Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supplementary Information

Superior Electrostrictive Strain Achieved Under Low Electric Field in Relaxor Ferroelectric Polymers

Zhicheng Zhang, Xiao Wang, Shaobo Tan, and Qing Wang**

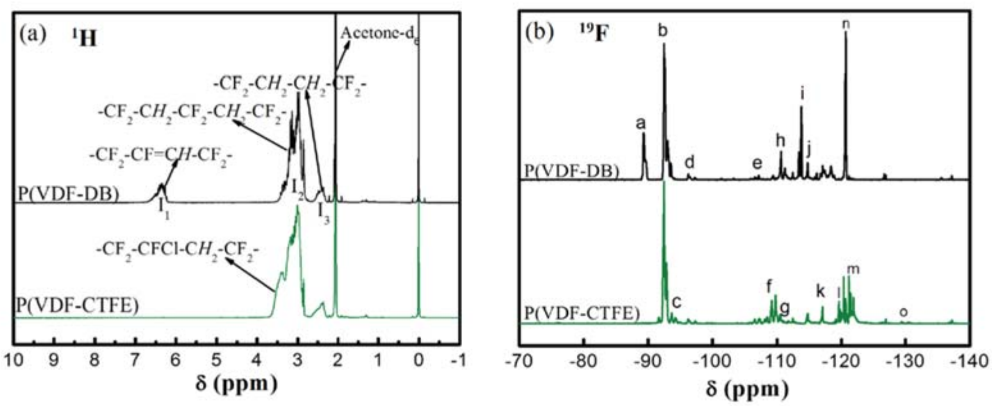


Fig. S1. a) ^{1}H NMR of P(VDF-CTFE) bearing 20 mol% CTFE and P(VDF-DB) synthesized from the fully dehydrochlorination of P(VDF-CTFE). b) ^{19}F NMR spectra of P(VDF-CTFE) with 20 mol% CTFE and P(VDF-DB) synthesized from the fully dehydrochlorination of P(VDF-CTFE).

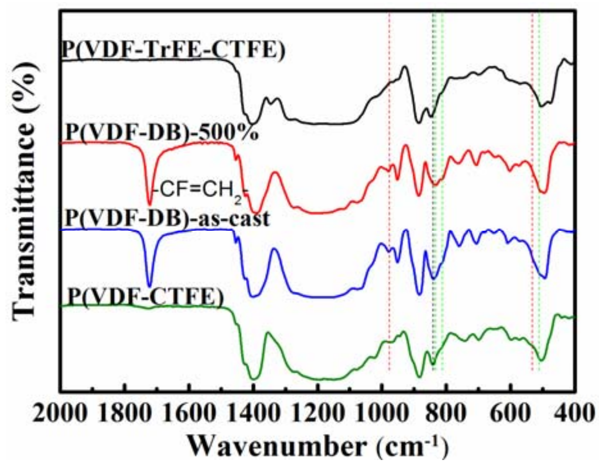


Fig. S2. FTIR spectra of P(VDF-TrFE-CTFE), P(VDF-DB)-500, P(VDF-DB)-as-cast and P(VDF-CTFE).

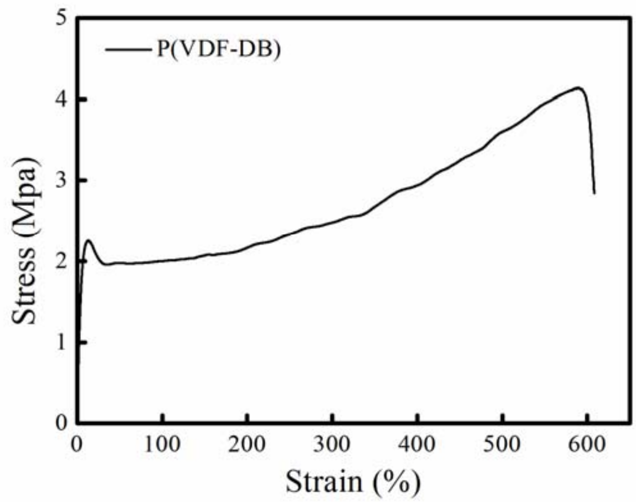
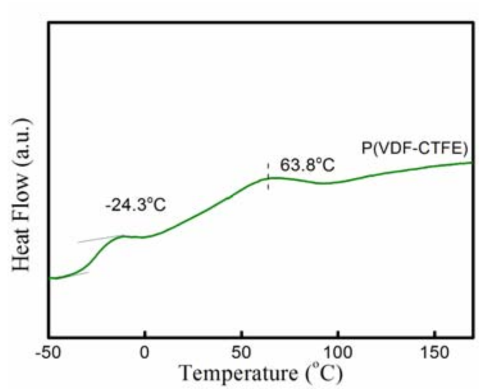


Fig. S3. Stress-strain curve of P(VDF-DB).



