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Supplementary information

Significantly increased energy density and discharge efficiency at high temperature in polyetherimide nanocomposite by a small amount of Al_2O_3 nanoparticles

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Fig. S1(a) presents the X-ray diffraction (XRD) patterns of the AO-nps, and all of the deflection peaks of the product are well indexed by the standard data of face-centered cubic γ-Al_2O_3 (PDF#29-0063), indicating the high purity of the nanoparticles.

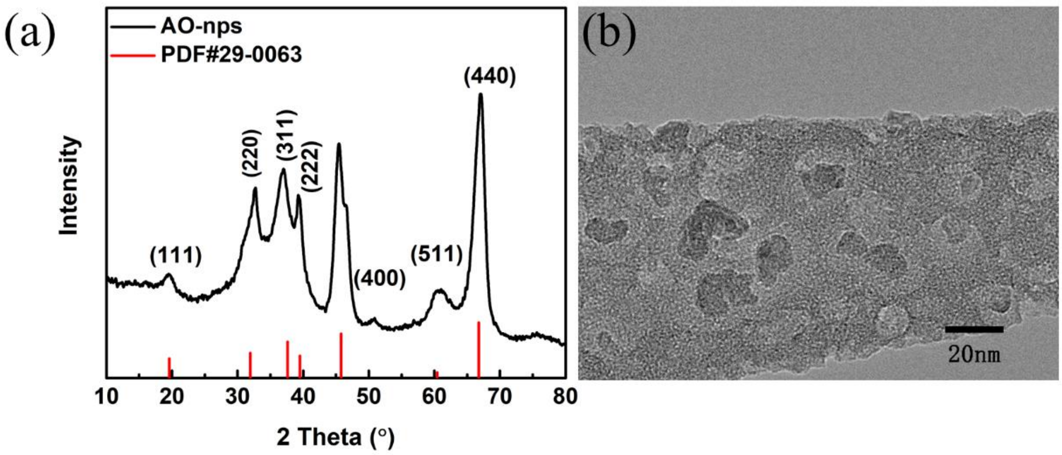

Fig. S1. (a) X-ray diffraction (XRD) patterns of the nanostructured Al_2O_3 fillers. (b) TEM image of Al_2O_3 particles.

