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Specialized Materials for Printed Electronics

A Look at Piezoelectric, Pyroelectric, and Ferroelectric Materials

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WHAT IS PRINTED ELECTRONICS?

Printed Electronics is an attempt to cut the cost of manufacturing item level electronics.

Ways of cutting costs

- Use of cheaper, more flexible substrates such as PET, PEN, paper, textiles, etc.
- Use of additive printing processes
- In some cases, use of novel materials
  - Ex. Nanometals for conductive inks, organic semiconductors
- In other cases, use of established materials in novel ways

IPC COMMITTEES

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Printed Electronics Technology Roadmap Subcommittee

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Printed Electronics Base Materials/Substrates Subcommittee

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Printed Electronics Functional Materials Subcommittee

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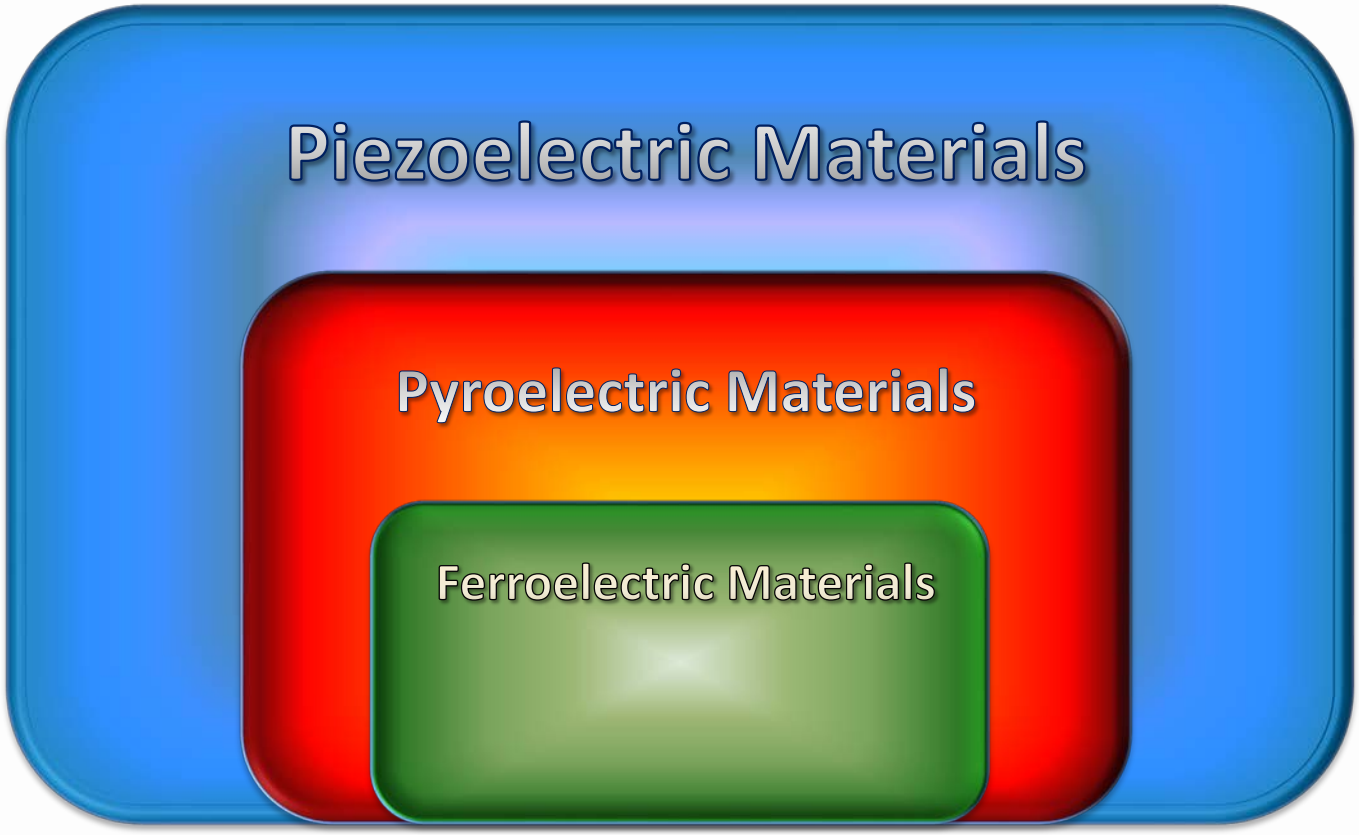
Printed Electronics Final Assembly Subcommittee

