Supporting Information

Improving long-term electrochemical performances of Li-rich cathode material via encapsulating three-in-one nanolayer

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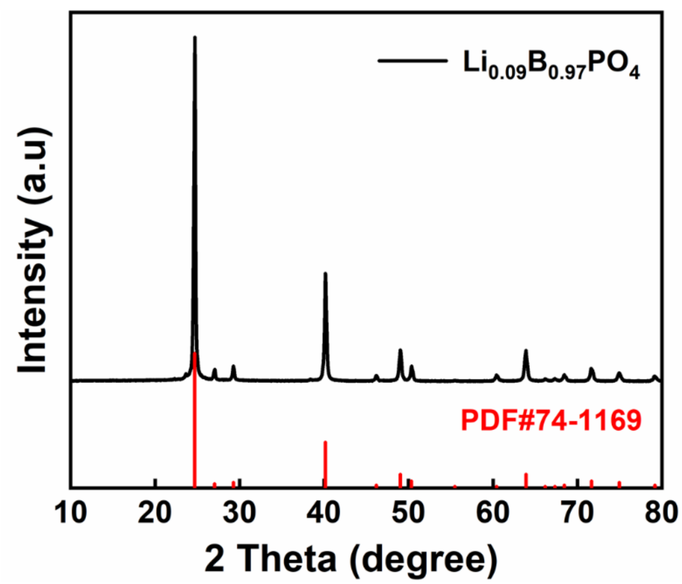

Fig. S1 XRD pattern of the as-synthesized $Li_{0.09}B_{0.97}PO_4$ sample under the same experimental condition as in the surface treatment of Li-rich cathode.

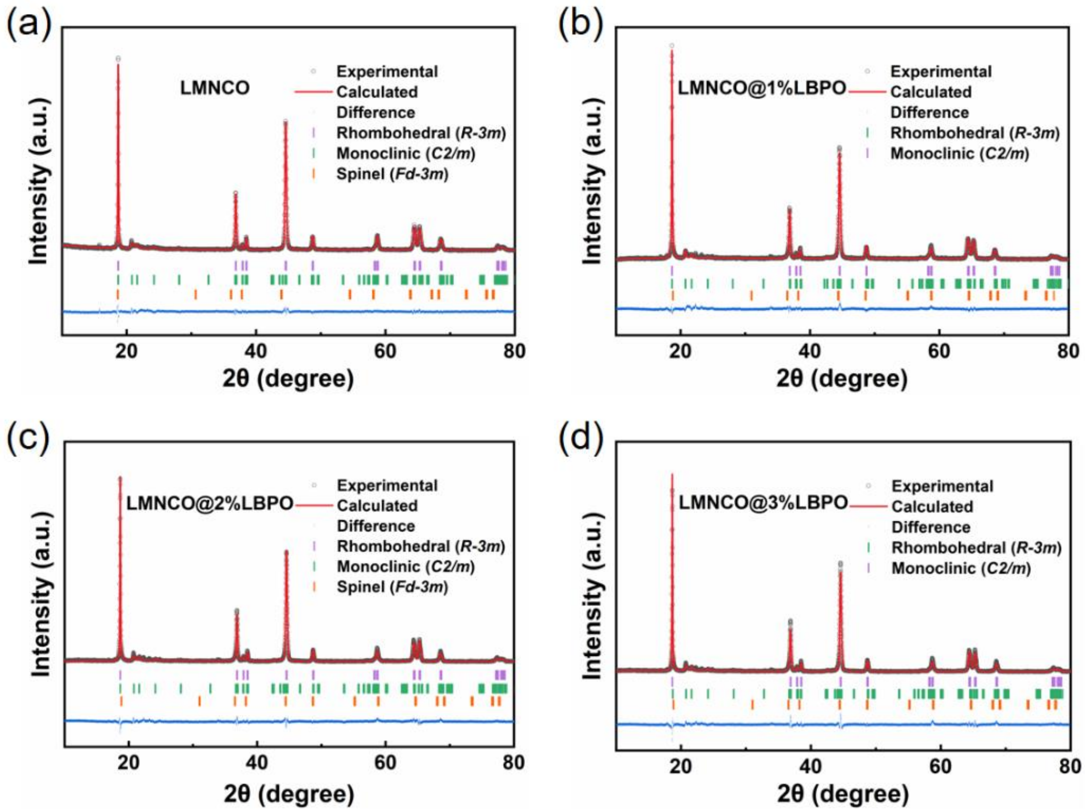

Fig. S2 Rietveld refinements of XRD patterns for the as-synthesized samples: (a) LMNCO, (b) LMNCO@1%LBPO, and (c) LMNCO@3%LBPO.

