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Supporting Information

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Experimental Methods

Materials: Graphene oxide (GO) powder (GO-V50) with ~30 μm lateral size and ~1 nm thickness was purchased from Standard Graphene Inc. Single-walled carbon nanotubes (eDIPS EC1.5) with 90 % purity and 1-3 nm diameter were purchased from Meijo Nano Carbon Inc. Styrene-ethylene/butylene-styrene (SEBS, G1657MS) was obtained from Kraton Inc. Ti$_3$AlC$_2$ MAX powder (400 mesh, <38.0 μm particle size) was obtained from Carbon-Ukraine. The MXene was synthesized via a modified minimally intensive layer delamination (MILD) method, which involves removing aluminum (Al) from the Ti$_3$AlC$_2$ MAX phase using a solution made of LiF (> 99.99%, Sigma-Aldrich, Korea) and 6.0 M HCl (35-38.0%, Daejung Chemicals & Metals, Korea). The dispersed MXene nanosheet preparation was described in detail in our other paper.\(^{39}\) Melamine foam was obtained from BASF Co. Ltd. Toluene (99%) was purchased from Daejung Chemical Co. Ltd. Lithium foil with 0.3 mm thickness was obtained from MTI Korea Co. Ltd. 1.0 M LiTFSi in DME/DOL (1:1 vol%) (Welcos Co. Ltd.) with 2wt% of LiNO$_3$ (99.999%, anhydrous, Alfa Aesar) were mainly used as an electrolyte. 1.0 M LiPF$_6$ in EC/DEC (1:1 vol%) with 7.5 wt% FEC electrolyte were purchased from Welcos Co. Ltd. For the Fenton reaction of the PVDF, PVDF (Mw ~ 534,000, powder, Sigma-Aldrich), FeSO$_4$·7H$_2$O, hydrogen peroxide with 35 wt % were mixed in ethanol (Sigma-Aldrich), and reacted with 1 M H$_2$SO$_4$ (Daejung Chemical). LiFePO$_4$ (LFP, RD2121900A, Aleees Co., Ltd.) particles were used for the active materials of the cathode. For the stretchable current collector, 325 mesh Nickel flake (Alfa Aesar), 1 μm, and 50 μm Ni particles (Sigma-Aldrich), and a multi-walled carbon nanotube (MWCNT, length of 20–100 μm, average diameter of ~20 nm, purity >95 wt %, CNT Co., Ltd.) were purchased. Poly(styrene-block-isobutylene-block-styrene) (SIBS, 103T, Kaneka Corporation) was used as a matrix of the
stretchable current collector and a stretchable encapsulant. A stretchable separator was prepared using poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP, average Mw ~ 400,000, pellets, Sigma-Aldrich).

**Preparation of GO, CNT, and MXene dispersion:** GO dispersion is prepared by mixing 105 mg of graphene oxide powder with 3.5 ml of water. After that, it is distributed to tip sonication with 40 % of amplitude and 04-01 s pulse for 30 min. CNT dispersion is prepared by mixing 150 mg of CNT with 30 ml of water. After that, it is distributed to tip sonication with 90 % of amplitude and 05-03 s pulse for 7 hr. Next, the MXene was dispersed in water (~25 mg/ml), and 2 ml of 1,4-Dioxane was added. Then, the GO, CNT, and MXene dispersions were mixed (weight ratio of the dispersants of 3.5:1.5:5) and stirred for 1 hr.

**Fabrication of Li-GCMMF electrode:** Melamine foam (MF) is cut to have a diameter of 30 mm and a thickness of 1 mm. The styrene-ethylene/butylene-styrene (SEBS) block copolymer was coated on the MF by immersing it in the SEBS solution (1 wt% in toluene) and drying by N2 blowing. Then, the MF is immersed in the GO, CNT, and MXene dispersion solution and gently pressed to allow the dispersion to soak into the foam. The GO/CNT/Mxene dispersion soaked in MF is placed on a copper plate and directionally freezes over liquid nitrogen. After that, freeze-dry the foam to sublimate the directionally developed ice columns. Then, reduce GO/CNT/MXene-MF with hydrazine hydrate vapor for 24 hours on a hot plate at 80 ℃. After plating lithium on the reduced GCMMF, the Li-GCMMF with reentrant structures could be obtained through radial compression.