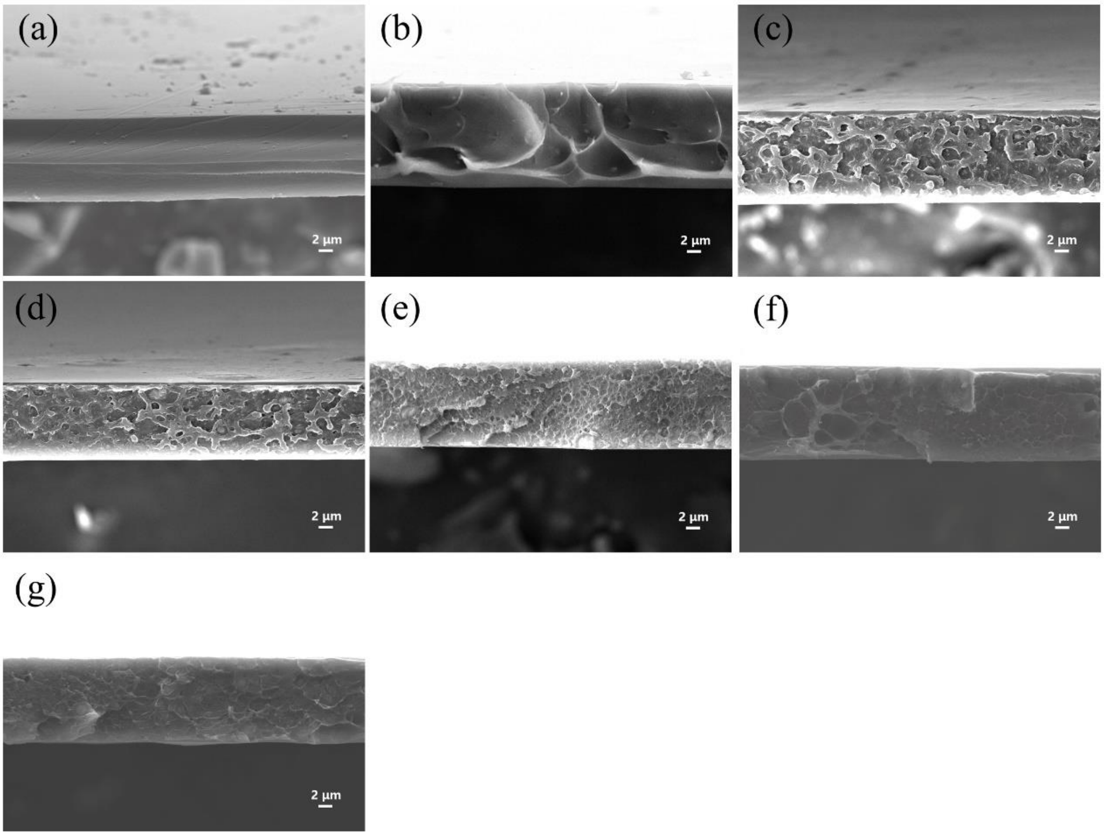

Fig. S2. Cross-sectional SEM images of (a) pure PEI film, (b) PEI nanocomposites with 0.5 vol% AO-nps, (c) PEI nanocomposites with 1 vol% AO-nps, (d) PEI nanocomposites with 2 vol% AO-nps, (e) PEI nanocomposites with 3 vol% AO-nps, (f) PEI nanocomposites with 5 vol% AO-nps, and (g) PEI nanocomposites with 7 vol% AO-nps.

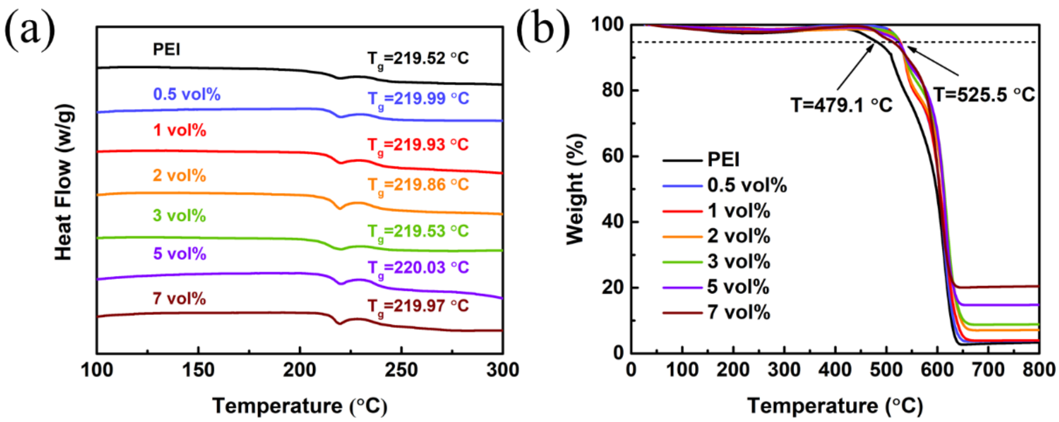

Fig. S3. (a) DSC and (b) TGA curves of pristine PEI and the PEI/AO-nps nanocomposite films.