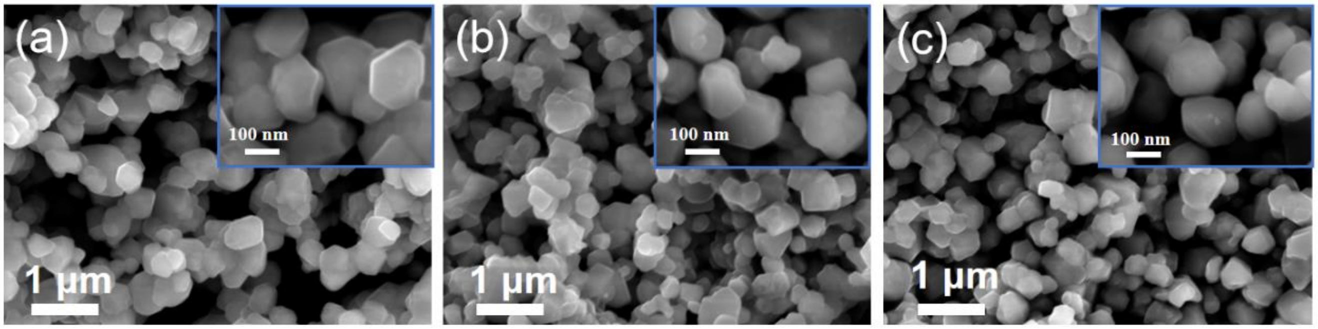

Fig. S3 SEM images of the as-synthesized samples: (a) LMNCO, (b) LMNCO@1%LBPO, and (c) LMNCO@3%LBPO.

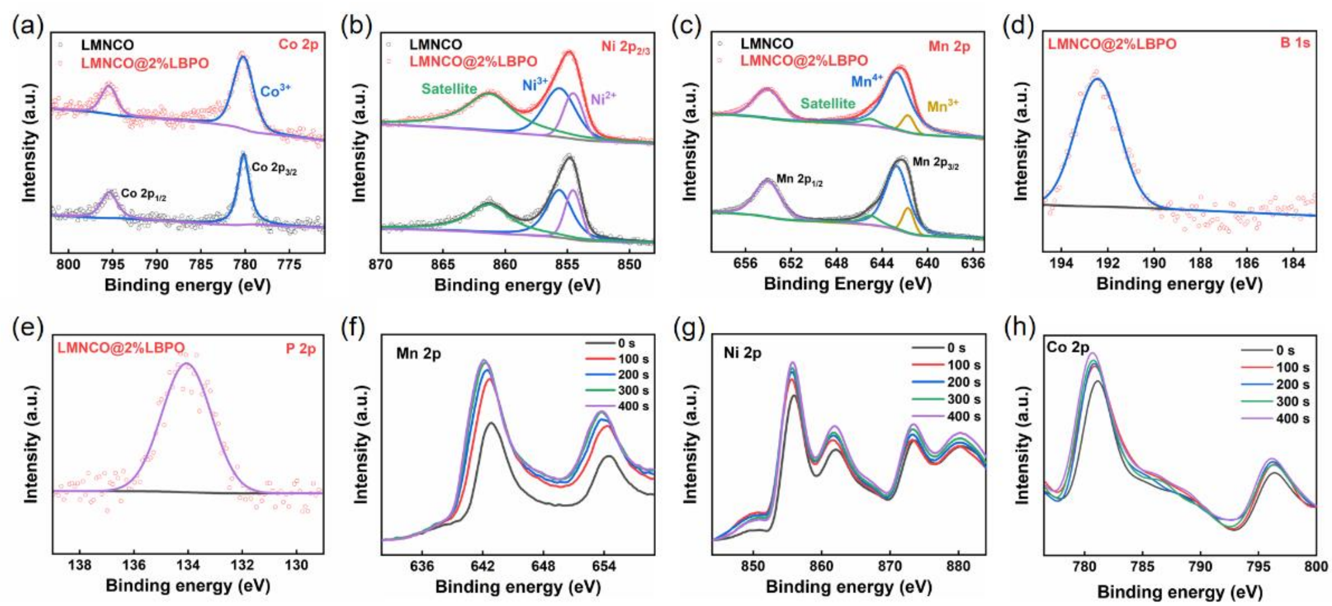

Fig. S4 Fitting analysis of XPS patterns of (a) Co 2p (b) Ni 2p and (c) Mn 2p for the pristine LMNCO and LMNCO@2%LBPO samples, (d) B 1s and (e) P 2p for the LMNCO@2%LBPO sample. In-depth XPS sputtered depth profiles of (f)Mn 2p (g) Ni 2p and (h) Co 2p in the LMNCO@2% LBPO sample.

