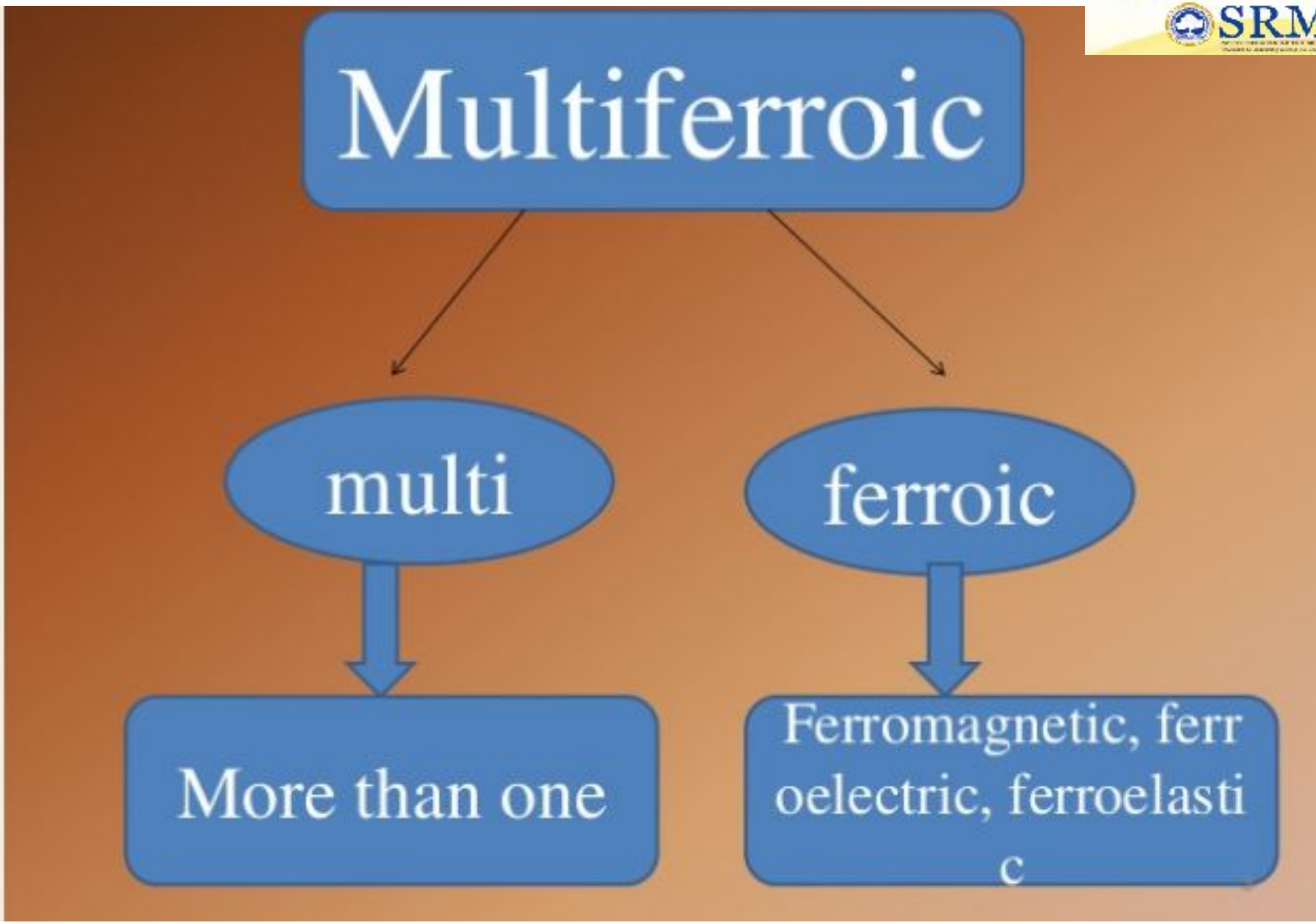
DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module 2 Lecture-15

Multiferroic Materials


Multiferroic
multi
ferroic
More than one
Ferromagnetic, ferr
oelectric, ferroelasti
c

