Lithium-Ion Conductive Ceramic Textile: A New Architecture for Flexible Solid-State Lithium Metal Batteries

Supplementary Data

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Abbreviations

LiTFSI, Lithium bis(trifluoromethanesulfonyl)imide; PEO, Poly-(ethylene oxide); PVP, Polyvinylpyrrolidone; DME, 1,2-dimethoxyethan; DOL, 1,3-dioxolane; CNT, Carbon nanotube.

Supplemental figures

Figure S1. Characterization of the flexible garnet textile.

(a) Thermogravimetric analysis of the garnet precursor solution impregnated textile template. (b) Cross-sectional SEM image of the pretreated textile template; (c) Cross-sectional SEM image of the precursor solution-impregnated textile template; (d) Cross-sectional SEM image of the garnet textile after pyrolysis of the template and sintering at high temperature;

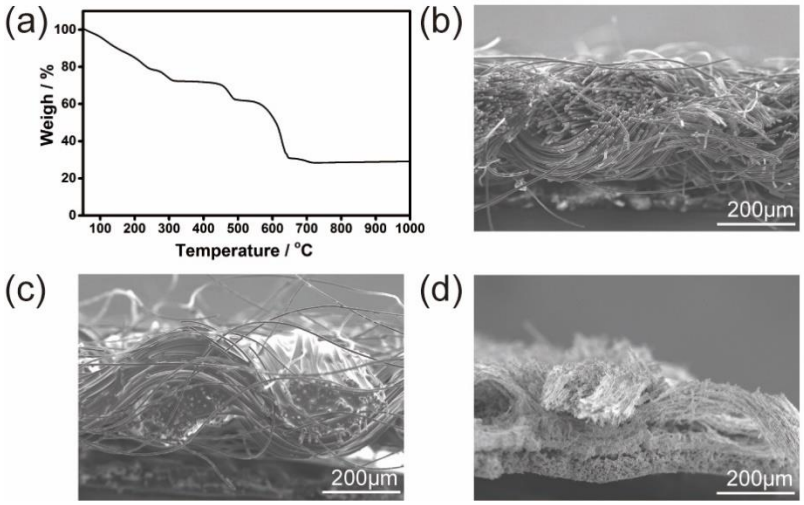


Figure S2. Flexible garnet textile in large dimensions and different shapes.

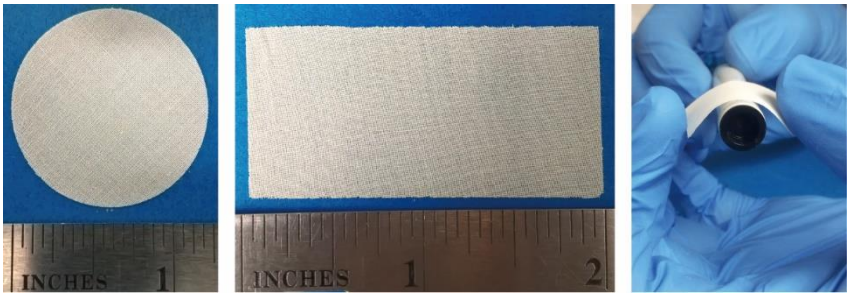


Figure S3. Characterization of Li-ion conducting garnet and insulating Al_2O_3 textile reinforced flexible CPE.

(a) Cross-sectional SEM image of the garnet textile reinforced flexible CPE; (b) The insulating Al_2O_3 textile fabricated using the identical template method; (c) Impedance plots of the controlled CPE at different temperatures.

