

SMART MATERIAL & CHARACTERIZATION LAB
DEPARTMENT OF APPLIED MECHANICS
INDIAN INSTITUTE OF TECHNOLOGY MADRAS

Temperature Dependent Electrical fatigue Studies on Bulk Piezoceramics

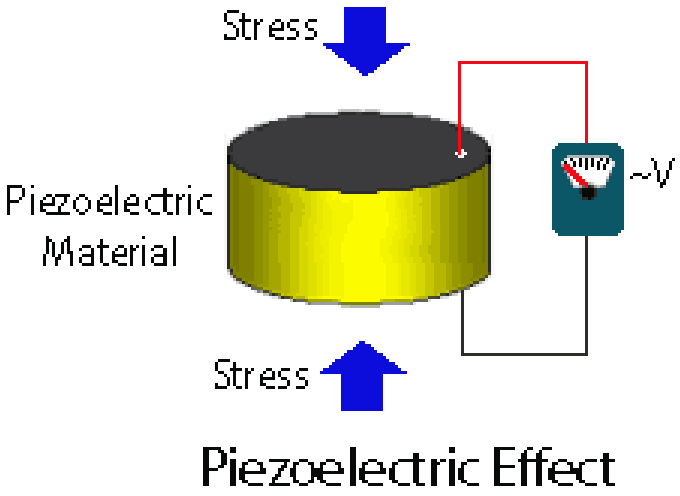
Y. Mohan, Mainak Bhattacharyya, A. Arockiarajan

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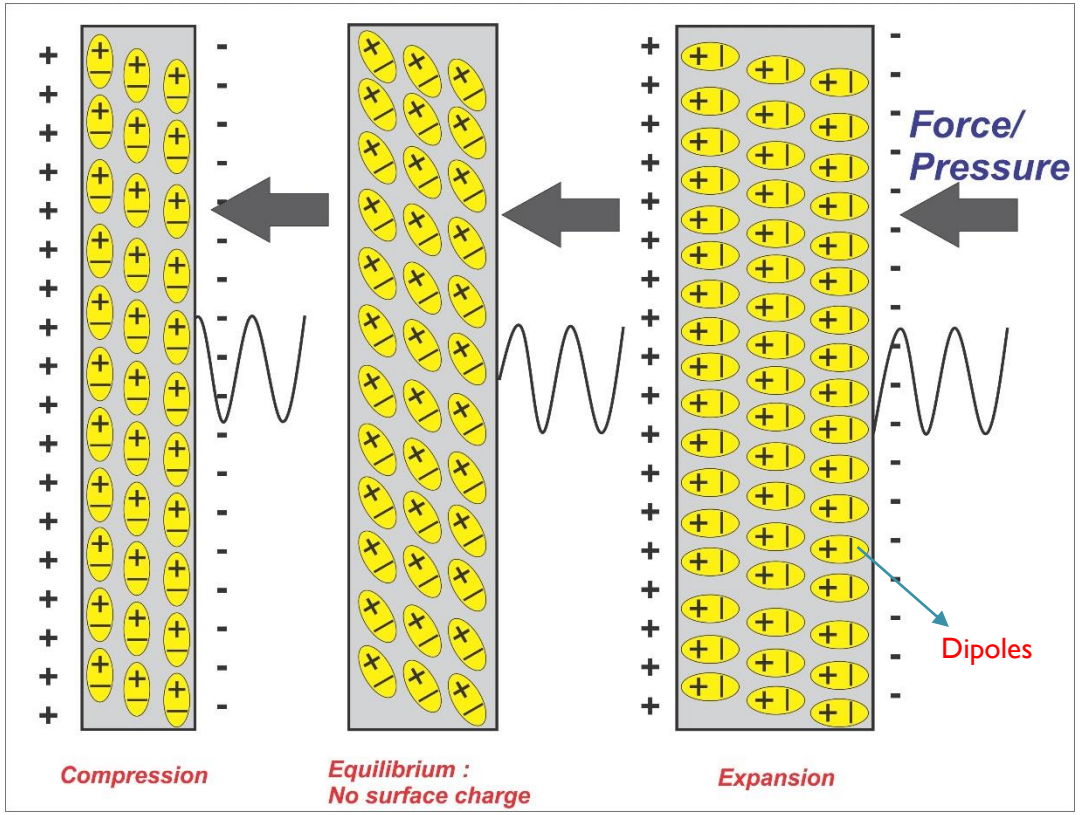
Outline

- Introduction
- Motivation
- Experimental characterization
- Electrical fatigue results for different loading cases
- Deterioration of material properties
- Summary

Sensor



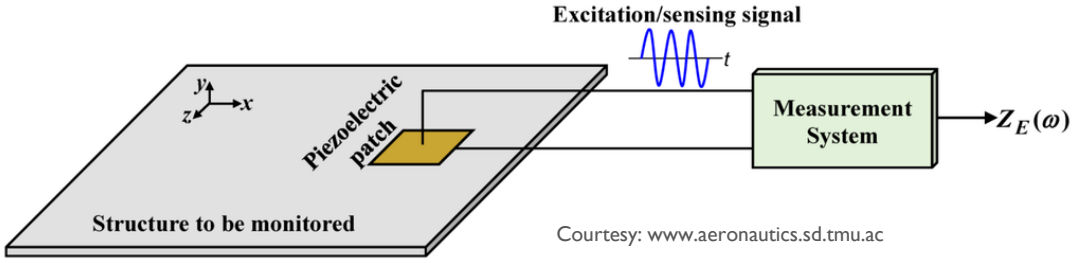
Courtesy: www.keramverband.de



$$D = d \cdot \sigma + \kappa \cdot \cancel{E}$$

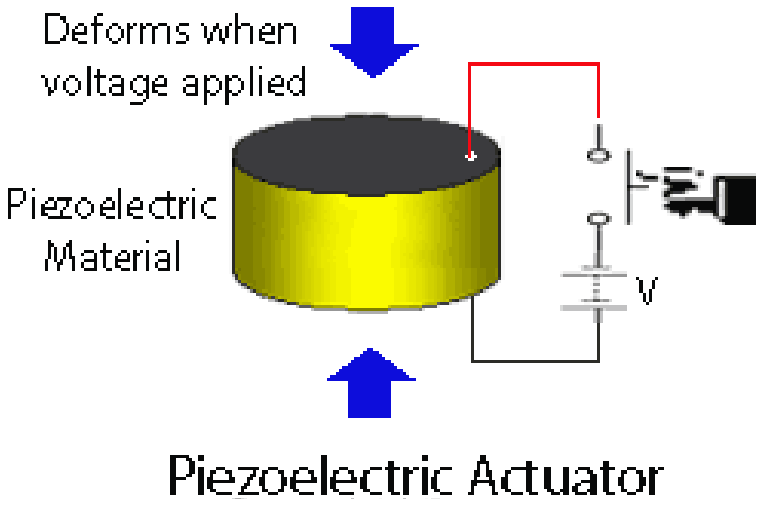
$$\varepsilon = C : \sigma + d^T \cdot \cancel{E}$$