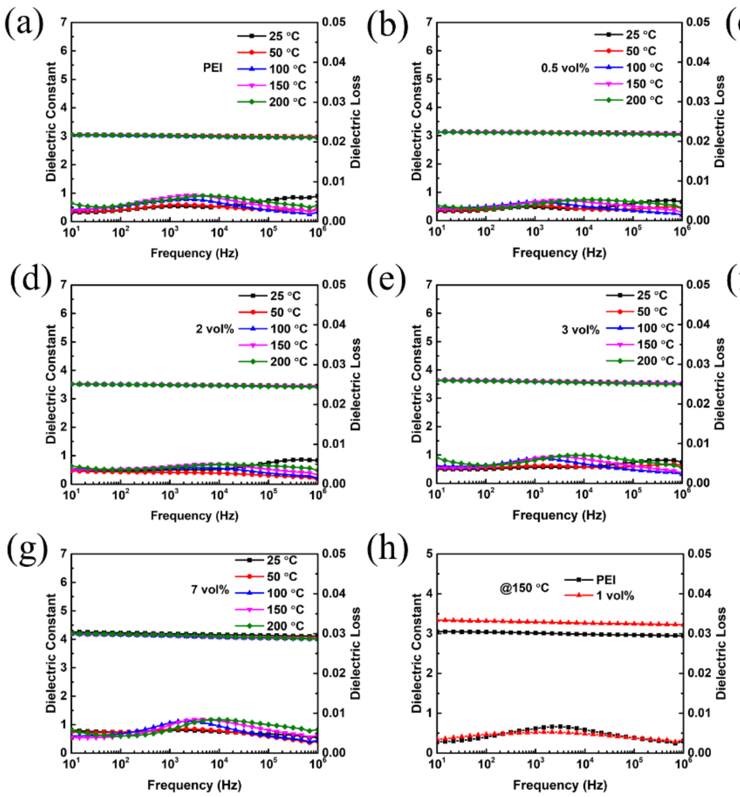

Fig. S4. Dielectric spectra of nanocomposites with varied frequency and temperature, (a) PEI, (b) 0.5vol%, (c) 1vol%, (d) 2 vol%, (e) 3 vol%, (f) 5 vol%, and (g) 7vol%. (h) Frequency-dependent dielectric properties of the PEI and PEI composite with 1vol% AO-nps at 150 °C.

Table S1 Breakdown strength of PEI and nanocomposites with varied content measured at different temperature.

成分	25 ℃		50 ℃		100 ℃		150 ℃	
	E_b (MV/m)	β	E_b (MV/m)	β	E_b (MV/m)	β	E_b (MV/m)	β
PEI	558.1	16.9	558.1	14.5	500.3	13.0	421.8	6.5
0.5 vol%	567.7	15.7	562.6	17.3	516.0	13.8	445.3	8.0
1 vol%	581.7	19.4	575.9	18.5	548.2	16.6	503.9	11.1
2 vol%	571.3	20.1	566.1	20.1	527.2	19.3	456.8	7.4
3 vol%	544.9	16.5	543.4	16.7	511.1	13.2	430.8	6.4
5 vol%	428.7	13.0						
7 vol%	384.3	8.6						

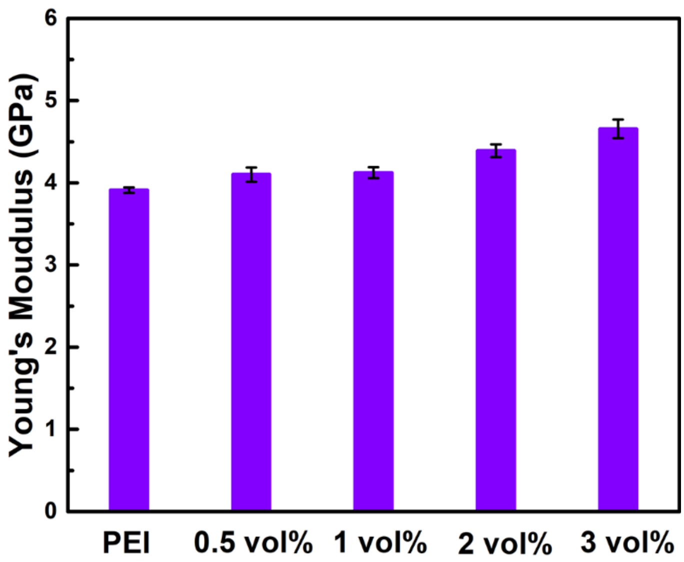

Fig. S5. Young's modulus of the nanocomposites with varied filler content measured at room temperature.