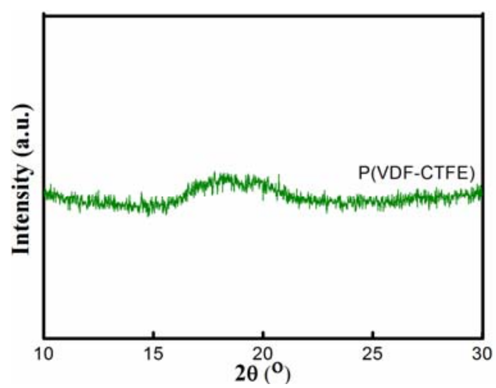


Fig. S4. DSC and XRD of P(VDF-CTFE).

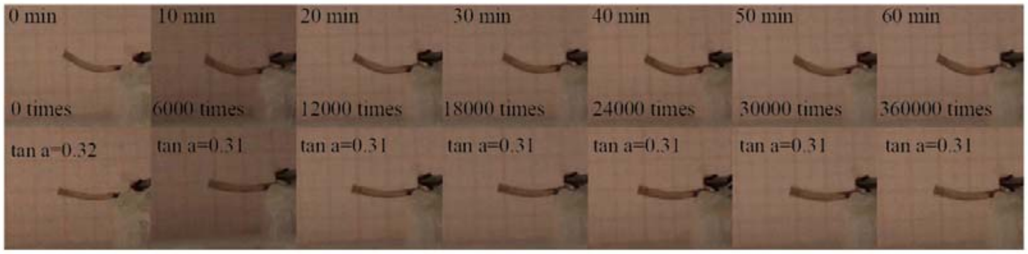


Fig. S5. The fatigue behavior of electrostrictive strain of P(VDF-DB)-500 with field.

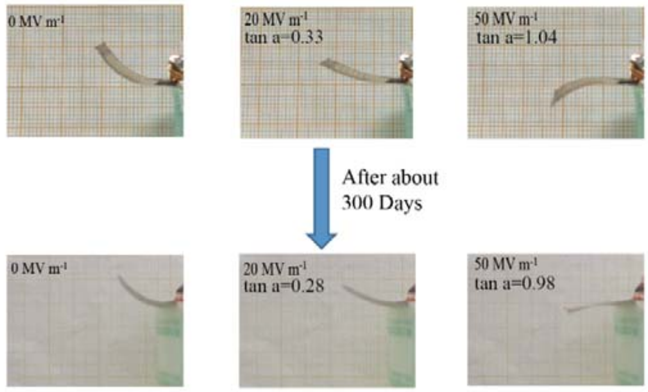


Fig. S6 The fatigue behavior of electrostrictive strain of P(VDF-DB)-500 with time.

