Polarization fatigure of organic ferroelectric capacitors

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Group meeting

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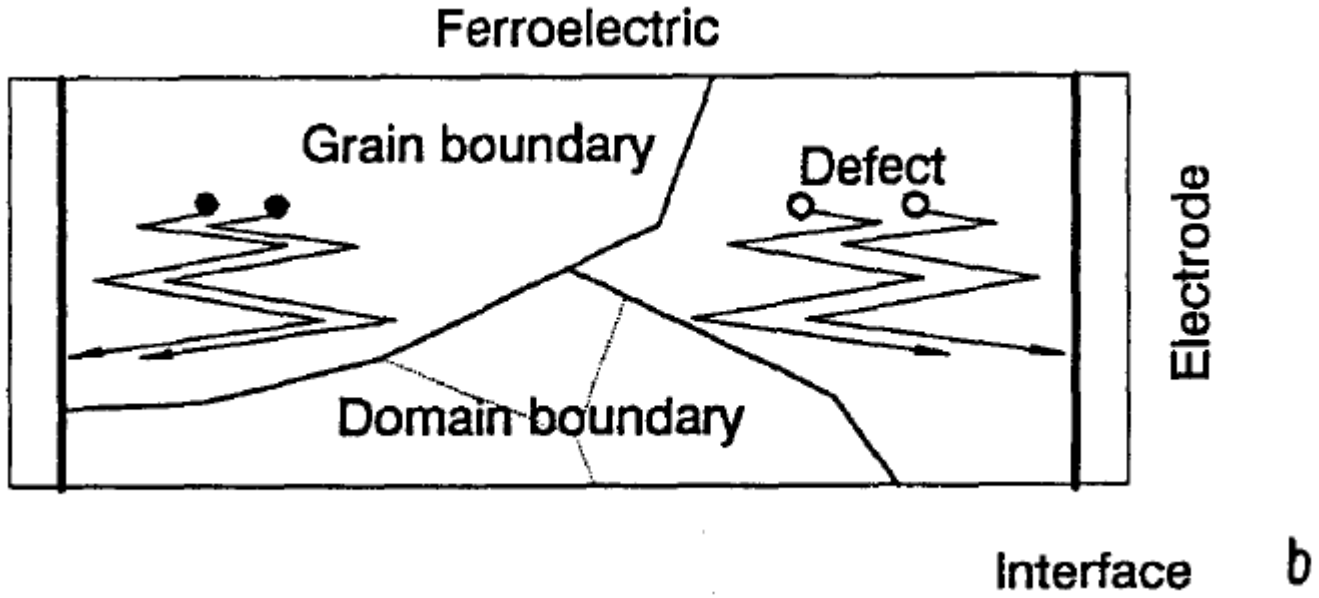
Fatigue of lead zirconate titanate (PZT)



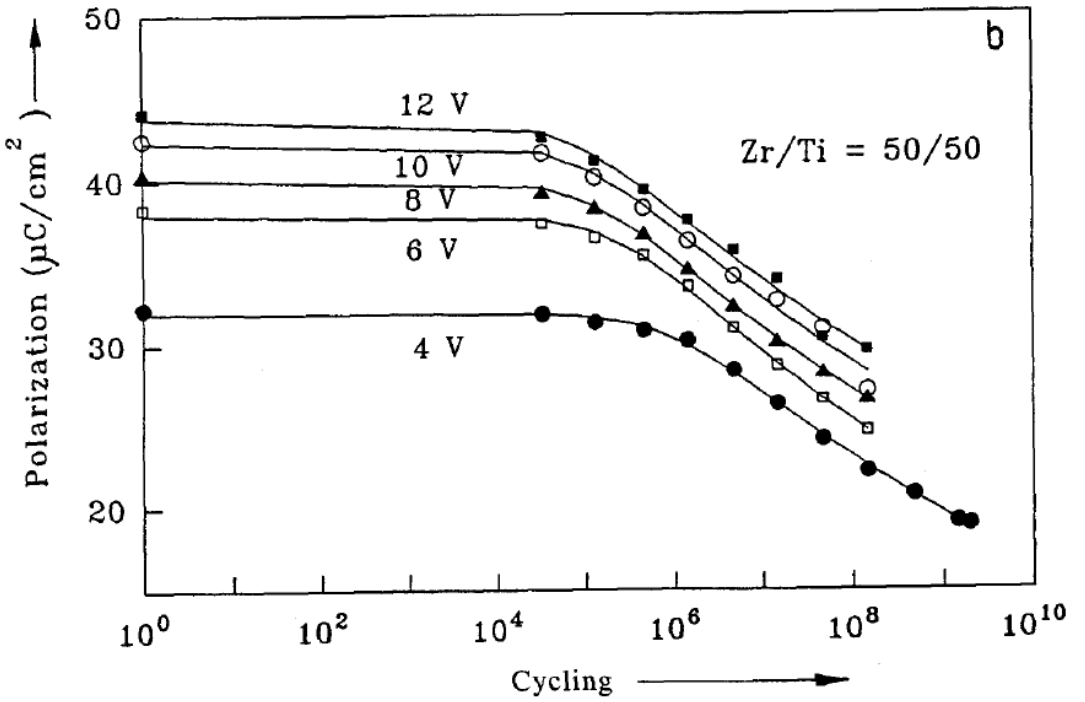


Fig. 2. a) Calculation of spontaneous polarization from pulse measurement data ($P_s = (P^* + P^\wedge + |-P^*| + |-P^\wedge|)/4$). b) Fatigue curve fittings at various voltages (thickness: 0.4 μm, size: 0.1×0.1 mm^2)

- Defect entrapment at interfaces.
- Oxygen vacancy or lead vacancy are most likely sources of fatigue

$$P = P_0(An + 1)^{-\mathrm{m}}$$

n is cycling numbers
P_0 initial polarization
m decay constant.