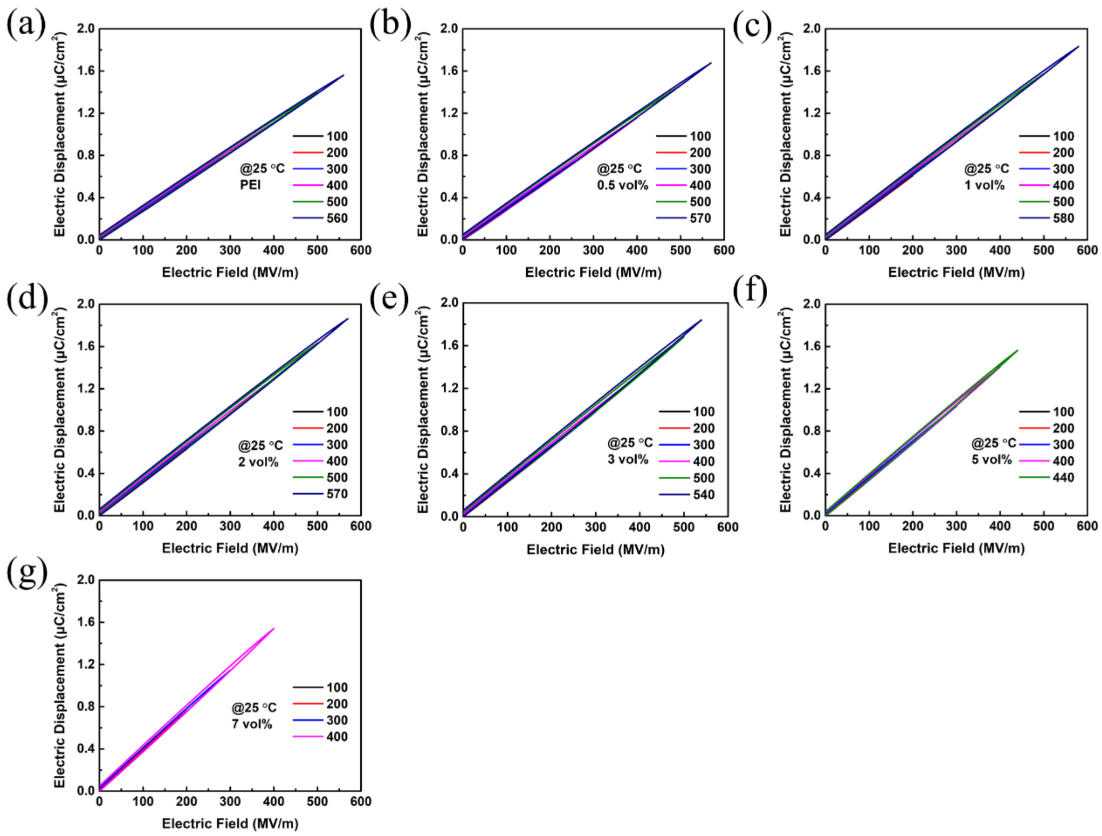

Fig. S6. Electric displacement-electric field (D-E) loops of nanocomposites with varied filler content measured at 25 °C, (a) PEI, (b) 0.5vol%, (c) 1vol%, (d) 2 vol%, (e) 3 vol%, (f) 5 vol%, and (g) 7vol%.

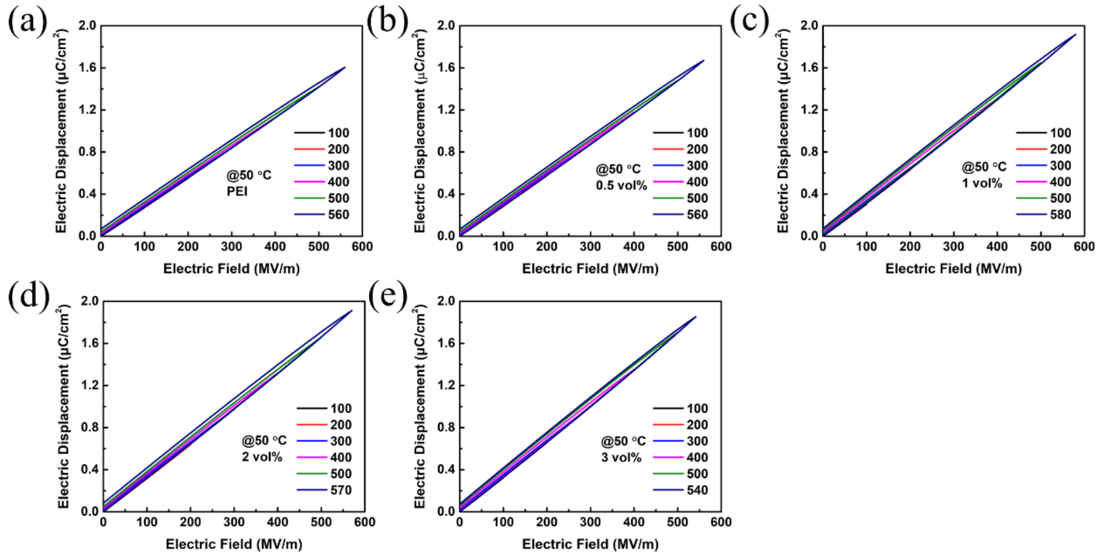

Fig. S7. Electric displacement-electric field (D-E) loops of nanocomposites with varied filler content measured at 50 °C, (a) PEI, (b) 0.5vol%, (c) 1vol%, (d) 2 vol%, and (e) 3 vol%.