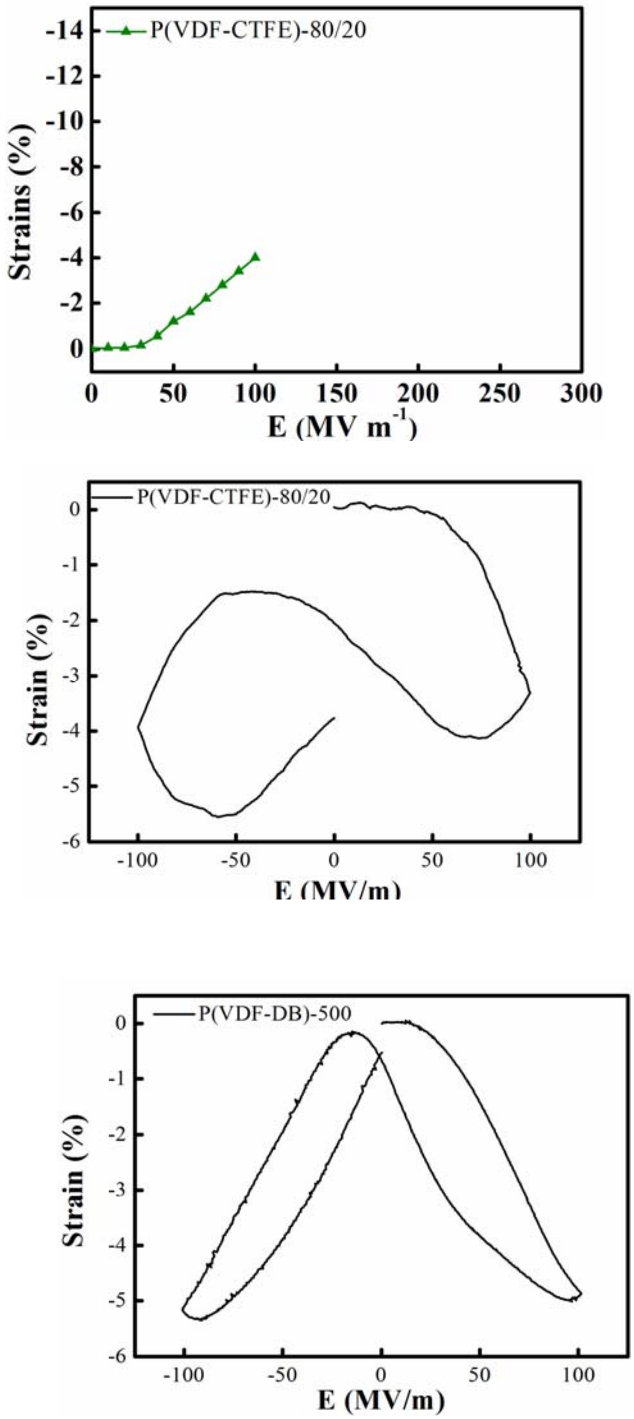


Fig. S7. Strain of P(VDF-CTFE) and P(VDF-DB)-500 under the applied field

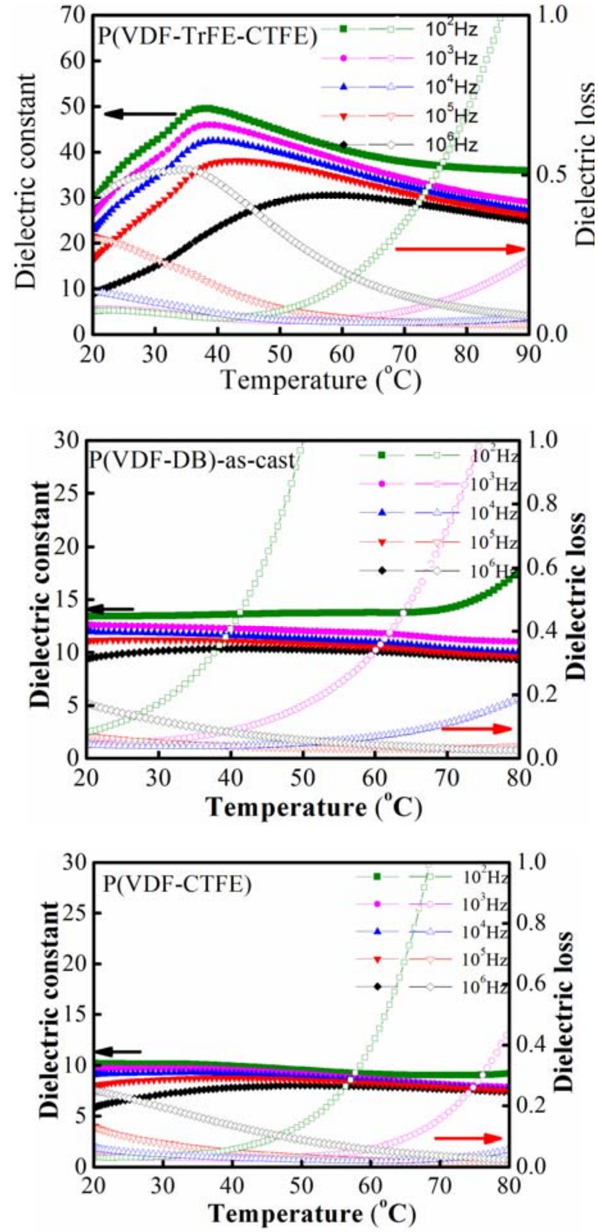
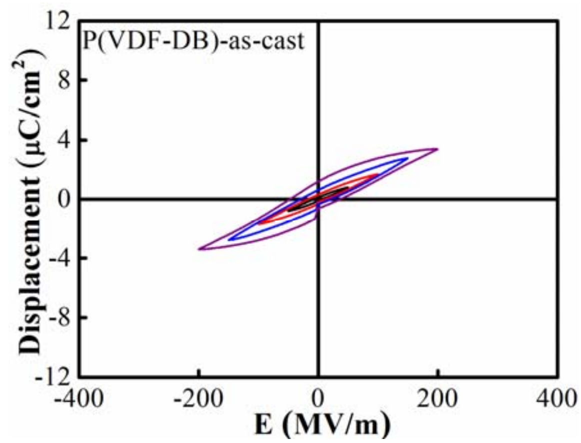


