ENGINEERING PHYSICS

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Class #56

- ***Polarization mechanisms in dielectrics***
- ***Non Linear dielectrics - $BaTiO_3$ structure and origin of non-centro symmetry of charges, phase changes***
- ***Peizo electric materials - Pyro electric materials properties and applications***
- ***Ferro electric hysteresis and application as memory materials***

Ferroelectric materials

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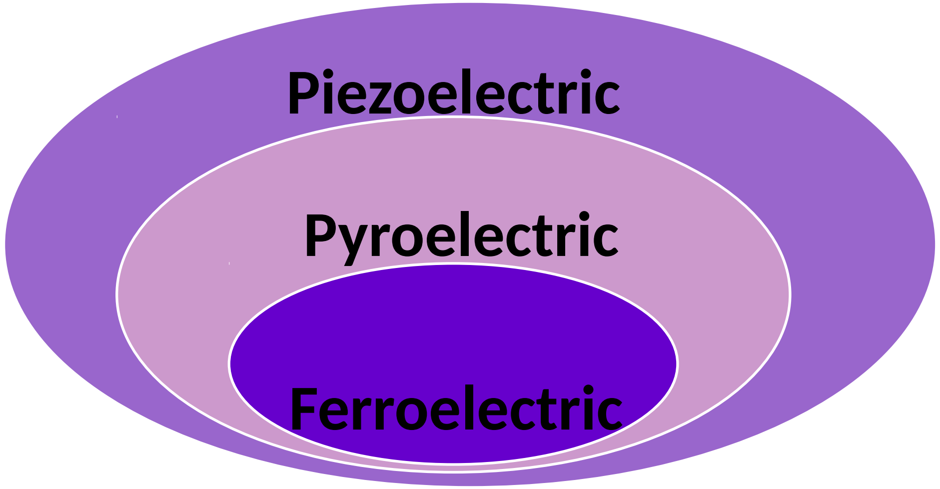
- ***Origin of ferroelectricity***
- ***Curie temperature***
- ***Domain walls***
- ***Hysteresis***
- ***Ferroelectric memory device***

Ferroelectric materials

- ***Suggested Reading***
- ***1. The Science and Engineering of Materials, Sixth Edition, Chapter 19, Donald R. Askeland, Pradeep P. Fulay and Wendelin J. Wright, 2010, Cengage Learning, Inc.***
- ***2. Learning material prepared by the Department of Physics***

Ferroelectric Materials

- *Ferroelectricity discovered in 1920*
- *Joseph Valasek observed in Rochelle salt*
- *More than one spontaneous polarisation orientations in the absence of electric field (E)*
- *Occurs in 10 pyro electric point groups*
- *E→ Switching of spontaneous polarization*



Ferroelectric Curie temperature

- *At T < Curie temperature (T_C), the material shows spontaneous polarization*
- *For T > $T_{c,}$ the material becomes para-electric*
- *Dielectric susceptibility for all T>T_c* $$\chi = \frac{C}{T - T_c}$$

  where C is a constant dependent on the material and T_c is the curie temperature

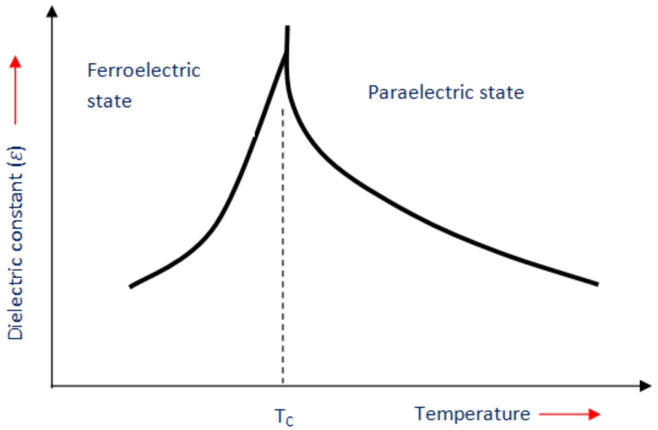


Figure 5

https://www.electrical4u.com/ferroelectric-materials/

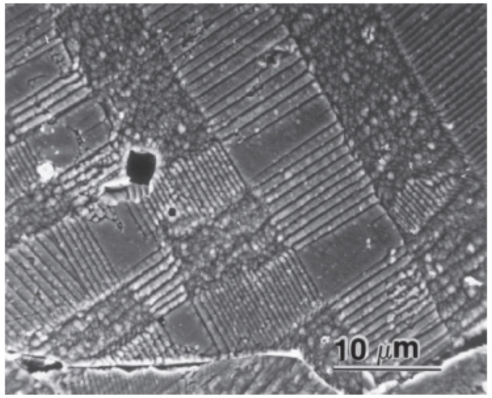
Ferroelectric materials examples

- ***Barium titanate and barium strontium titanate are the most well known***
- ***Others include tantalum oxide, lead zirconium titanate, gallium nitride, lithium tantalate, aluminium, copper oxide and lithium niobate***