Application: Structural health monitoring

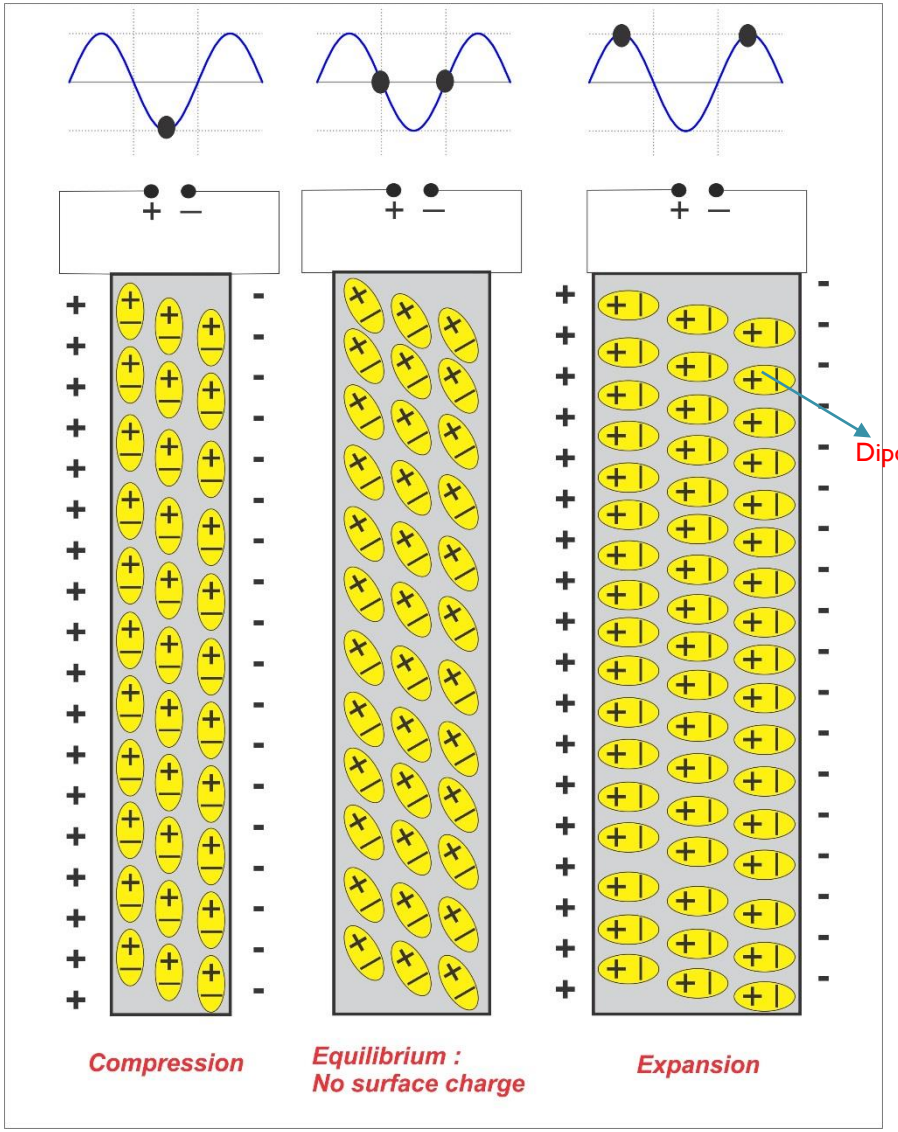


Courtesy: www.aeronautics.sd.tmu.ac

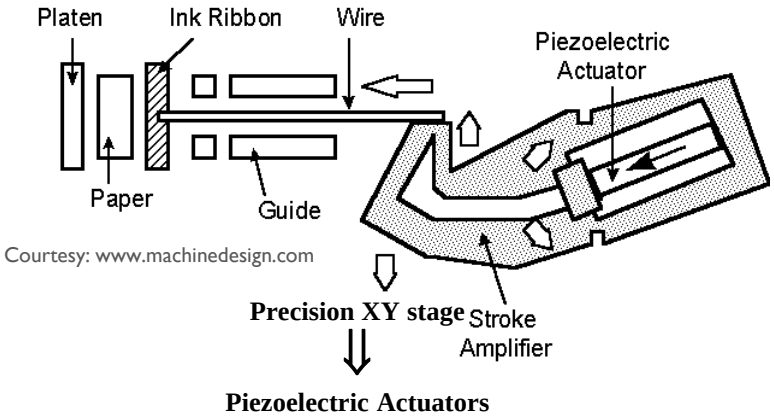
Actuator



Courtesy: www.keramverband.de



Application: Ink jet printer



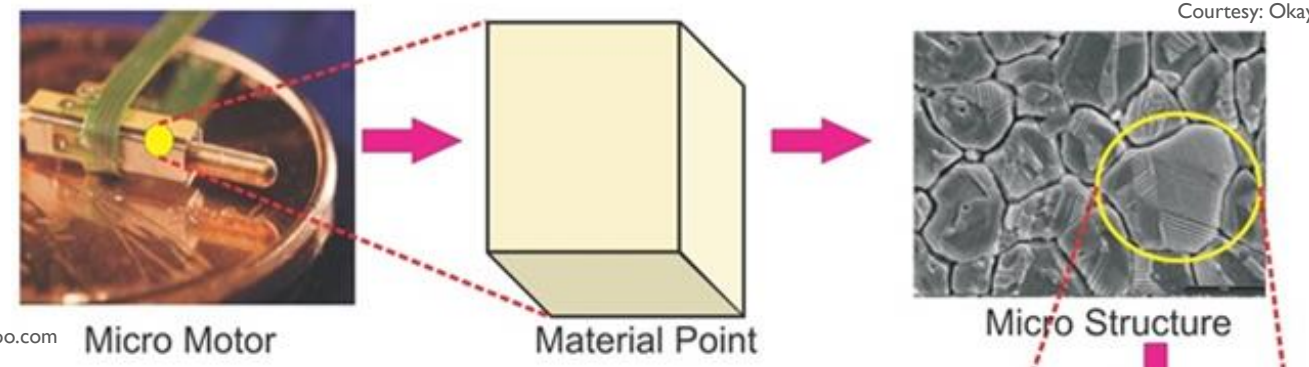
Courtesy: www.machinedesign.com

$$D = d\sigma + \kappa \cdot E$$

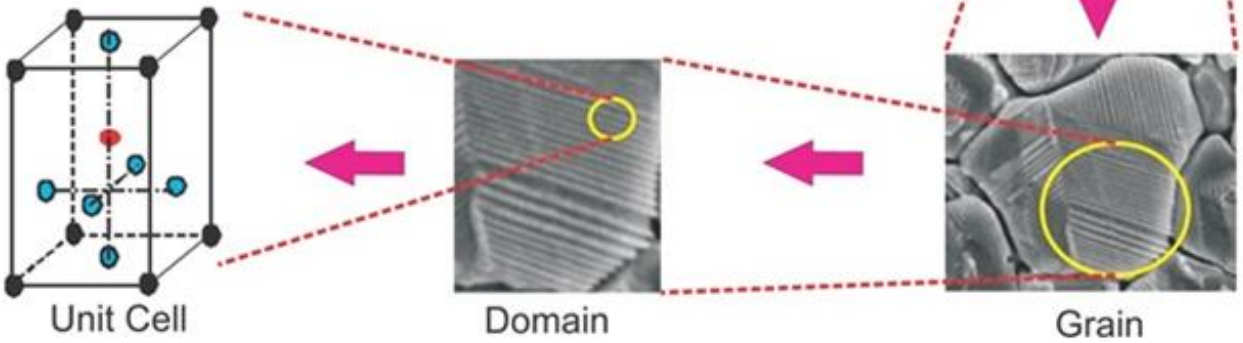
