Supporting Information

Garnet Solid Electrolyte Protected Li-Metal Batteries

Boyang Liu,[†,‡,§] Yunhui Gong,[†,‡,§] Kun Fu,[†,‡,§] Xiaogang Han,[†,‡] Yonggang Yao,[†,‡] Glenn Pastel,[†,‡] Chunpeng Yang,[†,‡] Eric D. Wachsman,[*,†,‡] and Liangbing Hu[*,†,‡]

[†]University of Maryland Energy Research Center, University of Maryland, College Park, Maryland, 20742, United States

[‡]Department of Materials Science and Engineering, University of Maryland, College Park, Maryland, 20742, United States

[§]These authors contributed equally to this work

*E-mail: ewach@umd.edu, binghu@umd.edu.

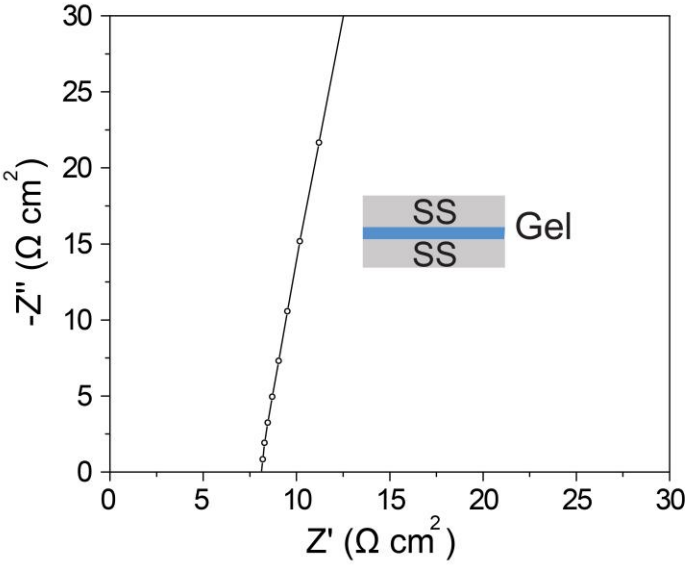


Figure S1. EIS of gel polymer between two stainless steel disks. The bulk resistance of the 40 μm thick gel polymer layer is 7 Ω cm^2.

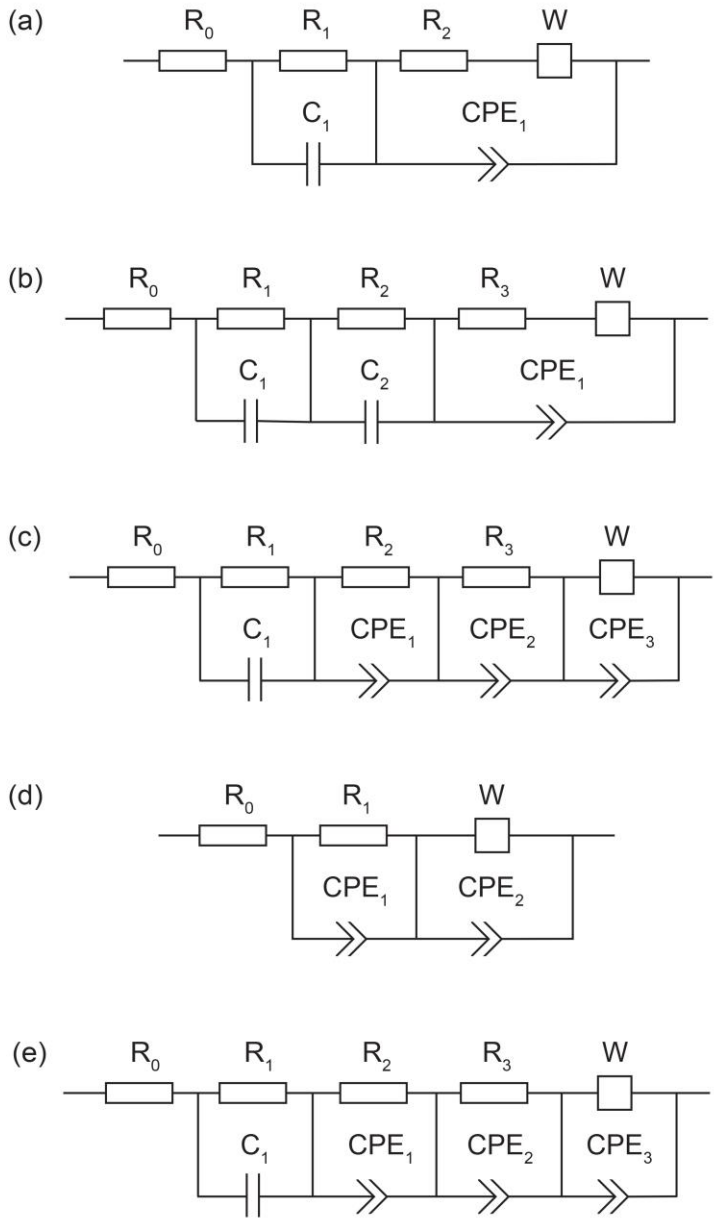


Figure S2. Equivalent circuits for different symmetric cells characterized in Figure 3. (a) Equivalent circuit for cathode/gel/cathode symmetric cell. R_0 = 20 Ω cm^2 is for bulk resistance of gel polymer. R_1 = 140 Ω cm^2 is for the interfacial R_{ct} of gel/cathode, and C_1 with capacitance 5×10^{-6} F cm^2 is for the interfacial capacitance on gel/cathode interface. The Warburg impedance element W, R_2 (50.8 Ω cm^2) and the constant phase element CPE_1 (1×10^{-5} F cm^2) are for diffusion impedance. Same circuit structure to analyze electrode/electrolyte interface is shown in