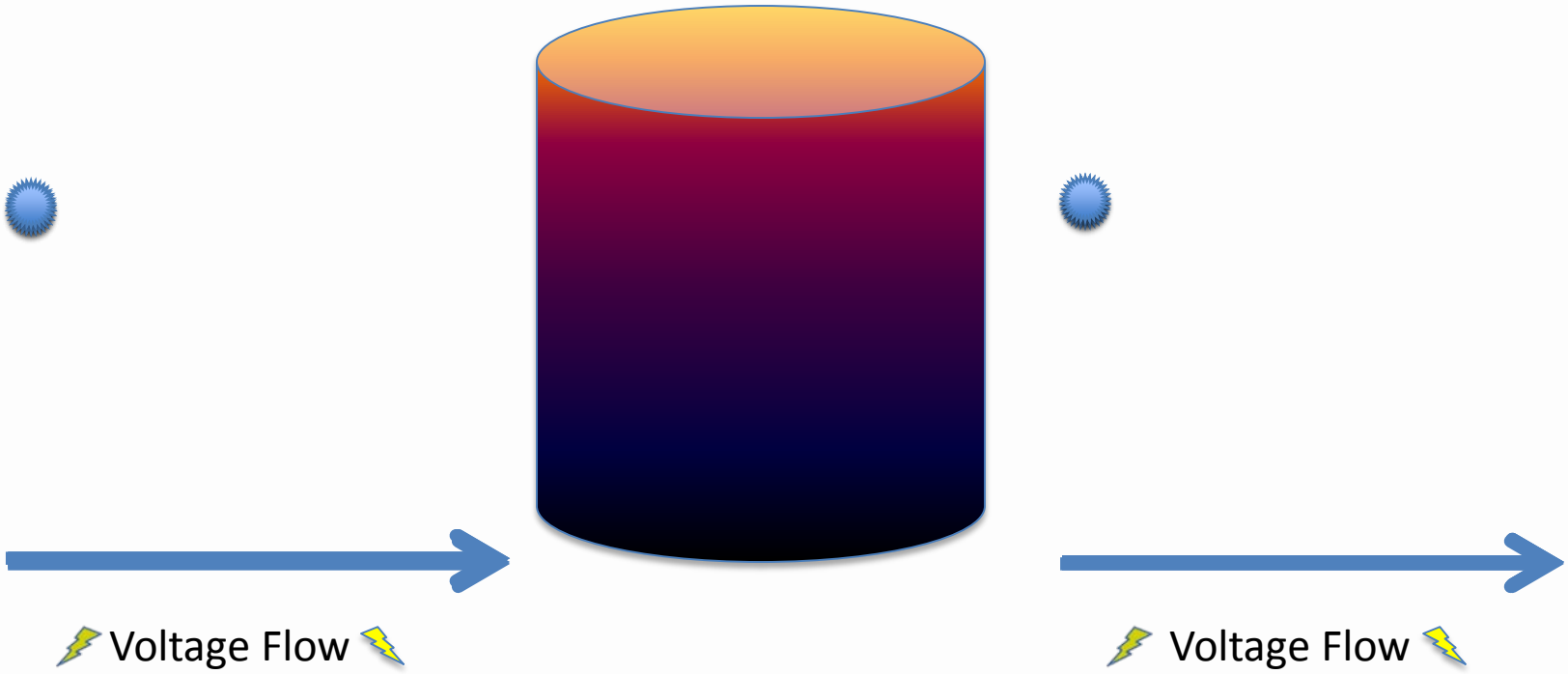

Piezoelectric Materials
Pyroelectric Materials
Ferroelectric Materials

PIEZOELECTRIC EFFECT

What is it?

- Piezoelectric Effect is the relationship between mechanical stress and electrical voltage
- As stress is applied to the solid material, electrons are bumped off making an electrical current.
- The reverse is also true. An electrical current can cause the solid to increase in volume.

PIEZOELECTRIC EFFECT



HISTORY

First demonstration of Piezoelectric Effect was in 1880 by Jacques and Pierre Curie by studying such materials as Quartz, sugar cane, and Rochelle salt (Sodium Potassium tartrate)

In 1910, Woldemar Voigt published the Textbook on Crystal Physics which described the 20 classes of natural crystals that were capable of piezoelectricity.

In 1917, the first practical application was used in WWI in sonar devices.

After this success, Piezoelectric materials were used in devices such as record players and microphones.

During WWII, the United States, Russia, and Japan developed barium titanate and lead zirconate titanate materials which lead to the development of such devices as aviation radio that helped to coordinate Allied air attacks.