Fig. S8. Dielectric spectra of P(VDF-TrFE-CTFE), P(VDF-DB)-as-cast and P(VDF-CTFE).



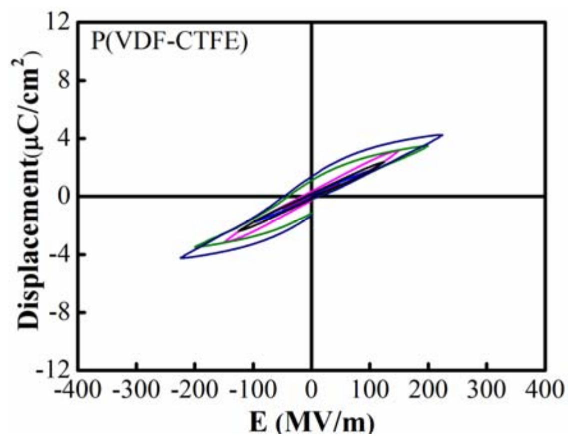


Fig. S9. D-E loops of P(VDF-DB)-as-cast and P(VDF-CTFE)

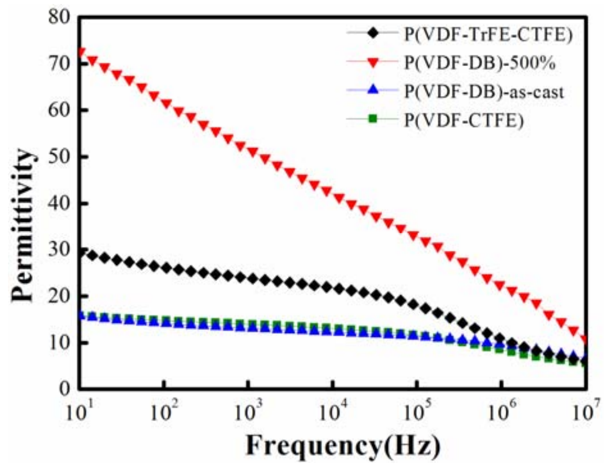


Fig. S10 The frequency dependent permittivity of P(VDF-DB)-as-cast, P(VDF-CTFE), P(VDF-TrFE-CTFE) and P(VDF-DB)-500.

