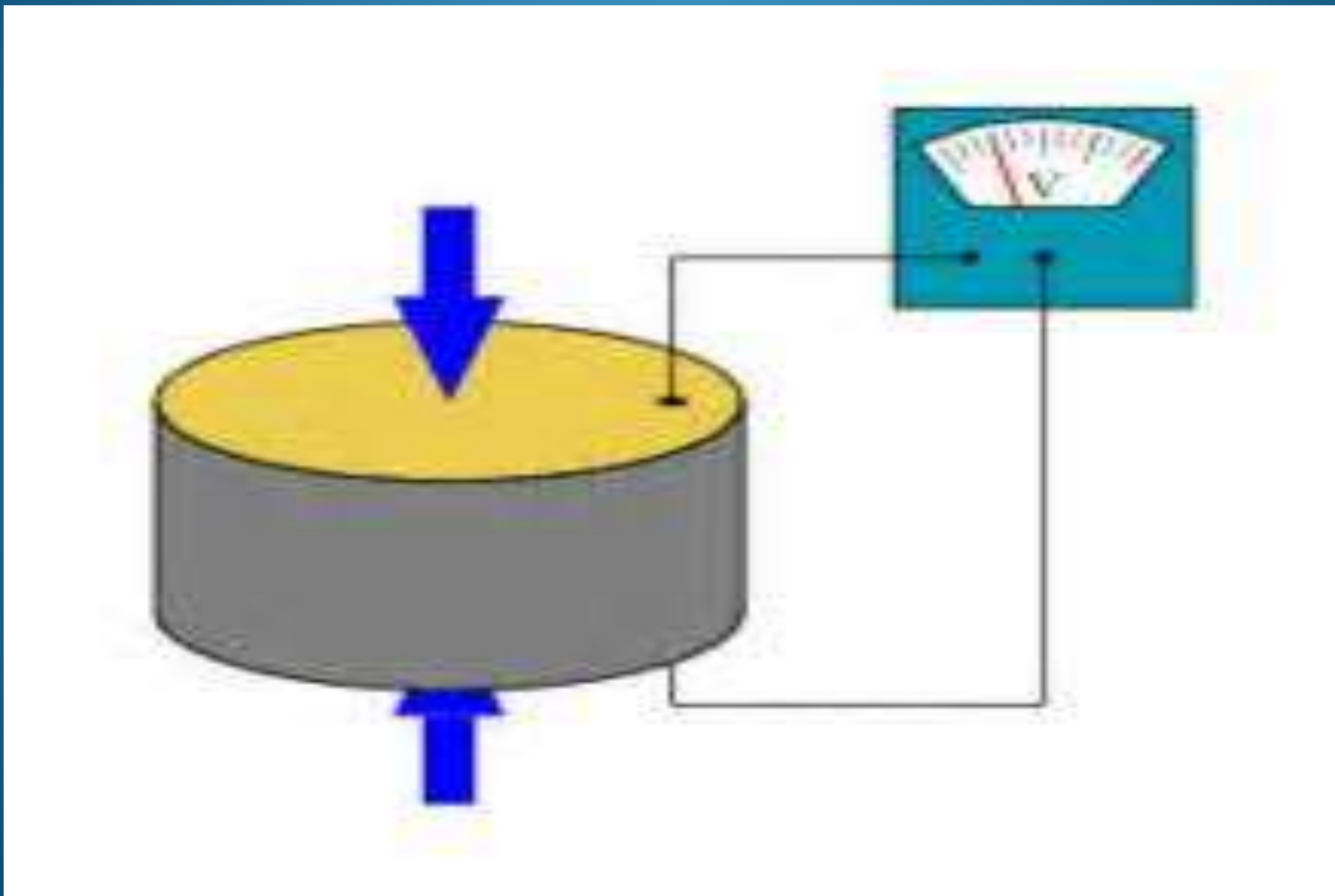
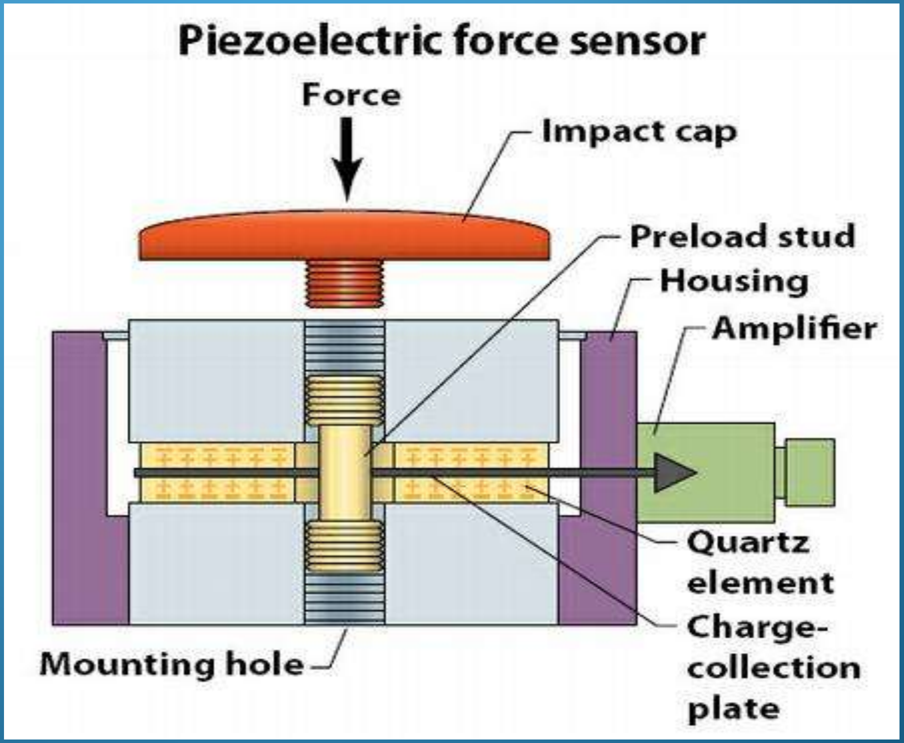
PIEZOELECTRIC SENS0R



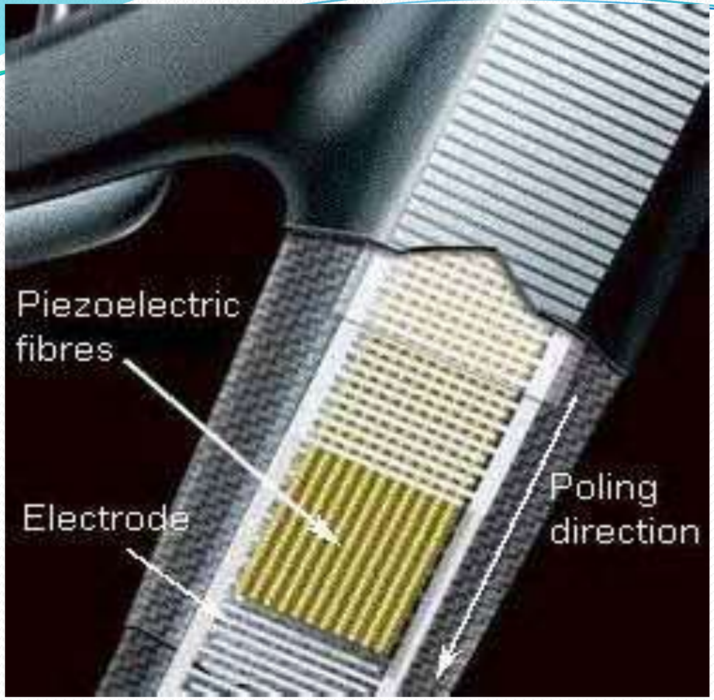
INTRODUCTION

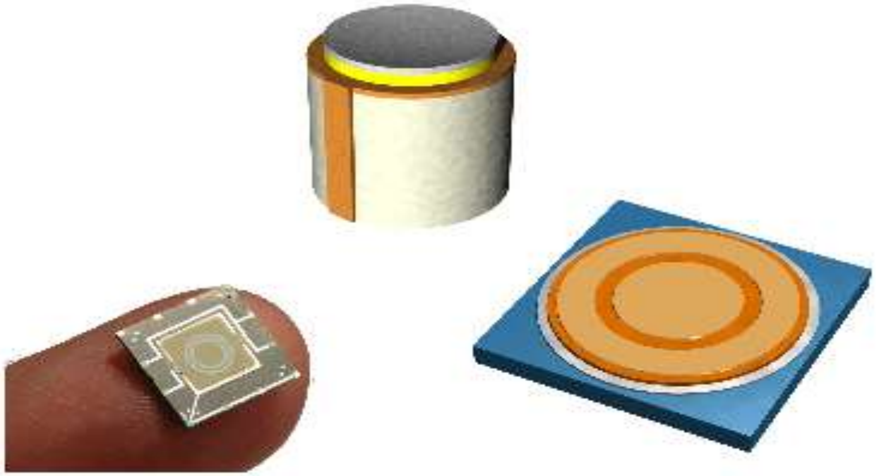
A piezoelectric sensor is a device that uses the piezoelectric effect, to measure changes in pressure, acceleration, temperature, strain, or force by converting them to an electrical charge.