Yoo, In-K., and S. B. Desu. "Mechanism of fatigue in ferroelectric thin films." *physica status solidi (a)* 133.2 (1992): 565-573.

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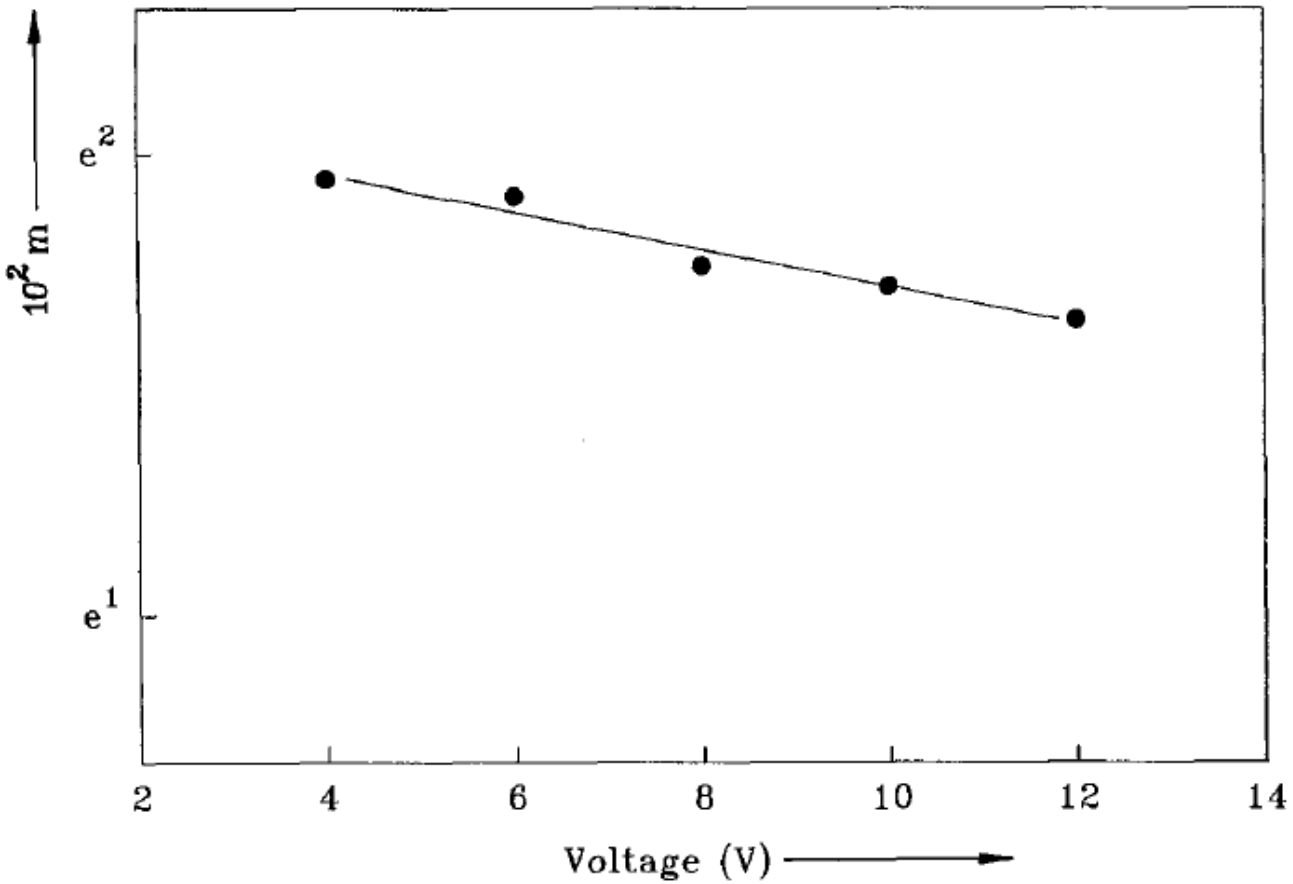


Fig. 3. Voltage dependence of decay constant.