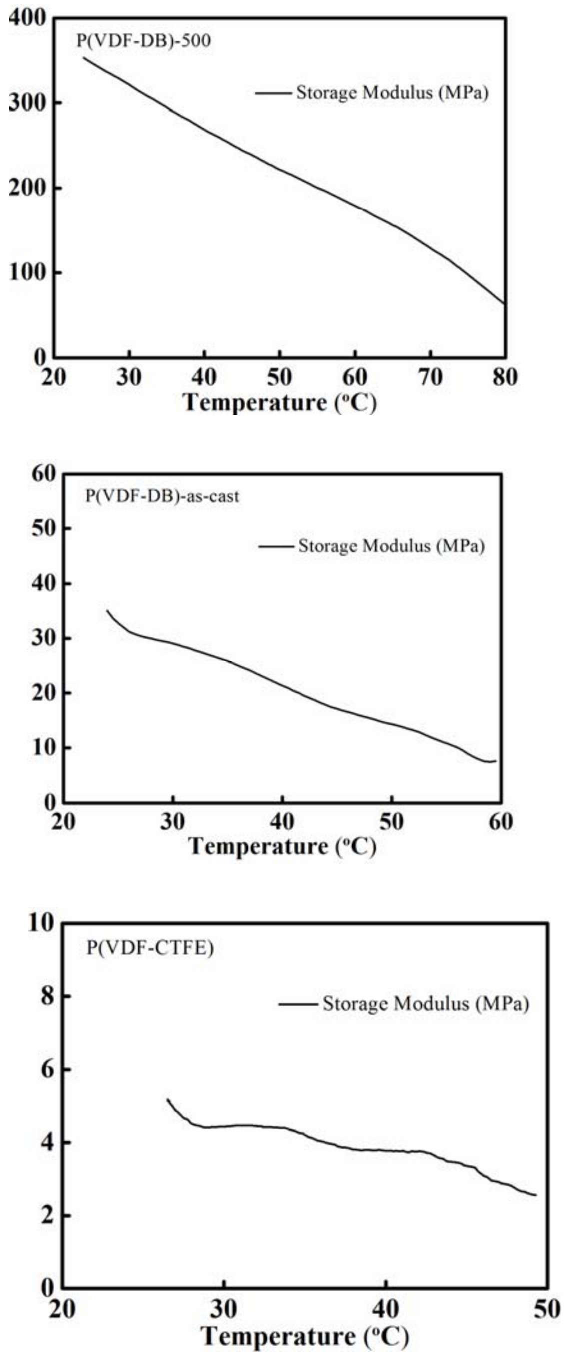


Fig. S11. DMA of P(VDF-CTFE)-500, P(VDF-DB)-as-cast and P(VDF-CTFE).

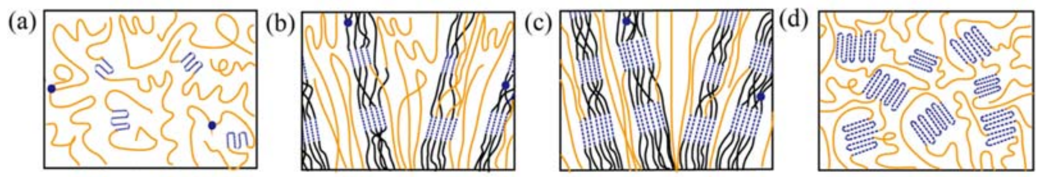


Fig. S12. Schematic of lamellae in crystalline and chains in a) P(VDF-DB)-as-cast. b) P(VDF-DB)-300. c) P(VDF-DB)-500 and d) P(VDF-TrFE-CTFE).

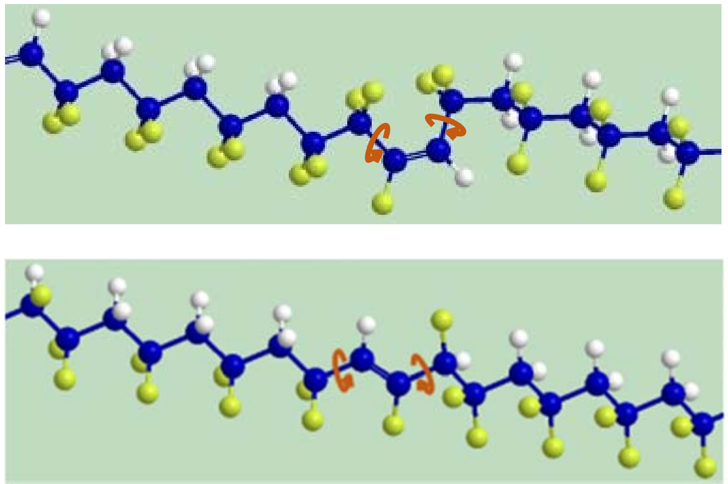


Fig. S13. Easily rotated σ-bonds in chains of *trans* formation of P(VDF-DB)-500 and *gauche* formation of P(VDF-DB)-500.

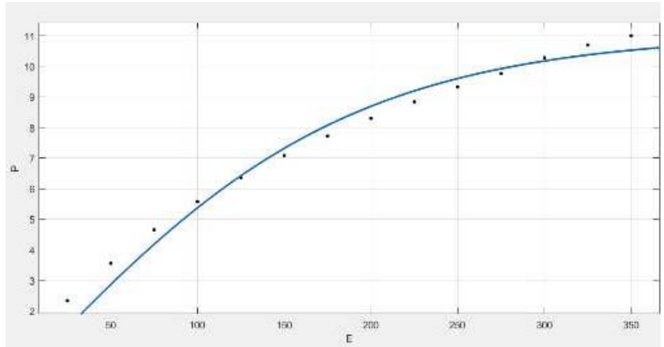


Fig. S14. The P_s and k are calculated from $|P_E| = P_S \tanh(k|E|)$ by Matlab; f(x)= a*(exp(2*b*x)-1)/(esp(2*b*x)+1), a=11.05 μC cm^{-2}, b= 0.5313*10^{-8} m/V (Ps is *a* and k is *b*).

