Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Facile synthesis of the sandwich-structured germanium/reduced graphene oxide hybrid: an advanced anode material for high-performance lithium ion batteries

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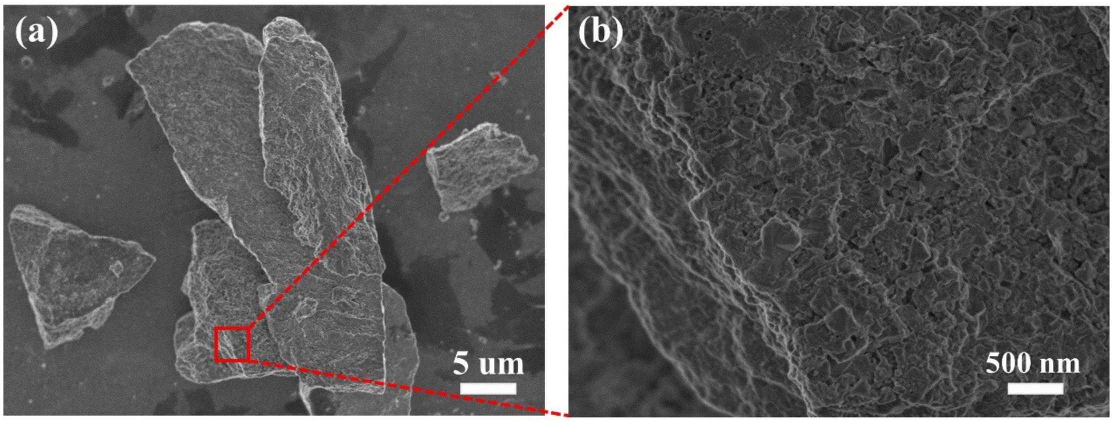

Figure S1: (a) Low and (b) high-magnification SEM images of $NH_4H(HGeO_3)_2$/GO composite.

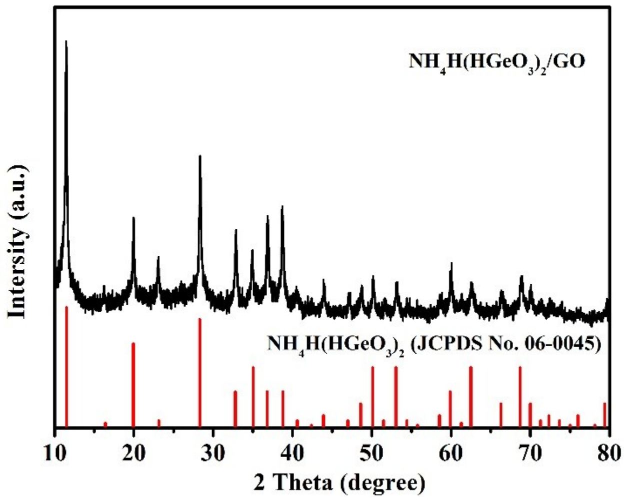

Figure S2: XRD pattern $NH_4H(HGeO_3)_2$/GO composite.

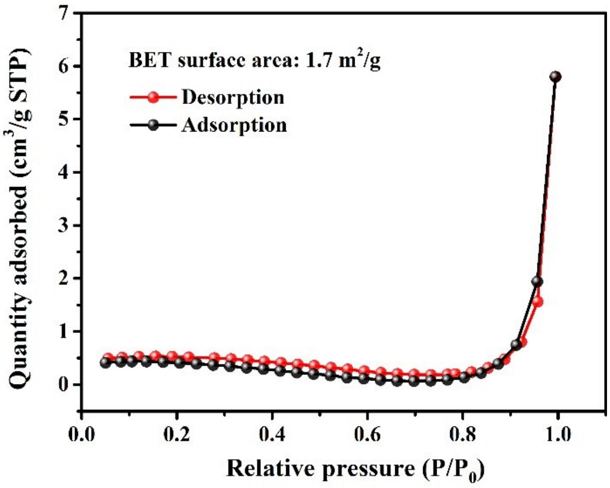

Figure S3: Nitrogen adsorption and desorption isotherms of pure Ge.