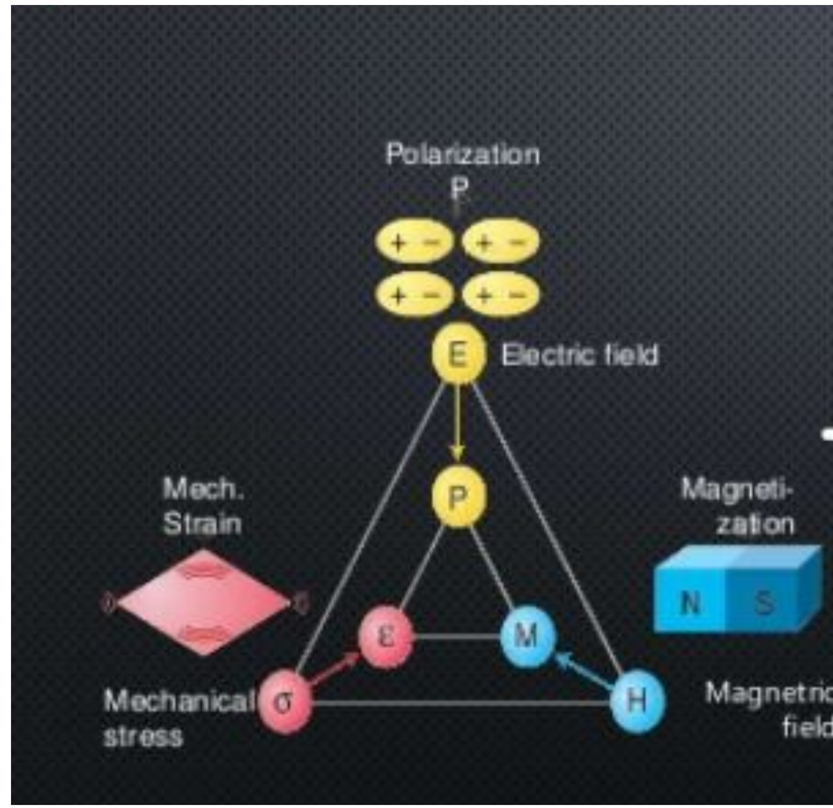
Ferroics

There are three types of primary ferroics:

Ferroelectric materials possess a spontaneous polarization that is stable and can be switched hysteretically by an applied electric field; antiferroelectric materials possess ordered dipole moments that cancel each other completely within each crystallographic unit cell.

Ferromagnetic materials possess a spontaneous magnetization that is stable and can be switched hysteretically by an applied magnetic field; antiferromagnetic materials possess ordered magnetic moments that cancel each other completely within each magnetic unit cell.

Ferroelastic materials display a spontaneous deformation that is stable and can be switched hysteretically by an applied stress.



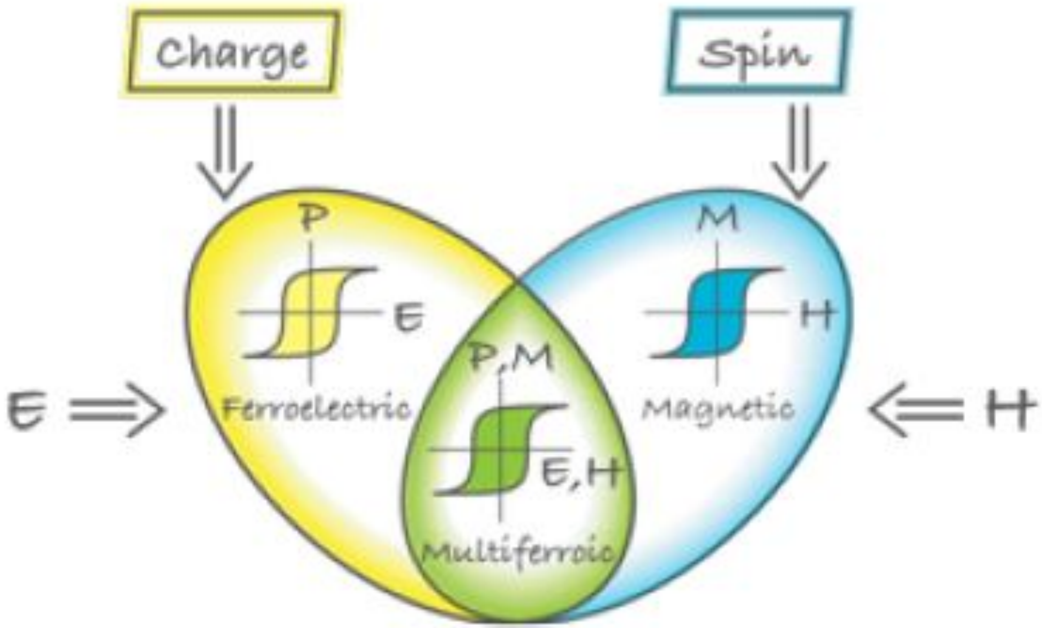
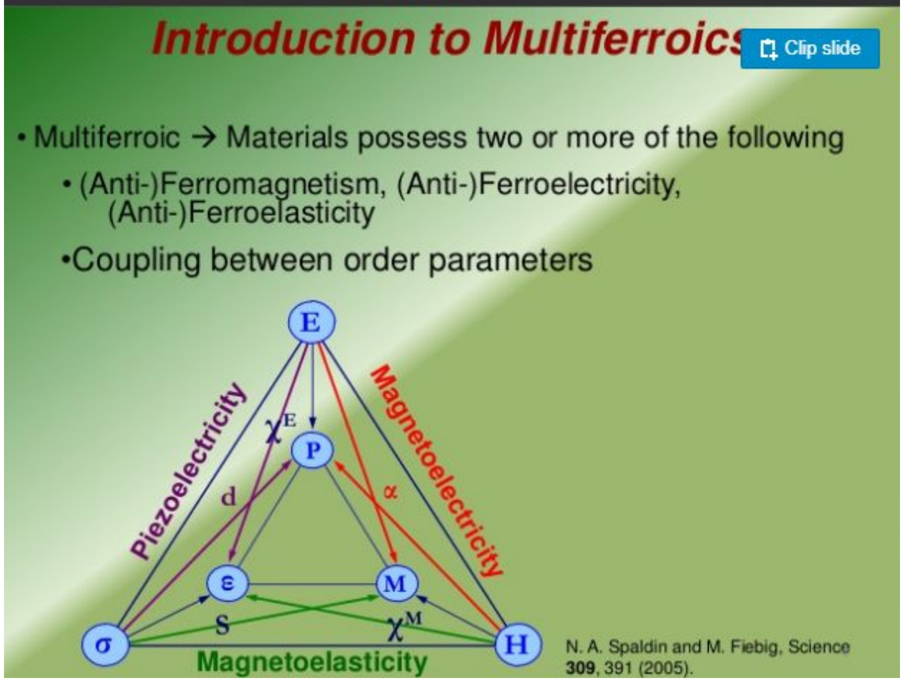


