PIEZOELECTRIC
MEMS

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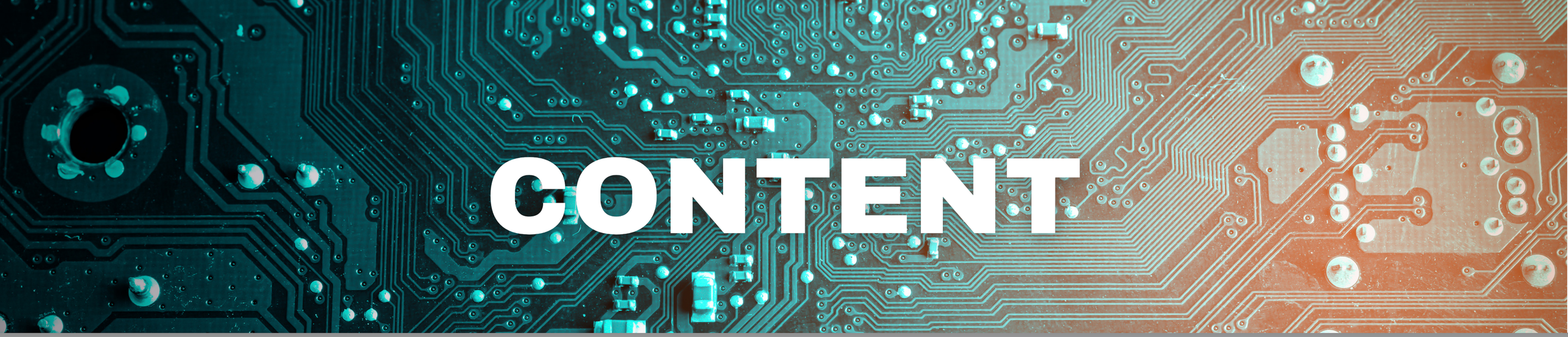

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Piezoelectric MEMS

UNDERSTANDING MEMS

MEMS Devices Basic Fundamentals

- What are MEMS devices?
  - Definition
  - Examples (accelerometers, gyroscopes, pressure sensors)
- Working principles of MEMS devices
  - Microfabrication techniques
    - Lithography
    - Deposition processes (physical and chemical)
    - Etching techniques (wet and dry)
  - Materials used in MEMS devices
    - Silicon-based materials (silicon, silicon dioxide)
    - Polymers
    - Metals (aluminum, gold)
- Components of a typical MEMS device
  - Sensing element/transducer
  - Actuation mechanism
  - Signal conditioning circuitry
- Applications of MEMS devices
  - Consumer electronics
  - Automotive industry
  - Biomedical applications
  - Aerospace and defense
  - Industrial sector

MEMS

Definition

- Micro-Electro-Mechanical Systems are miniature integrated systems that combine tiny mechanical and electromechanical components on a microscale or nanoscale.
- fabricated using microfabrication techniques, enabling the creation of complex devices on a small chip or substrate.