$$\varepsilon = C\sigma + d^T \cdot E$$

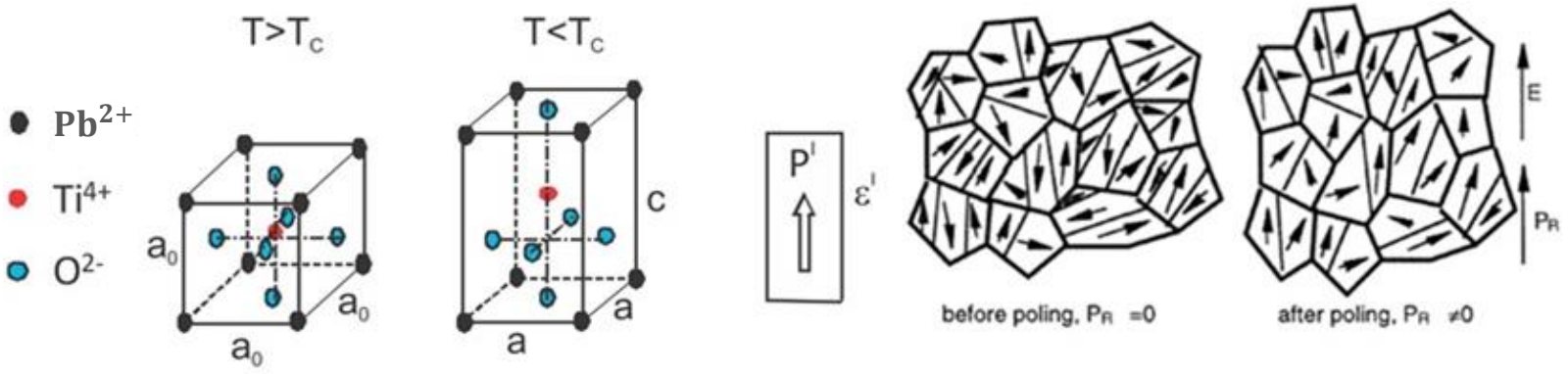
Macro to Microstructure

Courtesy: Okayasu.M ceramic international

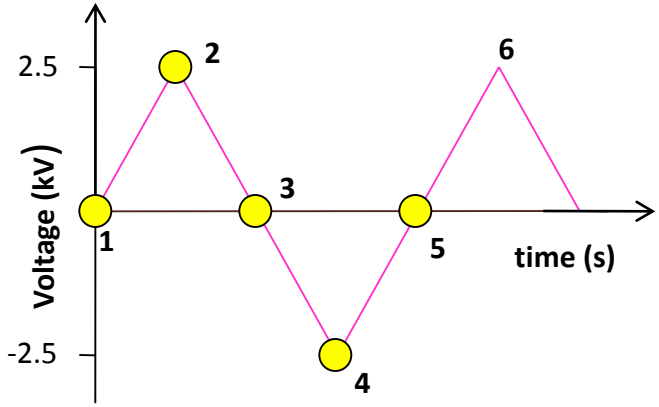


Courtesy: www.medicalexpo.com

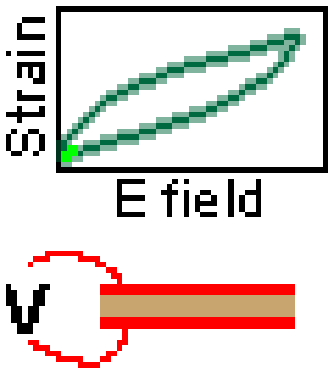


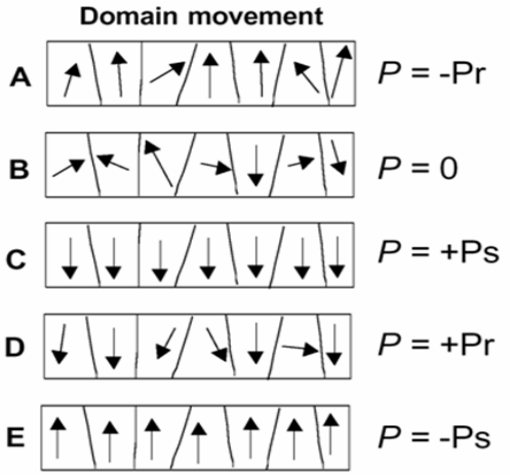


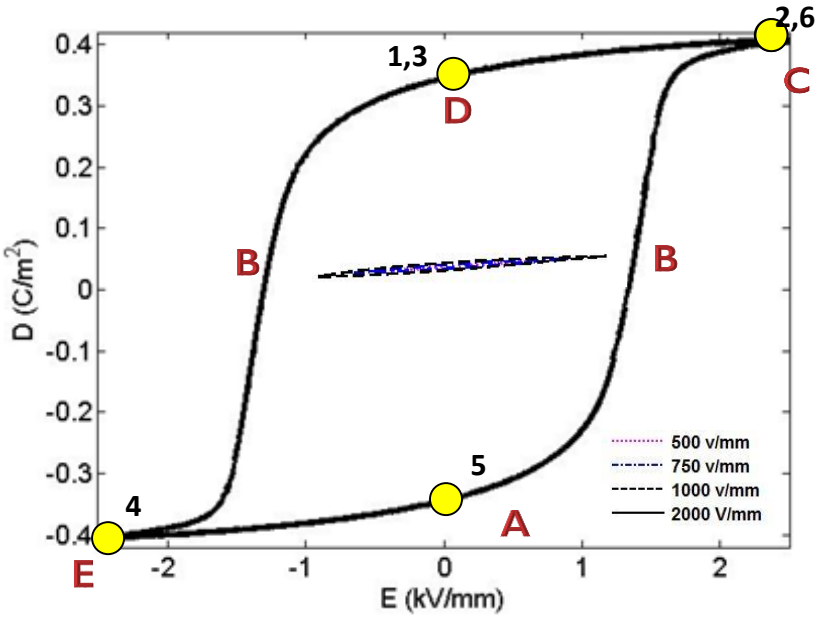
Behavior of piezoceramics(PZT)