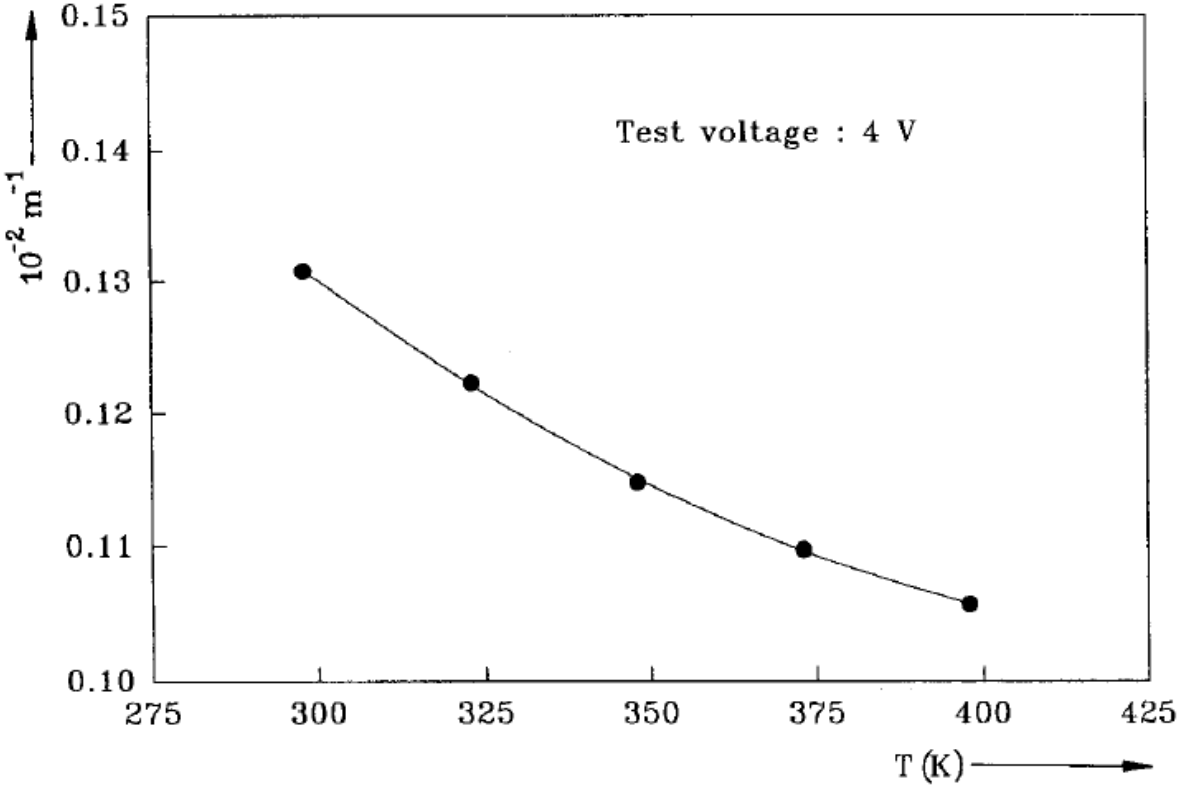
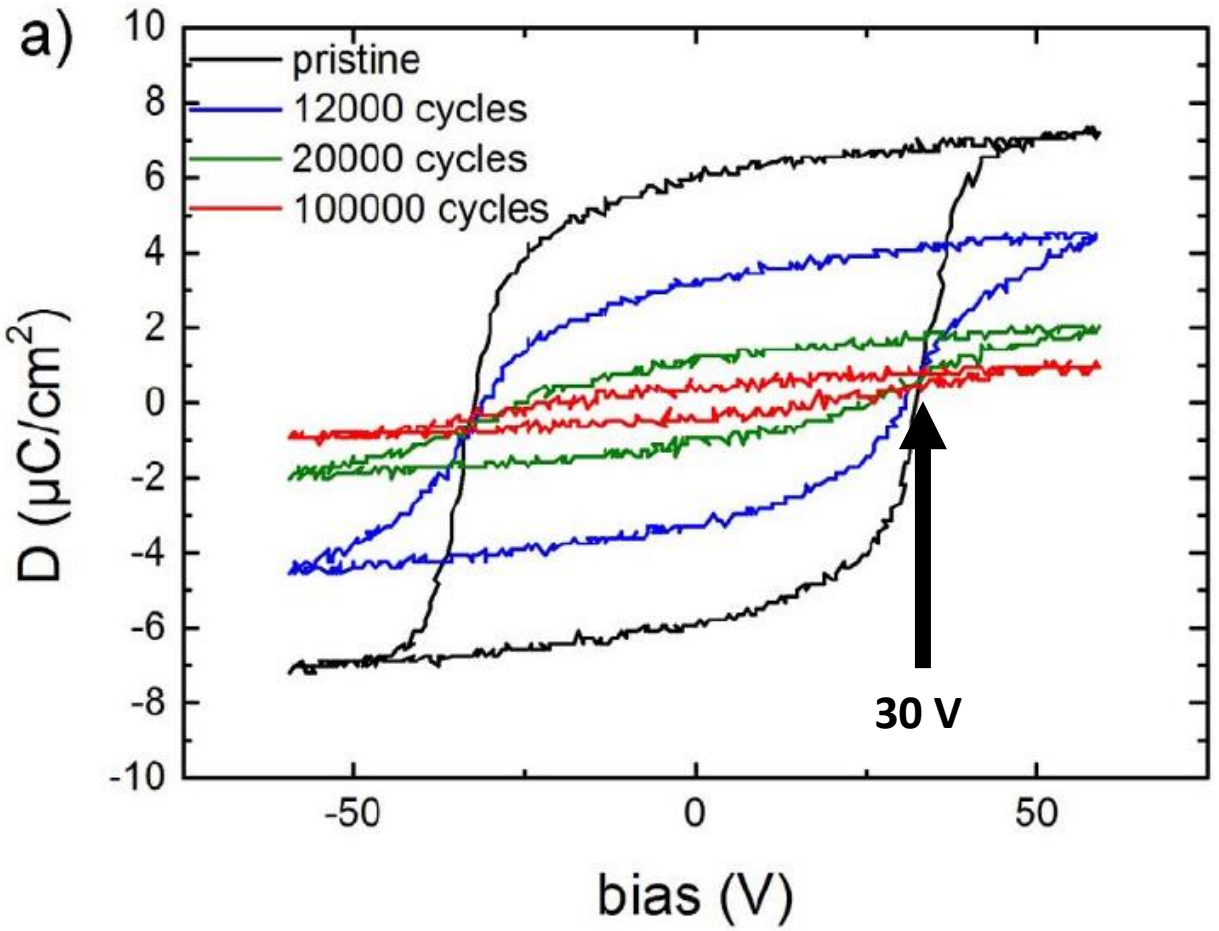