Ferroelectric	T_c (°C)
$BaTiO_3$	120
PZT	390
Lead metaniobate	570

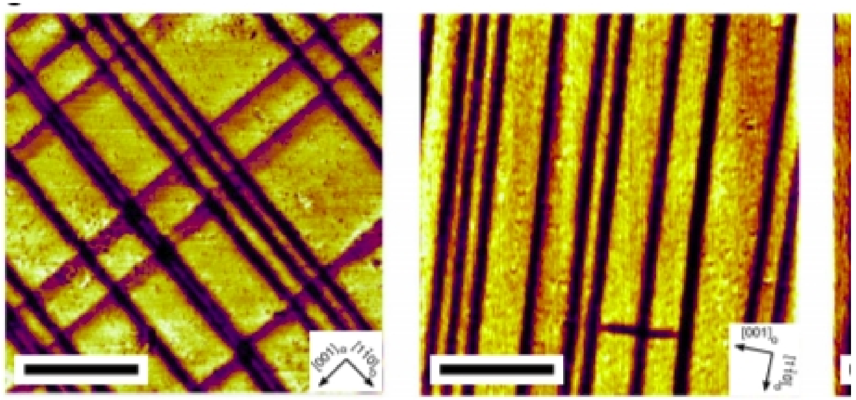
Ferroelectric domains

- *Reduction in elastic and electrostatic energies→ Domains*
- *Applied field/mechanical stress can displace domain wall*
- *180° and non 180° domain walls exists*
- *In $BaTiO_3$, Othorhombic→ 60°, 90°, 120° & 180° Rhombohedral→71°, 109° & 180° Tetragonal→ 90° & 180°*



Domains in barium titanate

R Donald et al



Controlled ultra fine domains in PZT

https://www.nature.com/articles/ncomms5677

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Ferroelectric - PE loop

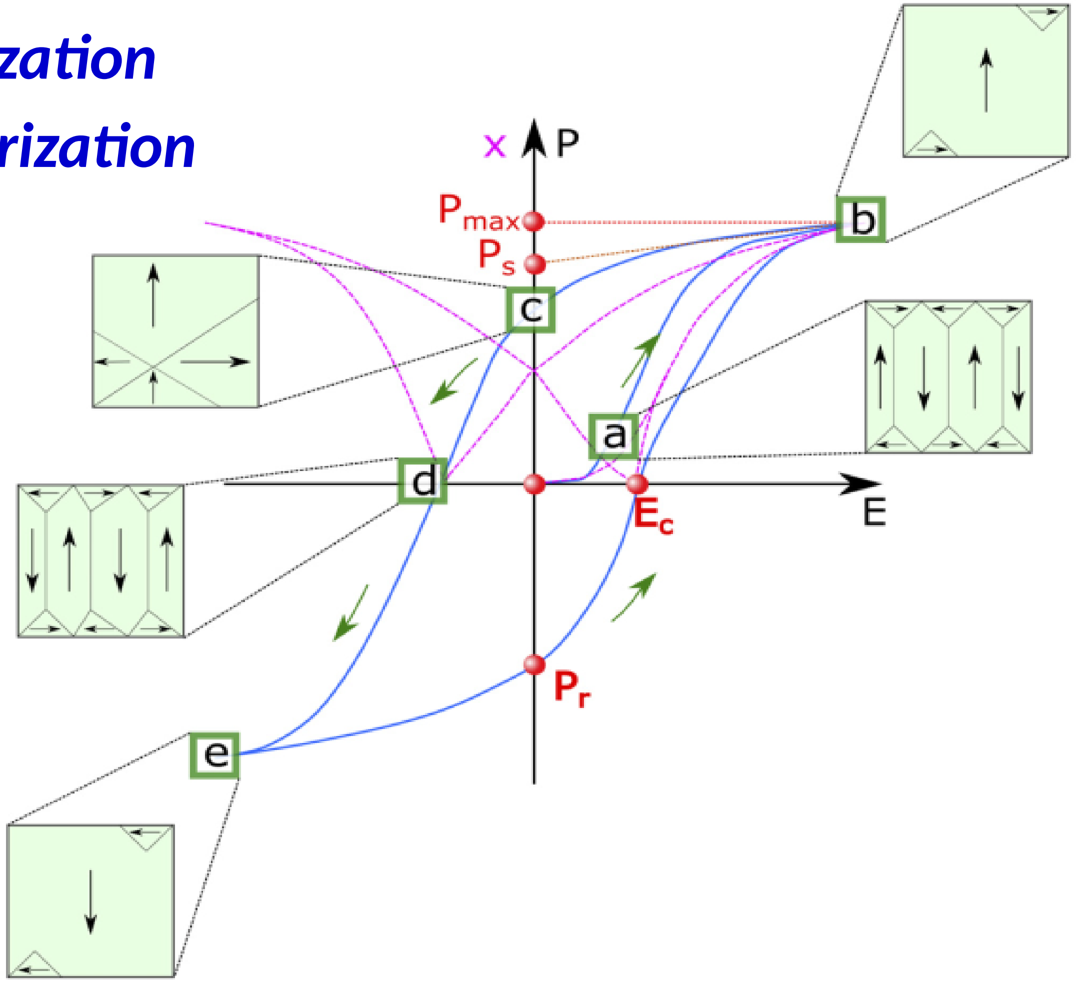
- *Fingerprint of ferroelectric materials*
- *Remnant polarization*
- *Saturation polarization*
- *Coercive Field*