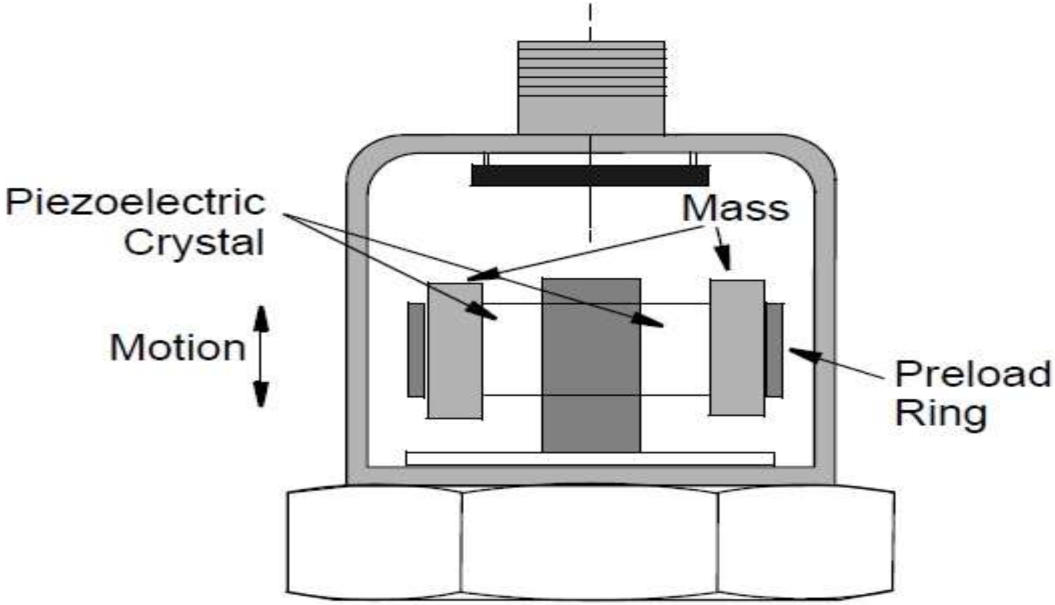


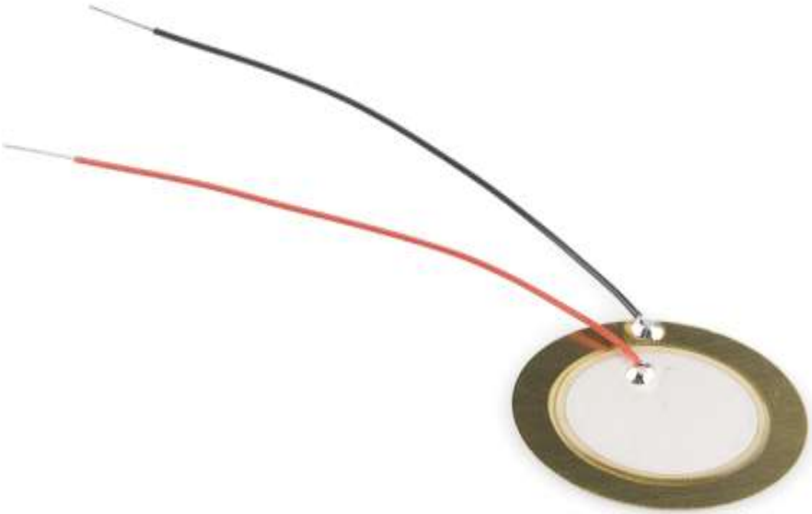
APPLICATIONS

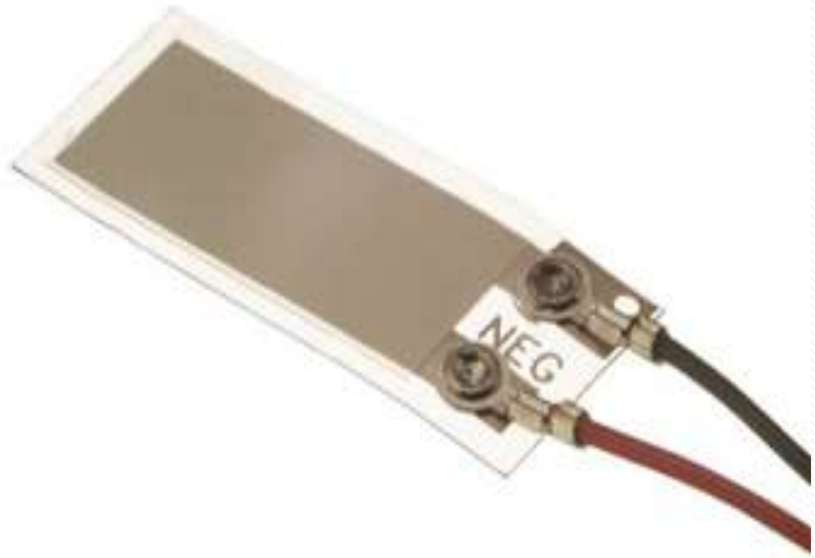
Piezoelectric sensors are versatile tools for the measurement of various processes. They are used for quality assurance, process control, and for research and development in many industries. Pierre Curie discovered the piezoelectric effect in 1880, but only in the 1950s did manufacturers begin to use the piezoelectric effect in industrial sensing applications. Since then, this measuring principle has been increasingly used, and has become a mature technology with excellent inherent reliability.

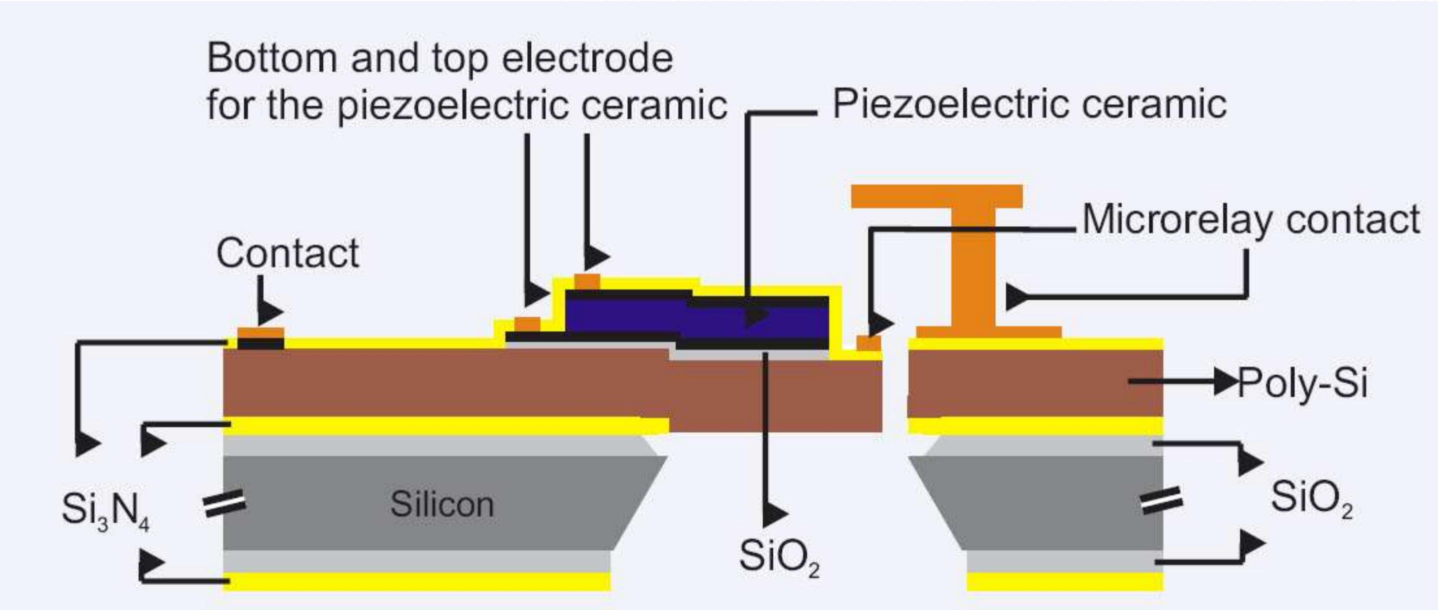

Piezoelectric
fibres
Electrode
Poling
direction

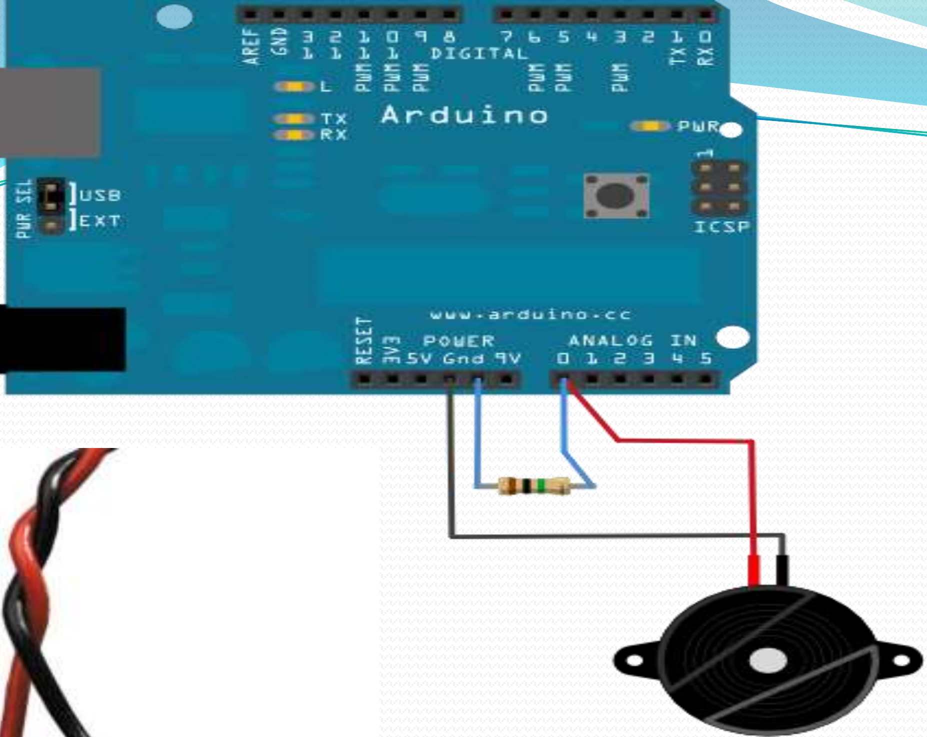



Piezoelectric
Crystal
Mass
Motion
Preload
Ring




NEG


Bottom and top electrode
for the piezoelectric ceramic
Piezoelectric ceramic
Microrelay contact
Contact
Poly-Si
Si_3N_4
Silicon
SiO_2
SiO_2


AREF
GND
13 12 11 10 9 8
DIGITAL
7 6 5 4 3 2 1 0
TX
RX
PWM
L
TX
RX
Arduino
PWR
ICSP
PWR SEL
USB
EXT
www.arduino.cc
RESET
3V3
POWER
5V Gnd 9V
ANALOG IN
0 1 2 3 4 5

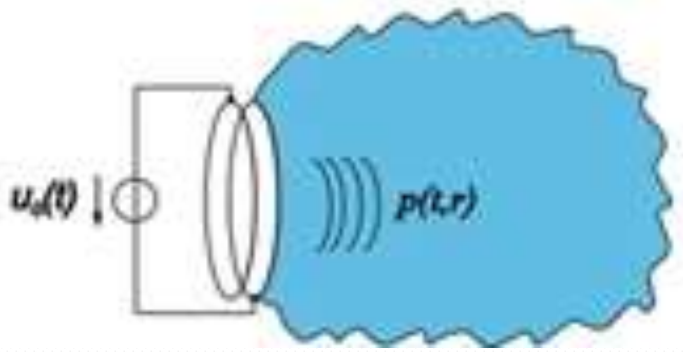

NEC

Acceleration Sensor

- Coupling of electrics and mechanics
- Calculation of:
  - Coulomb forces
  - electric fields, charges and impedances
  - mechanical stresses

- Moving /deforming body in an electric field
- Nonlinearities
  - geometric
  - contact

Ultrasonic Actuator



One disadvantage of piezoelectric sensors is that they cannot be used for truly static measurements. A static force results in a fixed amount of charge on the piezoelectric material. In conventional readout electronics, imperfect insulating materials and reduction in internal sensor resistance causes a constant loss of electrons and yields a decreasing signal. Elevated temperatures cause an additional drop in internal resistance and sensitivity

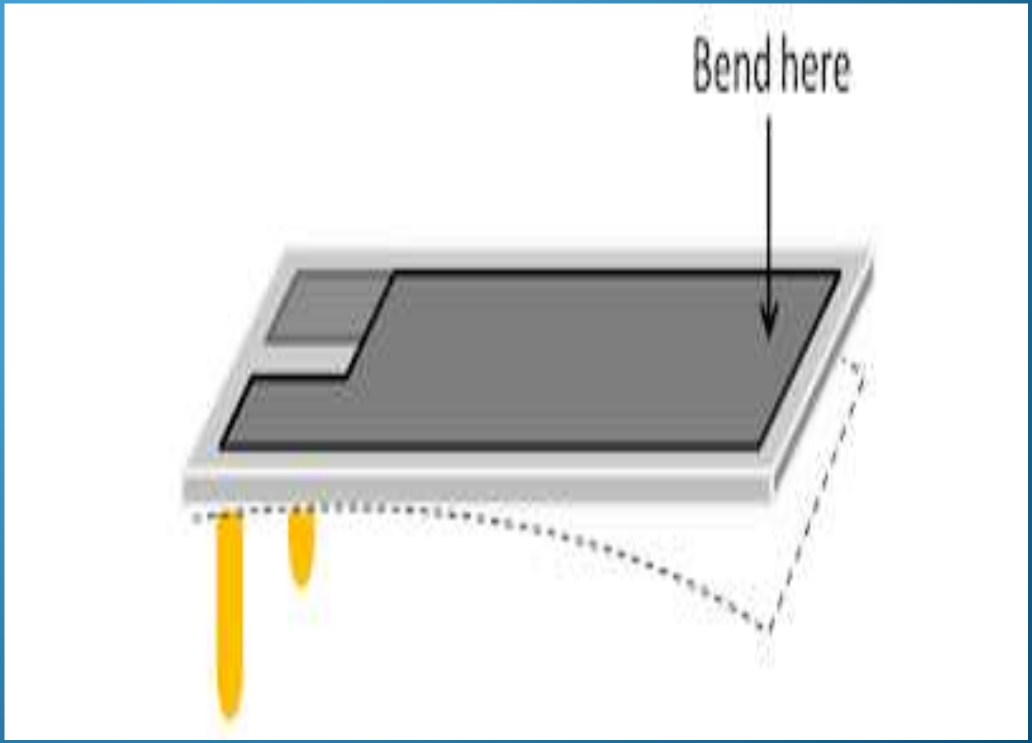
PRINCIPLE OF OPERATION

The way a piezoelectric material is cut produces three main operational modes:

Transverse

Longitudinal

Shear.