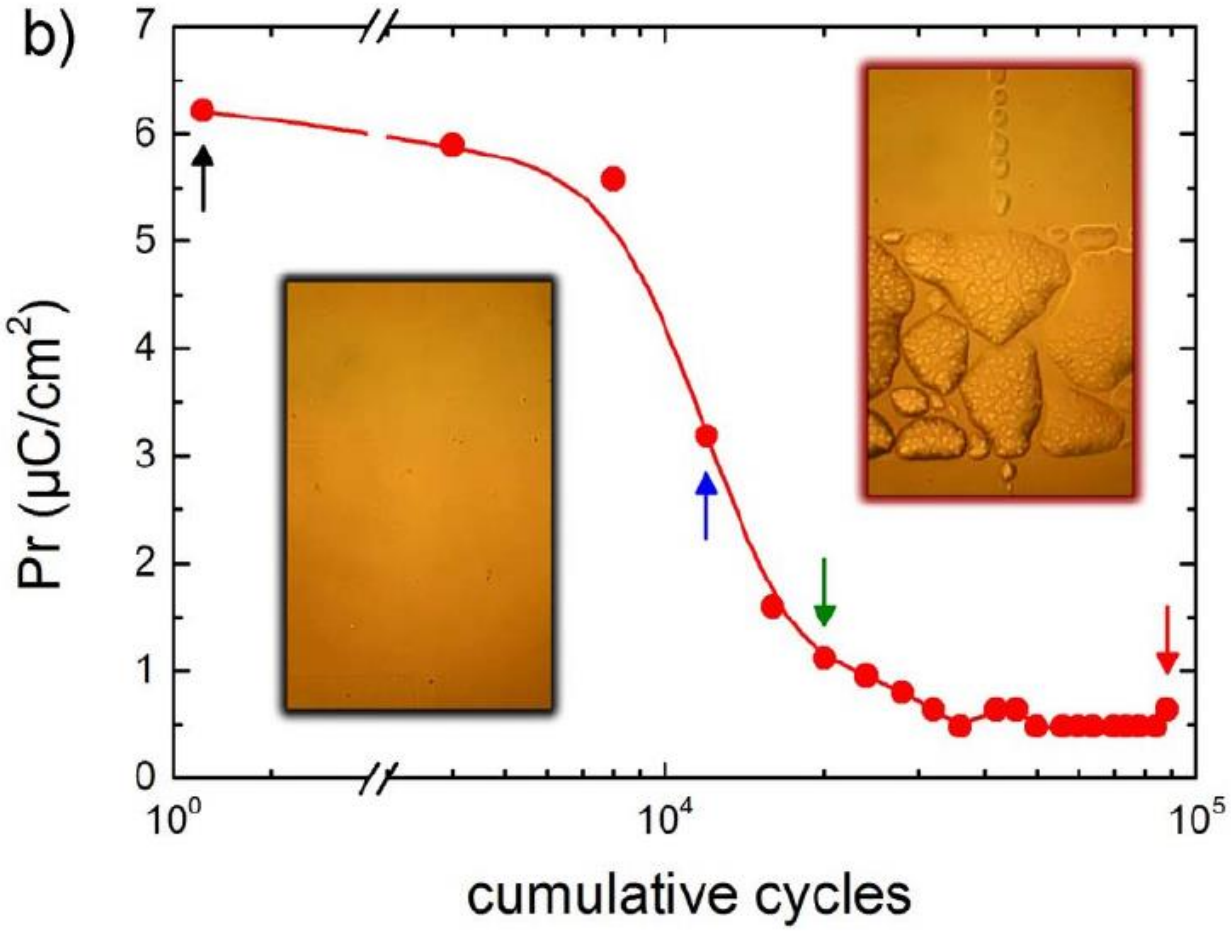
Fig. **4.** Temperature dependence **of** the decay constant

$$\ln(m) = \text{const} - \frac{zqb}{2kTd} U_A$$

$$\frac{1}{m} = \frac{\gamma}{v\mu_0} \Delta t \frac{zqb}{2kT} [\lambda_0 e^{(Q_w - Q_0 + zqbE_A/2)/kT} + \lambda_p e^{(Q_w - Q_p + zqbE_A/2)/kT}]$$

Fatigue of the ferroelectric polymer P(VDF-TrFE)





What's the reasons for the delamination of the top electrode?

Zhao, Dong, et al. "Polarization fatigue of organic ferroelectric capacitors." *Scientific reports* 4 (2014): 5075.

Fatigure of the ferroelectric polymer P(VDF-TrFE)