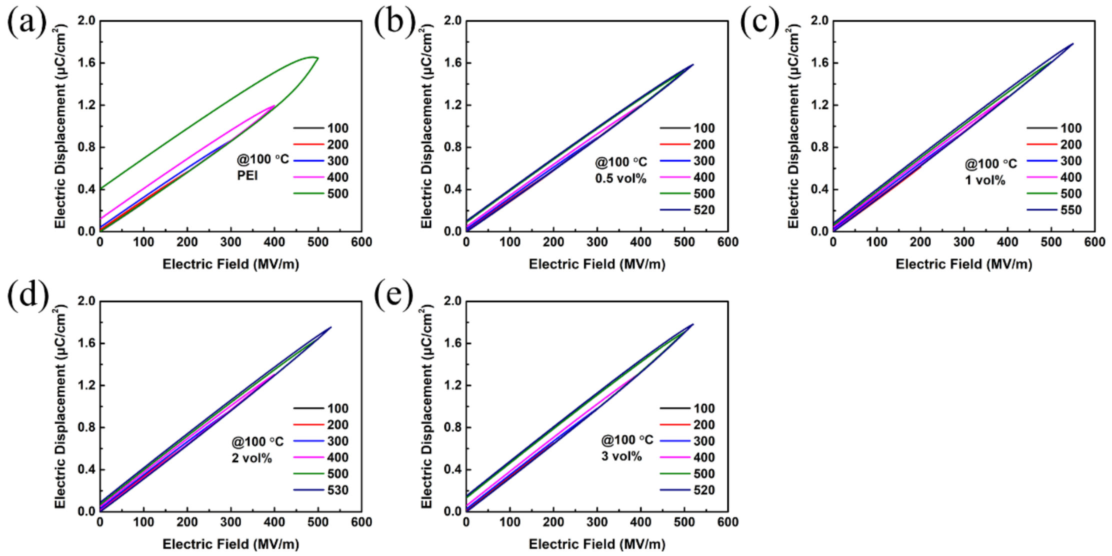

Fig. S8. Electric displacement-electric field (D-E) loops of nanocomposites with varied filler content measured at 100 °C, (a) PEI, (b) 0.5vol%, (c) 1vol%, (d) 2 vol%, and (e) 3 vol%.