Due to less restrictive patent laws following WWII in Japan, development of devices ramped up to include the first TV remote controllers and piezoelectric igniters for gas grills.

In 1969, PVDF (Polyvinylidene Fluoride), was discovered to have piezoelectricity. It was also observed to have a reverse piezoelectric expansion. In other words, it will compress when exposed to an electrical field.

PIEZOELECTRIC MATERIALS

Crystals

- Quartz
- Topaz
- Sucrose
- Rochelle Salt
- Tourmaline-group minerals

Ceramics

- Barium Titanate
- Zinc Oxide
- PZT (Lead Zirconate Titanate)
  - Family of ceramics called Perovskite

Miscellaneous

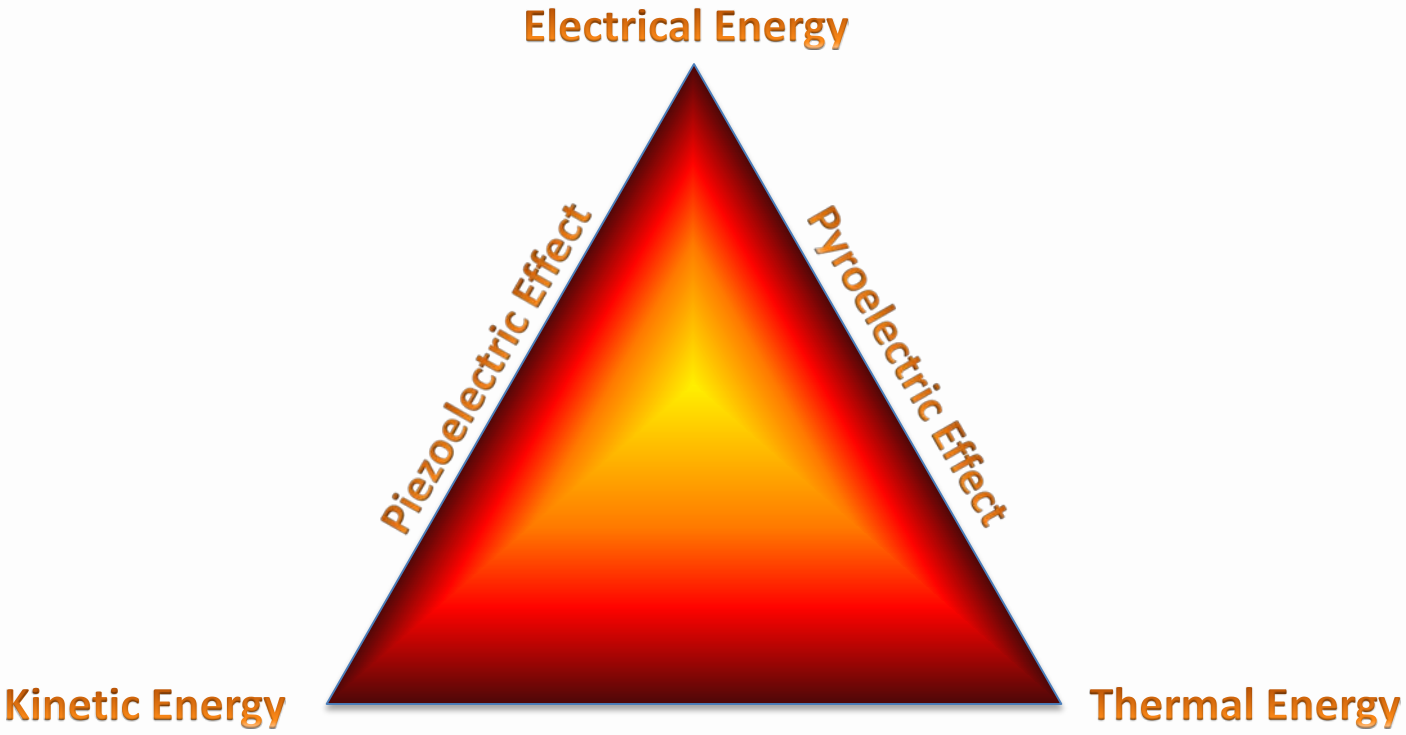
- PVDF (Polyvinylidine Fluoride)
- Bone
- Silk
- DNA
- Enamel

PYROELECTRIC EFFECT

What is it?