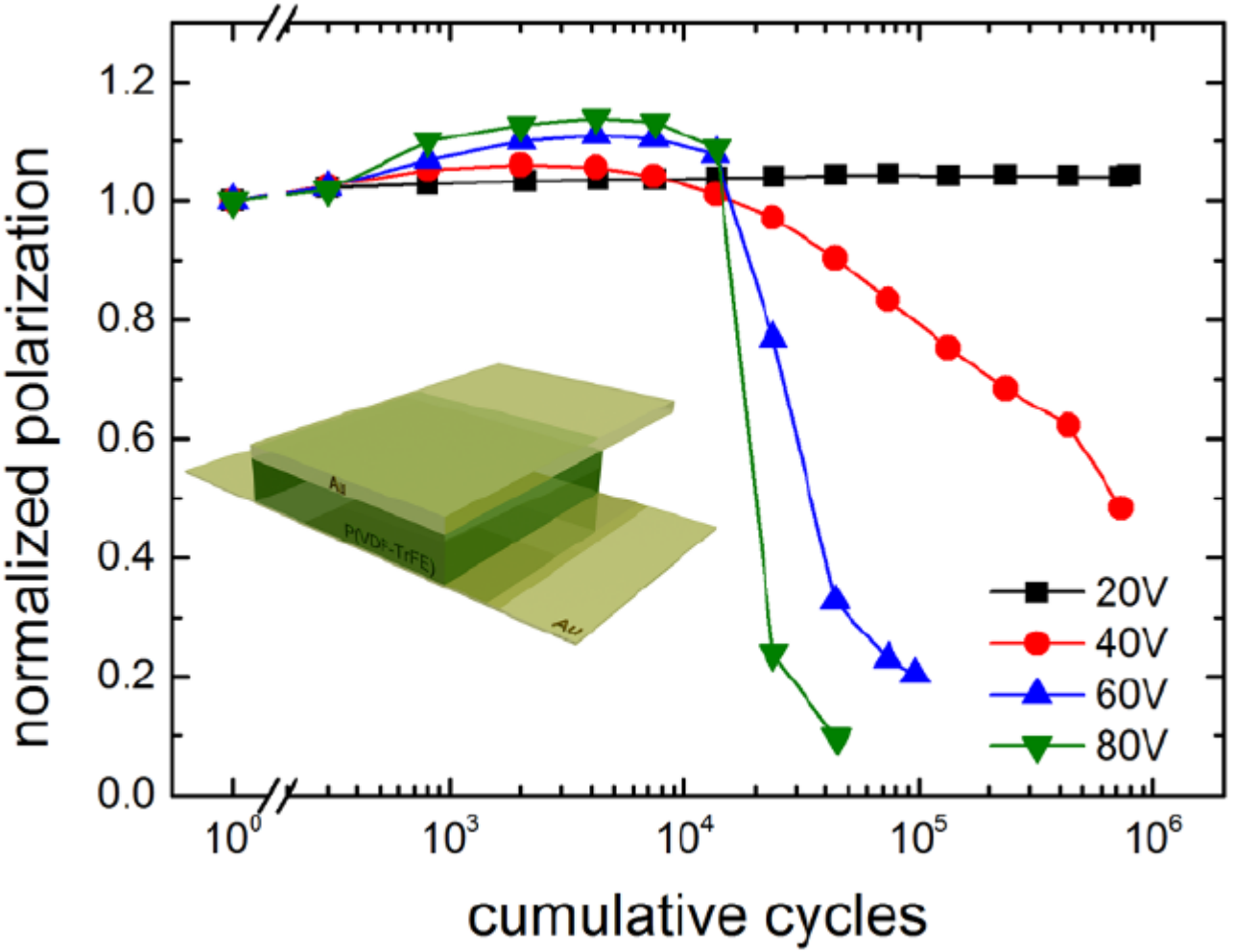
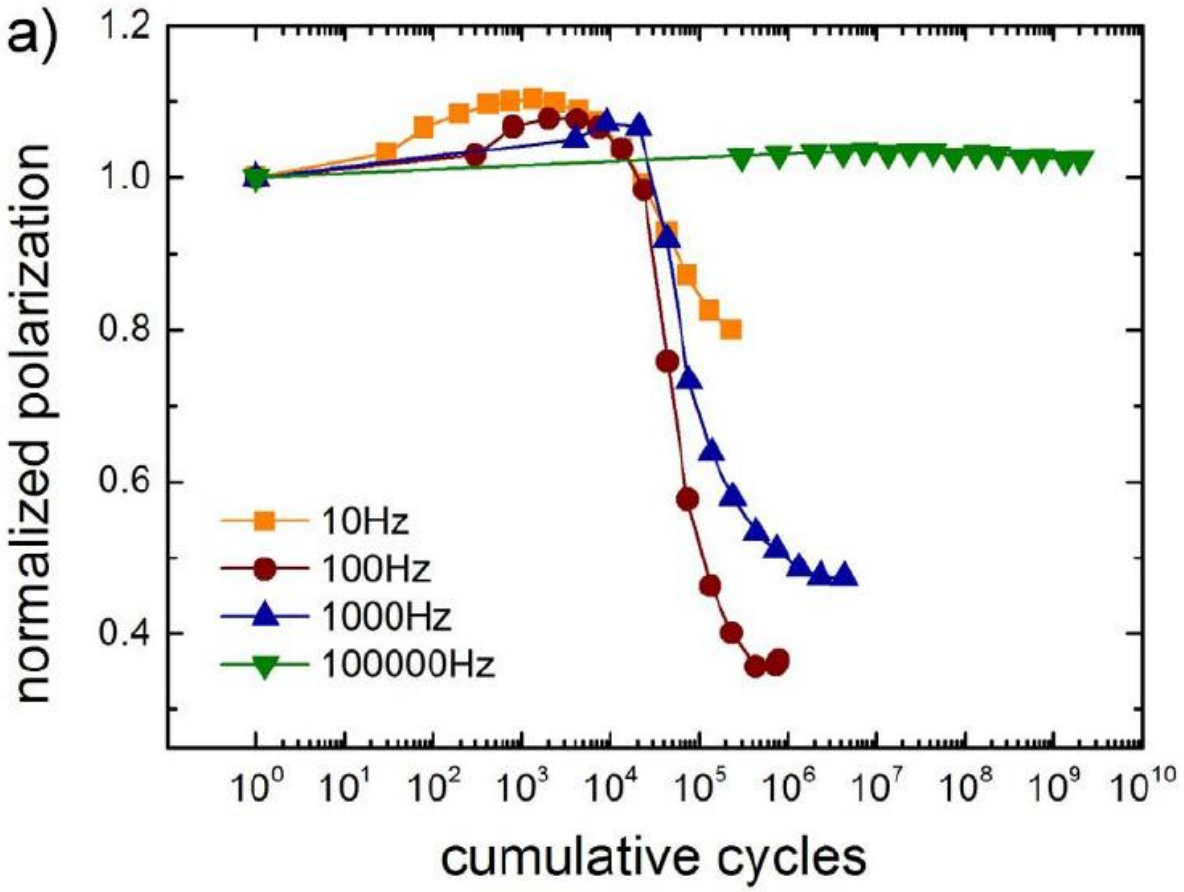
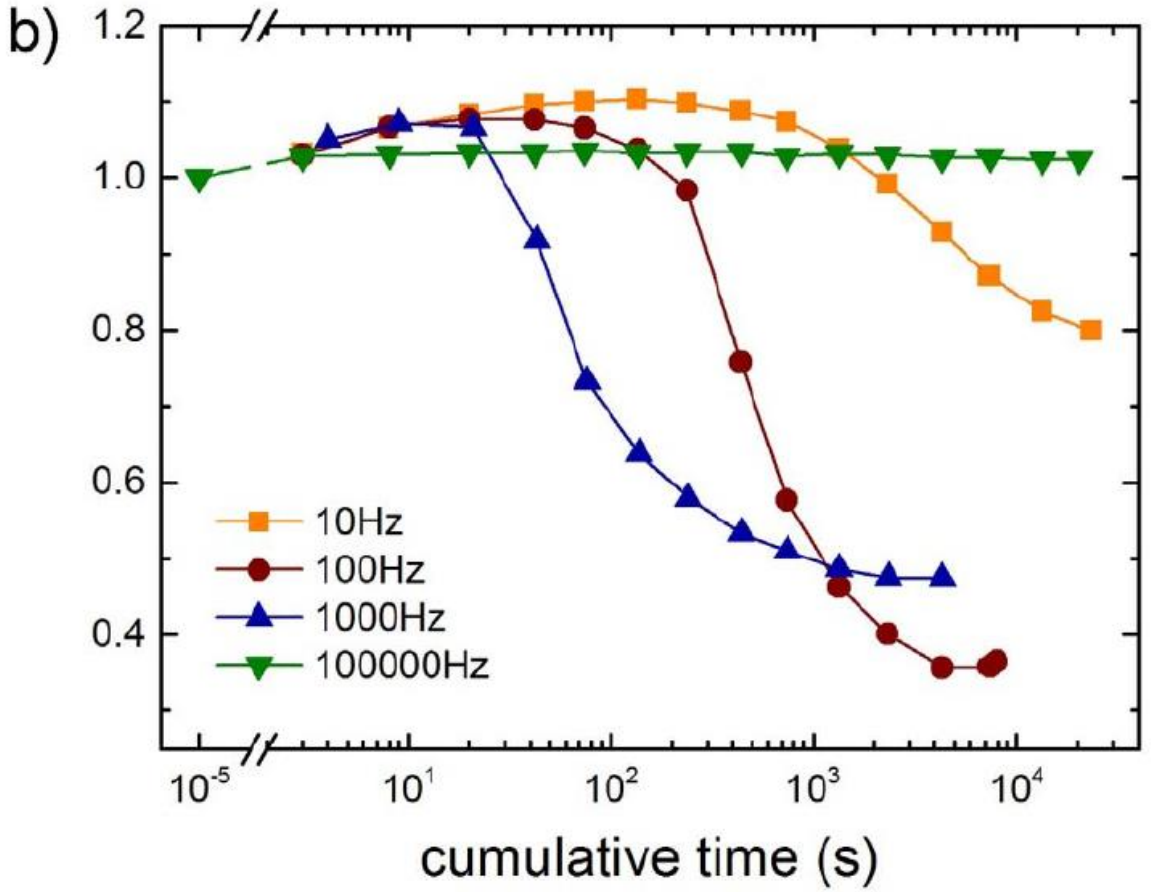


