Radiological Physics

Al-Mustaqbal University College

3rd

Radiology Techniques Department

By

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Theoretical Physics

First Semester

Lecture 2: Ultrasound Transducer

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What is Transducer?

The transducer is the device that actually converts electrical transmission pulses into ultrasonic pulses and, conversely, ultrasonic echo pulses into electrical echo signals.

- All transducers or transducer elements have the same basic components: a piezoelectric plate, lens, a matching layer and a backing layer, as shown in Figure below.
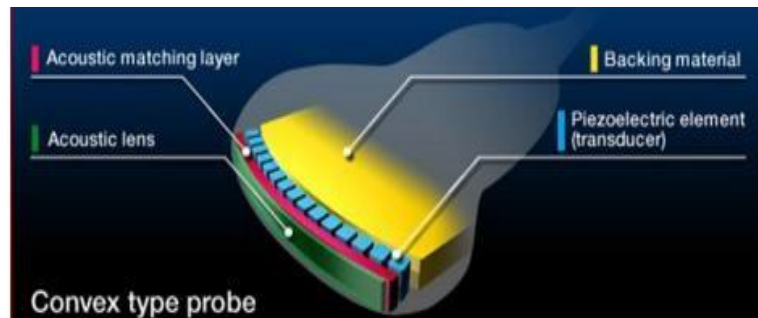
Piezoelectric plate

The actual sound-generating and detecting component is a thin piezoelectric plate.

Piezoelectric materials expand or contract when a positive or negative electric al voltage is applied across them and, conversely, generate positive or negative voltages when compressed or stretched by an external force as shown in figure
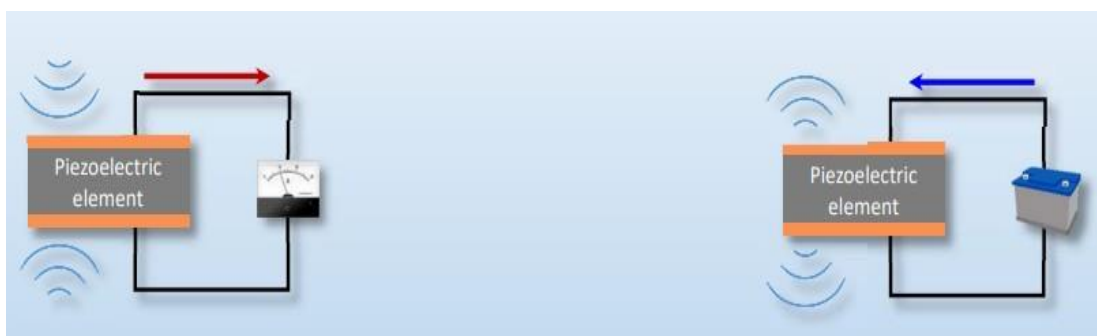
Direct piezoelectric effect, also called generator or sensor effect, converts mechanical energy into electrical energy.
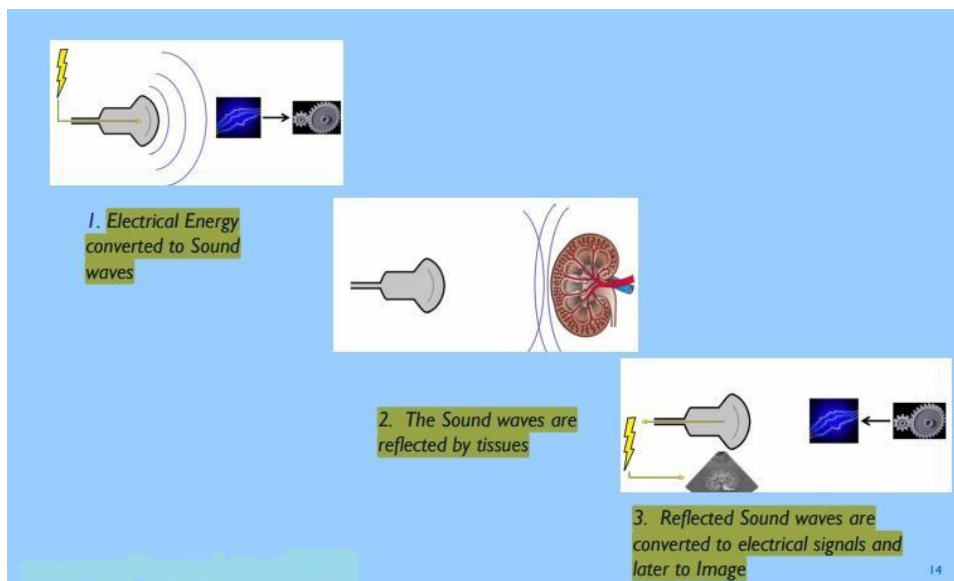
• Mechanical stress generates an electric charge proportional to that stress.

Inverse piezoelectric effect converts electrical energy into mechanical energy.

• Electrical voltage causes a change in length or vibration of piezoelectric material to generate a sound wave.