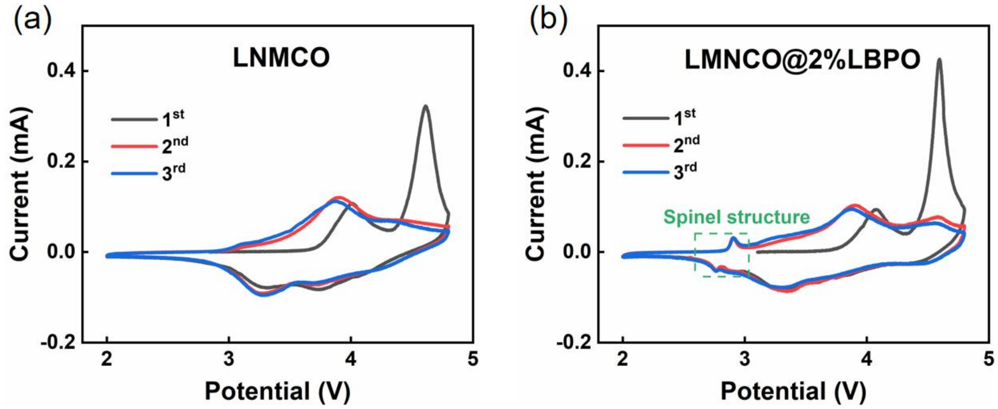

Fig. S5 Initial CV curves of (a) LMNCO and (b) LMNCO@2%LBPO cathodes at the scan rate of 0.1 mV s^{-1}.

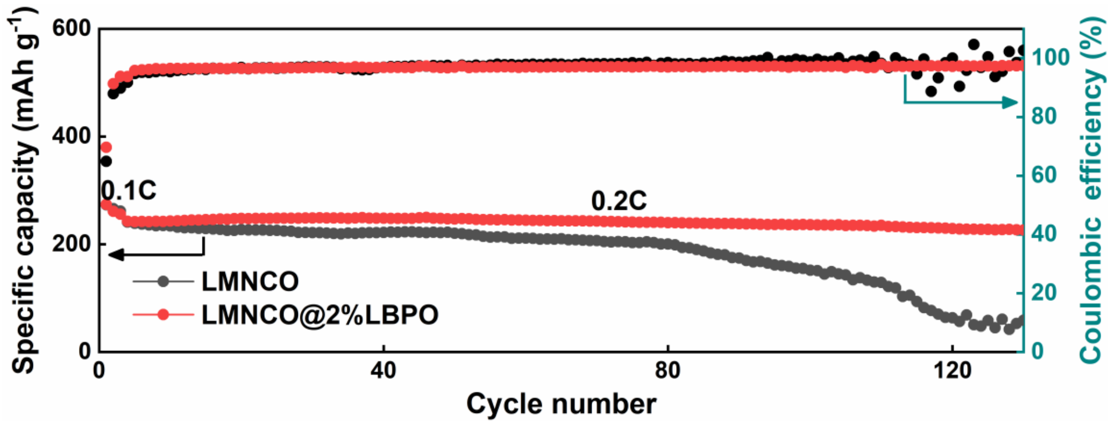

Fig. S6 Cycle performances of the pristine LMNCO and LMNCO@2%LBPO electrodes at the current density of 0.2 C under elevated temperature of 55 °C.