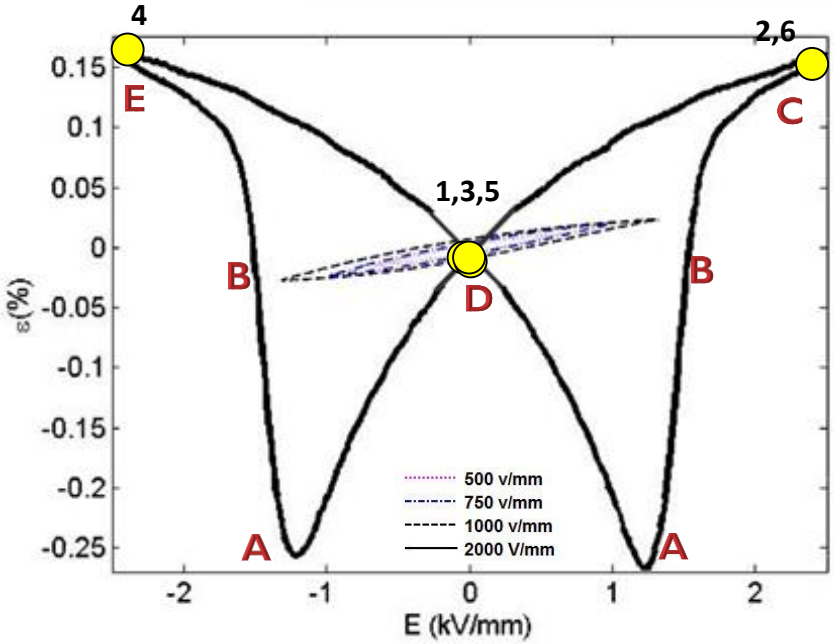
Input signal





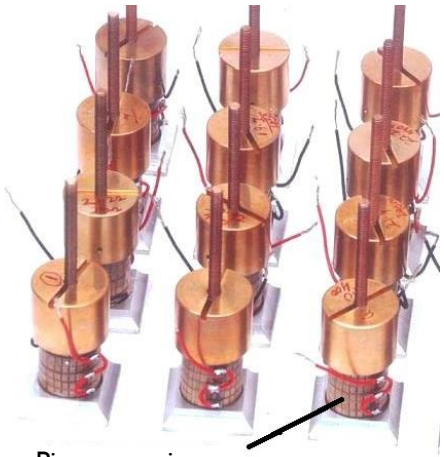


$$D = d \cdot \sigma + \kappa \cdot E + P^I$$

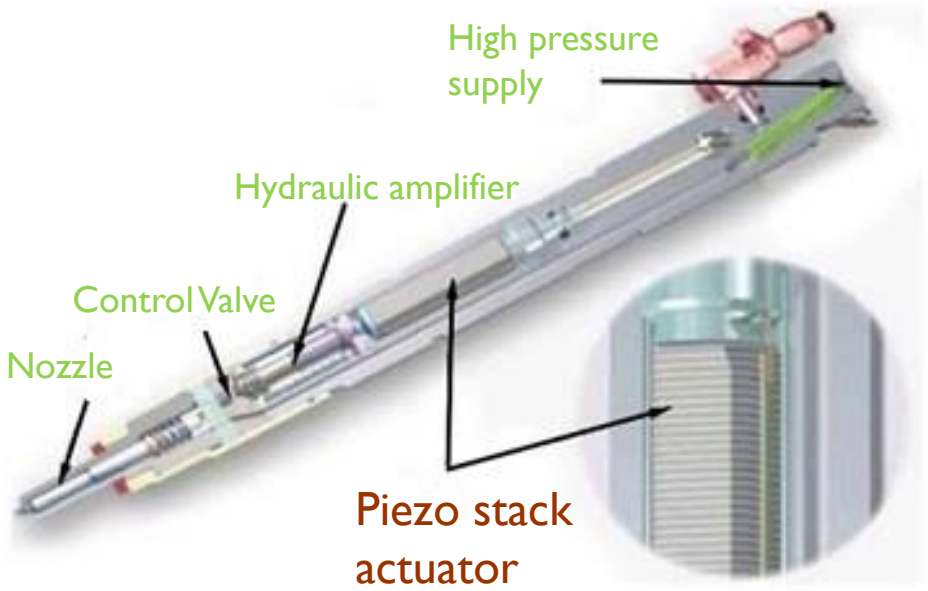


$$\varepsilon = C \cdot \sigma + d^T \cdot E + \varepsilon^I$$

Motivation



Source: Concord ceramics



Source: Bosch TOP4 CR PIEZO actuator

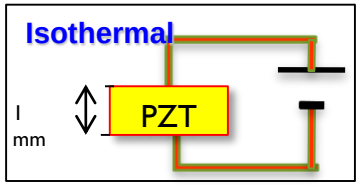
Objective

- To evaluate the performance of poled Bulk Piezoceramics (PZT 5A1) are subjected to bipolar electric cyclic fatigue exposed to elevated temperature under conditions equivalent to those of stack actuator applications.
- To carry out parametric study in order to under stand the deterioration caused by Thermo-Electric fatigue loading condition.

Experimental characterization

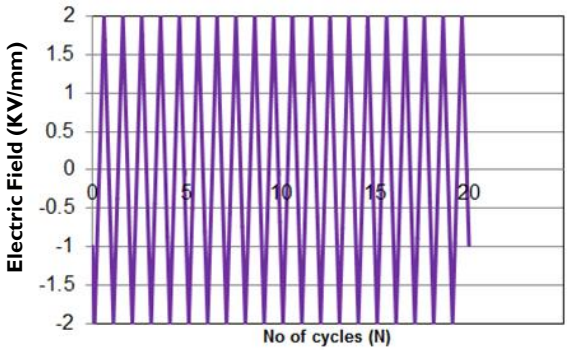
STIMULUS
- Electrical
- (Cyclic load)