Figure 2 | Bias dependence of fatigue. The normalized polarization as a function of the cumulative number of cycles The frequency was fixed at 100 Hz

- No polarization loss with voltage lower than coercive field
- Loss is due to switching
- Polarization enhancement might be due to field-induced recrystallization

Fatigue of the ferroelectric polymer P(VDF-TrFE)





The dissipated energy per cycle: $E_{in,cycle} = 2P_r \cdot 2E_c \cdot t \cdot \pi a^2$

The total dissipated power: $P = E_{in,cycle} * f$

- Polarization switching is a prerequisite for fatigue
- Fatigue rate increases with frequency hence with increasing dissipated power.

Fatigue of the ferroelectric polymer P(VDF-TrFE)

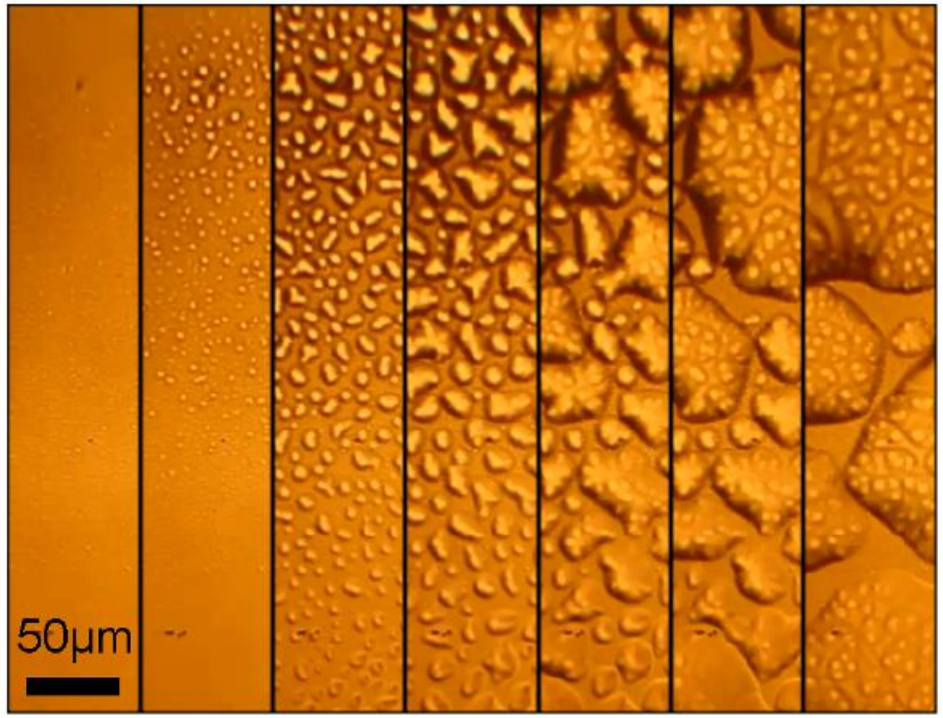


Figure 4 | Temporal evolution of the electrode morphology. A frequency of 1 kHz and an amplitude of 60 V.