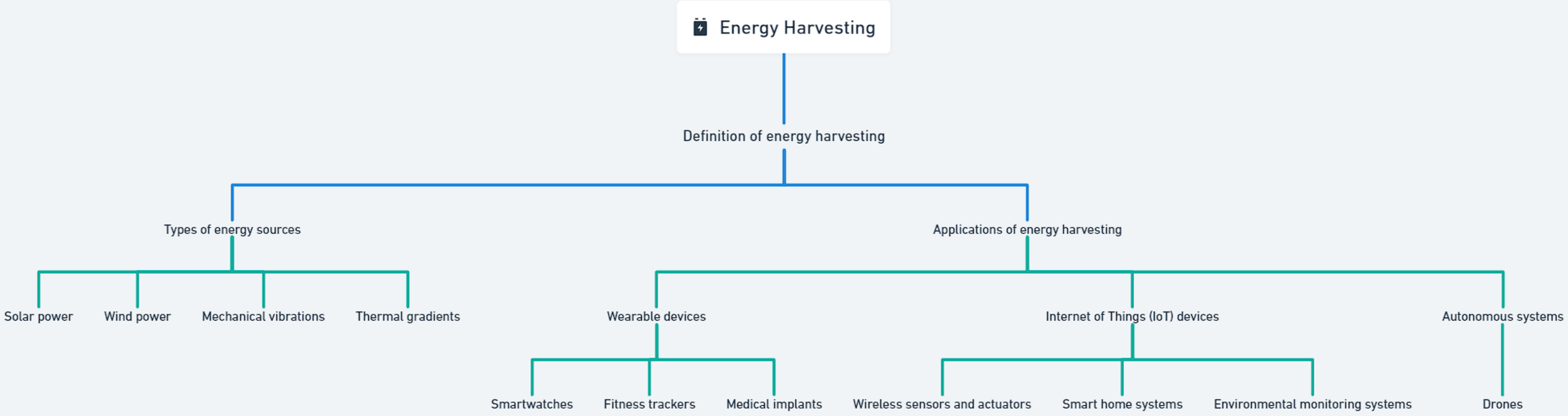
Fabrication

- MEMS are manufactured using specialized processes, including photolithography, etching, deposition, and bonding.
- These techniques allow for the precise creation of microstructures and components, such as sensors, actuators, and electronics, on silicon wafers or other substrates.

Applications

- MEMS technology finds use in various fields, including aerospace, automotive, healthcare, and consumer electronics.
- Used in accelerometers for sensing motion in smartphones, pressure sensors in medical devices, inkjet printer nozzles for precise printing, and gyroscopes for measuring angular velocity.

WHAT IS ENERGY HARVESTING?



Energy Harvesting

Energy Harvesting is the process of capturing and converting various forms of ambient energy from the environment like solar, mechanical vibrations, wind , thermal power into usable electrical energy.

Advanced applications

01 **Wearable gadgets** leverage naturally available energy sources to prolong battery life and reduce environmental impact.

- Self-charging smartwatches for continuous usage,
- body heat-powered health monitoring patches

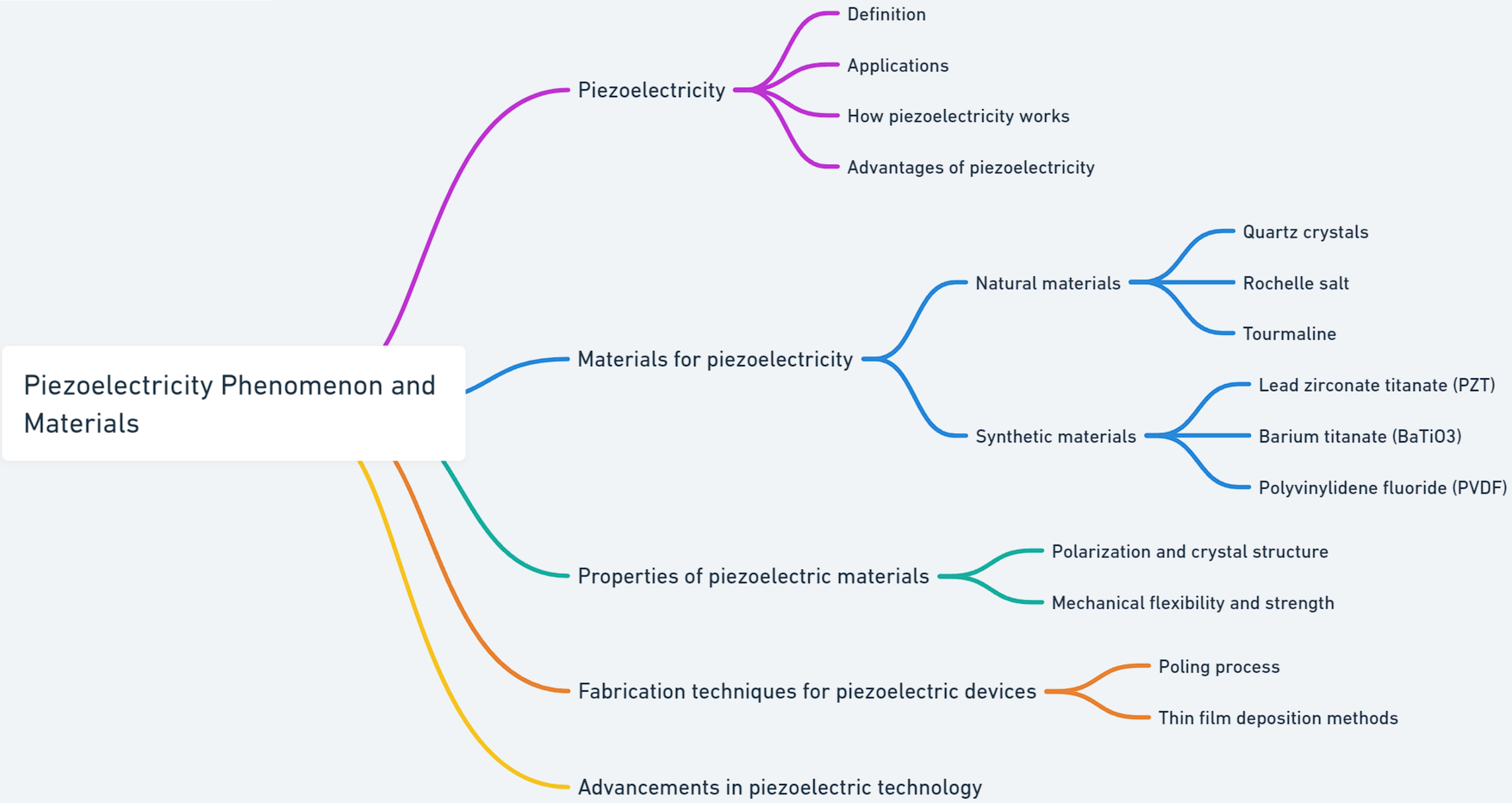
02 **IoT(Internet of Things)** devices utilize harvested ambient energy sources to ensure long-term, maintenance-free operation