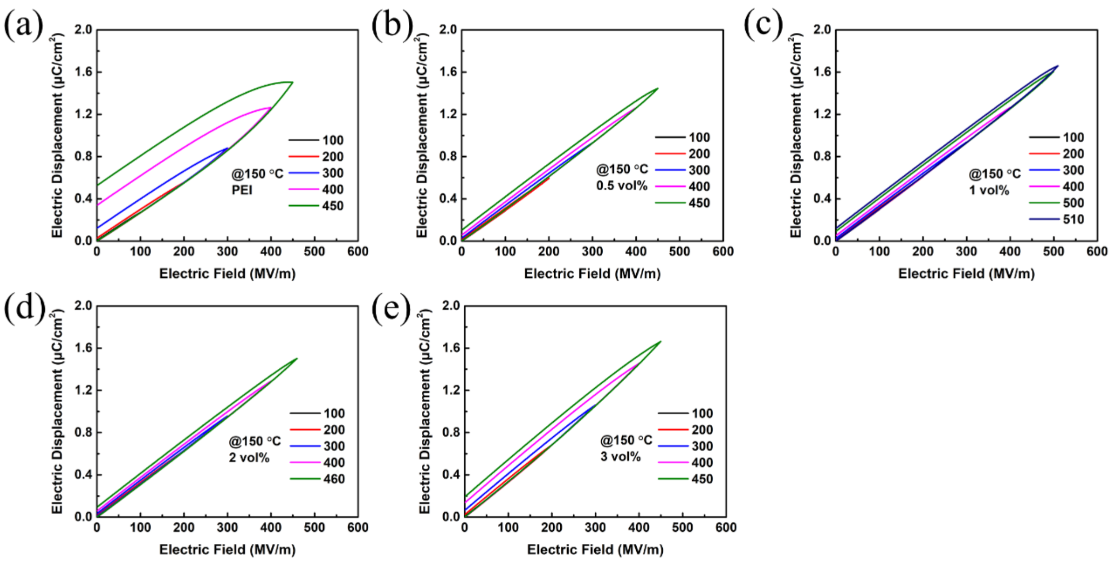

Fig. S9. Electric displacement-electric field (D-E) loops of nanocomposites with varied filler content measured at 150 °C, (a) PEI, (b) 0.5vol%, (c) 1vol%, (d) 2 vol%, and (e) 3 vol%.

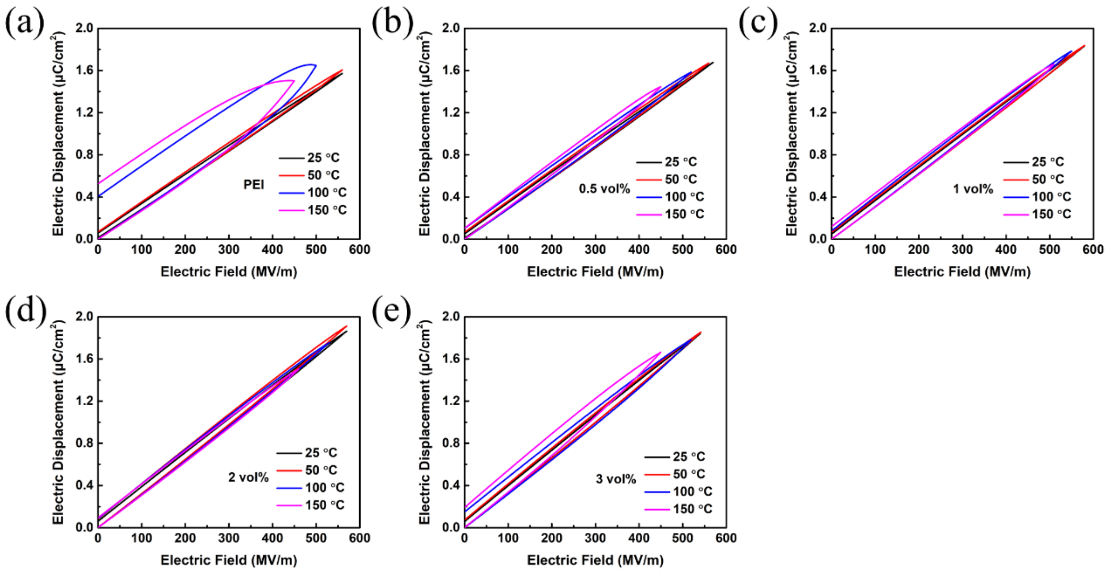

Fig. S10. Maximum electric displacement-electric field (D-E) loops of nanocomposites measured at different temperature, (a) PEI, (b) 0.5vol%, (c) 1vol%, (d) 2 vol%, and (e) 3 vol%.

Fig. S11(a) shows the TSDC spectroscopies of the nanocomposites, which are collected under a poling field (E_p) of 15 MV/m for a poling time of 30 min at poling temperature (T_p) of 150 °C. There is only a peak at 180-200 °C, which is supposed to be ascribed to the depolarization of the injected charges from electrodes, i.e., Schottky or thermionic emission. As shown in **Fig. S11**(b) The E_p-dependent TSDC test was performed for PEI with 1 vol% AO-nps to verify the hypothesis about injection charges. In general, for Schottky emission, the current density (J) scales as ln $J \propto E_p^{1/2}$. At equilibrium state, the injected charges equal to the leakage charges (C), which can be obtained from the TSDC spectrum as $\ln C \propto E_p^{1/2}$. **Fig. S11**(c) establishes the linear relationship between ln C and $E_p^{1/2}$, which supports our prediction. The increase of maximum displacement and decrease of remnant displacement bring about considerable improvement in high-temperature electric energy storage.