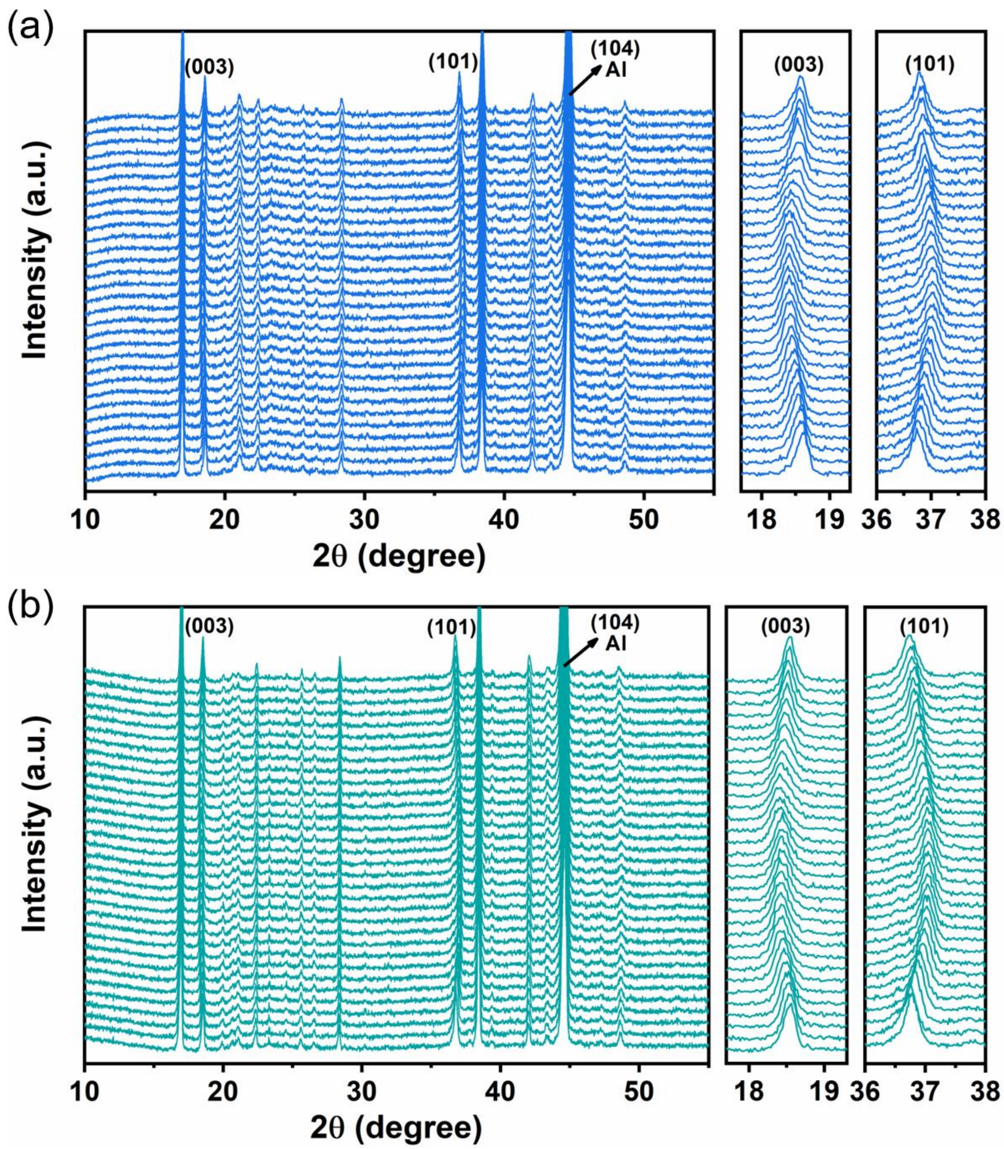

Fig. S7 In-situ XRD patterns with the magnified (003) and (101) peak regions for (a) LMNCO and (b) LMNCO@2%LBPO samples during the initial cycle with the voltage range of 2.0 － 4.8 V.