TRANSVERSE EFFECT

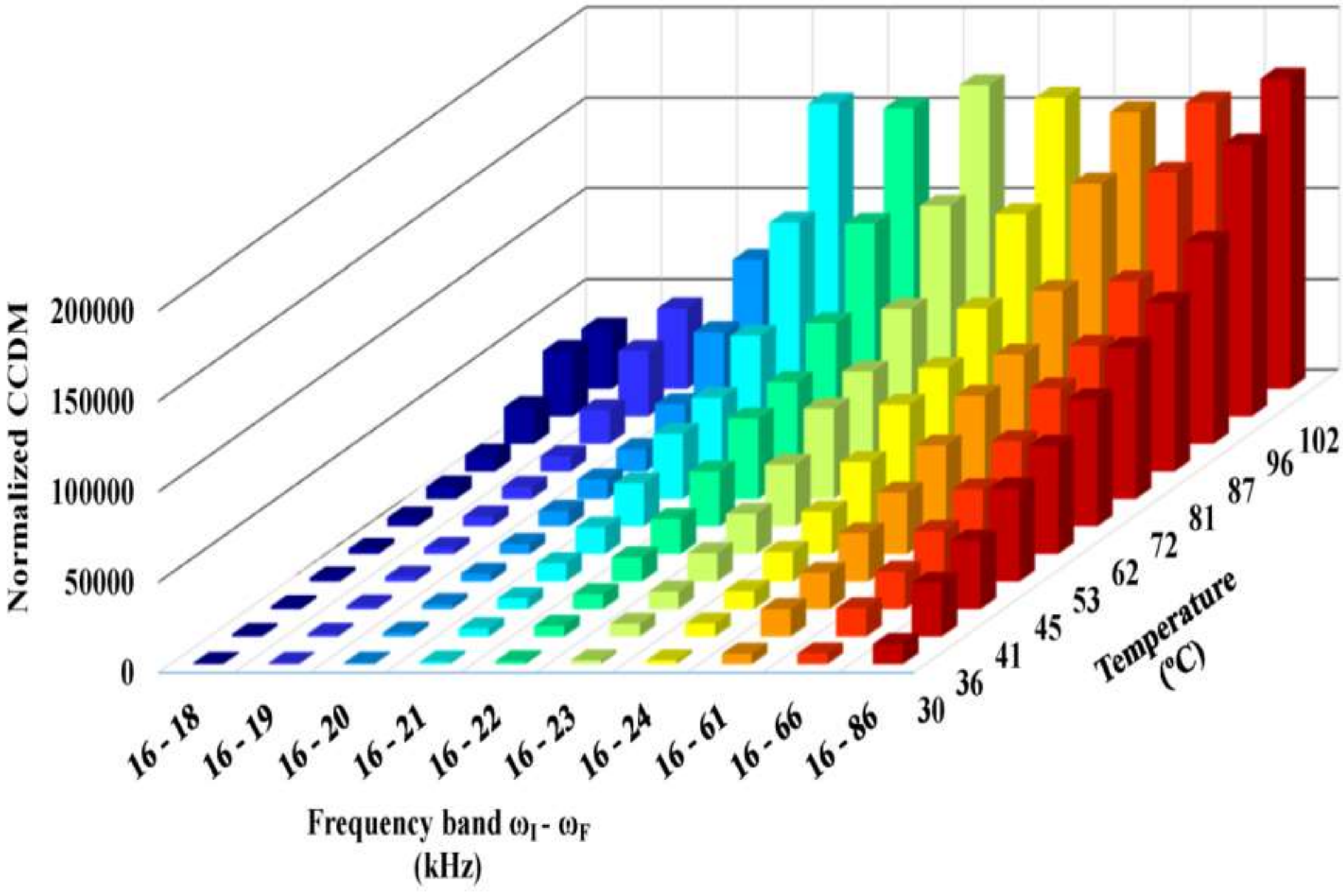
A force applied along a neutral axis (y) generates charges along the (x) direction, perpendicular to the line of force. The amount of charge ({\display style C_{x}}) depends on the geometrical dimensions of the respective piezoelectric element. When dimensions {\display style a,b,c} apply,

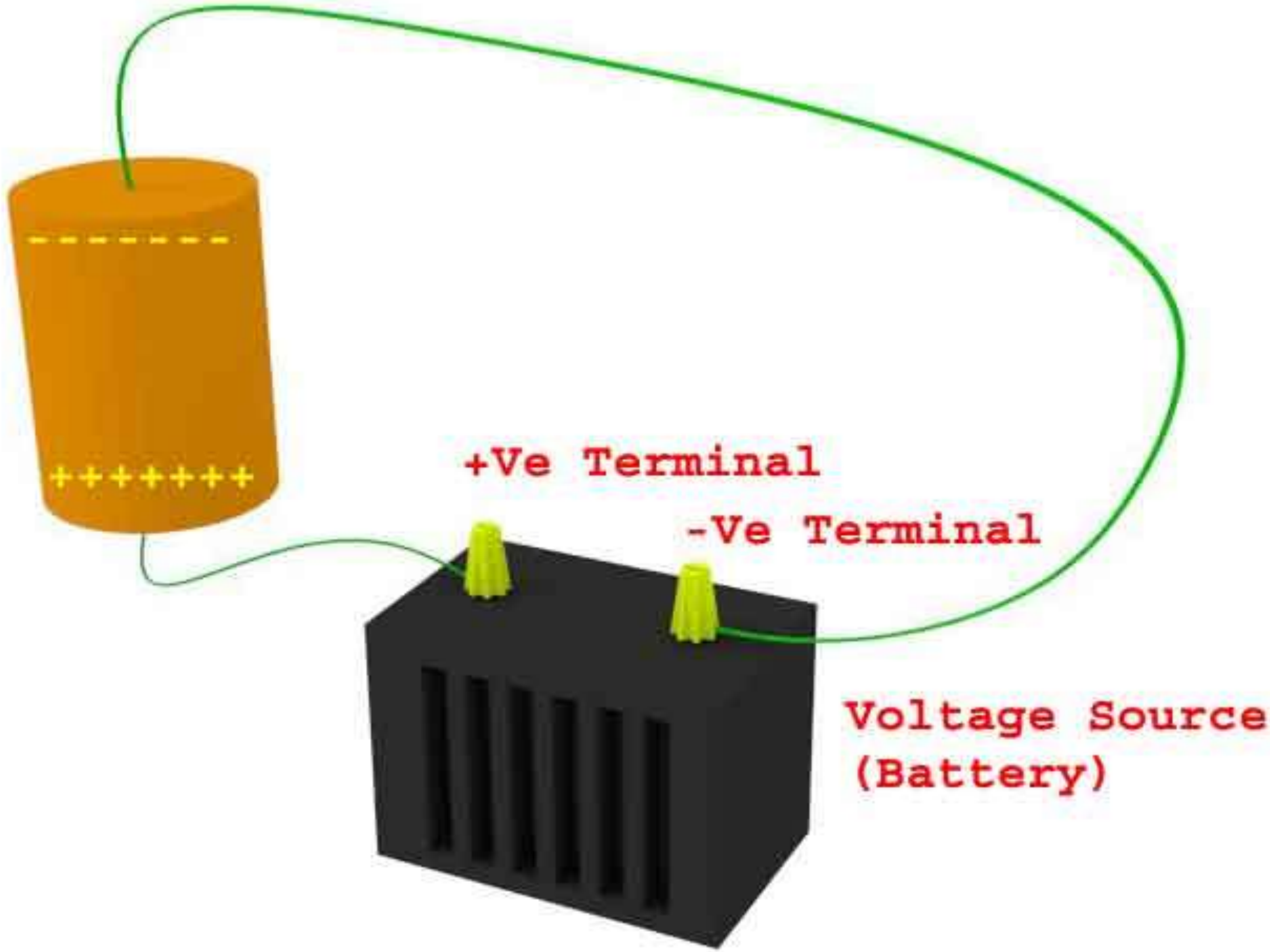
{\display style C_{x}=d_{xy}F_{y}b/a~},where {\display style a} is the dimension in line with the neutral axis, {\display style b} is in line with the charge generating axis and {\display style d} is the corresponding piezoelectric coefficient

LONGITUDINAL EFFECT

The amount of charge produced is strictly proportional to the applied force and independent of the piezoelectric element size and shape. Putting several elements mechanically in series and electrically in parallel is the only way to increase the charge output. The resulting charge is

