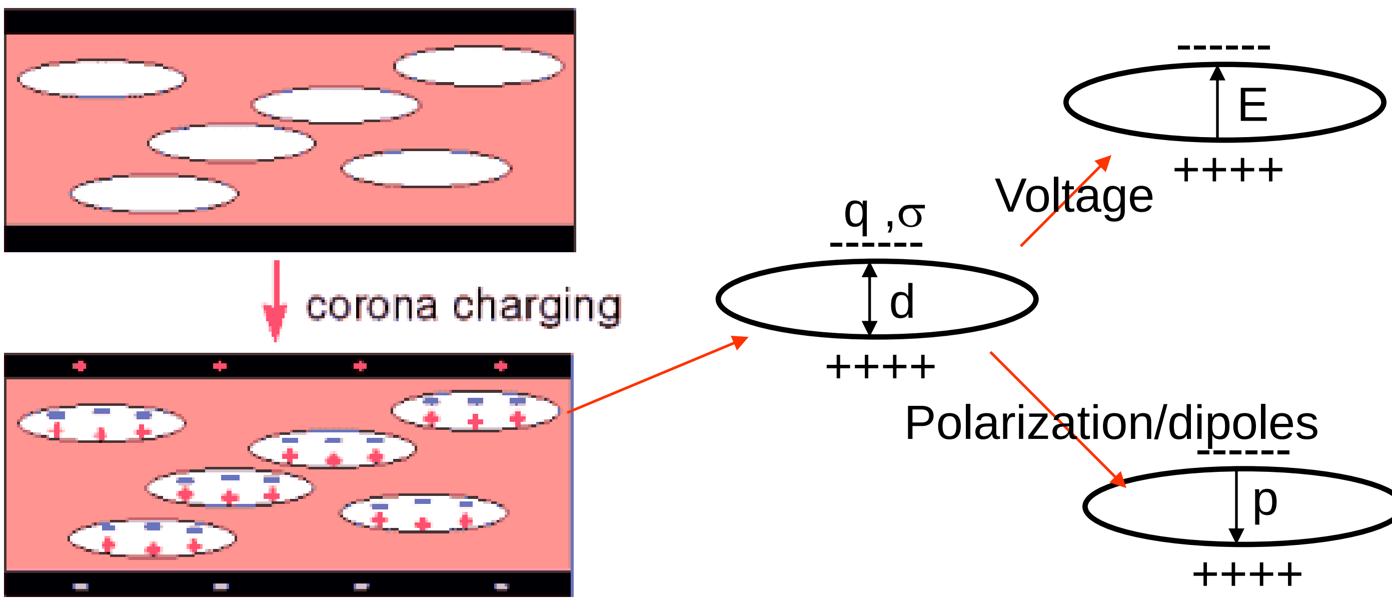
Piezoelectricity

Material from

- 3.6 Piezoelectric effect
- 7.5 Ultrasonic transducer
- 8.4 Piezoelectric accelerometer
- 8.7 Piezoelectric cable
- 9.2.2 Tactile sensor
- Appendix A
- Extra material on porous polypropylene