- Crystalline (quartz), Ceramic (lead zirconium titanate PZT), Polymers (PVDF)

----The piezoelectric effect occurs only in crystals with **a special crystal structure, which they lack of center of symmetry**. Under an applied force the centers of mass for positive and negative ions are shifted which results in a net dipole moment.
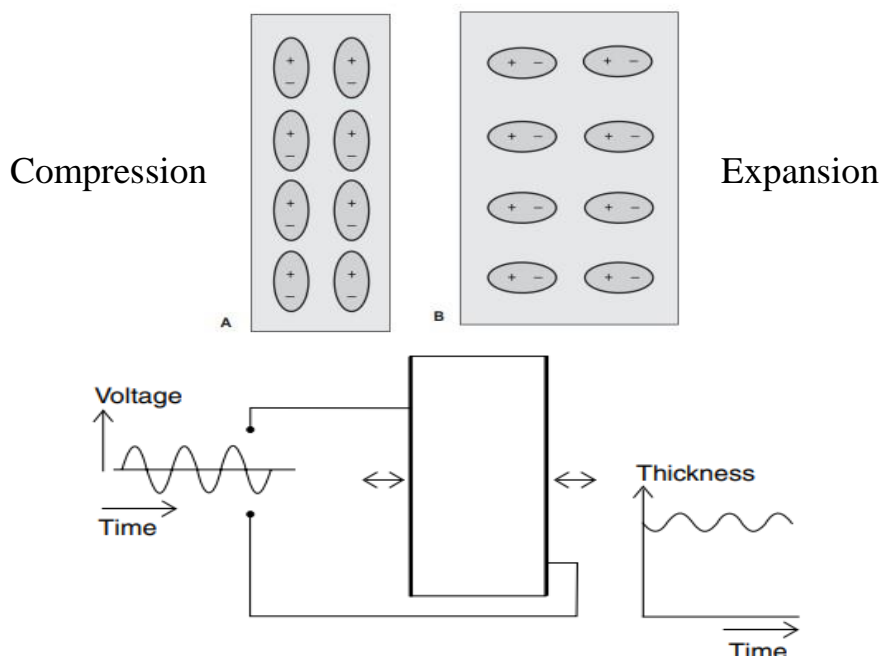
- Each molecule is polarized since one end is more negatively charged and the other end is positively charged, and is called a dipole

❖ The PZT slab vibrates most strongly at the frequency for which its thickness is half a wavelength, giving rise to the term 'half-wave resonance'.

Additional crystal thickness produces more attenuation, so the most efficient operation is achieved for a crystal with a thickness equal to half the wavelength of the ultrasound. A crystal of half-wavelength thickness resonates at υ :

$$\upsilon_T = \frac{C_T}{\lambda}$$

$$= \frac{C_T}{2t} \qquad \text{where:} \qquad \lambda = 2t$$

υ_T : resonance frequency, C_T: velocity of transducer, t: thickness of transducer

Example: For a 1.5-mm-thick quartz disk (velocity of ultrasound in quartz = 5740 m/sec), what is the resonance frequency?

- High-frequency ultrasound transducers employ thin (<1mm) piezoelectric crystals.

Backing (damping) layer

Unwanted ringing can be much reduced by having a backing (damping) layer behind the PZT, made of a material with both a high acoustic impedance ($Z = 3 \times 10^7$ kg m^{-2} s^{-1}) and the ability to absorb ultrasound

Advantage: reduce ranging ➡ reduce pulse width ➡ better axial resolution

Disadvantage: part of energy is absorbed ➡ lower penetration
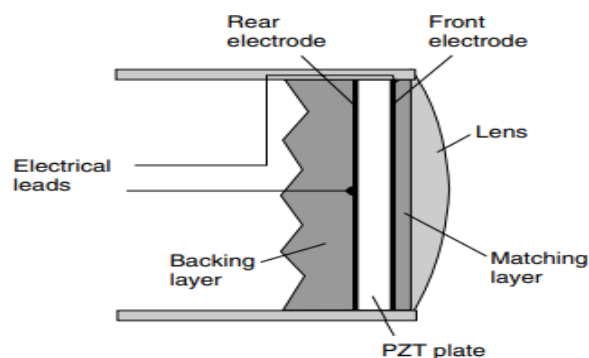
Matching layer

'Impedance matching layer' is bonded to the front face of the PZT. A single matching layer can increase the transmission across the front face to 100%

- Made from plastic with an acoustic impedance (Z) between the transducer and skin

Two important conditions

- First, the matching layer should have a thickness equal to a quarter of a wavelength.
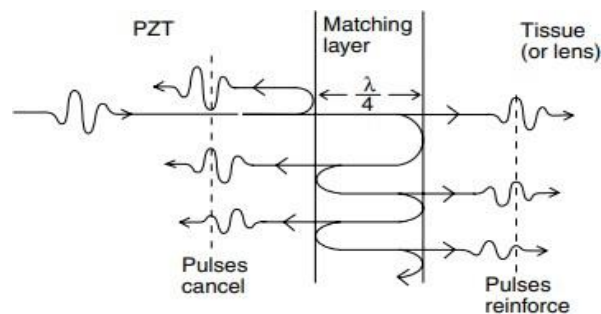
- Second, it should have an impedance equal to

$$Z_M = \sqrt{Z_{PZT} \times Z_T}$$

Where: Z_{PZT} is the impedance of PZT and Z_T is the impedance of tissue.

Lens

A lens is usually incorporated after the matching layer. Near the focus of the lens, the width of the beam is least and the transmitted amplitude, or receive sensitivity, is greatest. In linear-array transducers, focusing in the scan plane is achieved entirely by electronic means