ENGINEERING PHYSICS

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ENGINEERING PHYSICS

Unit 5 : Quantum mechanical treatment of Magnetic materials and Dielectrics

Class # 54

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

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Non linear dielectrics- $BaTiO_3$ structure and phase changes

Class #54

- *Non linear dielectrics*
- *Crystal structures – point groups*
- *Classification of dielectrics*
- *$BaTiO_3$ structure*
- *Phase changes in $BaTiO_3$*

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Non linear dielectrics- $BaTiO_3$ structure and phase changes

➢ ***Suggested Reading***

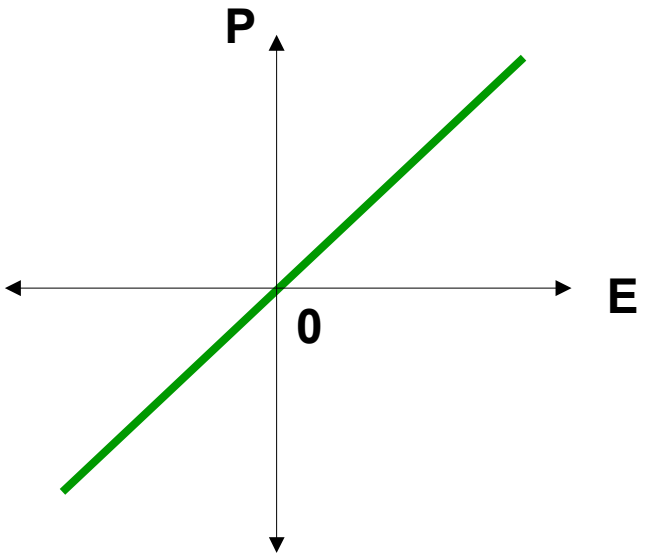
1. The Science and Engineering of Materials, Sixth Edition, Chapter 19, Donald R. Askeland, Pradeep P. Fulay and Wendelin J. Wright, 2010, Cengage Learning, Inc.

2. Learning material prepared by the Department of Physics

Non linear dielectrics

- *Polarization increases with the increase in applied field* (E)
- *In linear dielectrics, polarization* (P) *is linearly related to* E *and dielectric constant* (ε_r) *is constant*
- *Nonlinear dielectrics :* E *and* P *are not linearly related*

Linear dielectrics

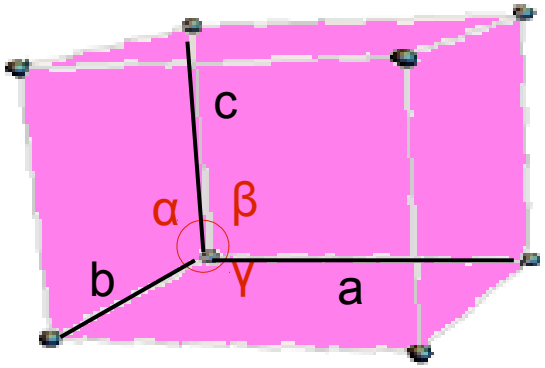


Unit cell

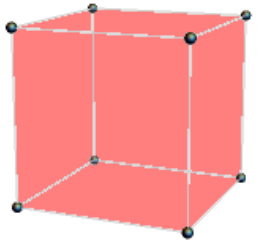
- *A crystal is a solid material having long range order with periodic structure*
- *Crystalline lattice: periodic pattern*
- *Unit cell : What is repeated*
- *Unit cell is characterized by lattice parameters*