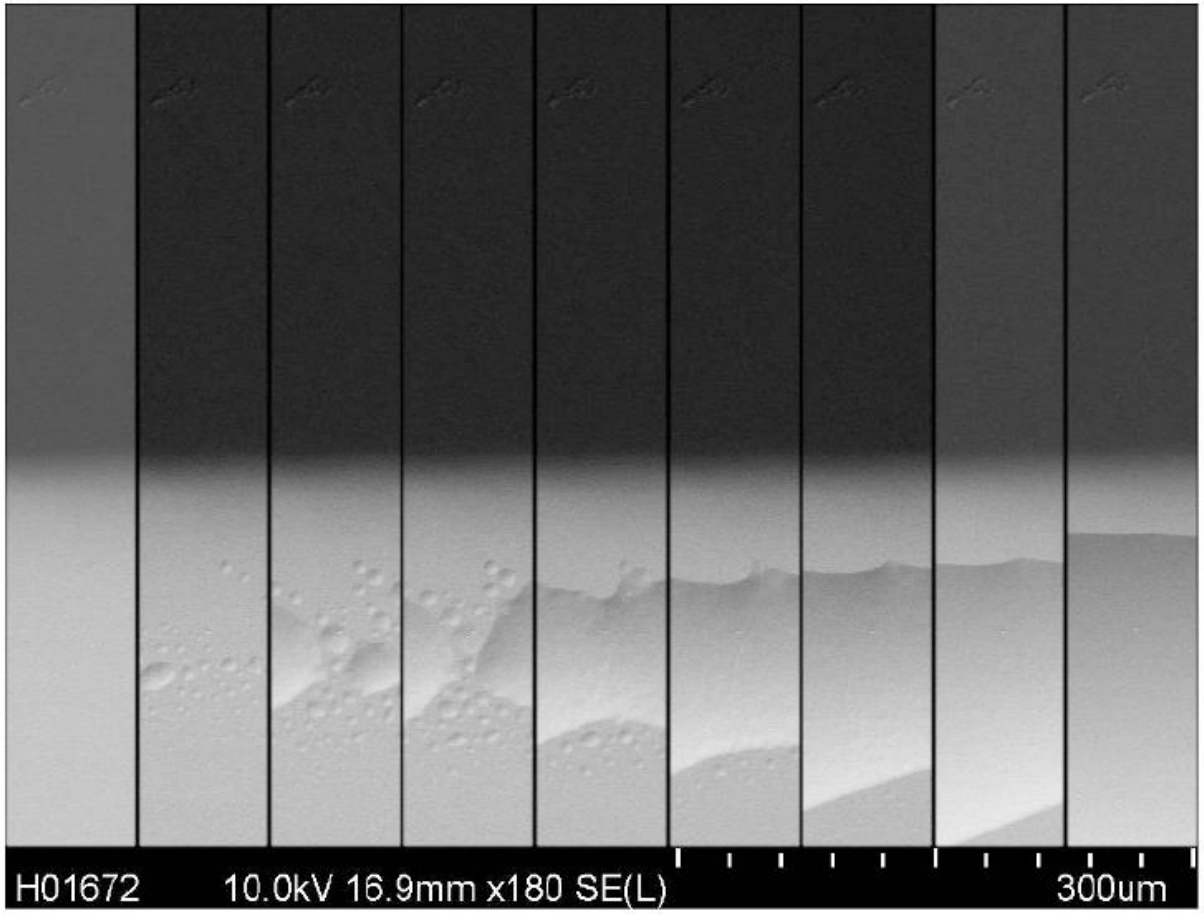
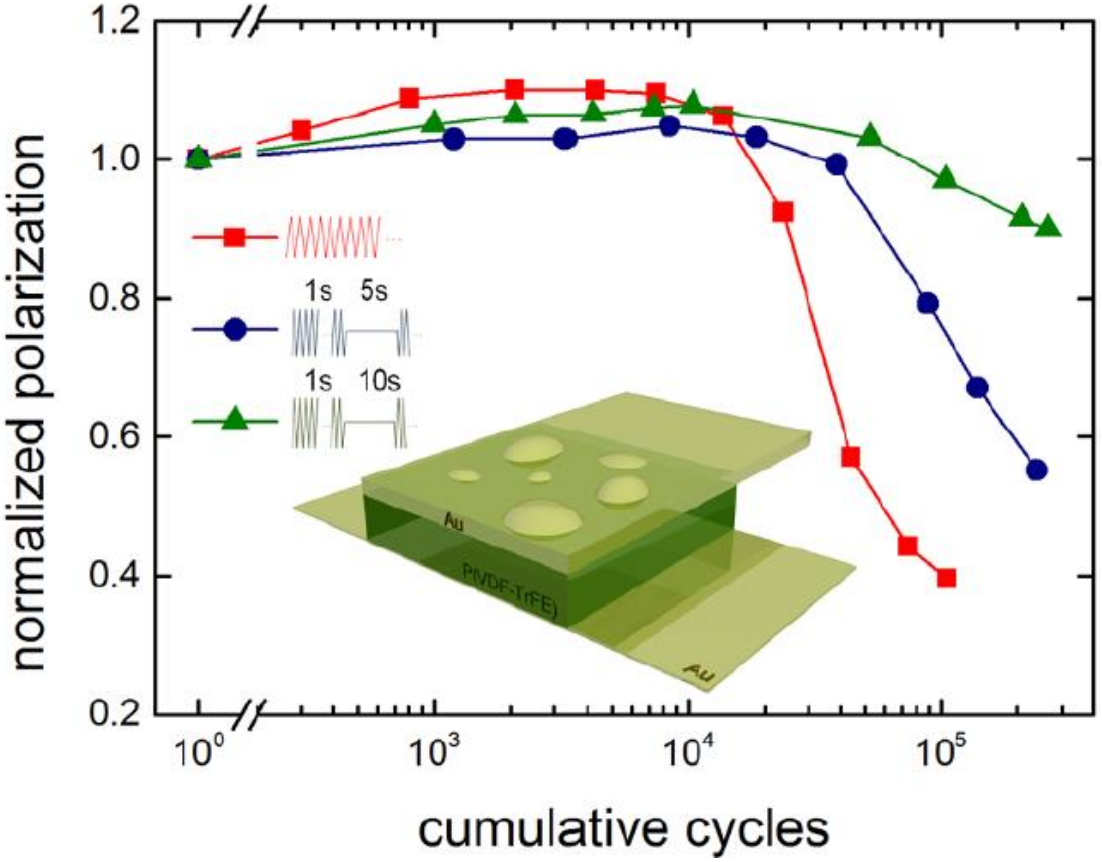