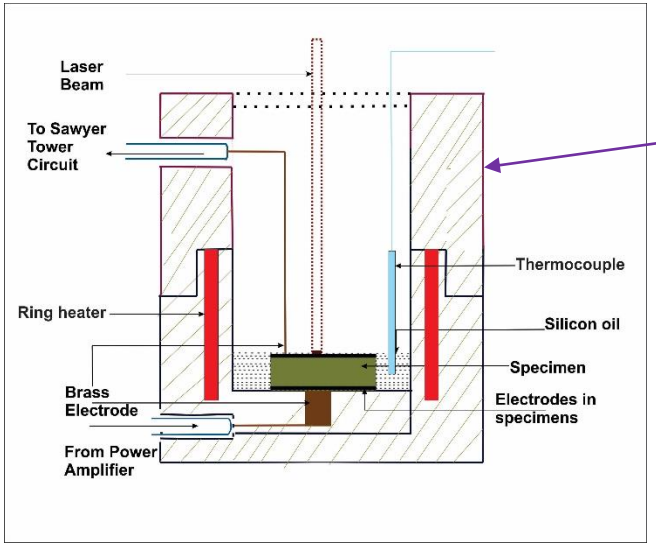
APPLY



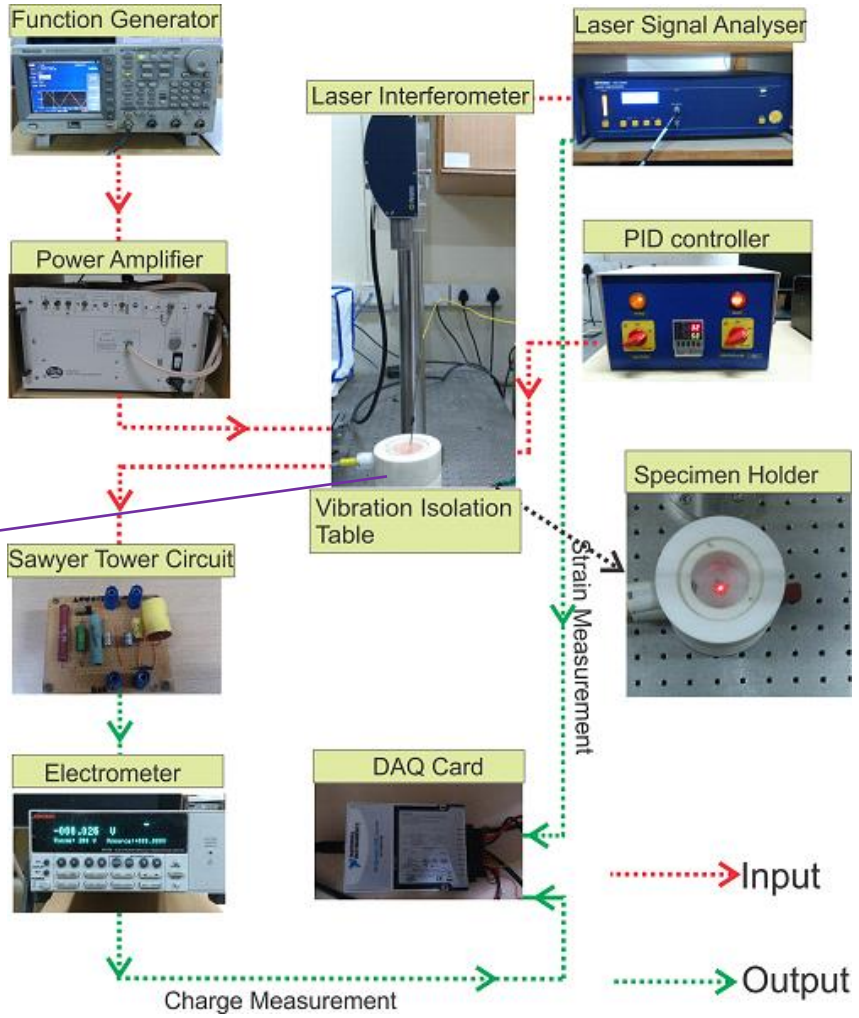
MEASURE

RESPONSE
- strain
- Charge



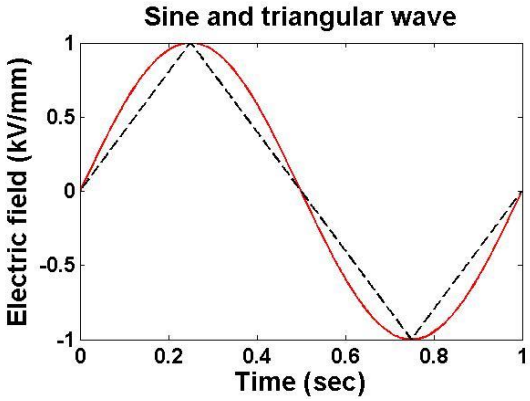


Specimen holder

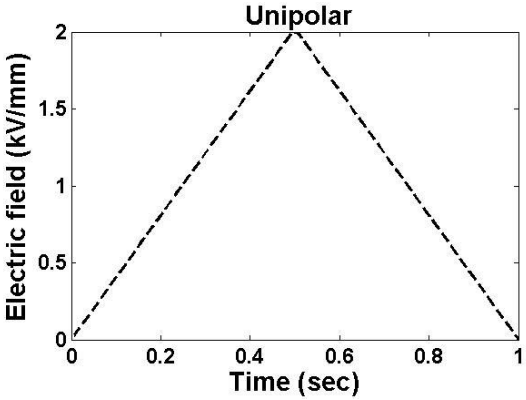


Electrical cyclic loading

The selection of waveform

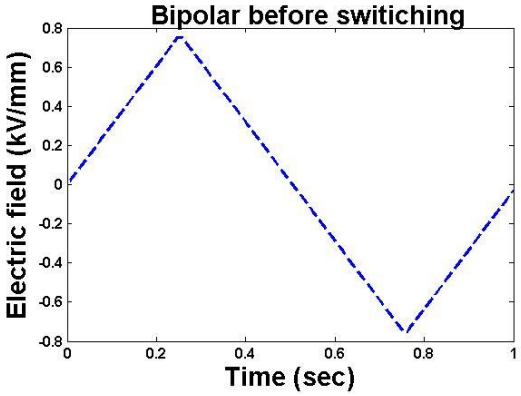


Case :1



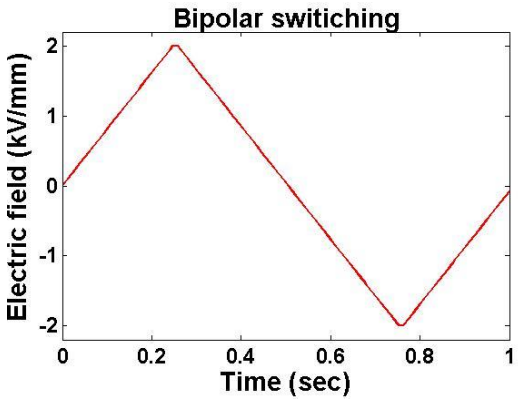
- High Voltage
- Electric field higher than Ec
- Closer to saturation the greater the fatigue