Figure: Combination of ferroelectrics and magnets


Introduction to Multiferroics
Clip slide
• Multiferroic → Materials possess two or more of the following
• (Anti-)Ferromagnetism, (Anti-)Ferroelectricity, (Anti-)Ferroelasticity
•Coupling between order parameters
E
P
ε
M
σ
H
Piezoelectricity
Magnetoelectricity
Magnetoelasticity
d
α
S
χ^E
χ^M
N. A. Spaldin and M. Fiebig, Science 309, 391 (2005).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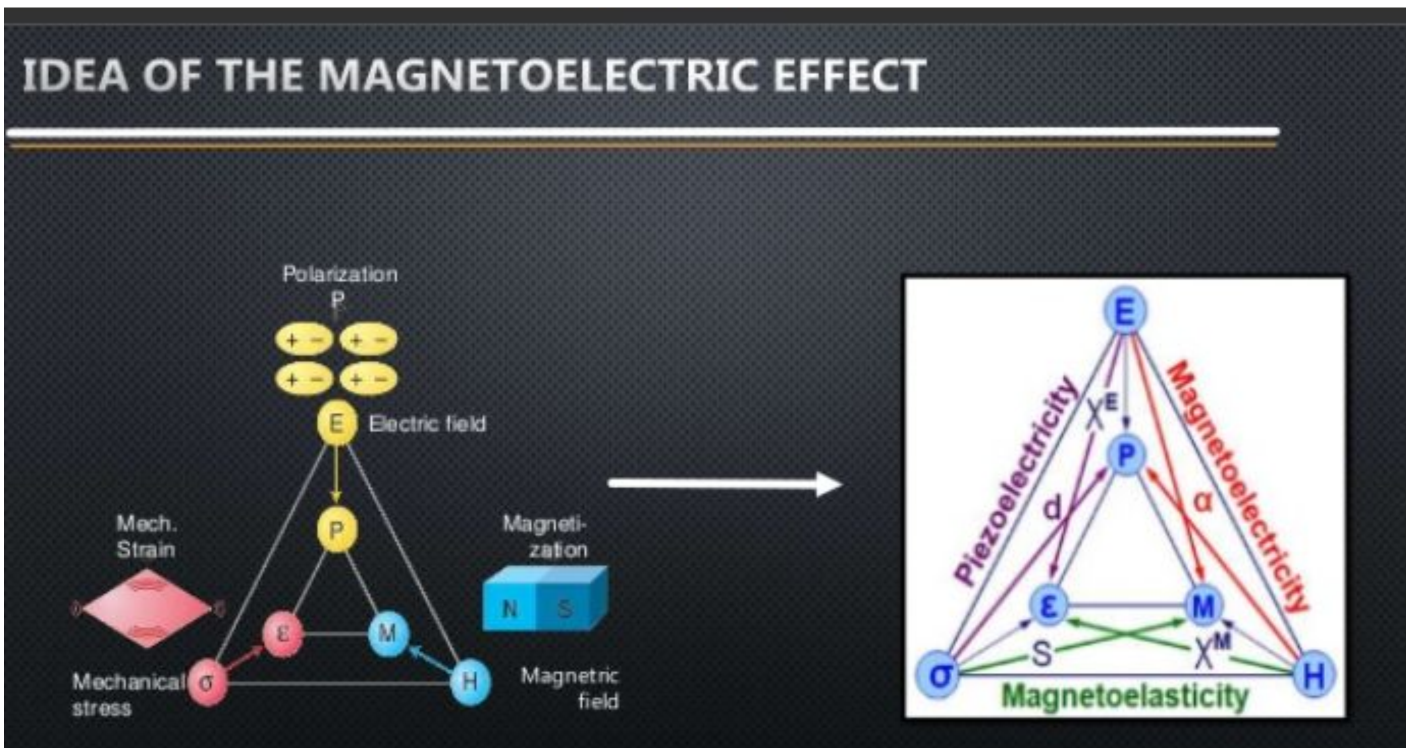