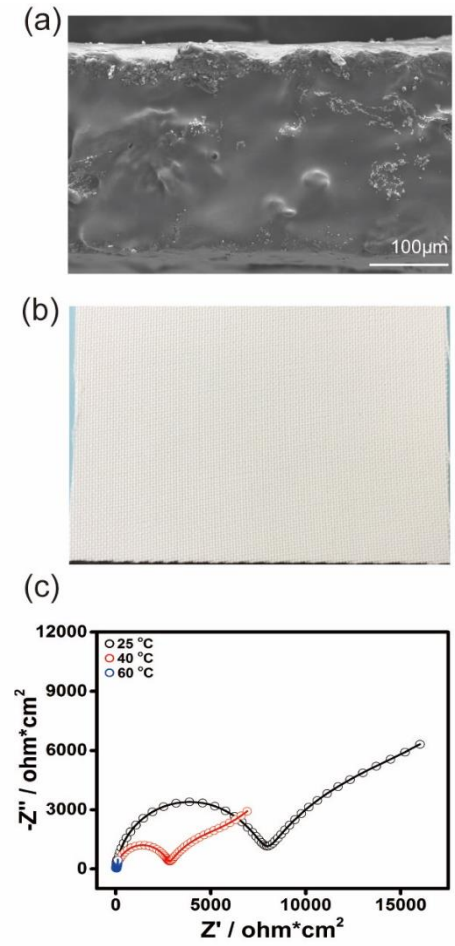


Figure S4. Electrochemical characterization of the garnet textile reinforced flexible CPE.

(a) Impedance plots of a Li/CPE/Li symmetrical cell before and after 500 h cycling at 60 ºC; (b) Room-temperature galvanostatic cycling measurements of Li/CPE/Li symmetrical cells at 0.05 mA/cm^2; (c) Galvanostatic cycling measurements of Li/CPE/Li symmetrical cells at 1 mA/cm^2 and 60 ºC.

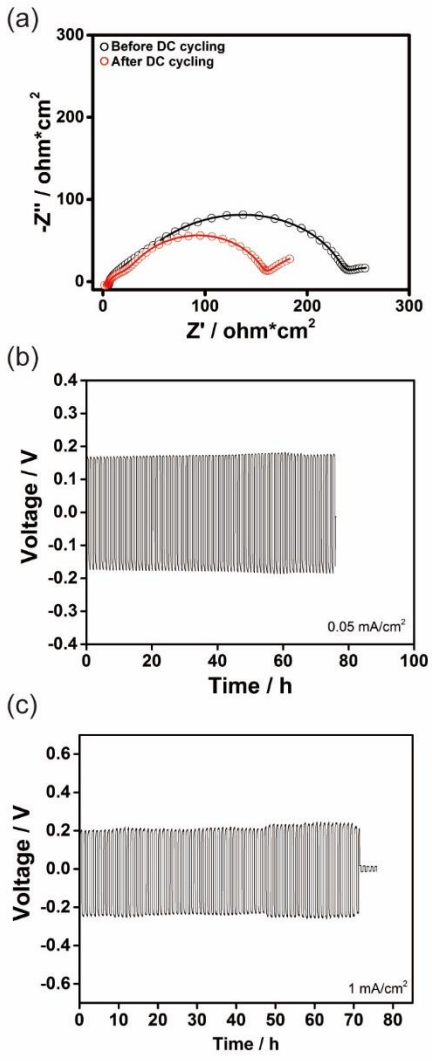


Figure S5. Characterization of the sulfur infiltrated 3D electrode built with garnet textile architecture for solid-state Li-S batteries.

(a) EDX elemental linear scan along the direction from the exposed yarn area to the dense electrolyte surface of the 3D sulfur cathode built with garnet textile; (b) High magnification cross-sectional SEM image and elemental mapping of the 3D sulfur cathode built with garnet textile.