**Lithium electroplating:** For the electroplating method, the working electrode was the GCMMF electrode, and the counter electrode was a lithium metal foil. Electroplating was carried out using
a 100 ml beaker cell. Cells were assembled in the glove box below 0.1 ppm oxygen and water level. As the electrolyte, 1 M LiTFSI in 1,3-dioxolane and 1,2-dimethoxyethane (DOL:DME, volume ratio 1:1) with 2 wt% LiNO₃ was used. The charging rate was 0.75 mA, gentle agitation (~15 rpm) was performed during charging, and the charging time was adjusted to control the amount of lithium plating.

**Fabrication of Stretchable Lithium Metal Battery:** The fabrication process for intrinsically stretchable LFP-based cathode, stretchable current collector, and stretchable separator is the same as our previously published paper.²⁹ For the stretchable collector, a 3:1 weight ratio mixed solution of Ni particles in three different sizes (1:1:1 weight ratio of 325 mesh, 1 μm, and 50 μm), SIBS in cyclohexane, and 10 mg of MWCNT was blade coated onto the glass substrate. The stretchable cathode was prepared by blade coating of functionalized PVDF (F-PVDF) obtained through Fenton reaction, SWCNT and LFP particles mixed in a mass ratio of 2.5:0.5:7 in acetone on the stretchable current collector. After that, the film was dried in a vacuum oven overnight. The SIBS film for the stretchable encapsulant was made by hot-pressing SIBS pellets at 240 °C. Then, the cathode, current collector, separator, and the Li-GCMMF were sequentially stacked between the SIBS films. The stretchable cell was sealed by 25 wt % SIBS in cyclohexane, and the electrolyte was injected into the cell using a syringe.

**Characterization:** The SEM images were obtained using a field-emission scanning electron microscope (JEOL, JSM-6701F) operated at 5 kV. EDS analysis was also performed using a field-emission scanning electron microscope (ZEISS, Sigma 300), combined with a Bruker XFlash 6I10 detector at acceleration voltage of 5 kV. The process of Li stripping and plating were investigated via Li foil/Li-GCMMF symmetric cells (2032-type coin cell) with PP separators. Li foil/Li-
GCMMF symmetric cells were assembled inside an argon-filled glove box (Korea Kiyon Ltd.). The electrolyte used for cell tests was 1 M LiTFSI in DOL:DME (v/v 1:1) with 2 wt% LiNO₃. The current density was set to 0.25 mA·cm⁻² and the charging capacity was set to 0.25 mAh·cm⁻². Electrochemical impedance spectroscopy was performed at current of 10 mA on a galvanostate in the frequency range of 0.1 Hz to 100 kHz. (Metrohm, Autolab PGSTAT302N & NOVA software 2.1) Battery testing was carried out with a 40-channel battery cycler (WonAtech, WBCS3000S). The stretching tests were performed on a motorized linear stage by subjecting cyclic strains of 40% at a speed of 2 mm·min⁻¹. And resistance change during the stretching tests were measured using a Keithley 2000 multimeter.
Figure S1. SEM images of melamine struts before and after SEBS-coating.

Figure S2. EDS elemental mapping of GCMMF: (a) an overlay of C, O, Ti, N, F (b) Carbon (blue), (c) Oxygen (orange), (d) Titanium (Purple), (e) Nitrogen (green), (f) Fluorine (Red).
Figure S3. EDS elemental mapping of Li-GCMMF: (a) an overlay of C, O, Ti, N, F (b) Carbon (blue), (c) Oxygen (orange), (d) Titanium (Purple), (e) Nitrogen (green), (f) Fluorine (Red).

Figure S4. High-resolution SEM images of 5 mAh·cm⁻² deposited Li-GCMMF:
Figure S5. Mechanical tension tests of 2D graphene/CNT microcellular frameworks without melamine form with lithium deposition.
Figure S6. Tensile test with resistance changes of (a) GCMMF and (b) Li-GCMMF electrodes.
Figure S7. (a) Representative charge/discharge curves of Stretchable LMB cell between 2.0 and 3.8 V at 0.5 C, including a precycle of 0.1 C. (b) Coulombic efficiencies of PCOG/LFP half cell at 0.5 C.