IDEA OF THE MAGNETOELECTRIC EFFECT
Polarization
P
Electric field
Mech.
Strain
Magneti-
zation
N
S
Mechanical
stress
Magnetic
field
E
P
ε
M
σ
H
Piezoelectricity
Magnetoelectricity
Magnetoelasticity
d
α
S
χ^E
χ^M

There has been increasing interest in magnetoelectric multiferroics, which are materials that show spontaneous magnetic and electric ordering in the same phase. In addition to the fascinating physics resulting from the independent existence of two or more ferroic order parameters in one material, the coupling between magnetic and electric degrees of freedom gives rise to additional phenomena.

Magnetoelectric multiferroics are attracting attention for fundamental physics due to their unique coupling behaviour between ferroelectricity, ferromagnetism and ferroelasticity and also because of their promising applications for devices in spintronics, information storage, sensing and actuation.

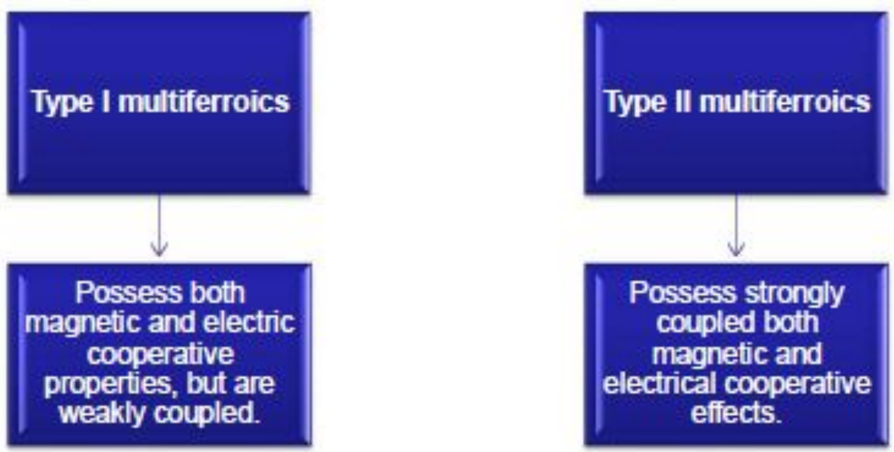
Due to the coexistence of ferroelectricity and magnetism in multiferroic materials, an external magnetic field can induce electric polarization and an external electric field can induce changes in magnetization.

Further most of the known multiferroics are ferroelectric-antiferromagnetic exhibiting ME (Magnetoelectric effect) coupling well below room temperature.

There are two types of multiferroics:

(1) type I multiferroics: there is a weak coupling between them. A famous example is BiFeO3, with TFE=1100K and TAF=643K.

(2) type II multiferroics. New developments. Here both orders are deeply coupled to one another. But unfortunately critical temperatures are small. In spite of this problem for applications, they are the most interesting intelectualy. $TbMnO_3$



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Applications

- Spintronics Devices (that includes a spin-based transistor)
- Information Storage Devices (magnetic tape, floppy disk etc)
- Spin Valve (device consisting of two or more conducting magnetic materials, that alternate its electrical resistance)
- Quantum Electromagnets (electromagnets are wire coils or loops, which tend to be bulky and difficult to fabricate)
- Microelectronic Devices (MOSFETs, Bipolar Transistor etc)
- Sensors (measures a physical quantity and converts it into a signal which can be read by an instrument)