reference 1. (b) Equivalent circuit for SS/gel/SSE/gel/SS symmetric cell. R_0 = 79 Ω cm^2 is for bulk resistance of garnet. R_1 = 202.2 Ω cm^2, and $C_1 = 6.304\times10^{-10}$ F cm^2 are for grain boundary impedance of garnet. R_2 = 311 Ω cm^2 and $C_2 = 8.67\times10^{-7}$ F cm^2 are for charge transfer resistance and double-layer capacitance on SSE/gel interfaces. W, R_3 = 46.9 Ω cm^2, and CPE_1 with capacitance 7.8×10^{-7} F cm^2 are for diffusion impedance on gel/SS interfaces. (c) Equivalent circuit for cathode/gel/SSE/gel/cathode symmetric cell. R_0 = 52.83 Ω cm^2 is for bulk resistance of garnet. R_1 = 74.28 Ω cm^2 and $C_1 = 3\times10^{-9}$ F cm^2 are for grain boundary impedance of garnet. R_2 = 400 Ω cm^2 and CPE_1 with capacitance 6.7×10^{-5} F cm^2 are for charge transfer resistance and double-layer capacitance of SSE/gel interface. R_3 = 95.34 Ω cm^2 and CPE_2 with capacitance 4.7×10^{-5} F cm^2 are for charge transfer resistance and double-layer capacitance of gel/cathode interface. W and CPE_3 with capacitance 4×10^{-5} F cm^2 are for diffusion impedance inside of cathode. (d) Equivalent circuit for Li/gel/Li symmetric cell. R_0 = 6.4 Ω cm^2 is for bulk resistance of gel. R_1 = 180.4 Ω cm^2 and CPE_1 with capacitance 5.8×10^{-6} F cm^2 are for charge transfer resistance and double-layer capacitance of Li/gel interface. W and CPE_2 with capacitance 1.8×10^{-3} F cm^2 are for diffusion impedance on Li/gel interfaces. (e) Equivalent circuit for Li/gel/SSE/gel/Li symmetric cell. R_0 = 20 Ω cm^2 is for bulk resistance of garnet. R_1 = 151.3 Ω cm^2, $C_1 = 1.8\times10^{-9}$ F cm^2 are for the grain boundary impedance of garnet. R_2 = 270 Ω cm^2, and $CPE_1 = 1.5\times10^{-5}$ F cm^2 are for charge transfer resistance and double-layer capacitance of Li/gel interface. R_3 = 157.9 Ω cm^2 and CPE_2 with capacitance 3.8×10^{-3} F cm^2 are for charge transfer resistance and double-layer capacitance of SSE/gel interface. W and CPE_3 with capacitance 2.6×10^{-2} F cm^2 are for diffusion impedance on Li/gel interfaces.

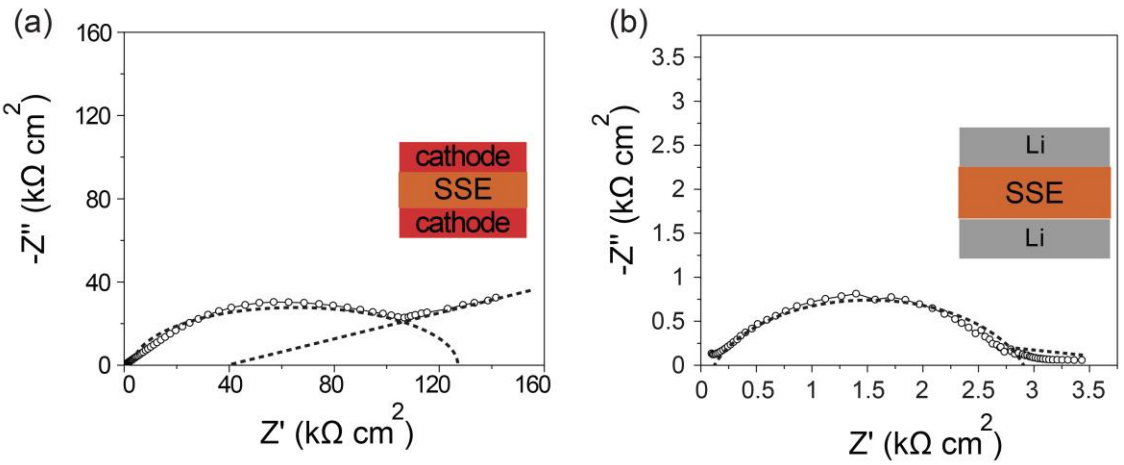


Figure S3. Impedance of electrode/SSE/electrode symmetric cells without gel interface. (a) EIS of cathode/SSE/cathode symmetric cell. (b) EIS of Li/SSE/Li symmetric cell.

References

(1) Zhang, S. S.; Xu, K.; Jow, T. R. EIS study on the formation of solid electrolyte interface in Li-ion battery. *Electrochim. Acta*, **2006**, *51*, 1636–1640.