S1. Scanning electron microscope (SEM) images and EDS elemental mappings of a) CA Ge Mem; b) PAN Ge Mem; c) PAN Ge Mem 30s; d) PAN Ge 2min; e) DC PAN Ge Mem 30s; f) SEM image of ball-milled Ge micron powders; g) and h) are transmission electron microscope (TEM) images of DC PAN Ge Mem 30s. Scale bars: 25 µm for a-e; 1 µm for f; 100 nm for g and h.
S2. Cross-sectional SEM image of PAN Ge Mem 30s and corresponding EDS line scan indicate the thickness of carbonaceous membrane coating is ~ 2 µm.
S3. Thermogravimetric analyses of a) micron powder Ge; b) CA Ge Mem; c) PAN Ge Mem; d) PAN Ge Mem 30s; e) PAN Ge Mem 2 min; f) DC PAN Ge Mem 30s.
S4. Electrochemical evaluations of micron powder Ge and Ge asymmetric membranes as LIB anode: a) cycling test of micron powder Ge electrode control; b) voltage profiles of PAN Ge Mem and CA Ge Mem in the first formation cycle; c) and d) voltage profiles of PAN Ge Mem 30s and DC PAN Ge Mem 30s in the first two formation cycles, respectively; e) and f) EIS Nyquist plots of DC PAN Ge Mem 30s before and after being cycled at 160 mA g\(^{-1}\) for 50 times and PAN Ge Mem 30s before and after being cycled at 400 mA g\(^{-1}\) for 170 cycles (Figure 5c).