Case :2

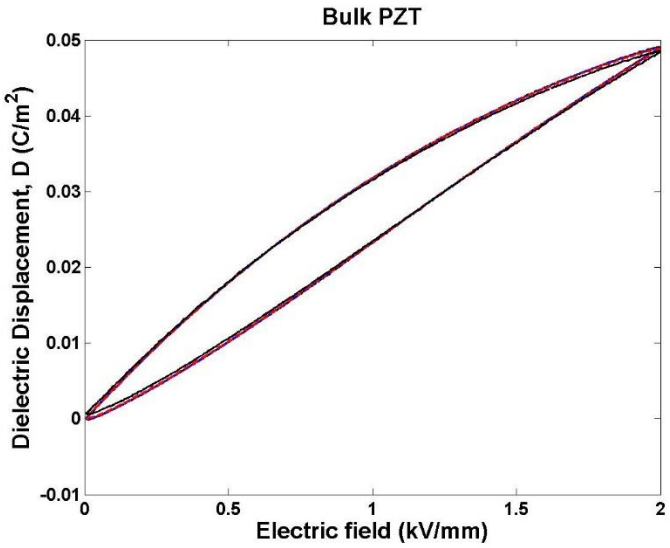


- Low Frequency
- More time for E to affect domains and difficult movement
- Domains become set = greater internal stresses to be overcome in reverse cycle

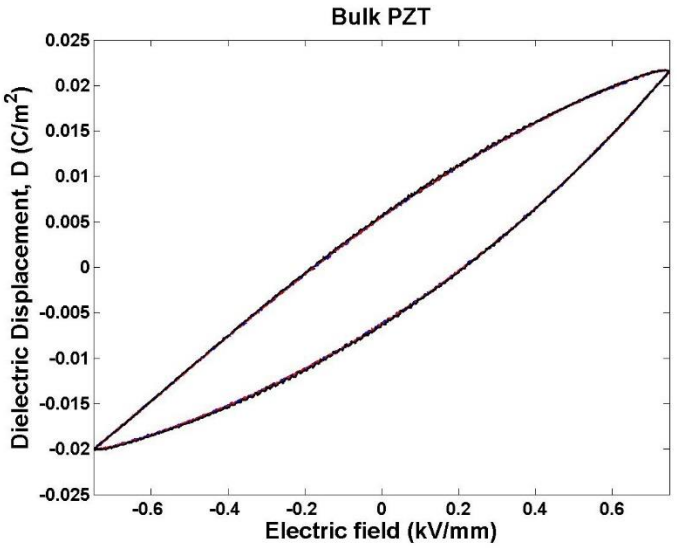
Case :3



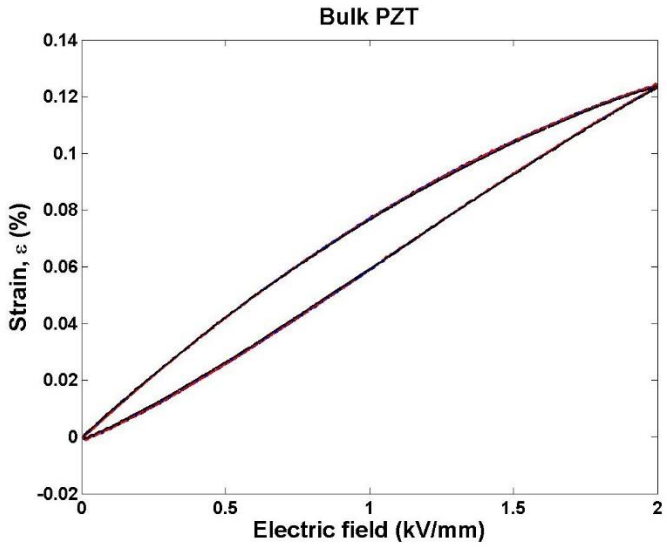
Case1

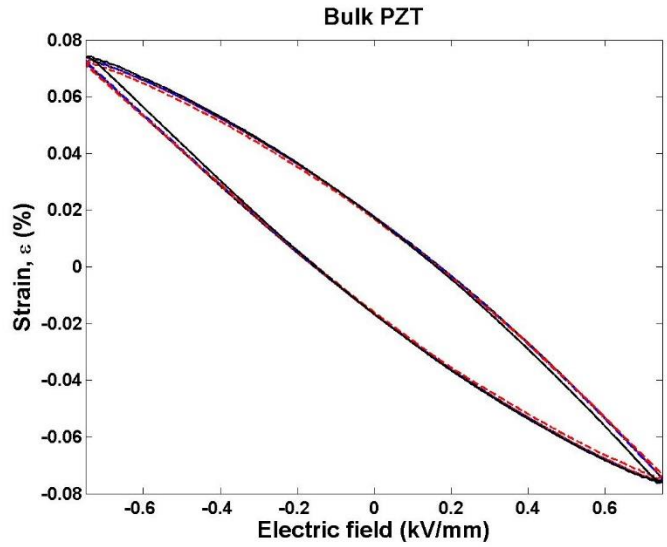

Bulk PZT
Dielectric Displacement, D (C/m^2)
Electric field (kV/mm)
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
0.5
1
1.5
2

Case 2

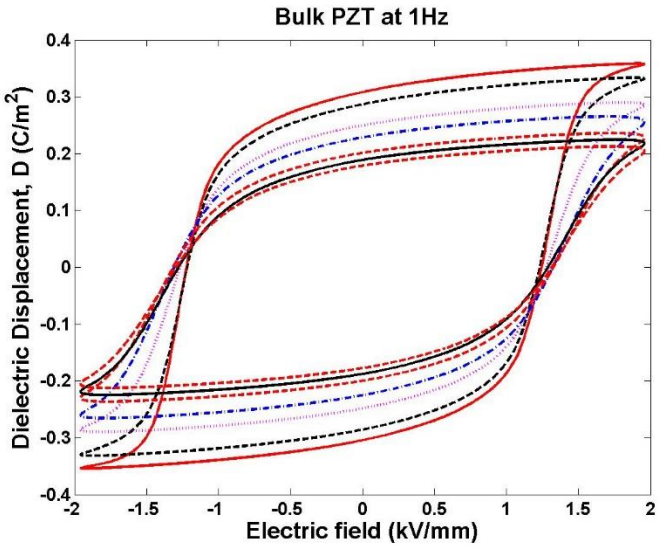

Bulk PZT
Dielectric Displacement, D (C/m^2)
Electric field (kV/mm)
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