Corundum crystal

Source: Wikipedia

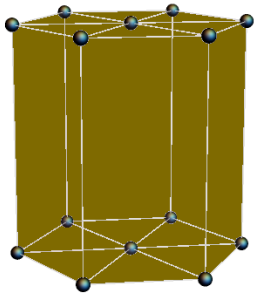


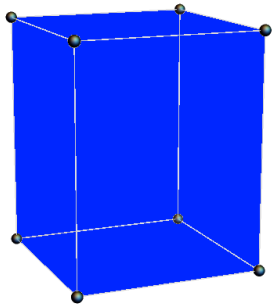
Crystal systems



Cubic ; a=b=c;
α=β=γ=90°

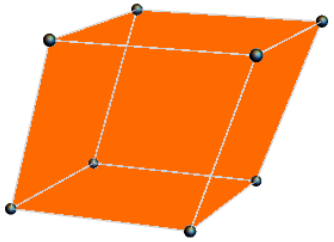
hexagonal ; a=b≠c;
α=β=90°,γ=120°

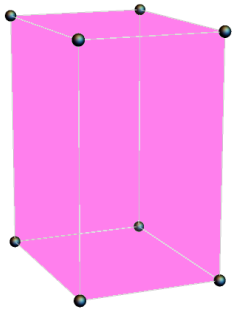




tetragonal; a=b≠c;
α=β=γ=90°

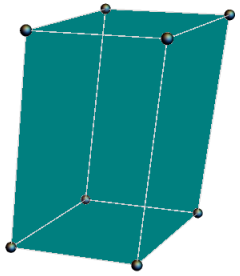
trigonal ; a=b=c;
α=β=γ≠90°

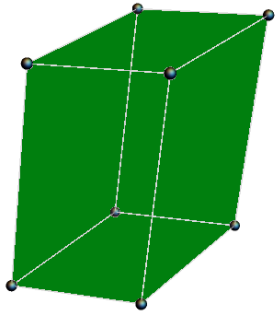




Orthorhombic; a≠b≠c;
α=β=γ=90°

monoclinic; a≠b≠c;
α=β=90°≠γ

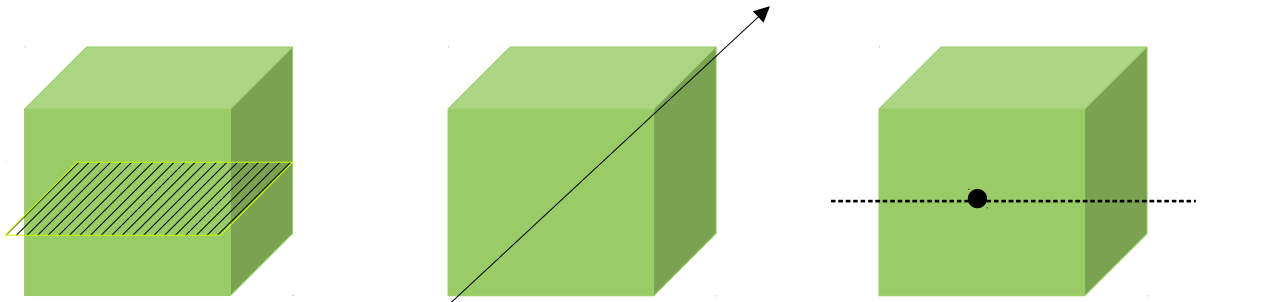




triclinic; a≠b≠c;
α≠β≠γ

Point groups

- *Orientation of crystal can be changed without seeming to change the positions of its atoms*
- *Changes of orientation: operations of reflection in a plane, rotation about an axis and inversion about a centre*
- *Point groups: 32 such distinct combinations*
- *Centro symmetric crystal: Centre of symmetry exists*



