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Electrical induced cracking of PZT films and its effect on electrical properties of piezoelectric capacitors

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Lead zirconate titanate, $\text{Pb}(\text{Zr}_{0.52}\text{Ti}_{0.48})\text{O}_3$ (PZT), offers a high piezoelectric coefficient and is used in many fields of MEMS actuator devices: optics (varifocal lens, micro-mirror), acoustics (micro-speaker), ultrasonics (PMUT), fluidics (inkjet head, micro-pump), and haptics (tactile feedback). In actuator mode, during operation, the piezoelectric film is subjected to an electrical signal resulting in a mechanical displacement. The piezoelectric layer must then show large electrical breakdown strength to prevent electrical failure. Mechanical failure may also occur, but it has been much less studied. In very recent papers, cracking of PZT films, either under mechanical or electrical stresses, has been reported [1]. Despite the appearance of cracks, PZT capacitors remain most often functional, with changed properties though. However, the modified properties are rarely, not to say never, detailed and quantified.

In the present study, PZT based capacitors (2 μm thick) were operated under electric field, either bipolar or unipolar with various amplitudes, until cracking. The density of cracks varies as a function of the applied signal conditions. The effect of the cracks on the PZT properties has been evaluated by conducting various electrical tests, before and after cracking: ferroelectric polarization loops, dielectric capacitance curves, leakage currents and piezoelectric measurements. Remnant polarization and maximum polarization tend to increase by almost 100% and 40%, respectively (Figure 1), whereas permittivity and piezoelectric coefficient $d_{33,f}$ decrease down to 20% and 30%, respectively. In addition, XRD measurements show a clear modification of the PZT crystallographic pattern, suggesting that the observed evolution of electrical properties results from a change in domain structure associated with stress relaxation.

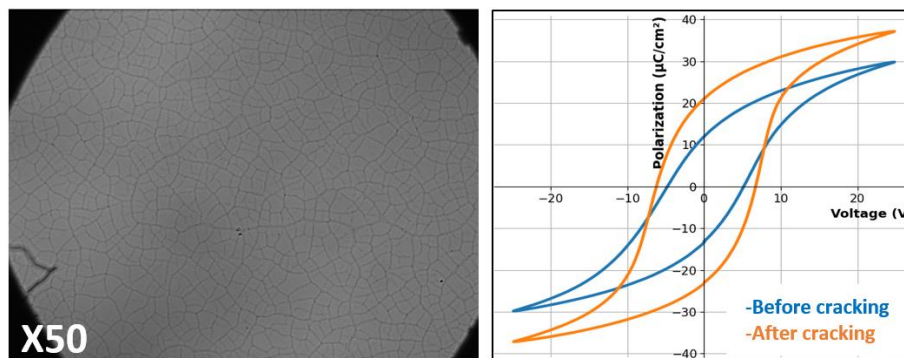


Figure 1: Optical image of cracked PZT film and effect of cracking on hysteresis PV loop.

Reference

[1] K. Coleman et al., *J. Eur. Ceram. Soc.* 41, pp. 2465-2471 (2021)