Figure 5 Electron-beam induced damage. the time evolution of a growing bump on the top Au electrode (light gray area).

- Electrically induced phase decomposition
- HF is formed in unzipping chain reactions
- The gold electrode acts as a gas barrier.

Fatigue of the ferroelectric polymer P(VDF-TrFE)



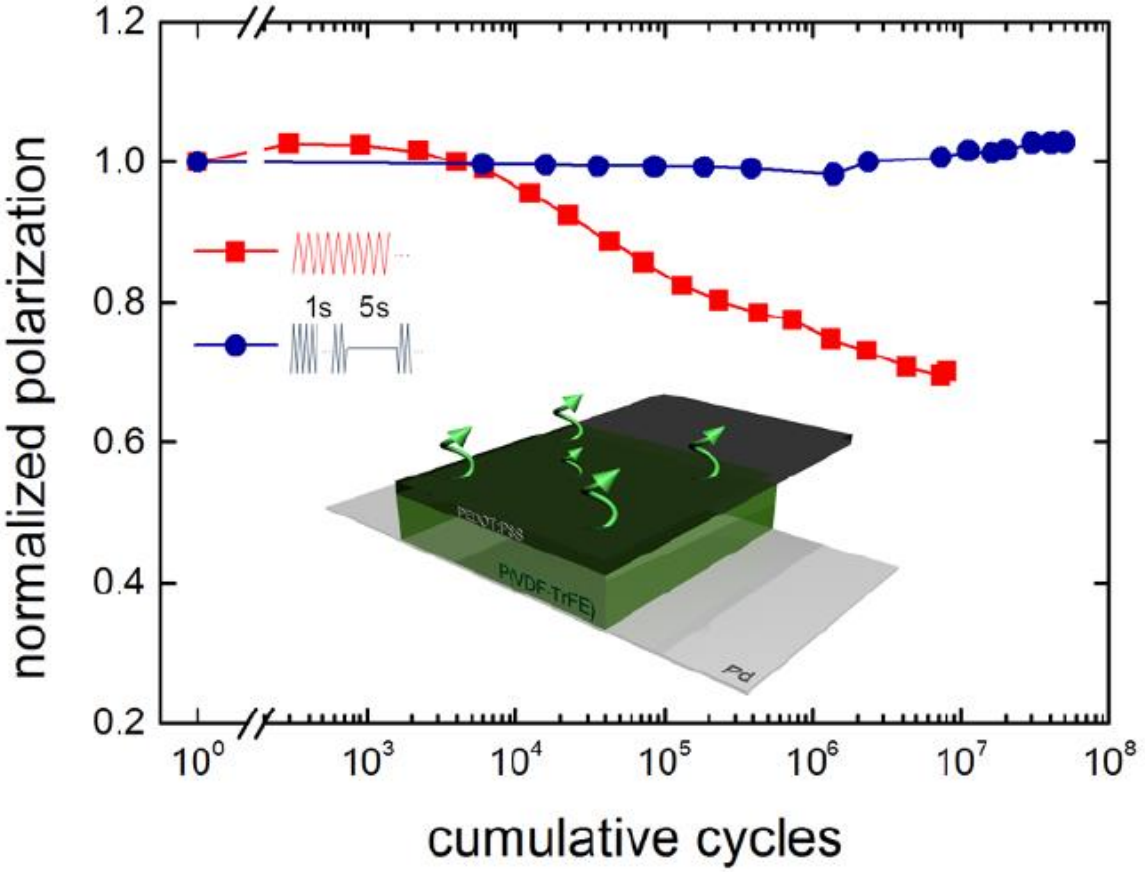


Figure 6 | the continuous cycling was interrupted every second with a waiting time of 5 and 10 seconds

- During the waiting time the gas can diffuse out of the capacitor.
- Polymeric conductor PEDOT:PSS whose gas diffusion coefficient is orders of magnitude higher.

Summary

1. The polarization fatigue of PZT is due to defect entrapment at interfaces.

2. Fatigue of PVDF is due to delamination of the Au top electrode, induced by phase decomposition.

3. A fatigue-free capacitor is realized by removing gas barrier and adapting the waveform

THANK YOU!