- Soil monitoring for precise irrigation
- Home Security Cameras

03 **Autonomous systems** tap into surrounding energy sources to power sensors and communication components, enhancing autonomy and reliability.

- Solar-powered drones for extended surveillance missions
- Vibration-powered autonomous robots

WHAT DO YOU MEAN BY PIEZOELECTRIC?



PIEZOELECTRICITY

What is it???

Piezoelectricity is a unique property exhibited by certain materials where they generate an ***electric charge*** or voltage when subjected to mechanical stress or pressure, and conversely, They deform or experience mechanical strain when an electric field is applied to them.

How does it work?

Crystal Deformation: Piezoelectric materials possess a non-symmetric crystal structure. When subjected to mechanical stress or pressure, this structure deforms, causing a displacement of positive and negative charges within the material.

Electric Charge Generation: The displacement of charges creates an electric dipole moment, leading to the generation of an electric field and voltage across the material's surface. This effect is proportional to the applied mechanical stress.

It is a **reversible** phenomenon.

MATERIALS

The lattice structure of piezoelectric materials directly influences their piezoelectric properties. By studying this structure, researchers can better comprehend how mechanical stress induces the displacement of charges within the crystal lattice, leading to the generation of electric voltage.

Quartz Crystal

naturally occurring crystal with a highly ordered structure, used primarily in precise time keeping.

Widely utilized in electronics, it serves as a stable oscillator for watches and communication devices.

PZT

Lead Zirconate Titanate is a versatile piezoelectric ceramic with a perovskite structure, applied in sensors, actuators, and transducers.

Found in ultrasound devices, inkjet printers, and precision positioning systems.

PVDF

Polyvinylidene Fluoride is a flexible and lightweight piezoelectric polymer, commonly used in flexible sensors and wearable devices.

Its flexibility allows it to conform to curved surfaces, making it ideal for various applications, including medical devices due to its bio-compatibility.

PIEZOELECTRIC MEMS

Piezoelectric MEMS Devices for Energy Harvesting

- Applications of Piezoelectric MEMS Devices in Energy Harvesting
  - Self-powered sensors and wireless sensor networks
  - Wearable electronics and smart clothing
  - Structural health monitoring of infrastructure
- Advantages of Using Piezoelectric MEMS Devices for Energy Harvesting
  - High energy conversion efficiency
  - Compact size and lightweight
  - Wide range of operating frequencies
- Challenges in Developing Piezoelectric MEMS Devices for Energy Harvesting
  - Material selection for optimal piezoelectric performance
  - Design optimization for maximum power output
- Recent Advances in Piezoelectric MEMS Devices Technology
  - Integration with other energy harvesting techniques (e.g., solar, thermoelectric)
  - Development of flexible and stretchable piezoelectrics
  - Enhanced durability and reliability through advanced packaging techniques
- Future Trends in the Field of Piezoelectric MEMS Devices for Energy Harvesting
  - Miniaturization towards nano-scale devices
  - Integration with IoT systems
  - Exploration of new materials with improved properties