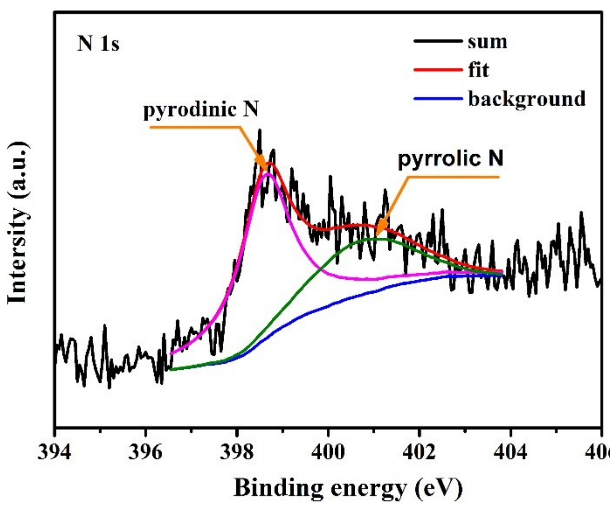

Figure S4: High-resolution of N 1s XPS spectrum of rGO/Ge/rGO

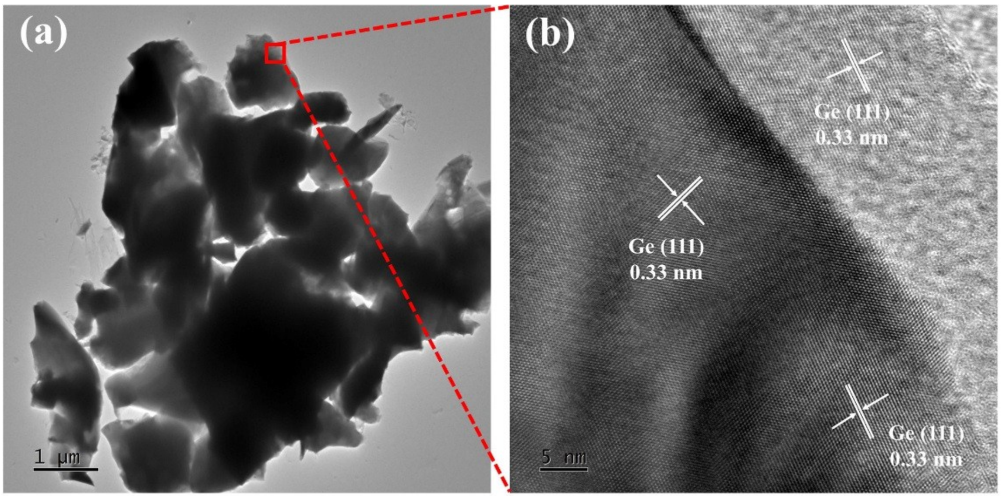

Figure S5: (a) SEM image and (b) TEM image of pure Ge

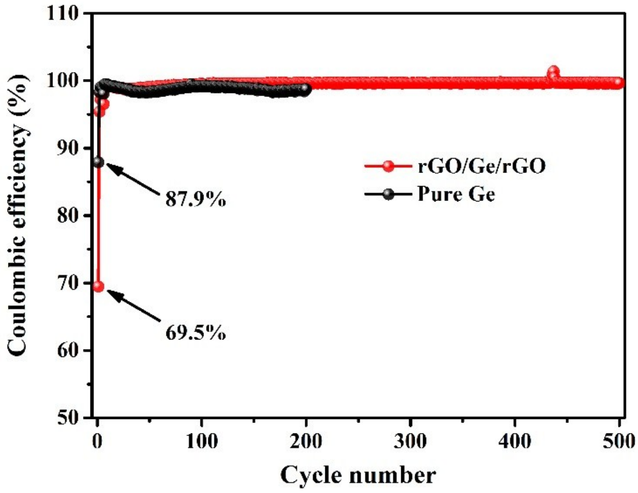

Figure S6: Coulombic efficiency of rGO/Ge/rGO and pure Ge electrodes at different cycles.

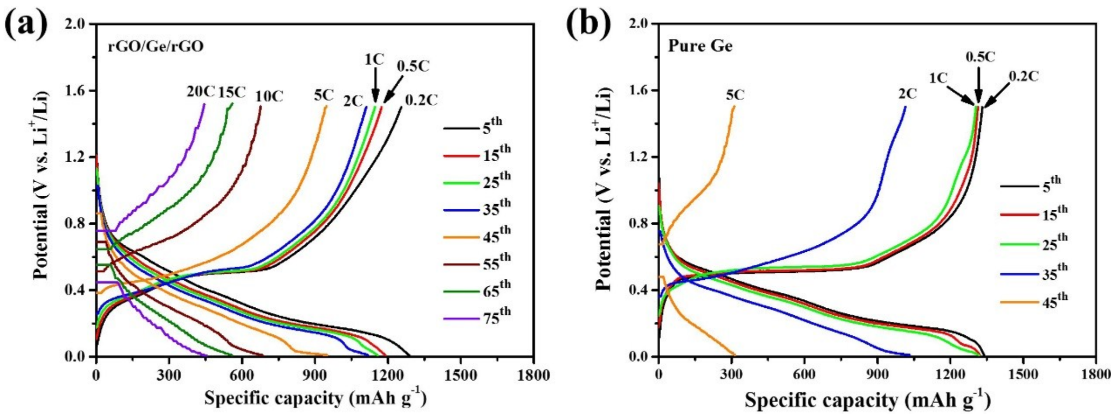

Figure S7: (a) Potential profiles of rGO/Ge/rGO and (b) Potential profiles of Ge corresponding to Figure 4(d). The potential profiles at 15C and 20C charge/discharge rates was not shown of pure Ge electrode since too short tome of charge/discharge.