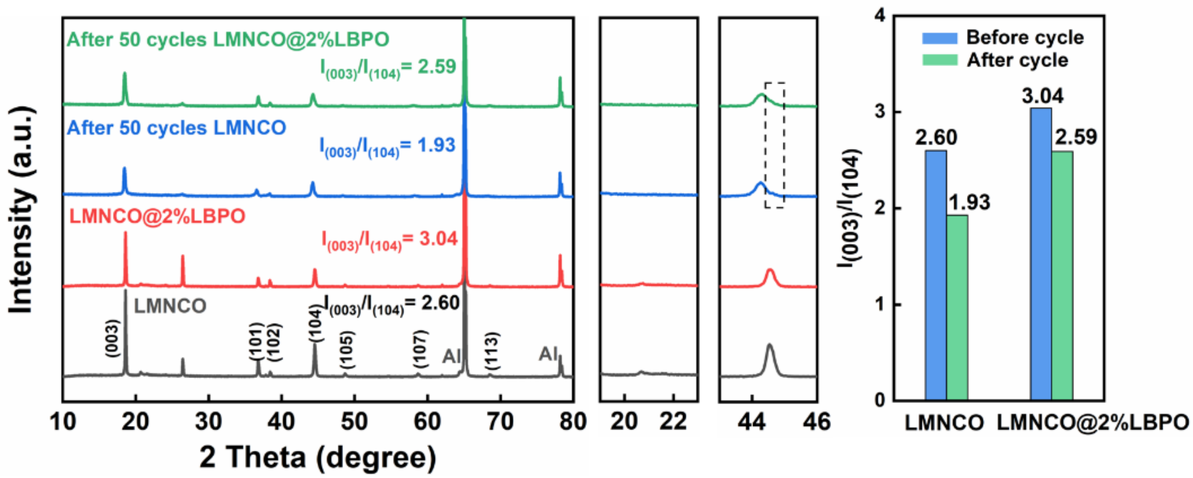

Fig. S8 XRD patterns with the magnified regions and relevant analysis for the pristine LMNCO and LMNCO@2%LBPO samples after 50 cycles at 0.2 C, meanwhile their XRD patterns without cycling supplied for comparison.

Table S1 XRD refined data for the pristine LMNCO and LMNCO@2%LBPO samples.

Samples			LMNCO	LMNCO@ 1%LBPO	LMNCO@ 2%LBPO	LMNCO@ 3%LBPO
Lattice parameter (Å)	R-3m	$a_{hex.}$	2.8576	2.8575	2.8572	2.8574
		$c_{hex.}$	14.2376	14.2467	14.2532	14.2534
	C/2m	$a_{mon.}$	4.9623	4.9430	4.9700	4.9639
		$b_{mon.}$	8.5315	8.5595	8.5329	8.5451
		$c_{mon.}$	5.0261	5.0346	5.0382	5.0352
	Fd-3m	$a_{cub.}$	8.2472	8.1657	8.1538	8.1425
Weight fraction (%)	Layered		100	98.67	97.3	97.17
	Spinel		0	1.34	2.70	2.83
Reliability factors	R_{wp} (%)		6.87	8.64	8.29	9.73
	R_p (%)		5.27	6.31	6.49	7.58
	χ^2		1.78	2.82	1.618	4.48

Table S2 Comparison of electrochemical performances among this work and reported representative modification studies on LMNCO cathode material.

Modification method	**Current density**	**Cycle number**	**Capacity retention** (%)	**Voltage decay** (mV cycle^{-1})	**Reference**
$Li_4Mn_5O_{12}$ coating	0.5C	300	67.0	1.60	S1
$Li_7La_3Zr_2O_{12}$ coating	0.5C	400	63.0	1.03	S2
Oleic acid modifying	1C	200	84.1	1.89	S3
$LiCoO_2$ coating	0.5C	140	85.1	1.86	S4
Fe^{3+} doping	1C	200	80.0	1.32	S5
$LiCeO_2$ coating	1C	200	84.3	2.04	S6
Li_2ZrO_3 coating	1C	200	72.8	2.72	S7
Zr^{4+} doping	1C	300	91.8	0.45	S8
Ta^{5+}–Mo^{6+} dual doping	1C	220	80.0	1.58	S9
PAN coating	0.5C	300	73.7	1.15	S10
Li_2TiO_3 coating	1C	240	66.4	1.31	S11
Ti^{4+} doping	1C	500	85.0	0.72	S12
Na_5AlO_4 coating	1C	400	61.0	1.03	S13
Concentration Gradient	1C	200	88.4	0.80	S14
$LiNbO_3$ coating	1C	200	83.3	1.05	S15
This work	1C	500	78.6	0.73	

Table S3 EIS fitting values of the LMNCO and LMNCO@2%LBPO electrodes.

Resistance	electrode	10th	30th	50th
R_{sf} (Ω)	LMNCO	11.9	16.5	20.2
	LMNCO@2% LBPO	10.1	14.2	16.7
R_{ct} (Ω)	LMNCO	420.5	578.9	725.3
	LMNCO@2% LBPO	168.3	301.5	381.8

Table S4 ICP data of LMNCO and LMNCO@2%LBPO samples.

Element concentration (mg L^{-1})	**Sample**	**1 week**	**2 weeks**	**3 weeks**
Mn	LMNCO	4.3	9.6	18.8
	LMNCO@2%LBPO	3.4	5.8	10.3
Ni	LMNCO	1.6	3.3	6.2
	LMNCO@2%LBPO	1.2	1.9	4.0
Co	LMNCO	0.6	1.3	2.6
	LMNCO@2%LBPO	0.5	0.8	2.0

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