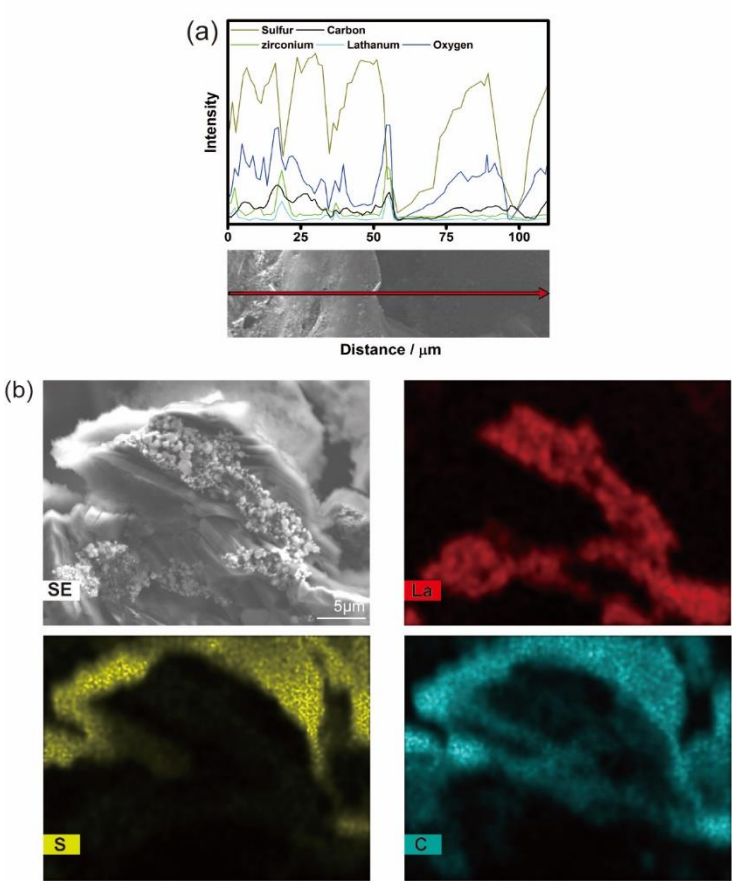


Figure S6. Characteristic features of the garnet electrolyte support fabricated by tape casting and hot lamination, and chemical compatibility of garnet electrolyte with polysulfide catholyte and liquid electrolyte.

(a) Cross-sectional SEM image of a 500 μm thick dense garnet electrolyte support; (b) XRD pattern of the crushed garnet electrolyte; (c) Lithium-ion conductivity of the dense garnet electrolyte in the temperature range of 25 ºC and 100 ºC. (d) Photograph of a fresh garnet electrolyte support polished in the glove box; (e) Photograph of the garnet electrolyte soaked in polysulfide catholyte and liquid electrolyte for 300 h; (f) Photograph of the garnet electrolyte rinsed with DME/DOL solvent afterward, with no obvious color change observed. (g) XRD patterns of the garnet electrolyte before and after the soaking experiment, with no chemical change observed.