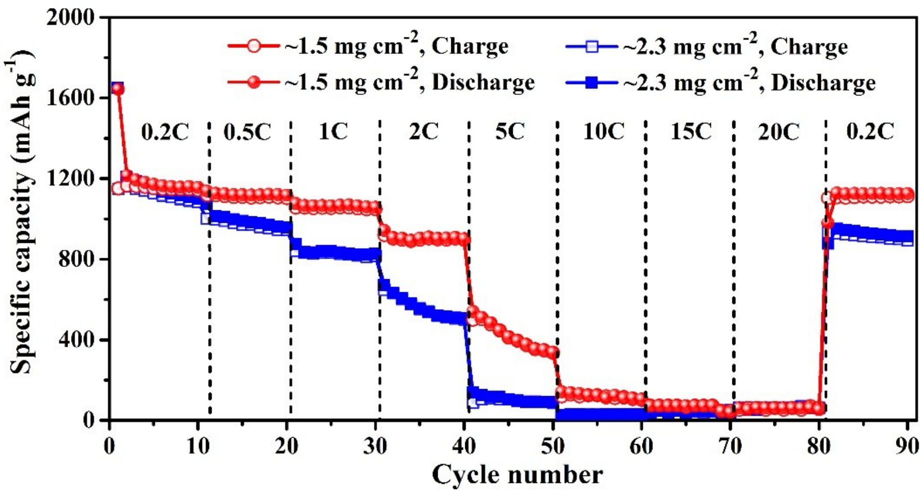

Figure S8: Rate capability of rGO/Ge/rGO with different electrode mass-loading.

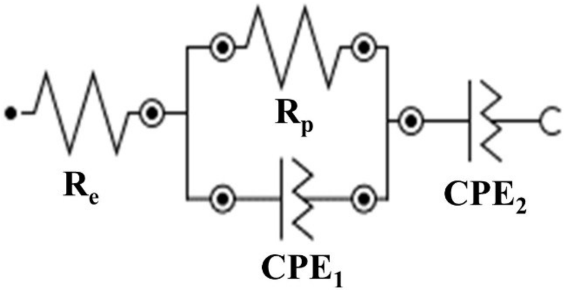

Figure S9: The equivalent circuit of Ge and rGO/Ge/rGO electrodes before cycling corresponding to the Figure 7(a). In the equivalent circuit, R_e represents the impedance contributed by the electrolyte; R_p represents the intrinsic electronic resistance of the materials. CPE (constant phase angle element) is used instead of capacitance to describe the constant change of phase angles. CPE1 represents the passivated film impedance on the lithium metal surface. CPE2 is the capacitance resistance of the anode.[1]

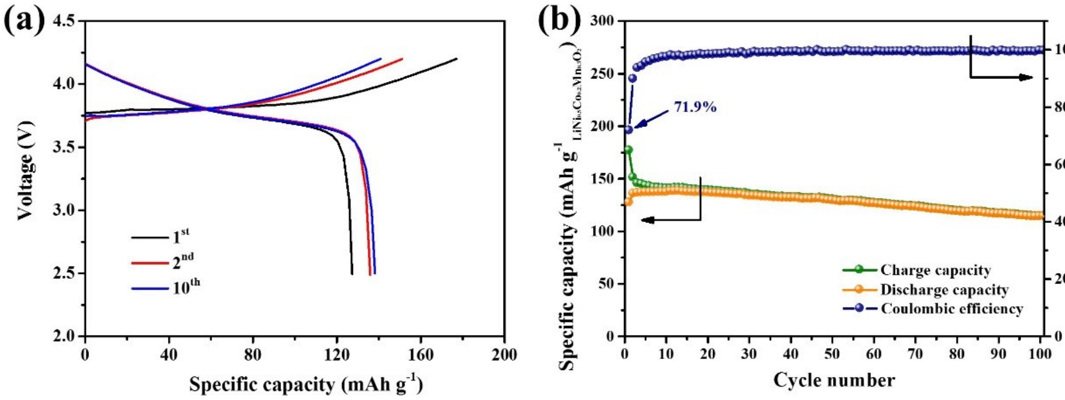

Figure S10: (a) Galvanostatic charge-discharge profiles and (b) Cyclability and coulombic efficiency of $LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$ cathode at the rate of 1C for 100 cycles (1C=160 mA g^{-1}).