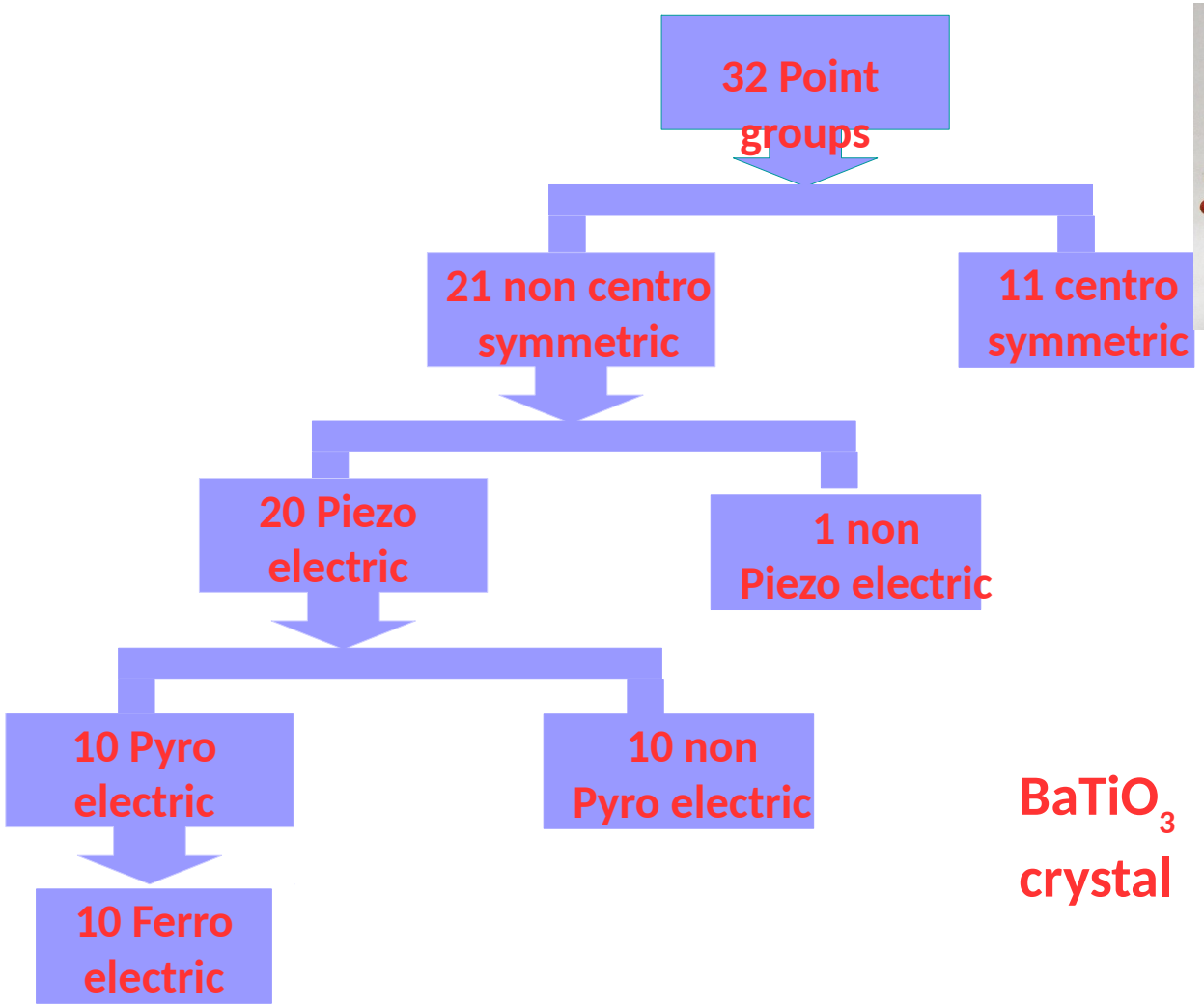
Plane of symmetry

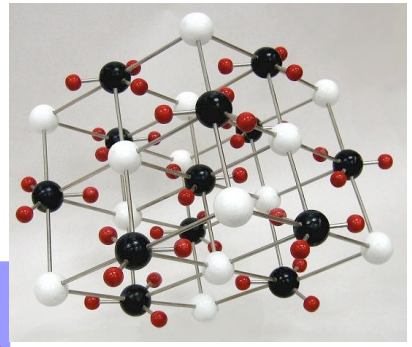
Rotation about an axis

Inversion centre

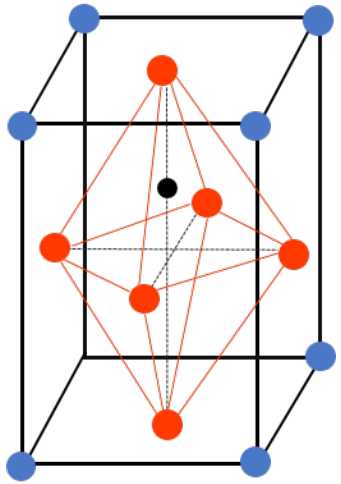
Classification of dielectric materials

Electrostriction: Polarization inducing a mechanical strain





$CaCO_3$ crystal
- Trigonal



$BaTiO_3$ crystal

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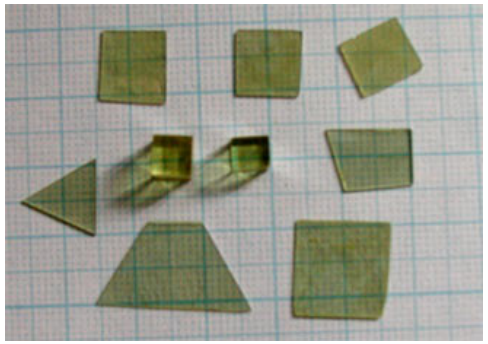
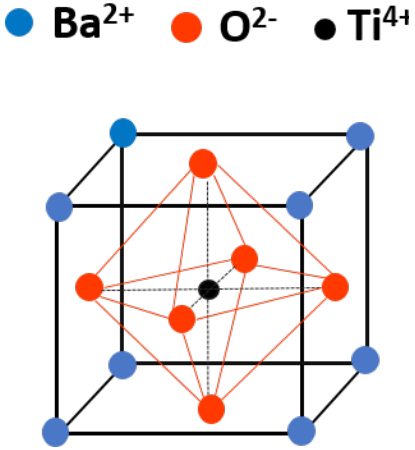
Barium titanate – origin of non centro symmetry of charges

- *$BaTiO_3$ discovered in 1940's*
- *It has extremely high relative permittivity*
- *It is a non centro symmetric crystal – pervoskite*
- *Ba^{2+} are located at the corners , Ti^{4+} at the centre of the unit cell, octahedrally coordinated by six 0^{2-}*