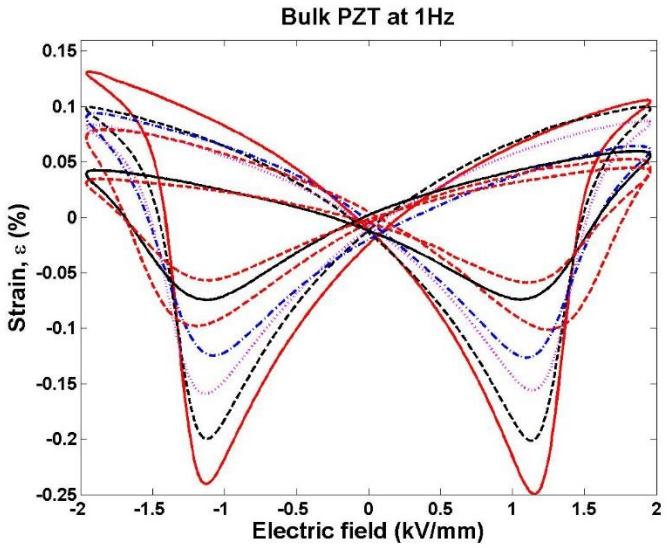

10^1 cycle
10^2 cycle
10^3 cycle
10^4 cycle
10^5 cycle
10^6 cycle


Bulk PZT
Strain, ε (%)
Electric field (kV/mm)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
0.5
1
1.5
2

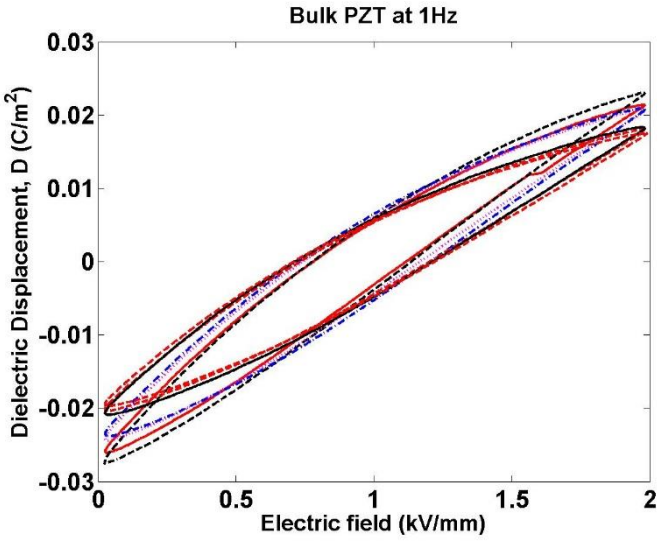

Bulk PZT
Strain, ε (%)
Electric field (kV/mm)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

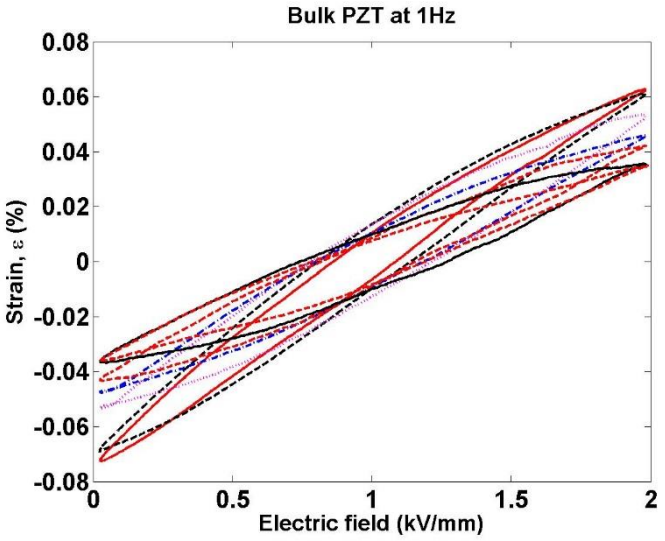
Case 3: Bipolar electrical fatigue



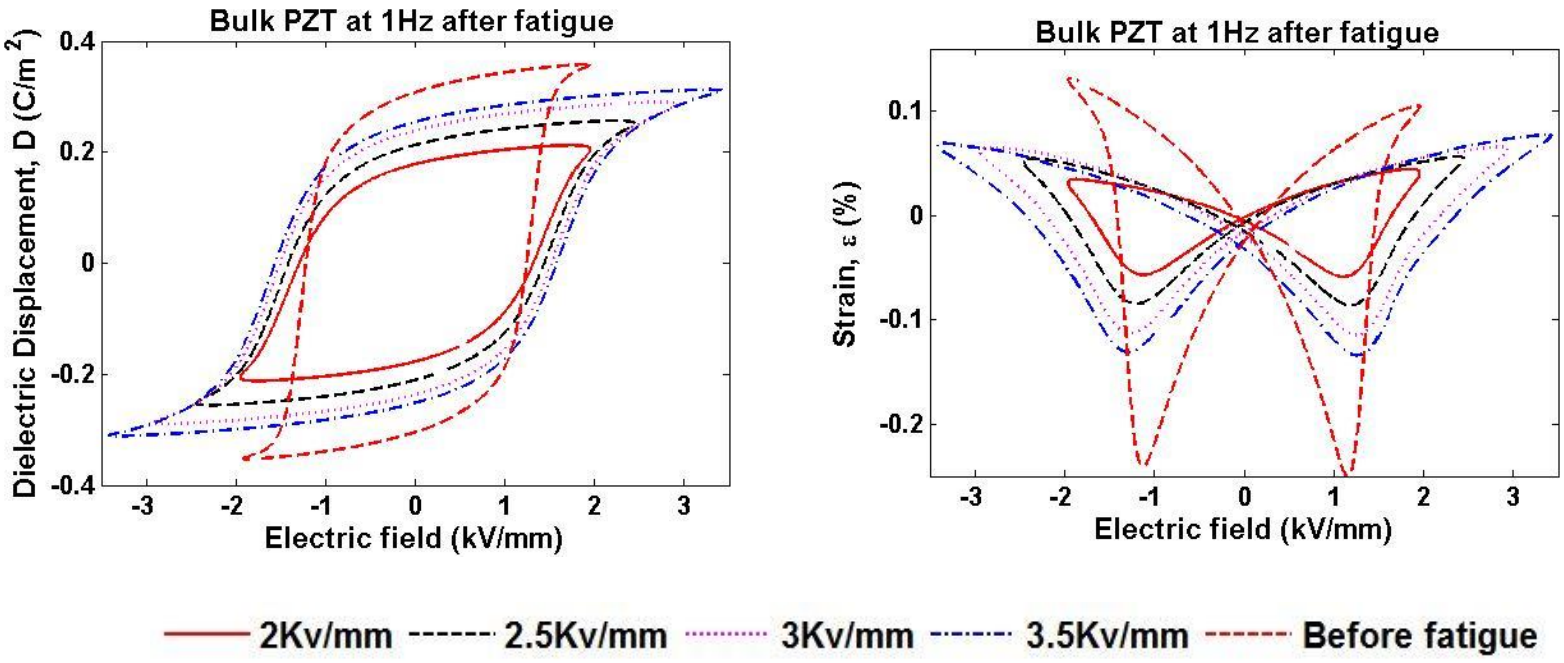


10^1 cycle 10^3 cycle 10^5 cycle $3*10^5$ cycle $5*10^5$ cycle $7*10^5$ cycle 10^6 cycle