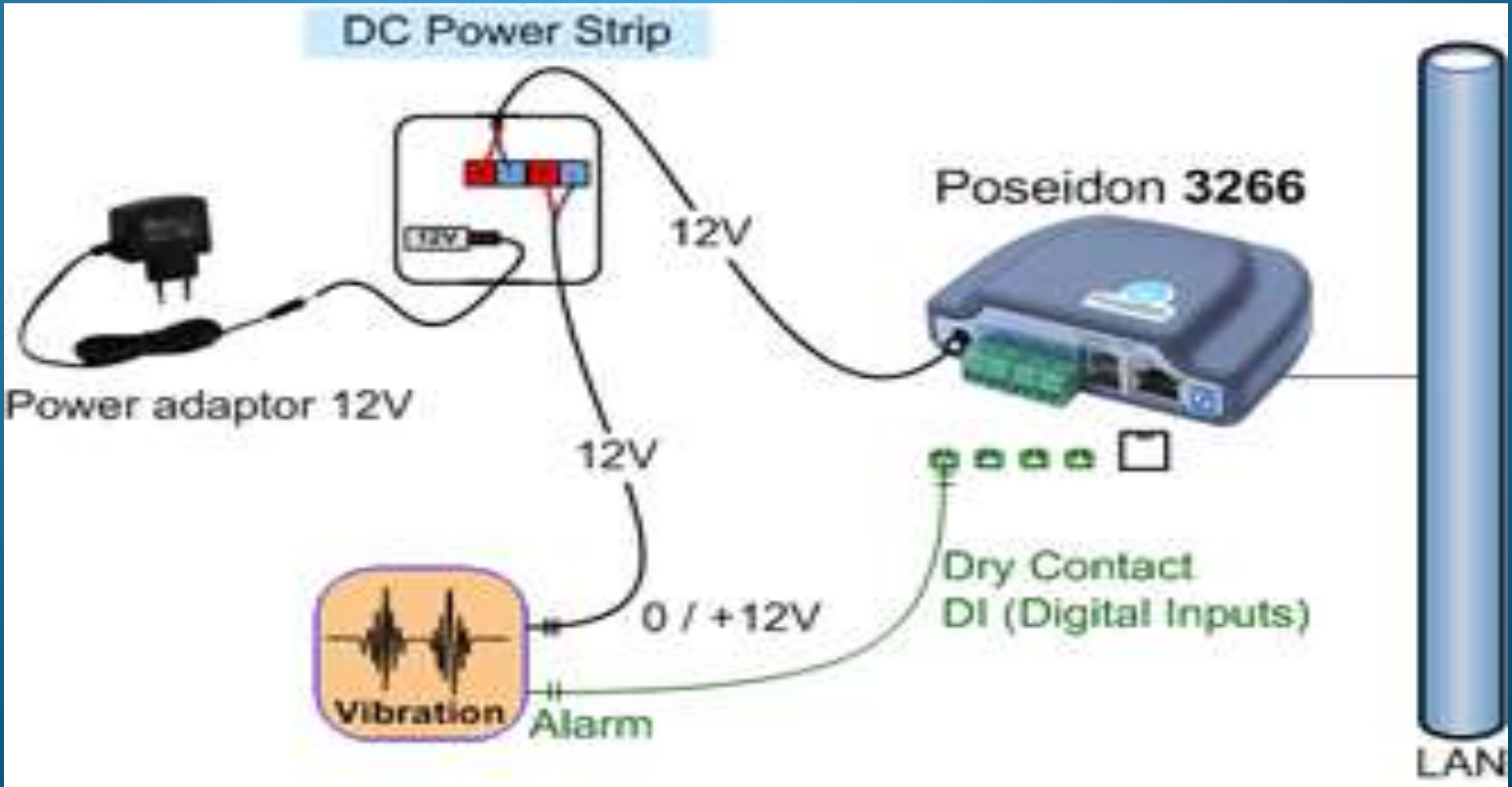
{\display style C_{x}=d_{xx}F_{x}n~},where {\display style d_{xx}} is the piezoelectric coefficient for a charge in x-direction released by forces applied along x-direction (in pC/N). {\display style F_{x}} is the applied Force in x-direction [N] and {\display style n} corresponds to the number of stacked elements.


Normalized CCDM
200000
150000
100000
50000
0
16 - 18
16 - 19
16 - 20
16 - 21
16 - 22
16 - 23
16 - 24
16 - 61
16 - 66
16 - 86
Frequency band ωI - ωF
(kHz)
30
36
41
45
53
62
72
81
87
96
102
Temperature
(ºC)


- - - - - - - -
+++++++
+Ve Terminal
-Ve Terminal
Voltage Source
(Battery)

ELECTRICAL PROPERTY

A piezoelectric transducer has very high DC output impedance and can be modeled as a proportional voltage source and filter network. The voltage *V* at the source is directly proportional to the applied force, pressure, or strain.



SENSOR DESIGN

Based on piezoelectric technology various physical quantities can be measured; the most common are pressure and acceleration. For pressure sensors, a thin membrane and a massive base is used, ensuring that an applied pressure specifically loads the elements in one direction.

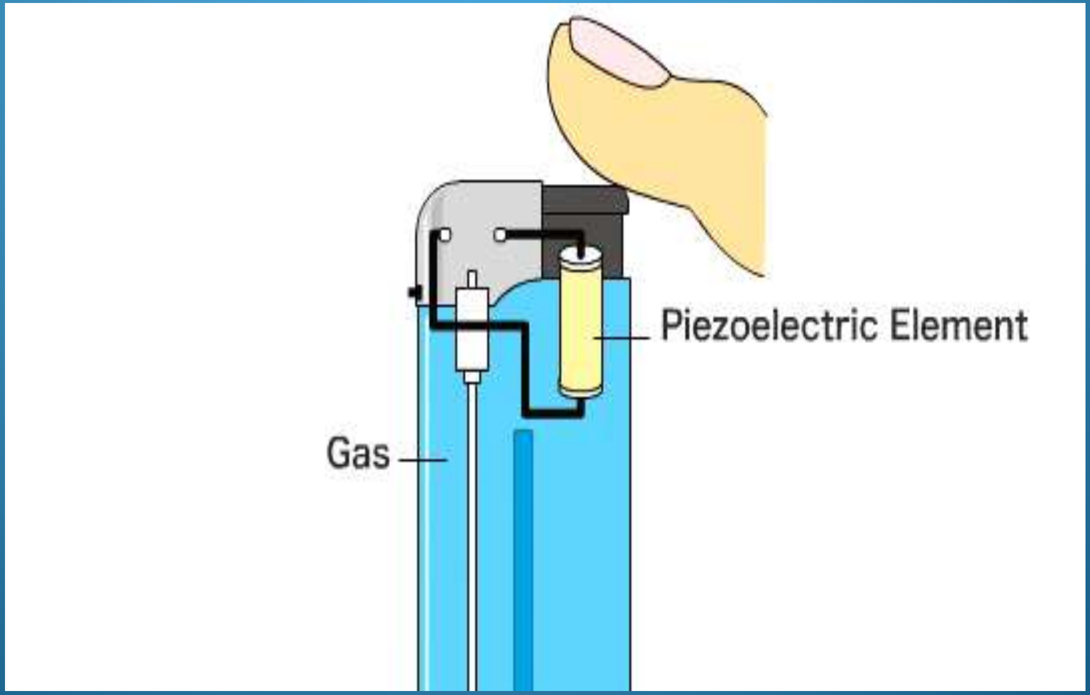
The main difference in working principle between these two cases is the way they apply forces to the sensing elements. In a pressure sensor, a thin membrane transfers the force to the elements, while in accelerometers an attached seismic mass applies the forces.

SENSING MATERIALS

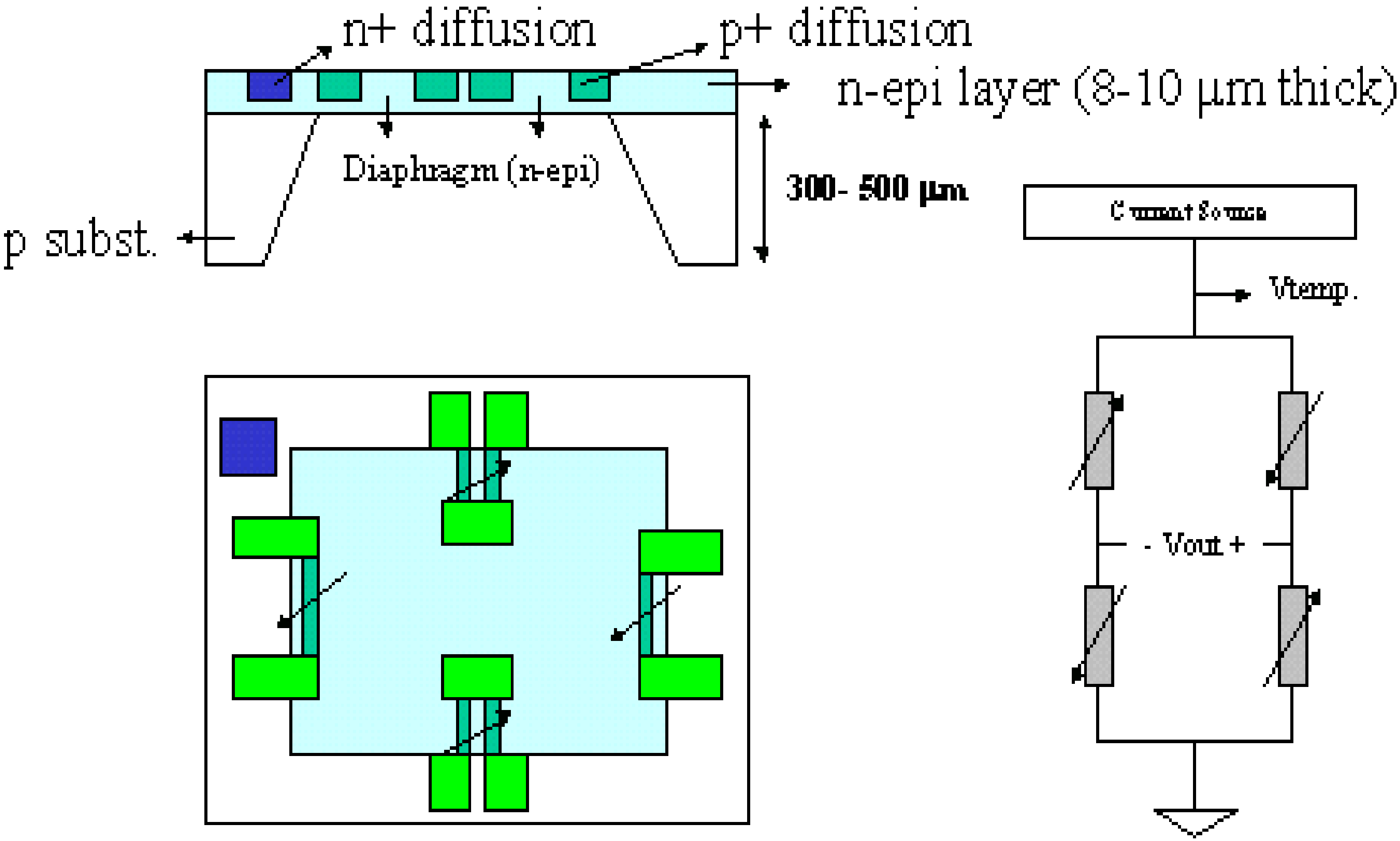
Two main groups of materials are used for piezoelectric sensors: piezoelectric ceramics and single crystal materials. The ceramic materials (such as PZT ceramic) have a piezoelectric constant/sensitivity that is roughly two orders of magnitude higher than those of the natural single crystal materials and can be produced by inexpensive sintering processes. The piezoeffect in piezoceramics is "trained", so their high sensitivity degrades over time.