Table S1. ^{19}**F NMR assignment of pristine P(VDF-CTFE) and resultant P(VDF-DB)**

Peak	Sequence	Chemical Shift (ppm)
a	$-CF=CHC\mathit{F}_2CH_2CF_2-$	-89.2
b	$-CF_2CH_2C\mathit{F}_2CH_2CF_2-$	-92.3
c	$-CFClCH_2C\mathit{F}_2CH_2CF_2-$	-93.16 to -93.67
d	$-CH_2CH_2C\mathit{F}_2CH_2CF_2-$	-94.26 to -97.31
e	$-CF_2CFClC\mathit{F}_2CFClCF_2-$	-106.5 to -107.82
f	$-CF_2CH_2C\mathit{F}_2CF_2CFCl-$	-108.0 to -109.34
g	$-CF_2CFClC\mathit{F}_2CFClCH_2-$	-109.34 to -113.10
h	$-CF_2CFClC\mathit{F}_2CF=CH-$	-110.1 to -111.6
i	$-CF_2CF_2C\mathit{F}=CHCF_2-$,$-CF_2CH_2C\mathit{F}_2CF_2CF=CH-$	-113.4 to -113.7
j	$-CF_2CH_2C\mathit{F}_2CF_2CH_2-$	-114.7
k	$-CH_2CF_2C\mathit{F}_2CH_2CH_2-$	-116.6 to -118.8
l	$-CH_2CF_2C\mathit{F}_2CFClCH_2-$	-118.25 to -119.98
m	$-CF_2CF_2C\mathit{F}ClCH_2CF_2-$	-120.35 to -123.32
n	$-CH_2CF_2C\mathit{F}_2CF=CH-$	-120.0 to -120.8
o	$-CF_2CH_2C\mathit{F}ClCF_2CH_2-$	-129.46 to -130.53

Table S2. The permittivity of the polymers measured at 20 ^{o}C

Polymer	ε_r (0.01 HZ)	ε_r (0.1 HZ)	ε_r (1 HZ)	ε_r (10 HZ)	ε_r (10^2 HZ)	ε_r (10^3 HZ)	ε_r (10^4 HZ)	ε_r (10^5 HZ)	ε_r (10^6 HZ)
P(VDF-TrFE-CTFE)	68.35	44.60	34.38	29.21	25.95	24.15	21.79	17.86	10.89
P(VDF-DB)-500	656.4	107.13	81.23	72.41	61.95	51.61	42.06	32.73	21.81
P(VDF-DB)-as-cast	473.6	33.82	19.89	15.73	14.15	13.03	12.36	11.46	9.55
P(VDF-CTFE)	231.8	18.86	13.14	11.35	10.78	9.94	9.33	8.09	6.51

Table S3. The electromechanical property of typical relaxor ferroelectric polymers

polymer †	S_{30} † (%)	S_{50} † (%)	S_M(%)	W_m (J cm^{-3})	k_{33}	*Ref*
Irradiated-P(VDF-TrFE) ᵗ 68/32	-0.6	-1.5	-5	0.5	0.3	32
P(VDF-TrFE-CTFE) † 65/35/10	-0.6	-1.6	-4	0.32	0.28	25
P(VDF-TrFE-CFE) † 68/32/4	0	-0.5	-4.5	1.1	0.55	17
P(VDF-TrFE-CFE) † 68/32/9	-0.3	-1.2	-7	0.73	-	12
P(VDF-DB)-500†	-1.3	-2.5	-13.4	3.1	0.5	This work

†S_{30} is the strain measured at 30 MV m^{-1}. S_{50} is the strain measured at 50 MV m^{-1}. Irradiated-P(VDF-TrFE), P(VDF-TrFE-CTFE) and P(VDF-TrFE-CFE) are measured at 1 Hz. P(VDF-DB)-500 is measured at 10 Hz.