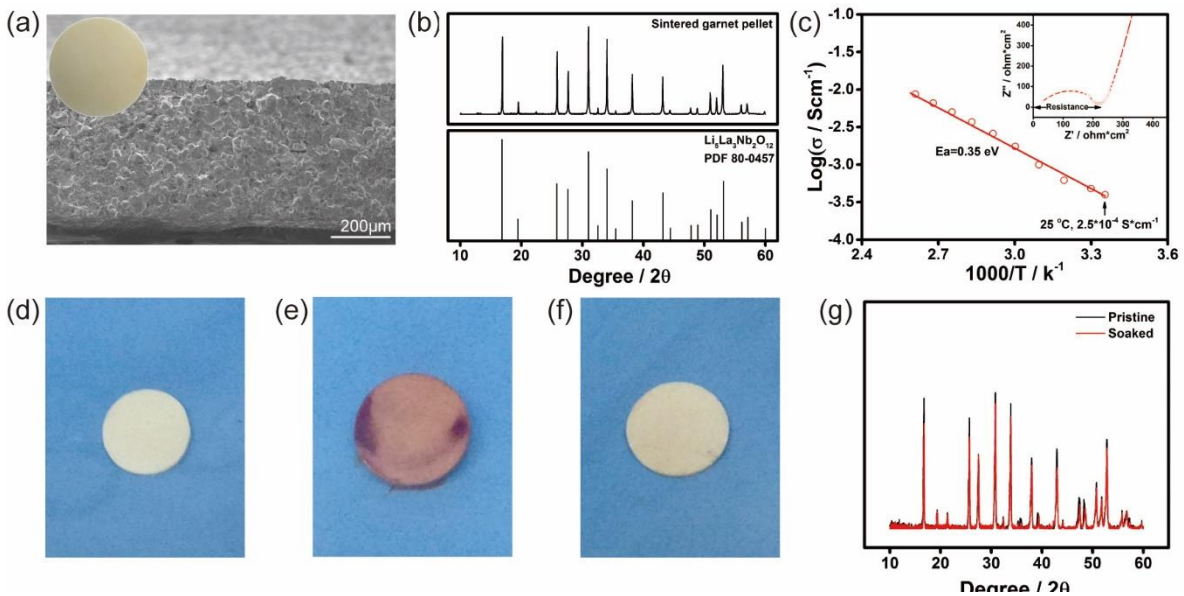


Figure S7. Discharge and charge profiles of the solid-state Li-S batteries built with garnet textile architecture with sulfur loading of 10.8 mg/cm^2 at 0.75 mA/cm^2.

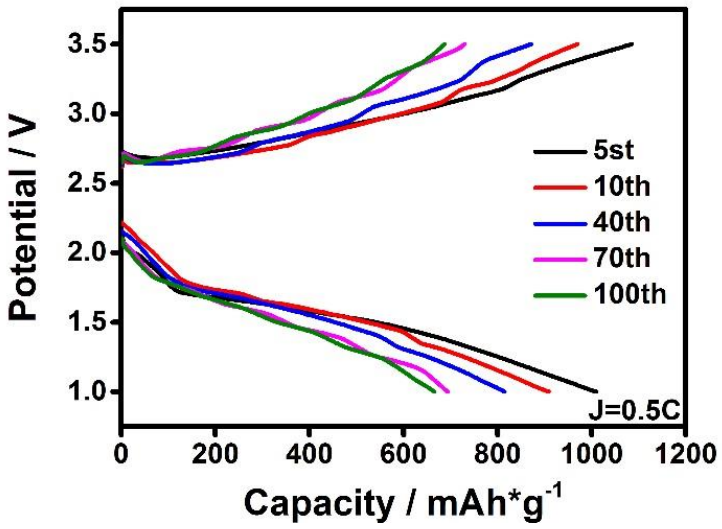


Figure S8. Discharge and charge profiles of the solid-state Li-S batteries built with garnet textile architecture with higher sulfur loading of 18.6 mg/cm^2 at 0.15 mA/cm^2.