Porous polypropylene

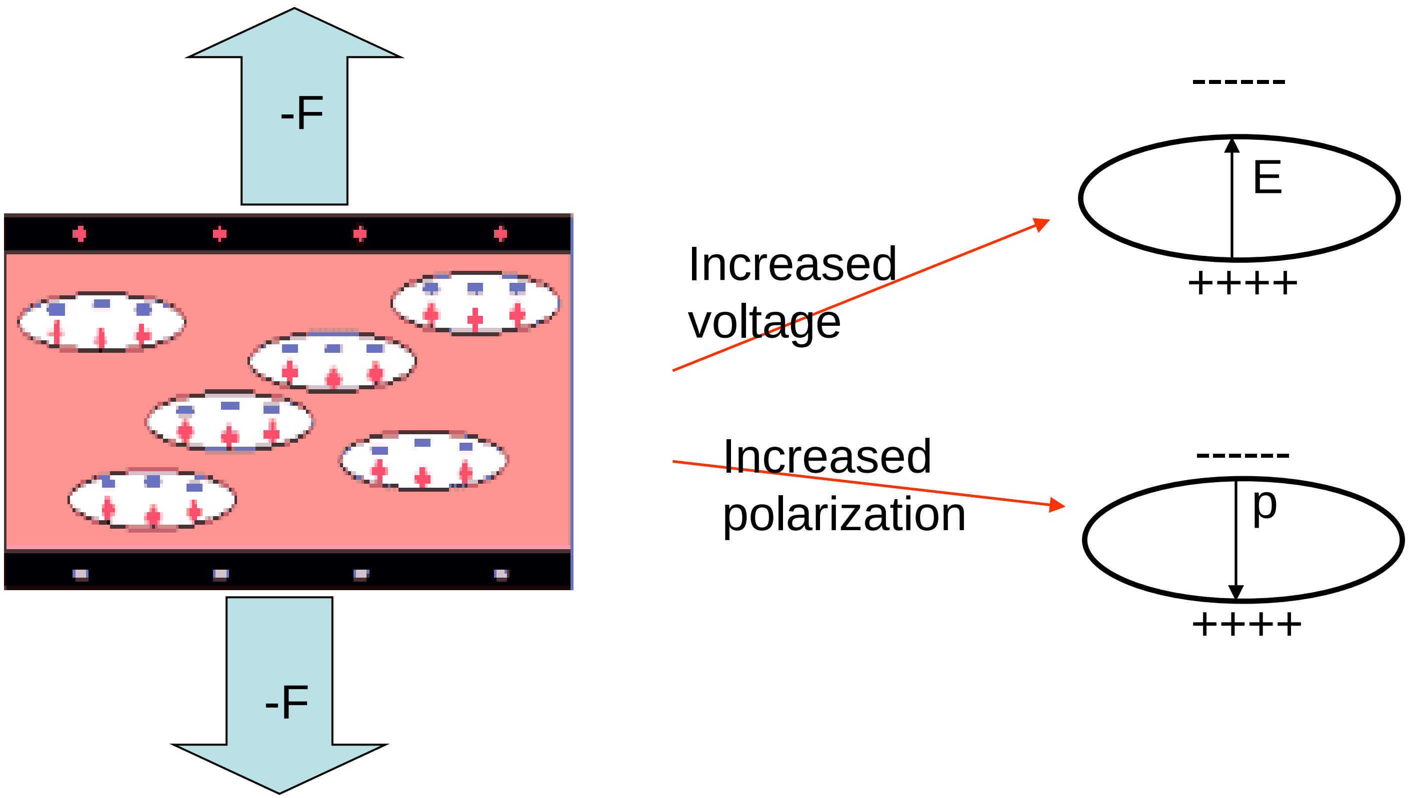


$$E = \frac{\sigma}{\varepsilon_0}$$

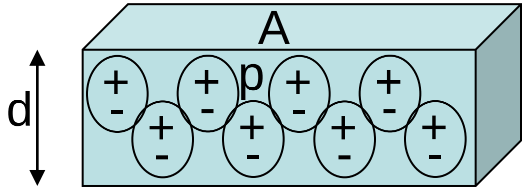
$$V = \frac{\sigma}{\varepsilon_0} d$$

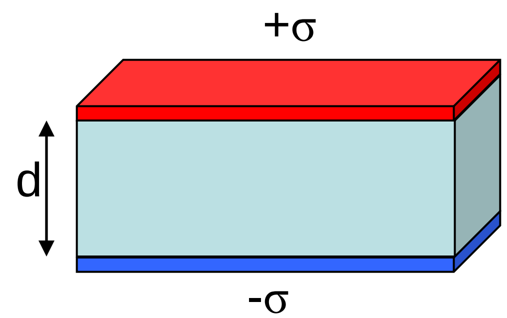
p = dq

Effect of tension



Polarisasjonstetthet/ overflateladning





p: dipolmoment/volumenhet

σ: flateladning (Q= σA)

Totalt dipolmoment:

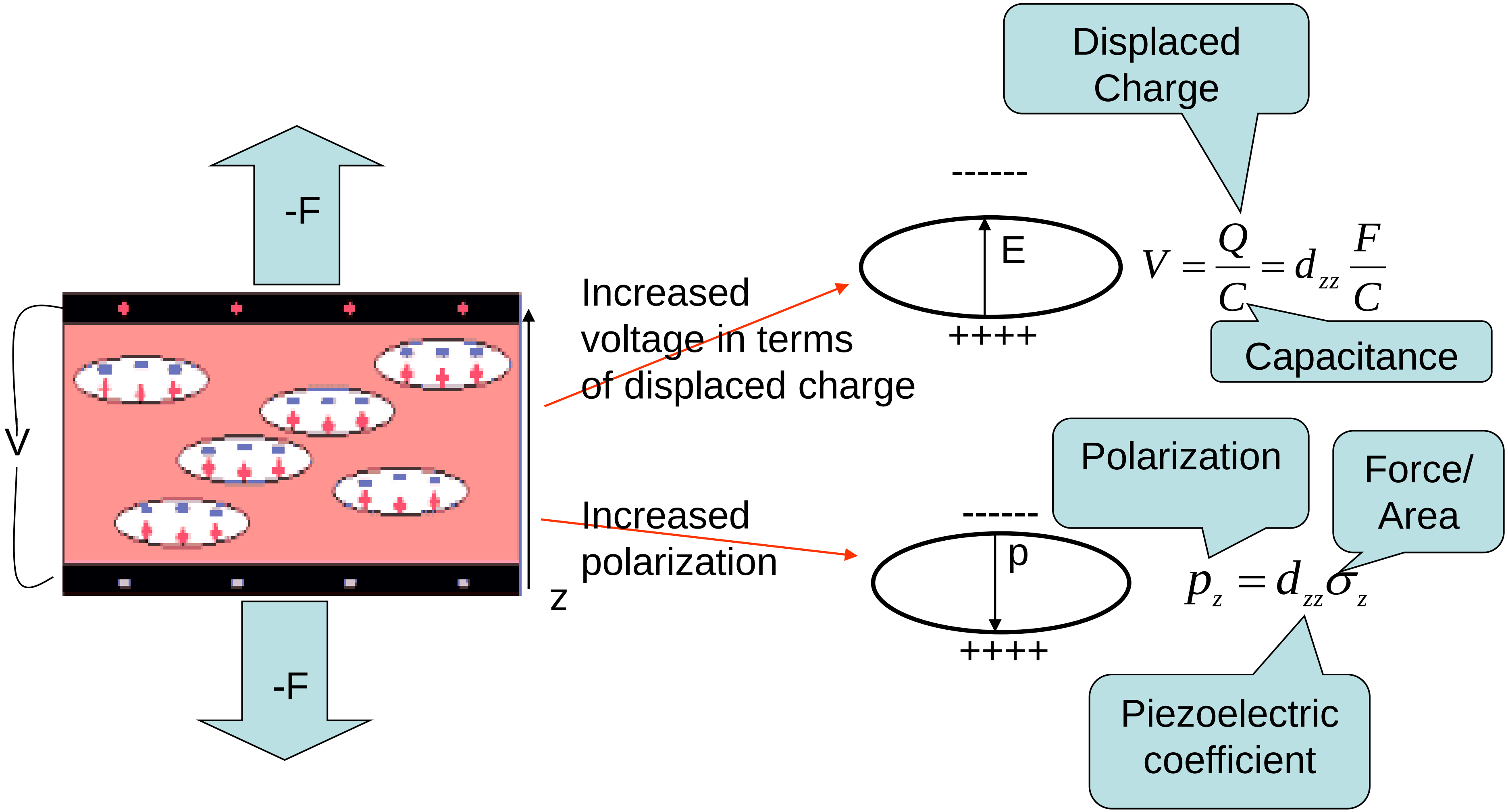
$$P = pV = pAd$$

Totalt dipolmoment:

$$P = Qd = \sigma Ad$$

$$p = \sigma$$

Piezoeectric coefficient



Quartz (SiO_2)