- *SE butterfly*
- *curve*

- *Relaxor*
- *ferroelectrics:*
- *Thin PE loop*

  Ex: Lead

  magnesium niobate



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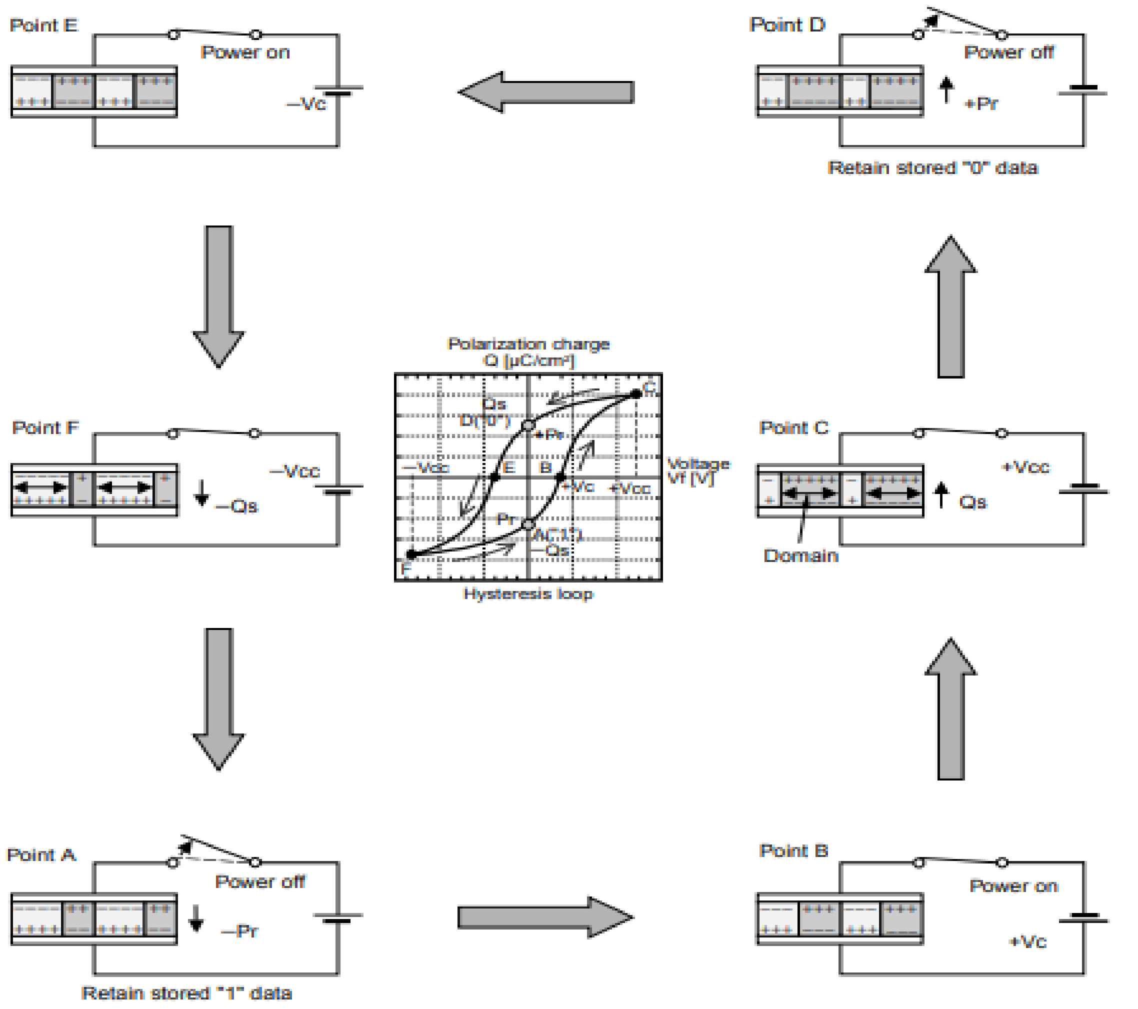
Ferroelectric RAM