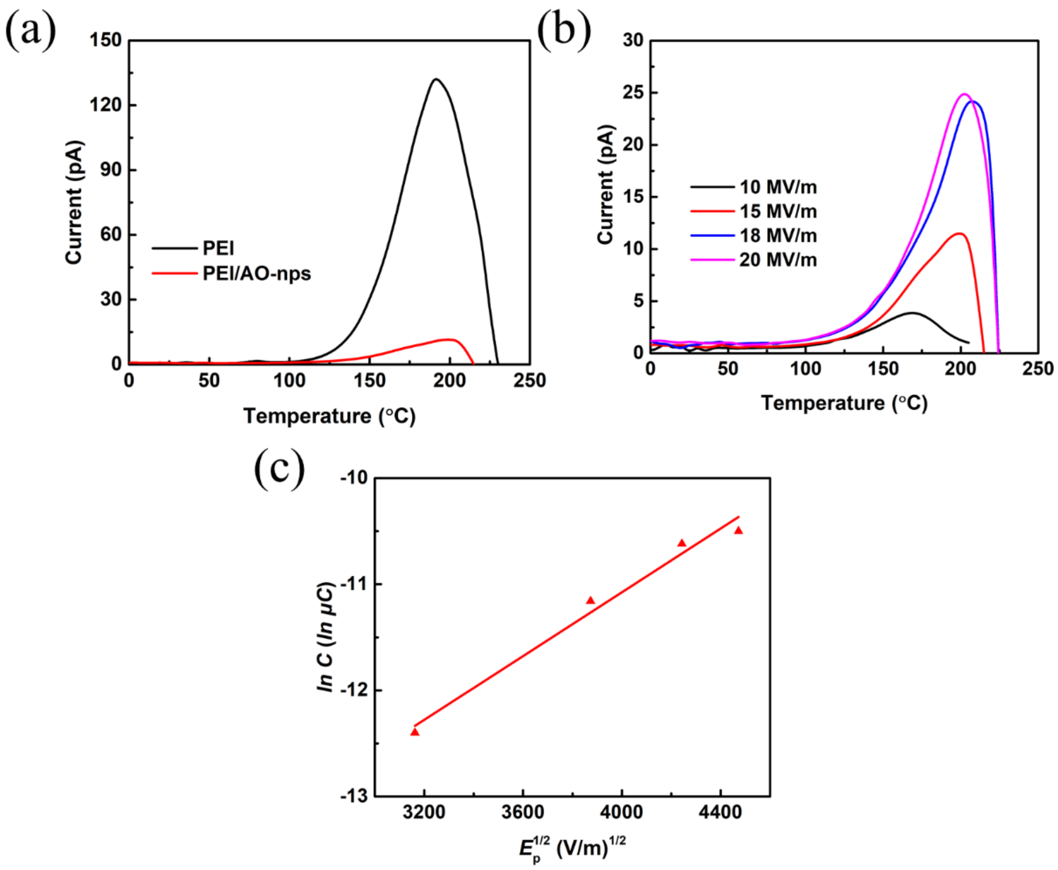

Fig. S11. (a) TSDC curves of PEI and PEI/AO-nps under poling electric field of 15 MV/m at 150 °C for 30 min. (b) TSDC spectra for PEI/AO-nps film under different poling electric field at 150 °C for 30 min. (c) The relationship between lnC and $E_p^{1/2}$.