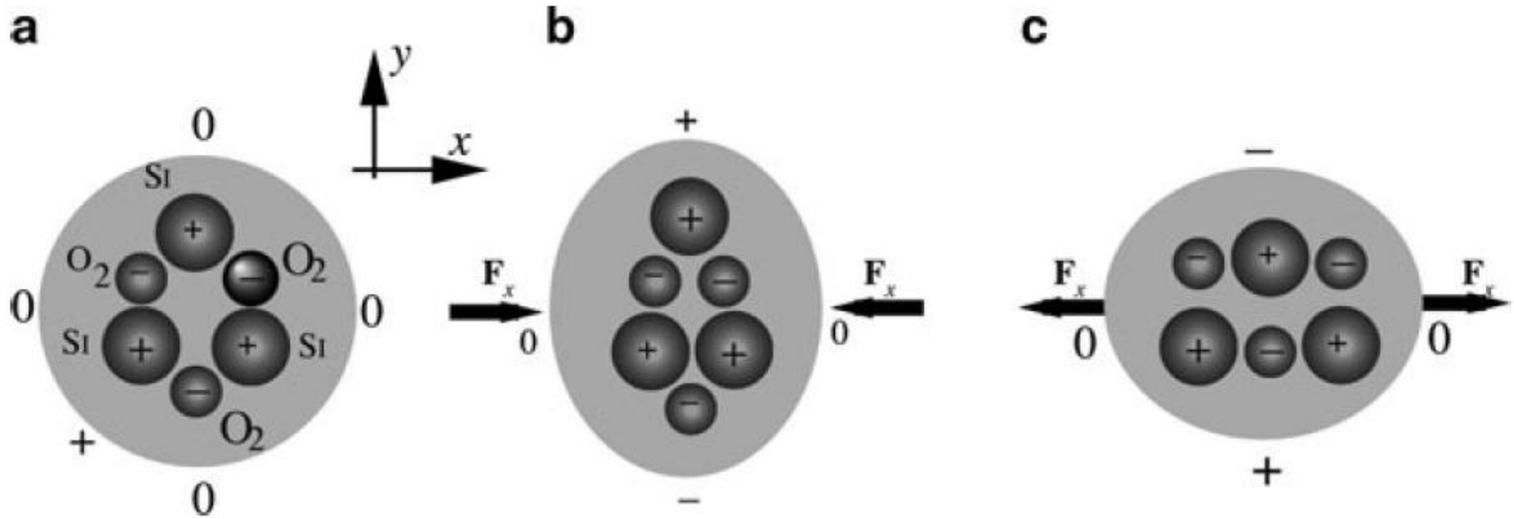


Fig. 3.21 Piezoelectric effect in a quartz crystal

PZT

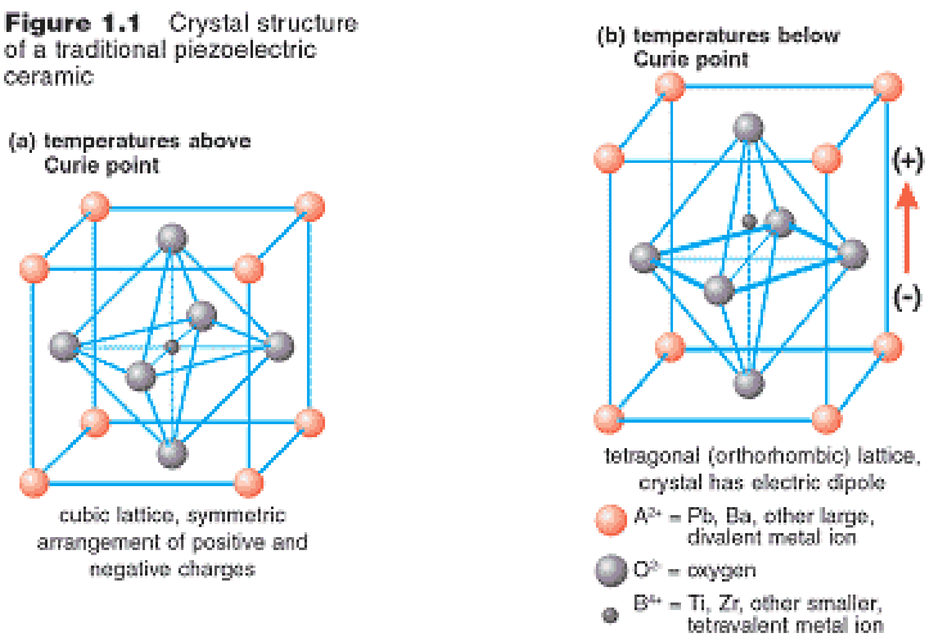
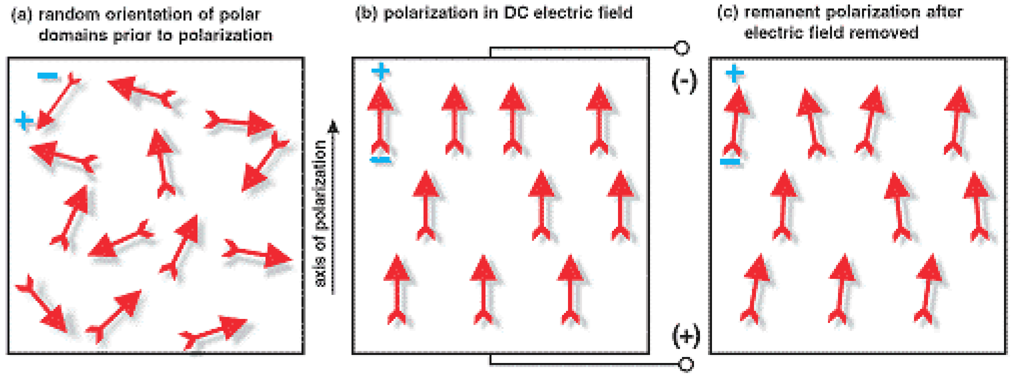
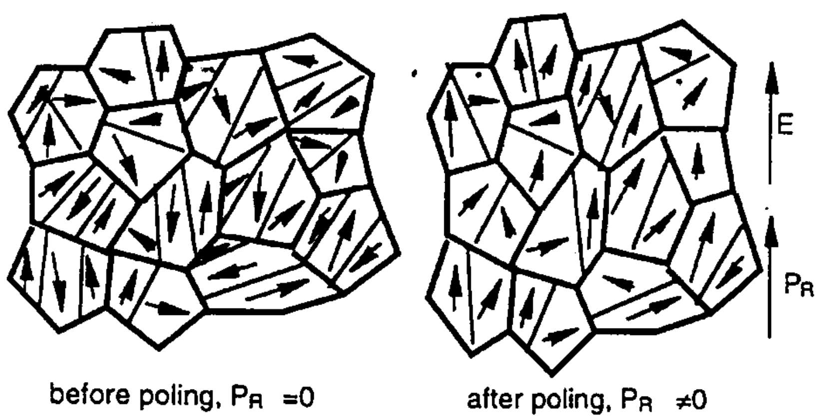