Source: https://www.fujitsu.com/downloads/MICRO/fme/fram/fram-guide-book.pdf

Advantages of ferro electric storage devices

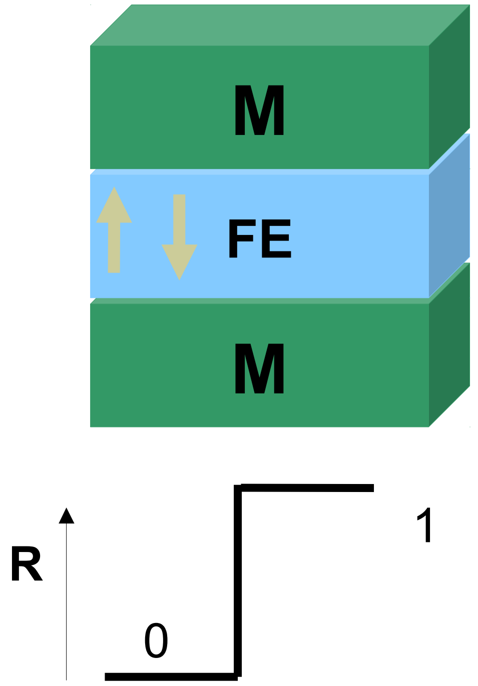
- *Remnant polarization → nonvolatile memory devices*
- *Information stored in the electric polarization is retained even after removing the power of the device*
- *Stored data can be erased by applying a field in the negative direction*

Characteristics

- *High read and write speed*
- *Ultra-low power consumption*
- *Unlimited writes*

Other applications of ferroelctric materials

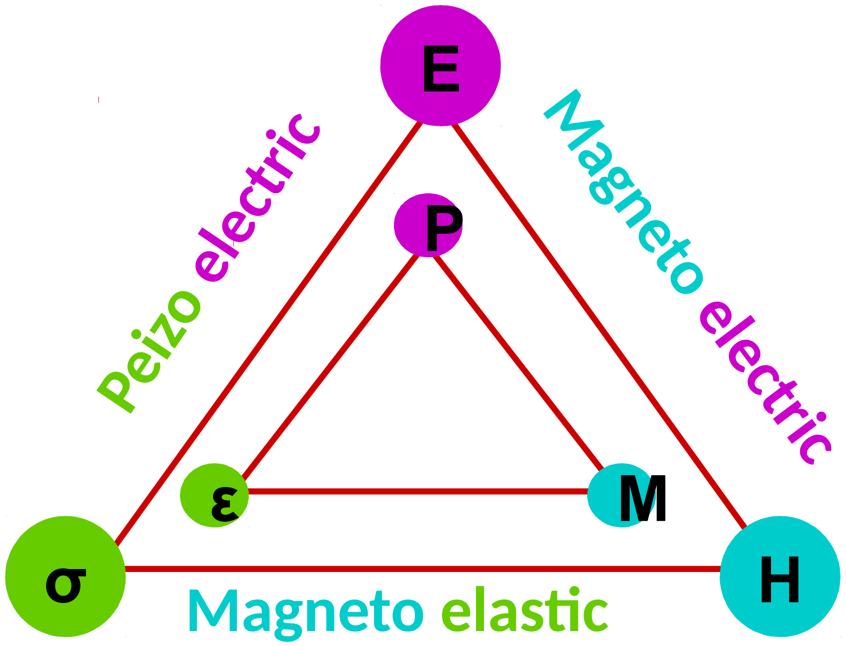
- *Ferroelectric tunnel junctions*
- *Non volatile memory devices*
- *Photovoltaic devices*
- *Ferroelectric capacitors*
- *Ferroelectric liquid crystal display*
- *Optical waveguide modulators*
- *Sensors and actuators*
- *Sonar*



FJT

Multiferroics

- ***Exhibit more than one of the primary ferroic properties***
- ***Magnetoelectric multiferroics (Bismuth ferrite)***
- ***External magnetic field → electric polarization***
- ***External electric field → Magnetization***



Class #56 …….. Quiz….

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The concepts related to this class which are true are…

1. Spontaneous polarization exists in all dielectric materials
2. In ferroelectric materials, there exists more than one spontaneous polarization directions
3. At temperatures above Curie temperature, the material behaves as ferroelectric
4. Domain wall orientations are dictated by crystal symmetry
5. Remnant polarization in ferroelectric materials are used to store data

THANK YOU

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