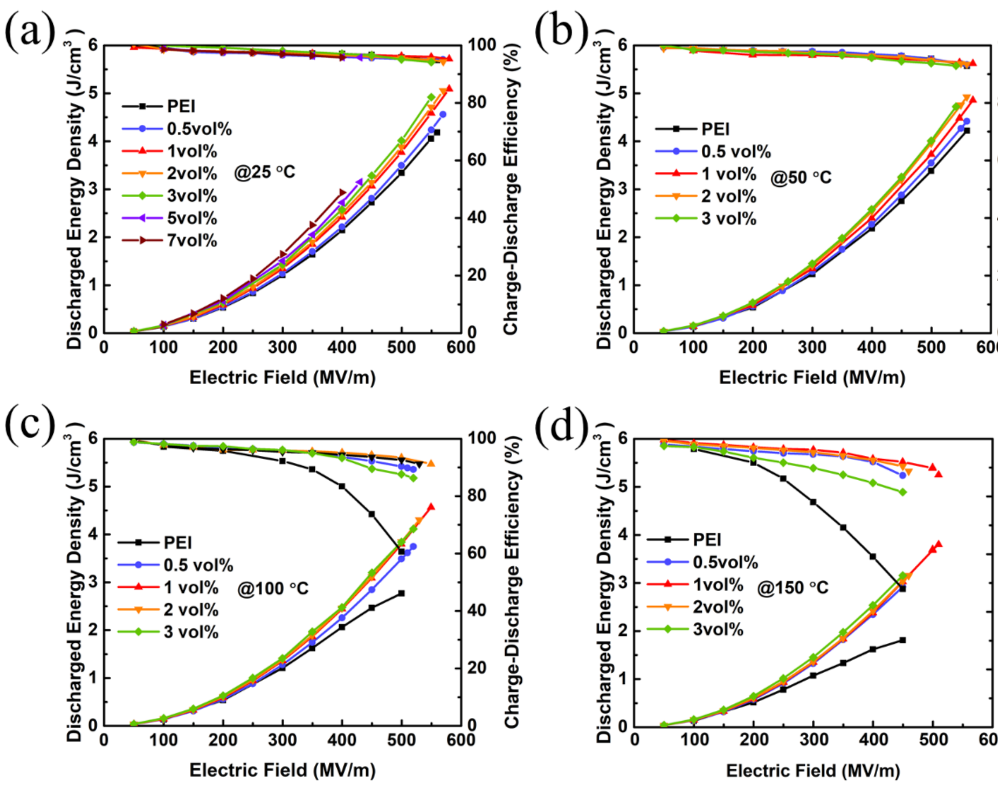

Fig. S12. Discharged energy density and charge-discharge efficiency of PEI/AO-nps nanocomposite films with varied filler contents measured at (a) 25 ℃, (b) 50 ℃, (c) 100 ℃, and (d) 150 ℃.

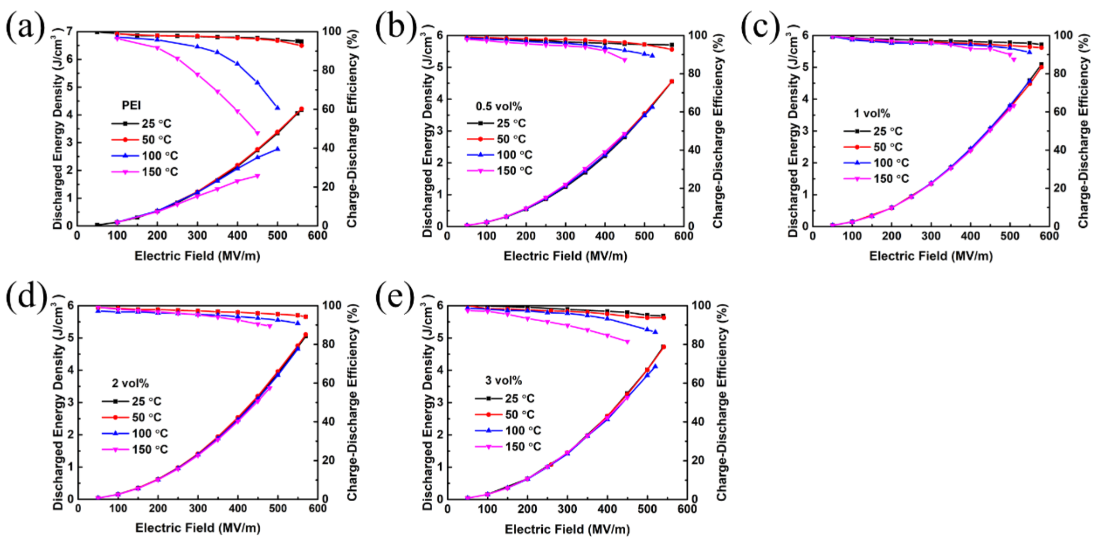

Fig. S13. Discharged energy density and charge-discharge efficiency of PEI/AO-nps nanocomposite films nanocomposites measured at different temperature, (a) PEI, (b) 0.5 vol%, (c) 1 vol%, (d) 2 vol%, and (e) 3 vol%.