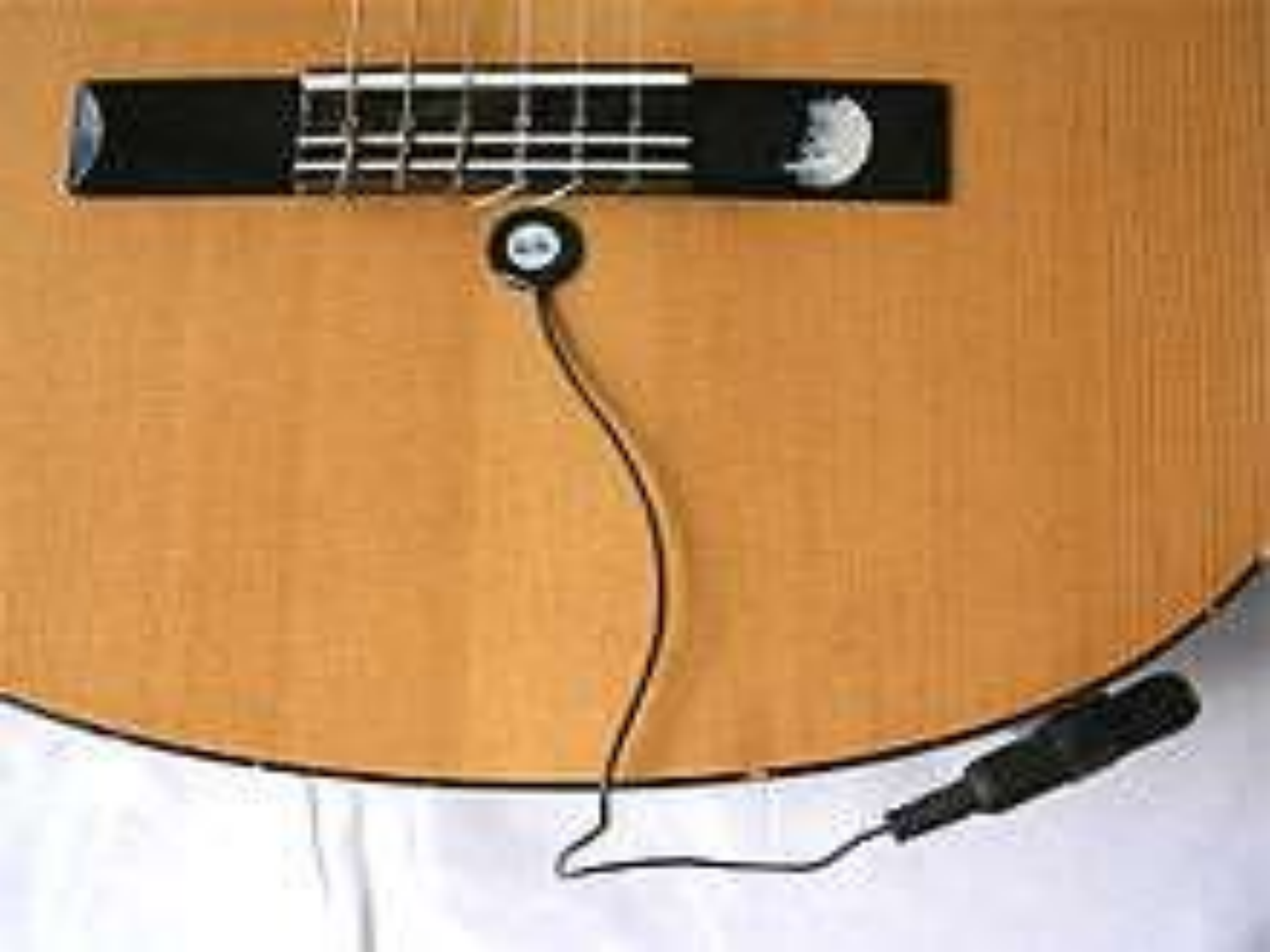
PIEZORESISTIVE EFFECT

The piezoresistive effect is a change in the electrical resistivity of a semiconductor or metal when mechanical strain is applied. In contrast to the piezoelectric effect, the piezoresistive effect causes a change only in electrical resistance, not in electric potential.



Basic Structure






Normalized RMSD
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1.0
5.5
490.0
273983.6
Healthy
Small damage
Large Damage
(a)

HISTORY

The change of electrical resistance in metal devices due to an applied mechanical load was first discovered in 1856 by Lord Kelvin. With single crystal silicon becoming the material of choice for the design of analog and digital circuits, the large piezoresistive effect in silicon and germanium was first discovered in 1954 (Smith 1954).

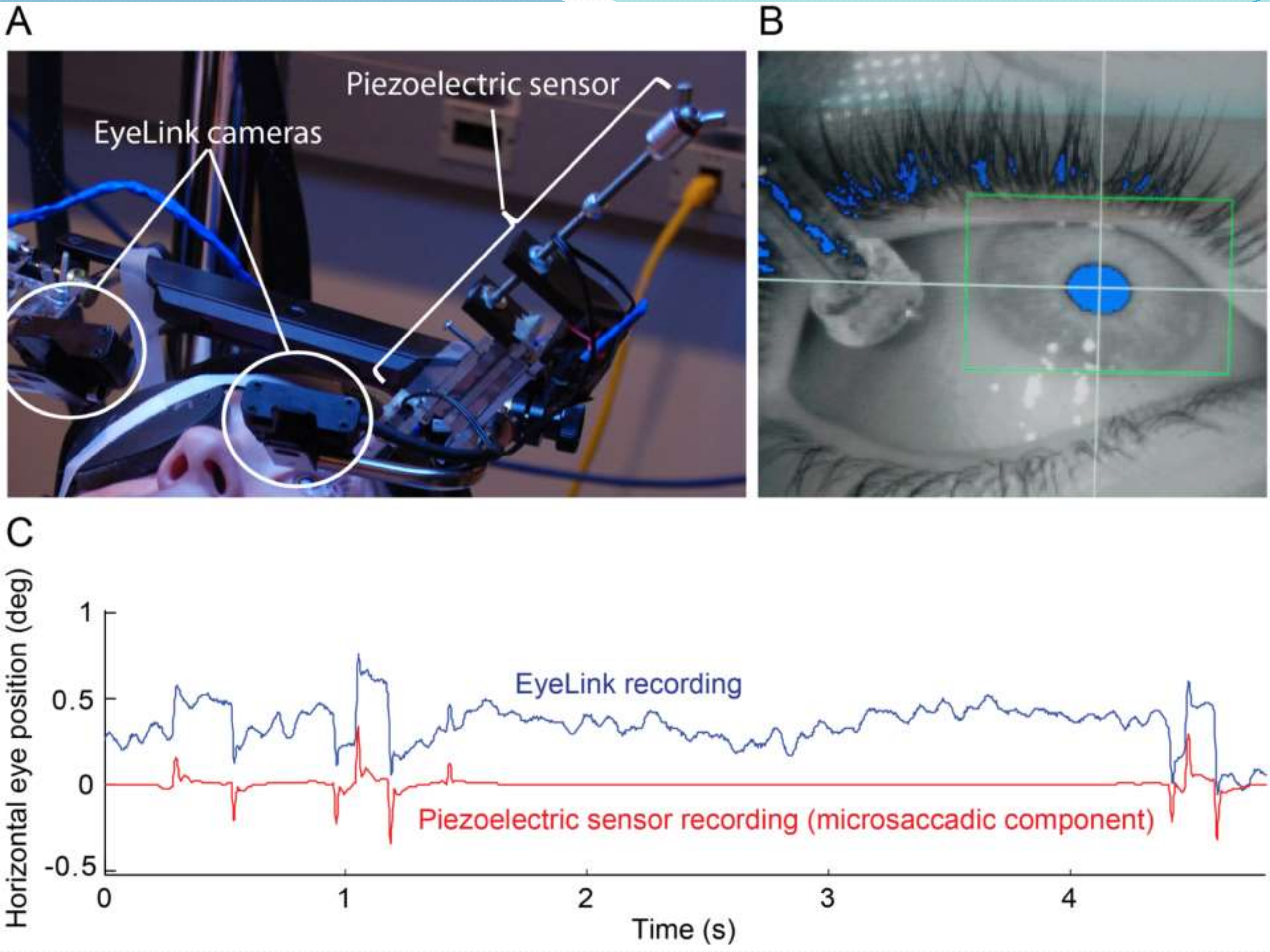
MECHANISM

In conducting and semi-conducting materials, changes in inter-atomic spacing resulting from strain affect the band gaps, making it easier (or harder depending on the material and strain) for electrons to be raised into the conduction band. This results in a change in resistivity of the material. Within a certain range of strain this relationship is linear, so that the piezoresistive coefficient

$${\displaystyle \rho _{\sigma }={\frac {\left({\frac {\partial \rho }{\rho }}\right)}{\varepsilon }}}$$

PIEZORESISTIVITY IN METALS

Usually the resistance change in metals is mostly due to the change of geometry resulting from applied mechanical stress. However, even though the piezoresistive effect is small in those cases it is often not negligible. In cases where it is, it can be calculated using the simple resistance equation derived from Ohm's law;


A
B
Piezoelectric sensor
EyeLink cameras
C
Horizontal eye position (deg)
1
0.5
0
-0.5
0
1
2
3
4
Time (s)
EyeLink recording
Piezoelectric sensor recording (microsaccadic component)

PIEZO ELECTRIC EFFECT IN SEMICONDUCTORS

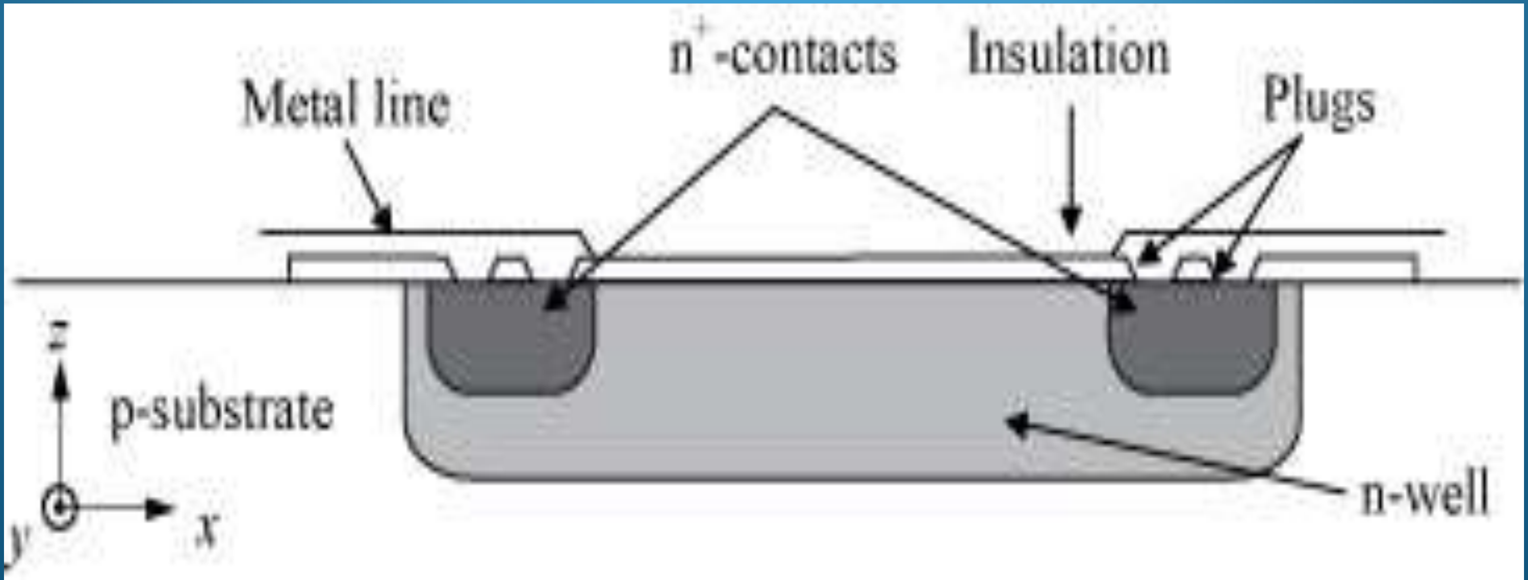
The piezoresistive effect of semiconductor materials can be several orders of magnitudes larger than the geometrical effect and is present in materials like germanium, polycrystalline silicon, amorphous silicon, silicon carbide, and single crystal silicon. Hence, semiconductor strain gauges with a very high coefficient of sensitivity can be built.