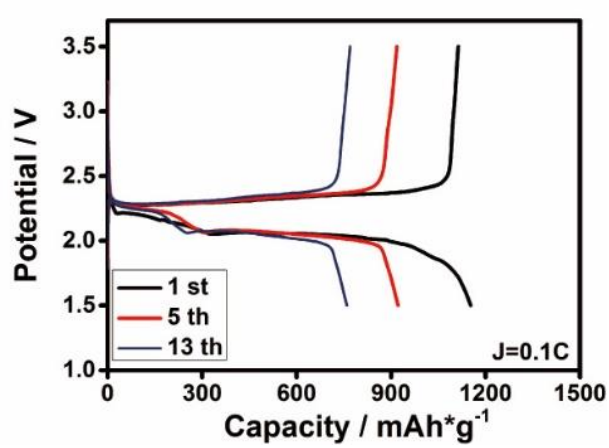
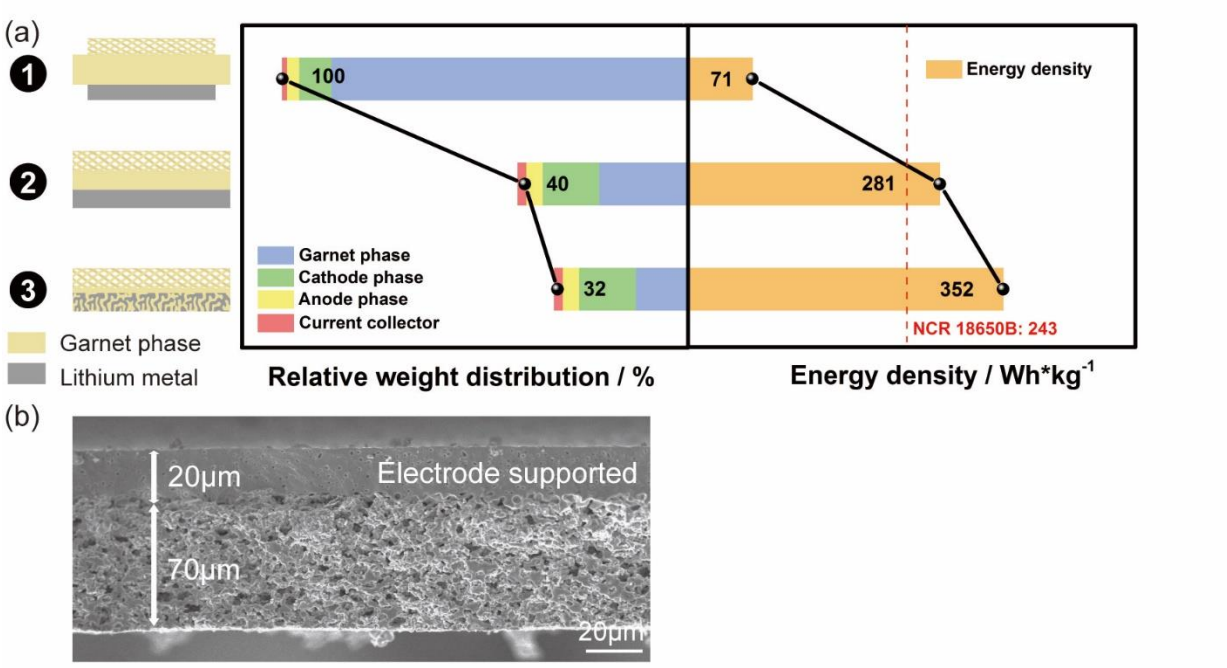


Figure S9. Relative weight and energy density of the solid-state Li-S batteries with 18.6 mg/cm^2 sulfur loading in different electrolyte support structural configurations.

(a) Relative weight distribution of garnet, cathode, anode and current collector in solid-state Li-S batteries and corresponding energy densities: (1) 500 μm thick electrolyte support and 63 % utilization of electrolyte area; (2) 100 μm thick electrolyte support and 100 % utilization of electrolyte area. (3) Bi-layer support structure consisting of thin dense electrolyte (20 μm) and porous substrate (70 μm), and 100% utilization of electrolyte area. (b) Representative SEM image of the low-weight bi-layer supporting structure.



Supplementary Tables

Table S1. Densities of the constituent materials in solid-state Li-S battery

Materials	Density(g/cm^3)
Garnet	5.1
Sulfur	1.96
1M LiTFSI in DME/DOL	1.13
PVP	1.2
Carbon nanotube	1.6
Lithium	0.53
Carbon felt	0.15

Table S2. Structural parameters of different electrolyte support configurations

	Thickness of electrolyte support (μm)	Relative density of electrolyte support (%)	Electrolyte/electrode contact area (cm^2)
①	500	92	0.49
②	100	92	0.78
③	20/70	99/30	0.78

Table S3. Parameters of cathode components

Cathode	Parameters
Thickness of garnet textile (μm)	200
Porosity (%)	85
Sulfur loading (mg/cm^2)	18.6
PVP (mg/cm^2)	2.35
CNT(mg/cm^2)	2.35
Liquid (μl)	10

Table S4. Parameters of anode component

Anode	Parameters
Lithium metal Weight (g)	0.005