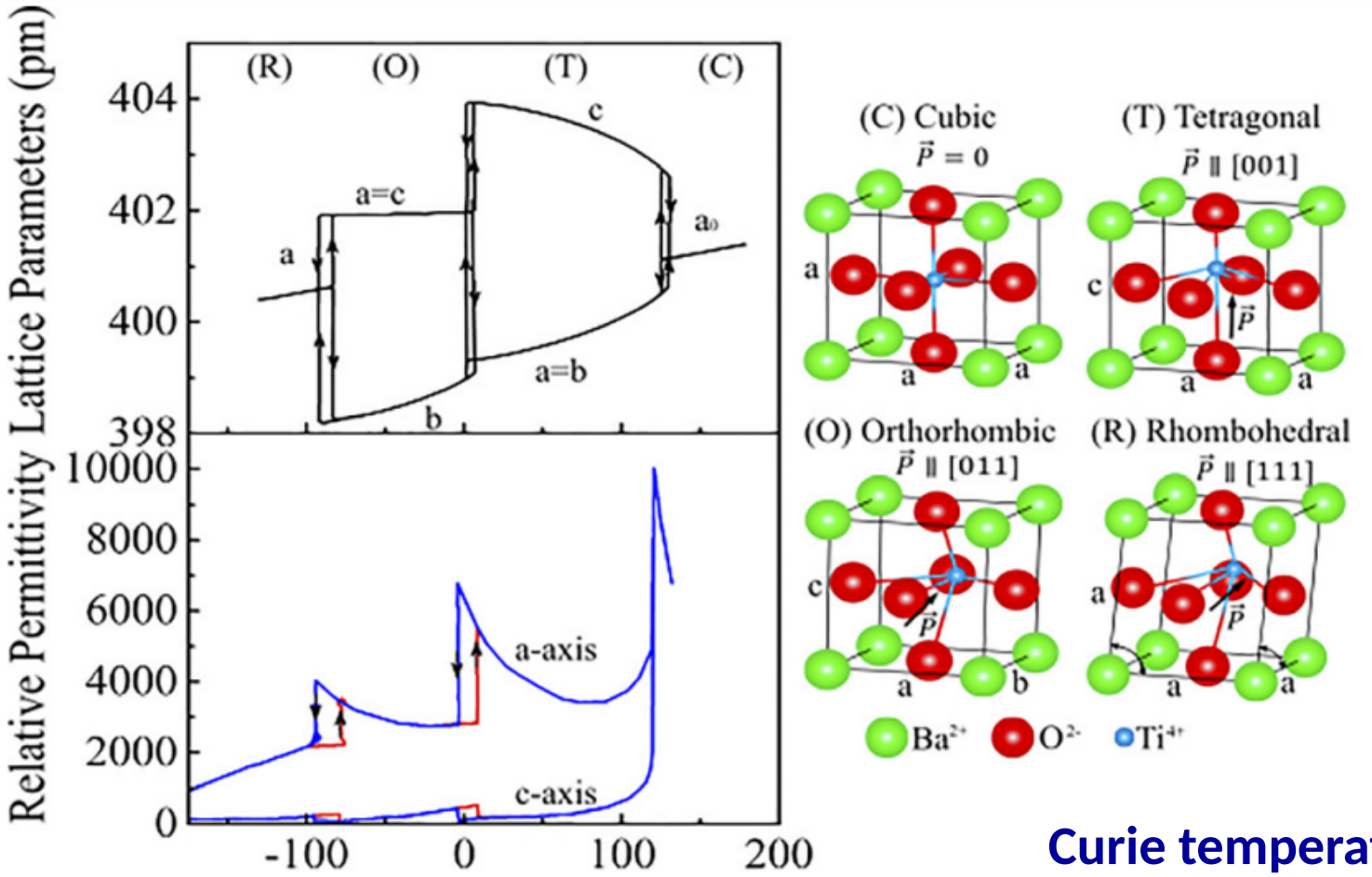
Single crystal

http://www.crystal-material.com/Single-Crystal-Materials/Barium-titanate-BaTiO3-single-crystal.html



Unit cell in cubic phase

Phase changes in $BaTiO_3$

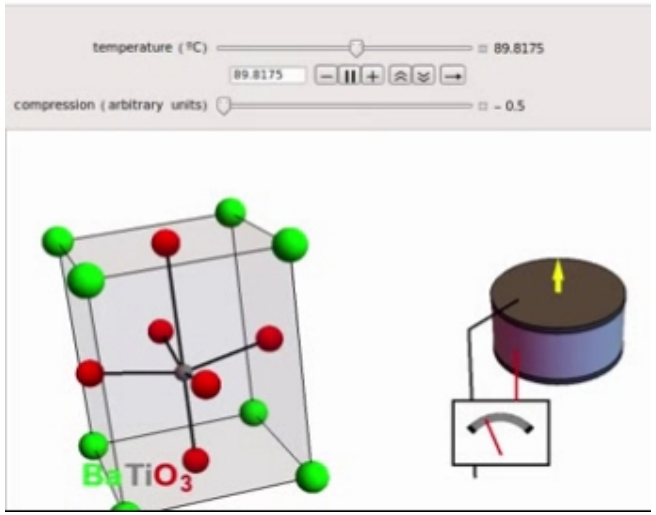


Curie temperature- 120°C

Source:
https://aip.scitation.org/doi/pdf/10.1063/1.4990046

Phase changes in $BaTiO_3$

- *All phases exhibit ferroelectric behaviour to some extent except cubic*
- *Cubic phase: paraelectric*
- *Tetragonal $BaTiO_3$: Ferroelectric: An average relative displacement along the c-axis of titanium*



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Class #54 …….. Quiz….

The concepts related to this class which are true are ……..

1. Dielectrics in which dielectric constant do not change with applied field are known as non linear dielectrics
2. Unit cell is same for all the crystal structures
3. Barium titanate at temperatures greater than 120°C is centro symmetric
4. Displacement of titanium ions give rise to non centro symmetric behaviour in $BaTiO_3$
5. $BaTiO_3$ can exist in cubic, orthogonal, monoclinic or tetragonal phases depending on its temperature
6. All phases of $BaTiO_3$ exhibit ferroelectric behaviour to some extent

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THANK YOU

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