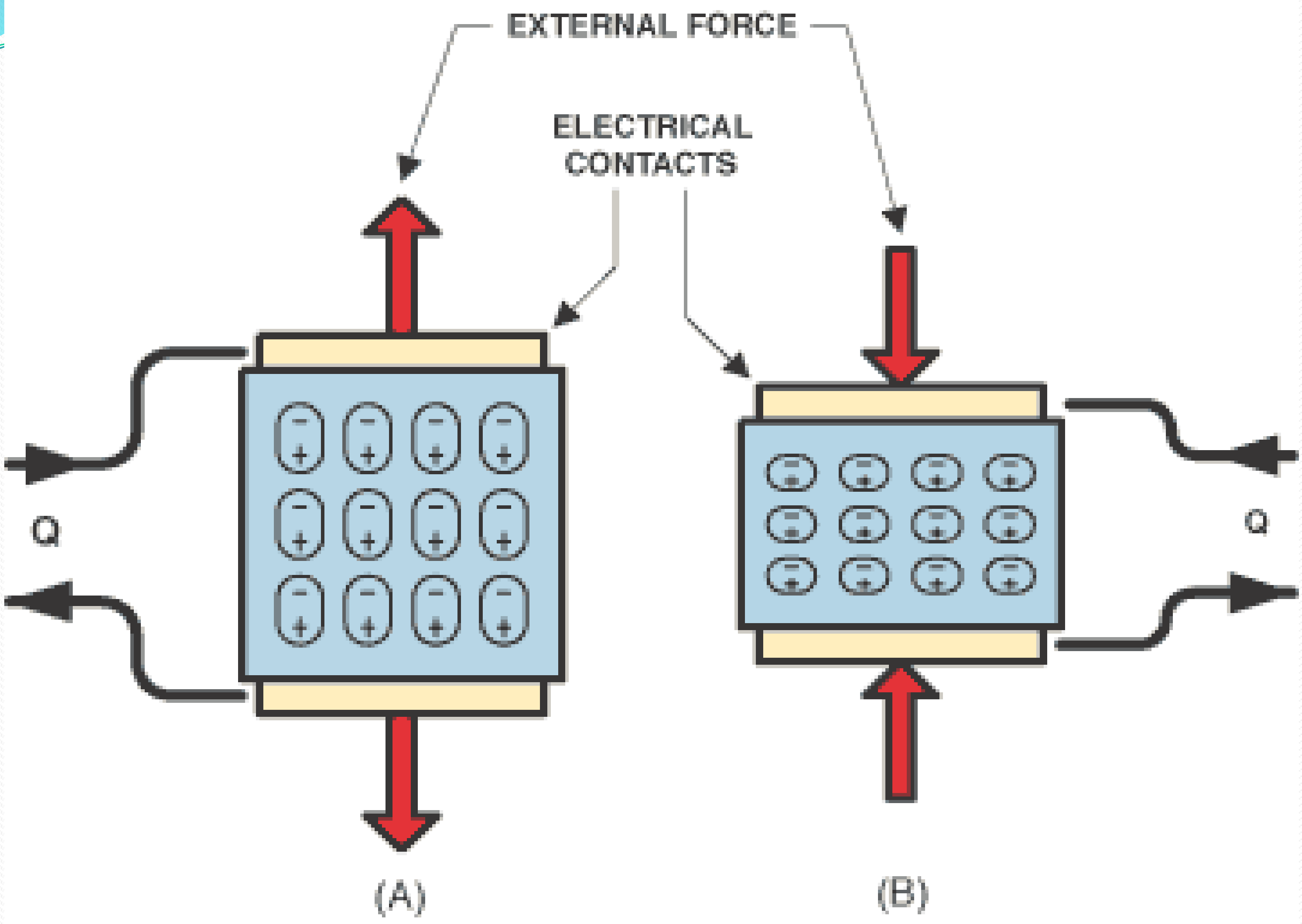
PIEZORESISTIVE SILICON DEVICES

The piezoresistive effect of semiconductors has been used for sensor devices employing all kinds of semiconductor materials such as germanium, polycrystalline silicon, amorphous silicon, and single crystal silicon. Since silicon is today the material of choice for integrated digital and analog circuits the use of piezoresistive silicon devices has been of great interest. It enables the easy integration of stress sensors with Bipolar and CMOS circuits.

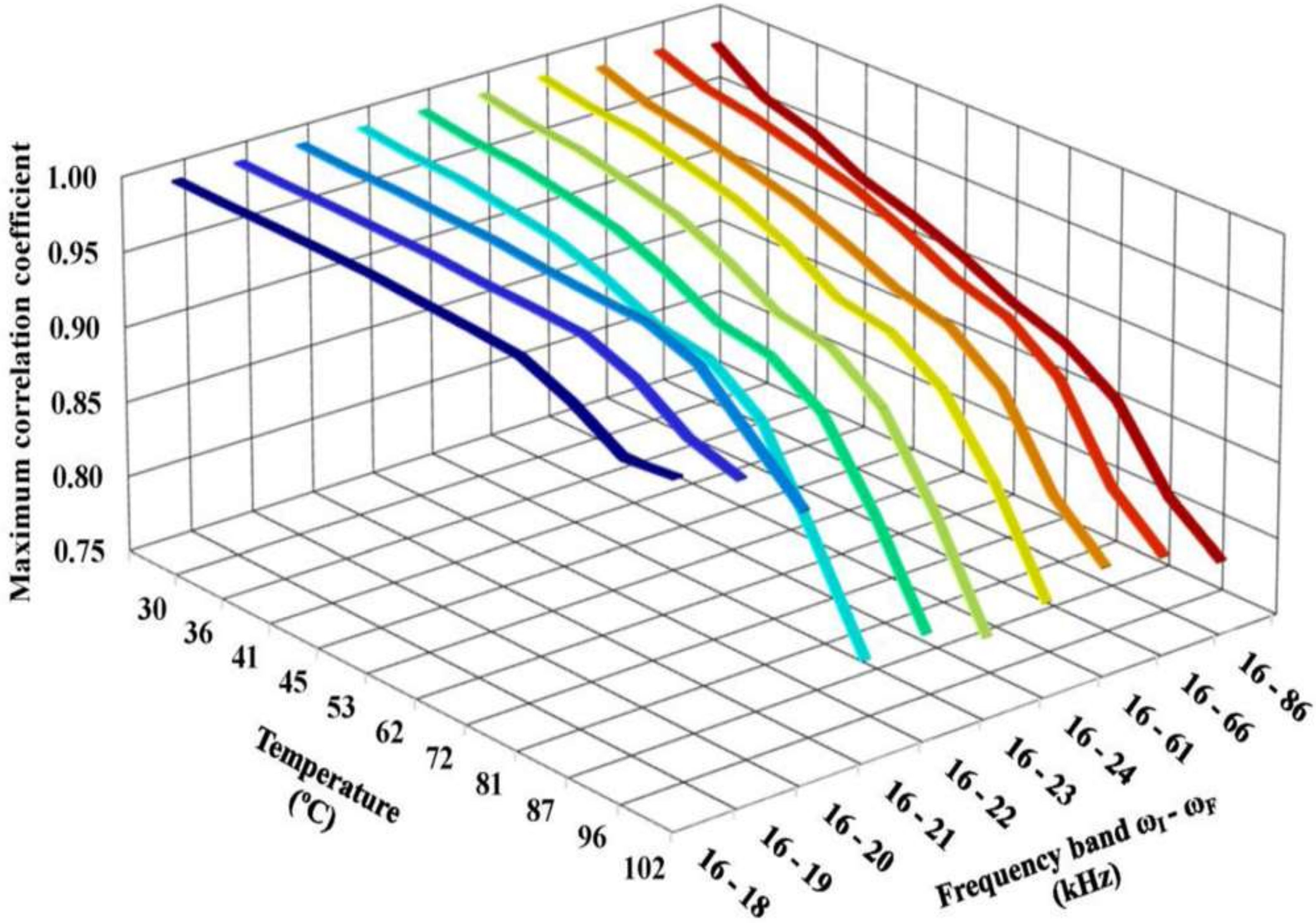
FABRICATION

Piezoresistors can be fabricated using wide variety of piezoresistive materials. The simplest form of piezoresistive silicon sensors are diffused resistors. Piezoresistors consist of a simple two contact diffused n- or p-wells within a p- or n-substrate. As the typical square resistances of these devices are in the range of several hundred ohms, additional p+ or n+ plus diffusions are necessary to facilitate ohmic contacts to the device.




EXTERNAL FORCE
ELECTRICAL
CONTACTS
Q
Q
(A)
(B)


Sooxma



Maximum correlation coefficient
1.00
0.95
0.90
0.85
0.80
0.75
30
36
41
45
53
62
72
81
87
96
102
Temperature (°C)
16 - 18
16 - 19
16 - 20
16 - 21
16 - 22
16 - 23
16 - 24
16 - 61
16 - 66
16 - 86
Frequency band ωI - ωF (kHz)

1. Piezoelectric Ceramic List

(It was not all list here. In order to provide you the right one accordingly, would you tell us your applications

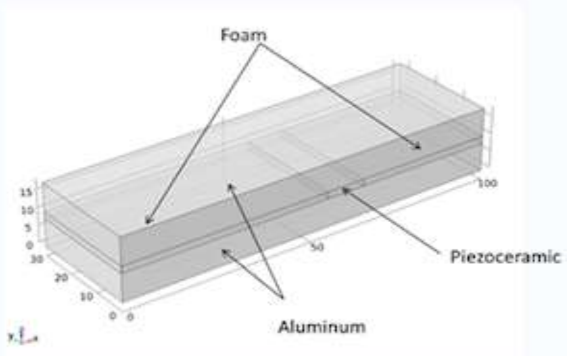
shape & dimensions of the piezoelectric ceramic etc.)