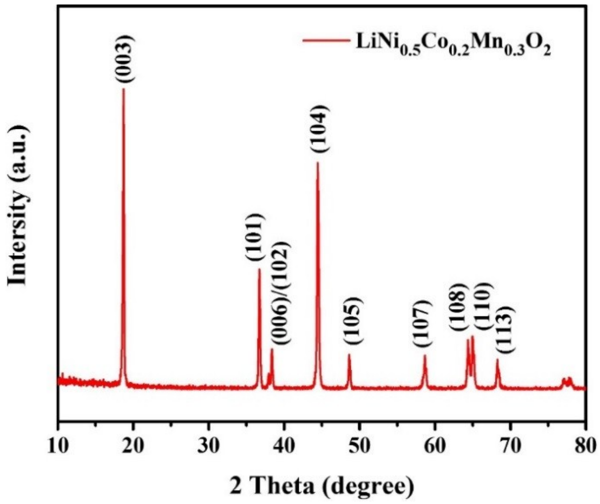

Figure S11. XRD pattern of $LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$ cathode

The XRD pattern of $LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$ powder is shown in Figure S11, all the diffraction lines are well indexed in the rhombohedral $_{3m}$ space group. The XRD diagram display a single-phase α-NaFeO2-type structure and no impurity phases are detected. It is worth noting that, both the (006)/(102) and (108)/(110) doublets are well resolved, which indicates a well-developed layered LNCMO materials and is similar to the previous reports[2, 3].

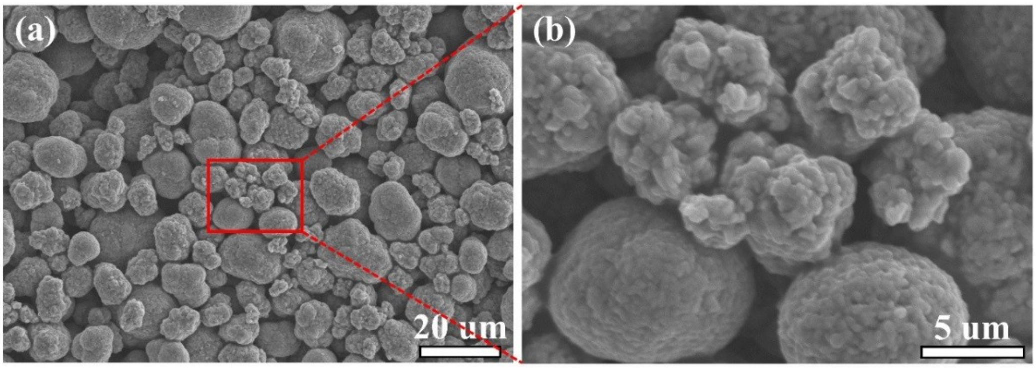

Figure S12. (a) Low and (b) high-magnification SEM images of $LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$ cathode.

Figure S12 presents the SEM images of $LiNi_{0.5}Co_{0.2}Mn_{0.3}O_2$ cathode. The low-magnification SEM image (Figure S12a) reveals agglomerates ranging in size from 2-20 um, which consist of smaller primary particles of 100-300 nm in size.

Table S1. Impedance parameter of the pure Ge and rGO/Ge /rGO electrodes before cycling.

Sample (before cycling)	R_e (Ω)	R_p (Ω)
Ge	2.0	99.8
rGO/Ge/rGO	1.6	77.2

Table S2. Impedance parameter of the pure Ge and rGO/Ge /rGO electrodes after 100 cycles cycling at fully discharged state.

Sample (100th full lithiated)	**R_e (Ω)**	**R_f (Ω)**	**R_{ct} (Ω)**
Ge	**4.6**	**21.3**	**13.3**
rGO/Ge/rGO	**3.9**	**10.5**	**8.7**

Reference

1 J. Y. Song, H. H. Lee, Y. Y. Wang and C. C. Wan, *J. Power Sources*, 2002, **111**, 255-267.

2 X. Zhang, W. Jiang, A. Mauger, F. Gendron and C. Julien, *J. Power Sources*, 2010, **195**, 1292-1301.

3 M. He, C. C. Su, Z. Feng, L. Zeng, T. Wu, M. J. Bedzyk, P. Fenter, Y. Wang and Z. Zhang, *Adv. Energy Mater.*, 2017.