- Pyroelectric materials generate a temporary voltage when they are heated or cooled.
  - Not to be confused with Thermoelectricity. This where one part of a thermoelectric device undergoes a temperature change inducing a permanent voltage change.
- All Pyroelectric materials are also Piezoelectric. Of the 20 classes of crystal symmetry in Piezoelectric materials, 10 are also Pyroelectric.
- Pyroelectric effect was first noted in about 400 BC by Theophrastus. It wasn't until the 1800's that the effect was given its name. The study of Pyroelectric effect by the Curie brothers lead to the discovery of some of the principles behind Piezoelectricity.

THINK ABOUT IT THIS WAY



PYROELECTRIC MATERIALS

Natural

- PZT (Perovskite structures)
- Tourmaline
- TGS (Triglicine sulphate)
- Rochelle Salt
- Zinc Oxide

Synthetic

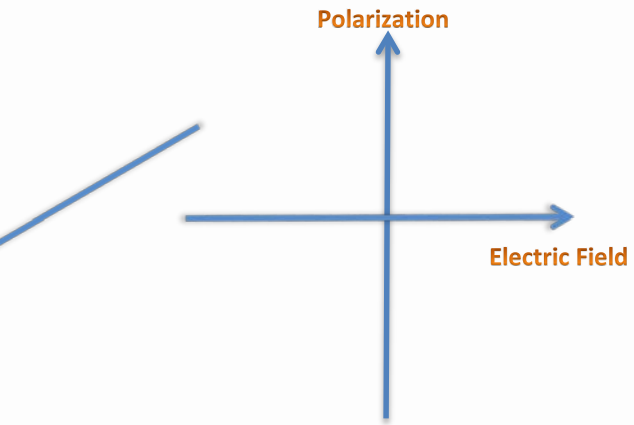
- PVDF (Polyvinylidine Fluoride)
- Cesium Nitrate
- Gallium Nitride
- Lithium Tantalate

FERROELECTRIC EFFECT

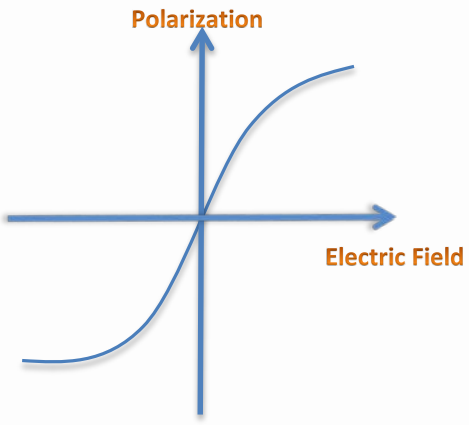
What is it?

- In Dielectrics materials, the polarization of the material is almost exactly proportional to the applied electric field.
- In Paraelectric materials, the polarization curve is non-linear with regards to the applied electric field.
- In Ferroelectric materials, the polarization curve is non-linear, displays a spontaneous nonzero polarization when zero electric field is applied, and this spontaneous polarization can be reversed in by an applied electric field giving a hysteresis loop.

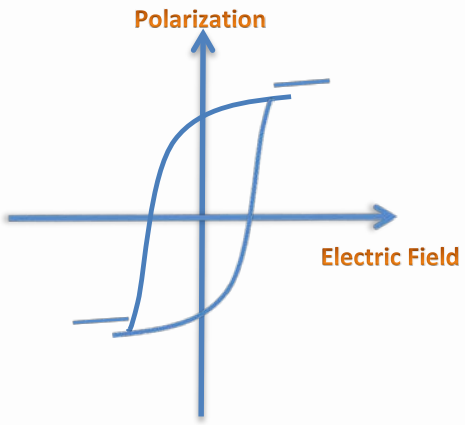
VISUALIZING FERROELECTRIC EFFECT



Dielectric Polarization



Paraelectric Polarization



Ferroelectric Polarization

FERROELECTRIC EFFECT

Other Characteristics

- Typically, ferroelectric materials demonstrate their unique properties below the Curie (T_c) phase transition temperature.
  - Above the T_c, ferroelectric materials have paraelectric properties.
- Ferroelectric materials are have both Piezoelectric and Pyroelectric properties.
- Even though "ferro" is the prefix meaning iron, most ferroelectric materials do not contain iron.
- Ferroelectric properties are not just limited to crystalline materials. Chemicals such as nitrous oxide when laid down in a film several hundred molecules thick exhibit "Spontelectric" properties. The film spontaneously generates an electric field!

FERROELECTRIC MATERIALS

- PVDF (Polyvinylidine Fluoride)
- PZT
- Barium Titanate
- Rochelle Salt

DEVICES ON THE HORIZON?

PRINTED MEMORY

FLEXIBLE REMOTES

POWER GENERATION

ENERGY HARVESTING

SENSORS

Thank you!

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