	A. Normal Ultrasonic Piezoelectric Ceramic Transducer (Disc Shape)		B. Normal Ultrasonic Piezoelectric Ceramic Transducer (Annulus Shape)
1. Standard piezoelectric ceramic in flaky			
			
Segmentation electrode wafer	Segmentation electrode square	Tile shape	Thin Disc
			
Rectangular	Annulus	Bilateral symmetry lead electrode	Single lead electrode

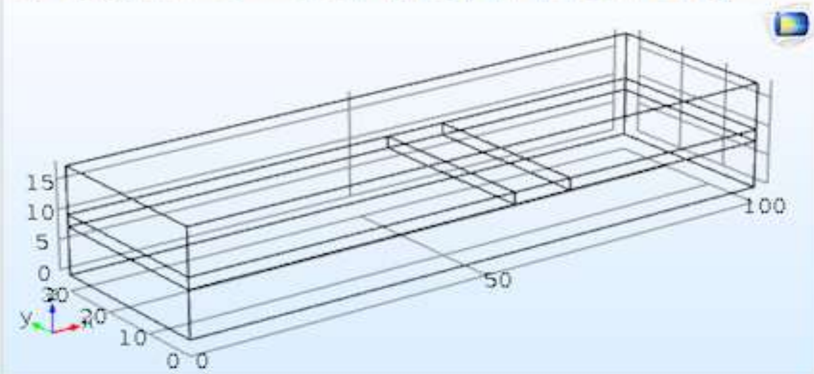
Piezoelectric Shear-Actuated Beam

COMSOL MULTIPHYSICS

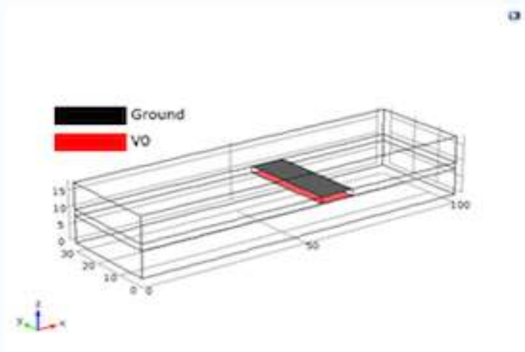
Model Schematic



Geometry | Mesh | Displacement | Electric Potential | PZD Coodinate System



Boundary Conditions for PZD



Model Parameters

Input Volatge applied to Piezo: 20 V

Number of Mesh elements across the thickeness: 2

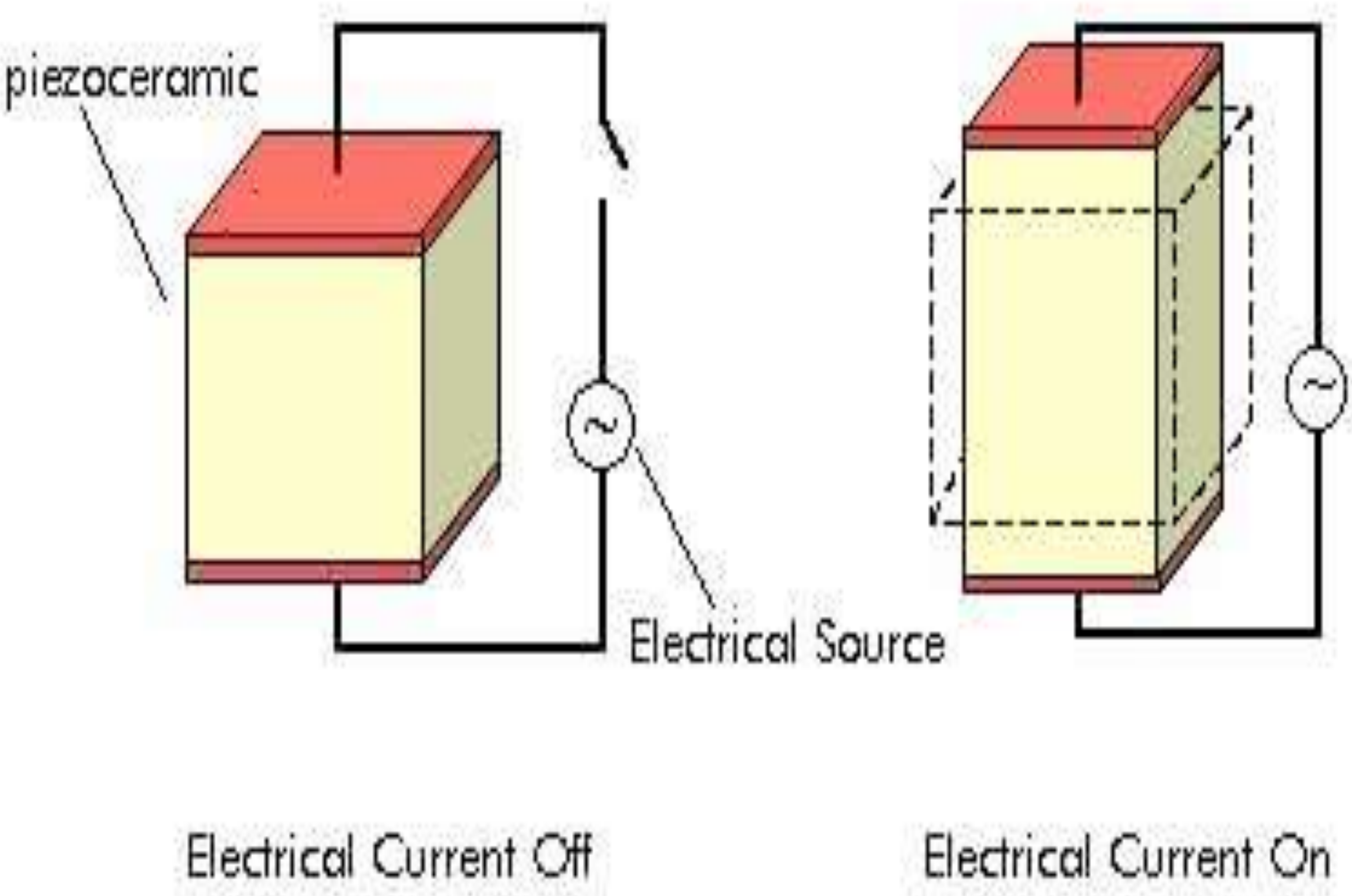
Piezoelectric Devices: Poling information

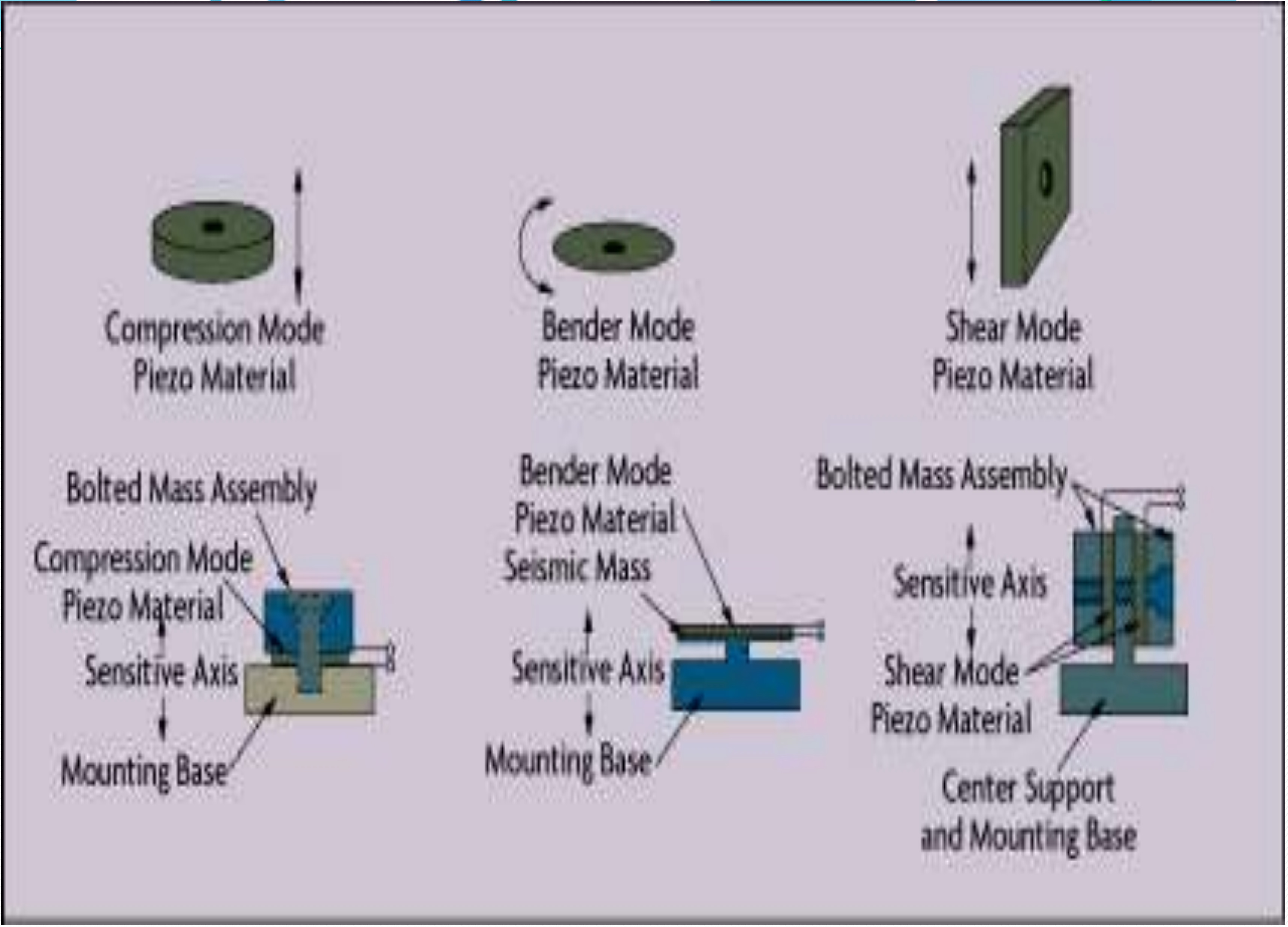
Information

The matrix components for the piezoelectric material properties refer to a coordinate system, where the poling direction is the z direction. Because the poling direction of the piezoceramic actuator in this model is aligned with the x-axis, you need to use a local coordinate system in the material settings to rotate the piezoceramic material.

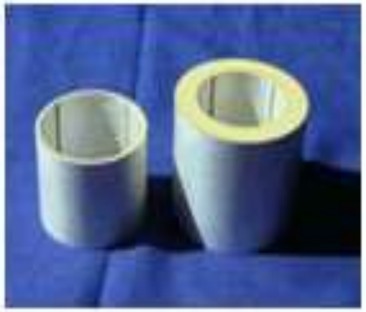
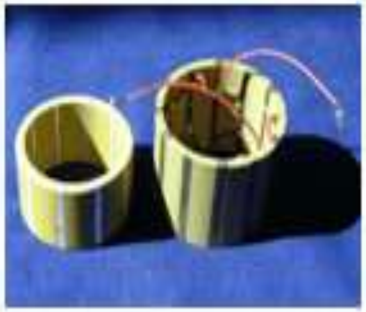
Number of Mesh elements across the thickness: Memory requirement will increase by increasing this number.

