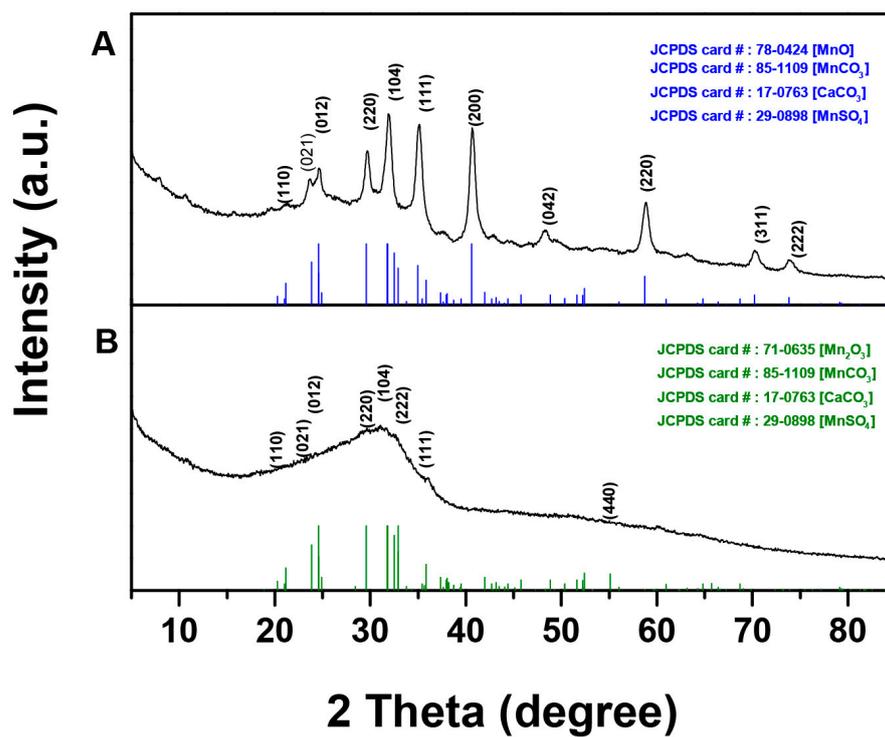
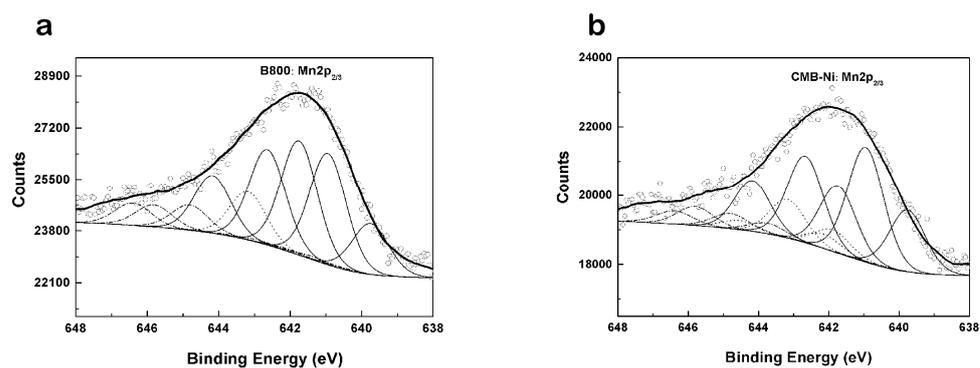


Figure S9. XRD patterns of (A) B600 and (B) B400. The Bragg positions and intensities are marked.



**Figure S10.** XPS patterns of the Mn ( $2p_{3/2}$ ) spectrogram of B800 (**a**) and CMB-Ni (**b**) prepared at 800 °C. The upper circles represent the observed data. The thick, solid curve indicates the best fit of the data. The dashed–dotted curves represent the  $Mn^{4+}$  multiplet peaks, the dotted lines represent  $Mn^{3+}$ , and the thin solid lines represent  $Mn^{2+}$ .