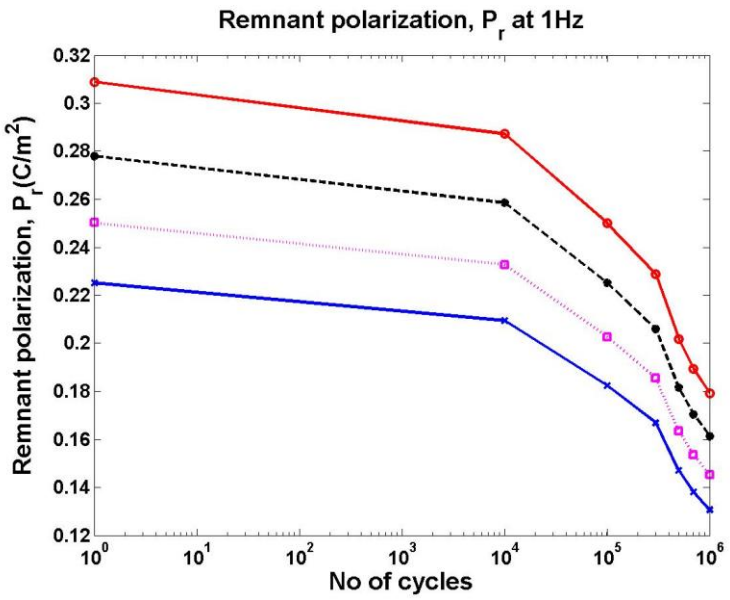
Unrecoverable properties

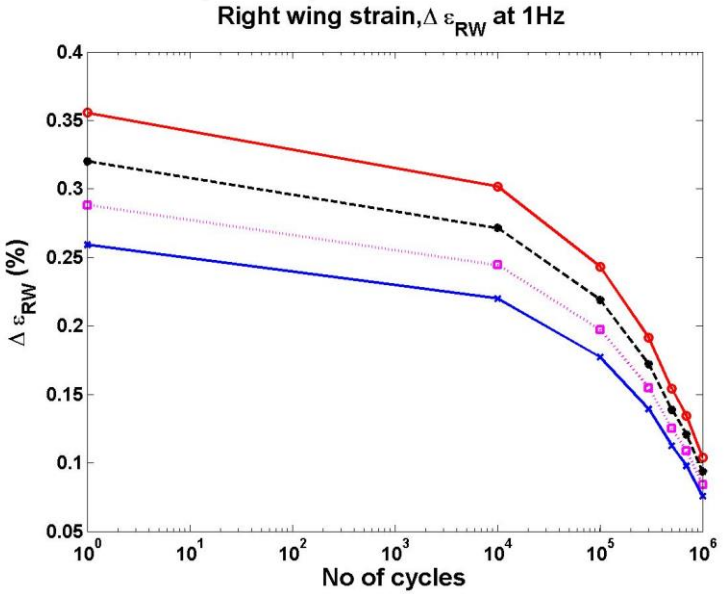


Inference:

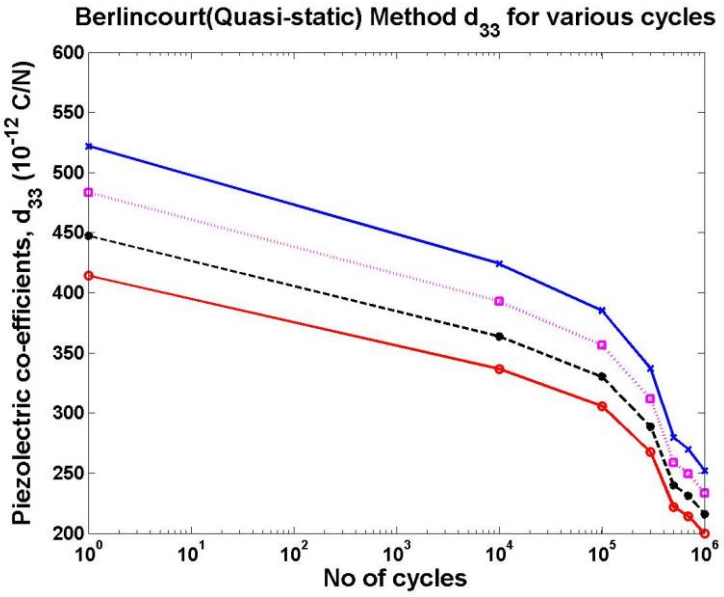
- *The domain wall causes more deterioration during frequent domain switching.*
- *In unipolar and bipolar at lower fields will not cause domain switching , hence there is no deterioration*

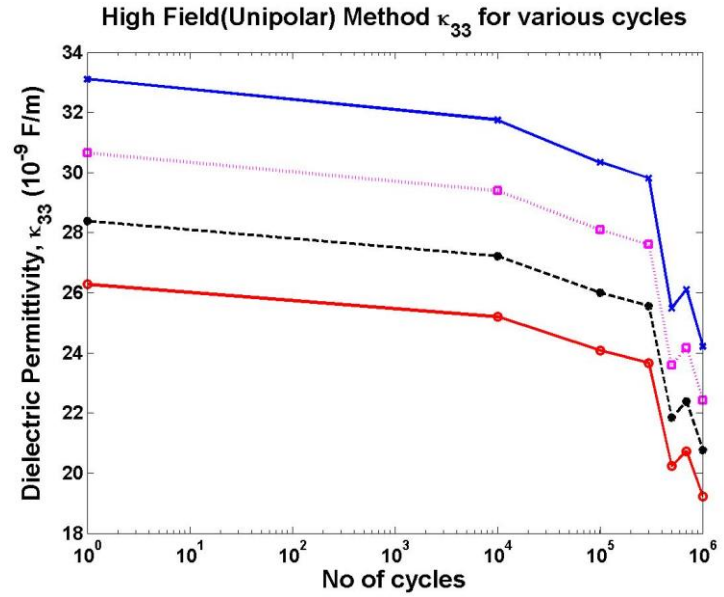
Deterioration of material properties





27° C 50° C 75° C 100° C





Summary

- Electrical fatigue experiments are performed on Bulk Piezoceramics at different loading amplitude and environment.
- Material properties are identified in quasi static and at dynamic fields, the influencing parameter for deterioration identified as domain switching.
- Thus the present study explores the insight of Electrical fatigue effects on 1-3 piezocomposites. The results obtained will be useful the device design of the material

References

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- R. Jayendiran, A. Arockiarajan, "Modelling of dielectric responses of 1-3 type piezocomposites" , Journal of Applied Physics , 112 (2012).

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Thank You!
Mohan Y