About


piezoceramic
Electrical Source
Electrical Current Off
Electrical Current On

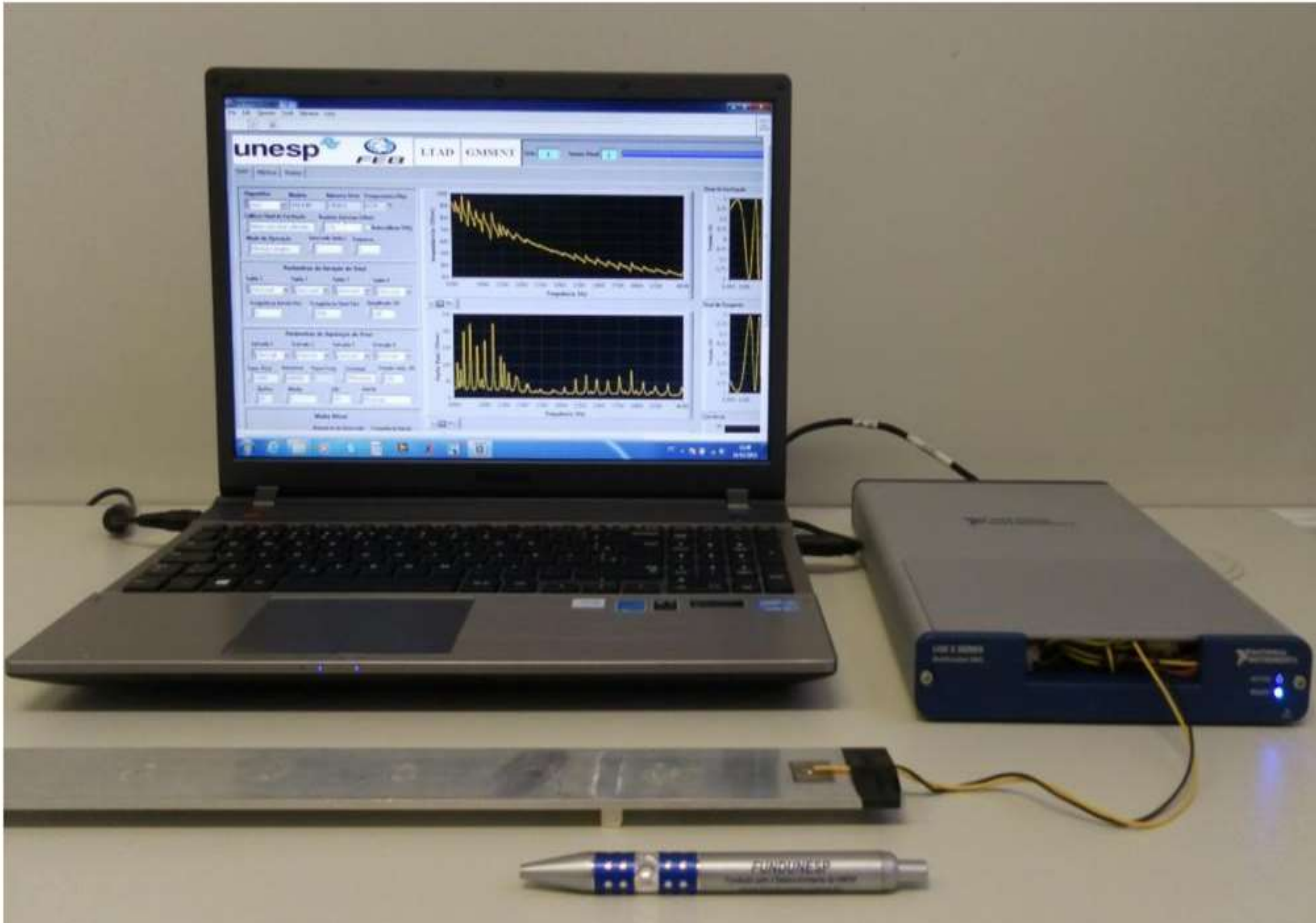


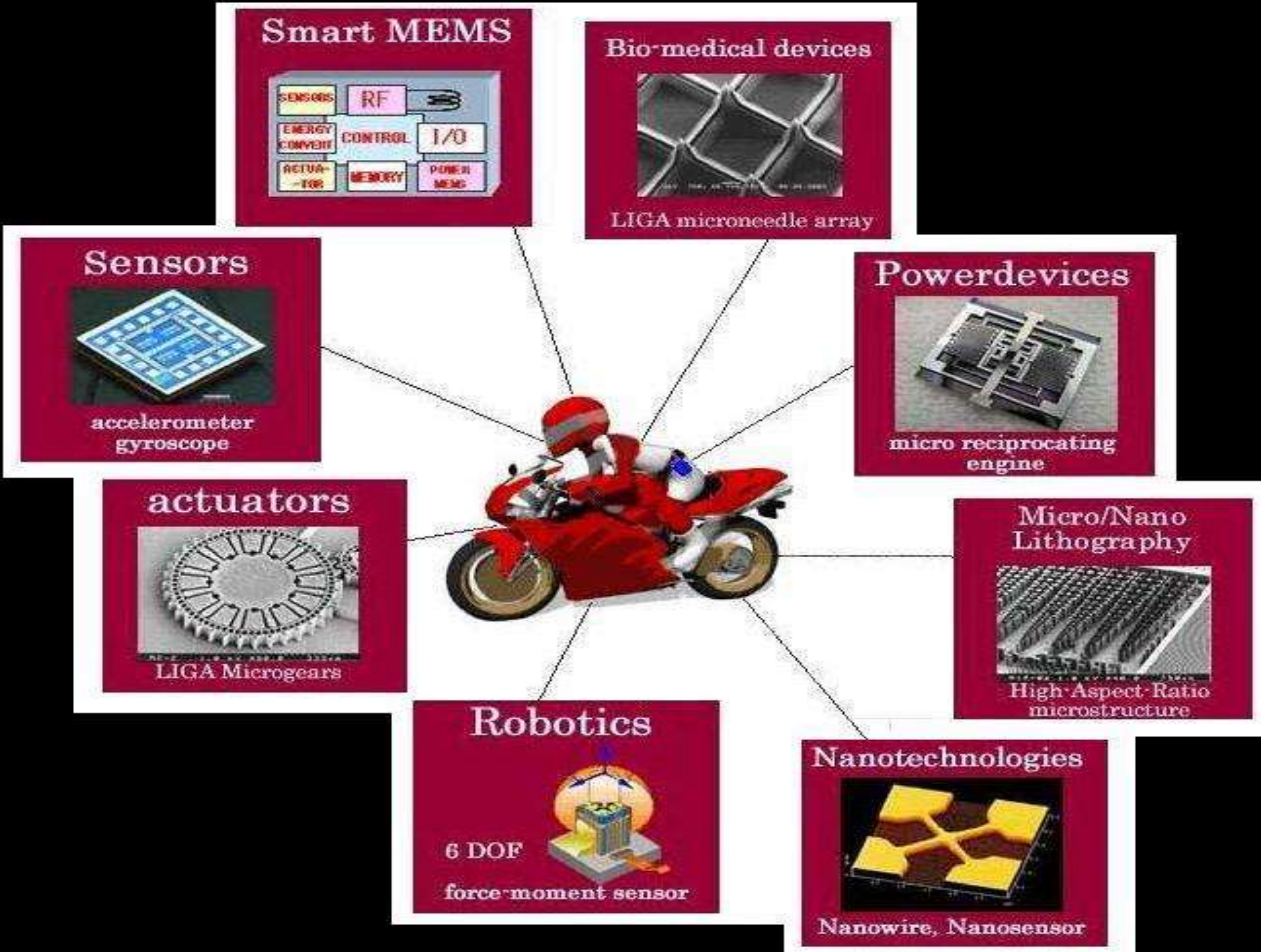
Compression Mode
Piezo Material
Bender Mode
Piezo Material
Shear Mode
Piezo Material
Bolted Mass Assembly
Compression Mode
Piezo Material
Sensitive Axis
Mounting Base
Bender Mode
Piezo Material
Seismic Mass
Sensitive Axis
Mounting Base
Bolted Mass Assembly
Sensitive Axis
Shear Mode
Piezo Material
Center Support
and Mounting Base

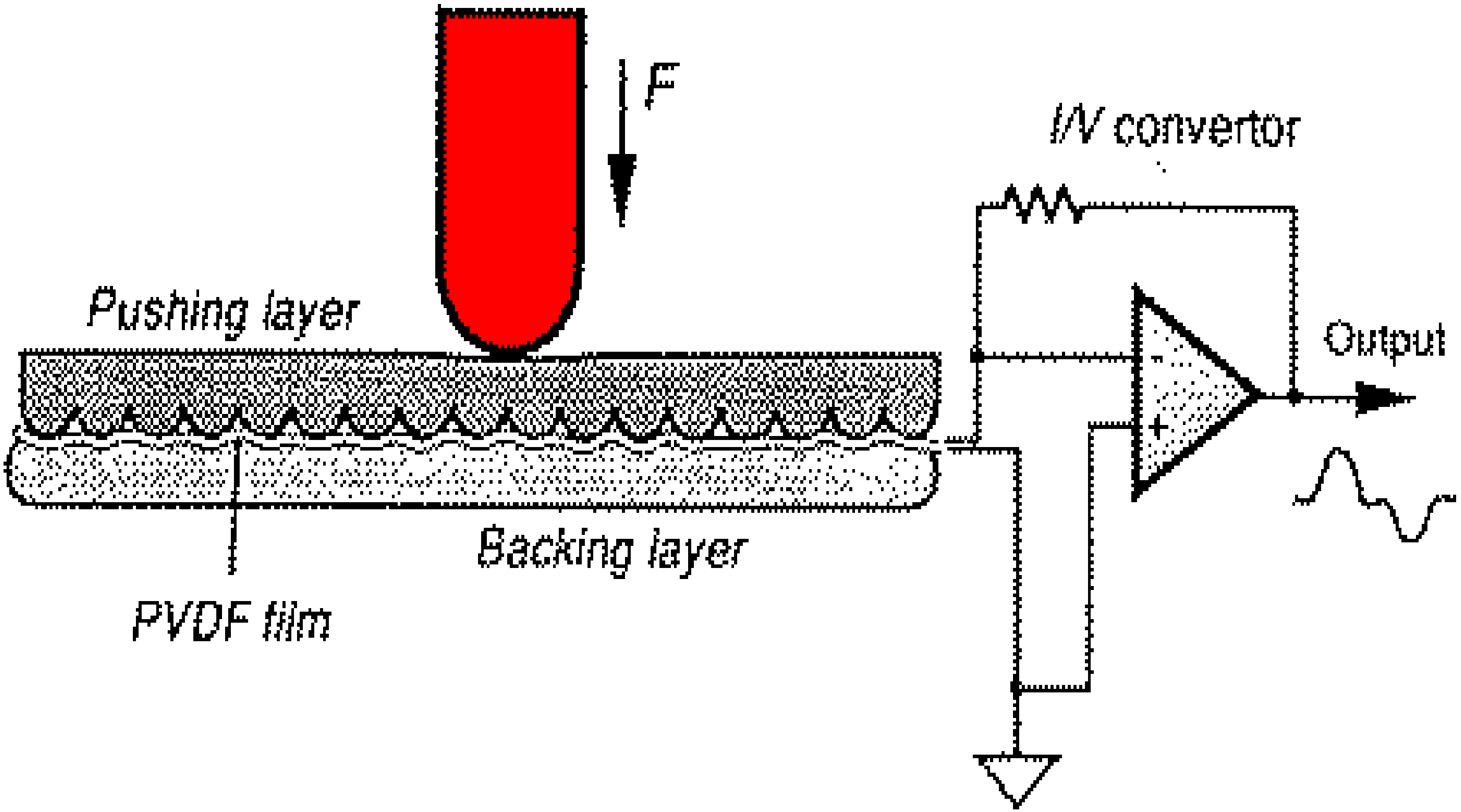
			
Rectangular	Annulus	Bilateral symmetry lead electrode	Single lead electrode
2. Tubular shape Piezoelectric Ceramics			
			
Segmentation polarization	Longitudinal polarization	Tangential polarization	Radial polarization

Piezoelectric sensor

- Piezoelectric sensor is used for the measurement of pressure, acceleration and dynamic-forces such as oscillation, impact, or high speed compression or tension.
- It contains piezoelectric ionic crystal materials such as Quartz.
- On application of force or pressure these materials get stretched or compressed.


unesp
LTAD
GMMNT
FUNDUNESP


Smart MEMS
SENSORS
RF
ENERGY CONVERT
CONTROL
I/O
ACTUA-TOR
MEMORY
POWER MEMS
Bio-medical devices
LIGA microneedle array
Sensors
accelerometer
gyroscope
Powerdevices
micro reciprocating engine
actuators
LIGA Microgears
Micro/Nano Lithography
High-Aspect-Ratio microstructure
Robotics
6 DOF
force-moment sensor
Nanotechnologies
Nanowire, Nanosensor



Piezoelectric force rate sensor

THANK YOU