Figure 1.1 Crystal structure of a traditional piezoelectric ceramic

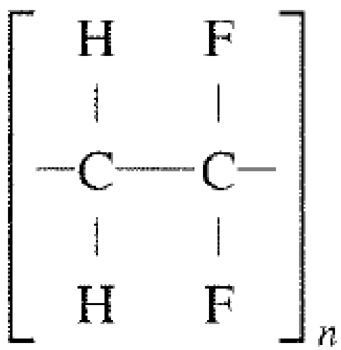
Poling

Figure 1.2 Polarizing (poling) a piezoelectric ceramic*





PVDF



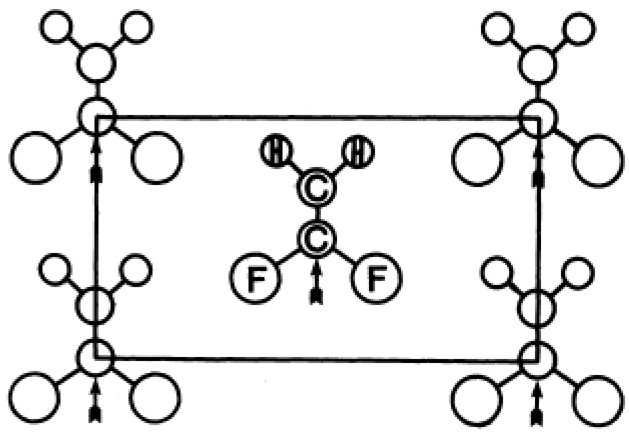


Fig. 1—Relative positions of atoms in poly(vinylidene fluoride) in all-transconformation when viewed parallel to the chain axis and relative positions of chains in the unit cell of β crystal phase when projected onto the ab plane. Arrow indicates net dipole moment perpendicular to chain axis.

Piezoelektriske kabler

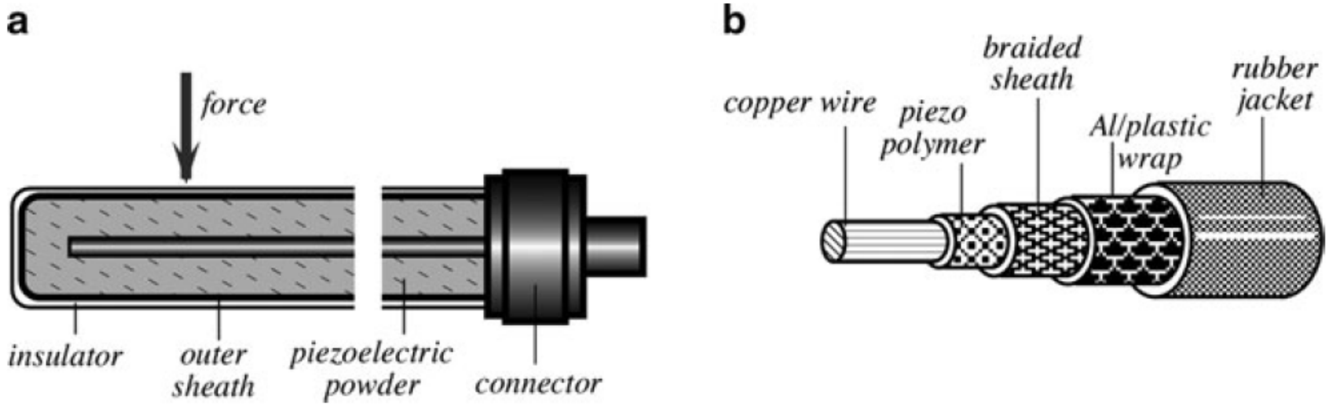


Fig. 8.15 Piezoelectric cable sensors. Construction of *Vibracoax* (**a**); polymer film as a voltage generating component (**b**) (adapted from [13])

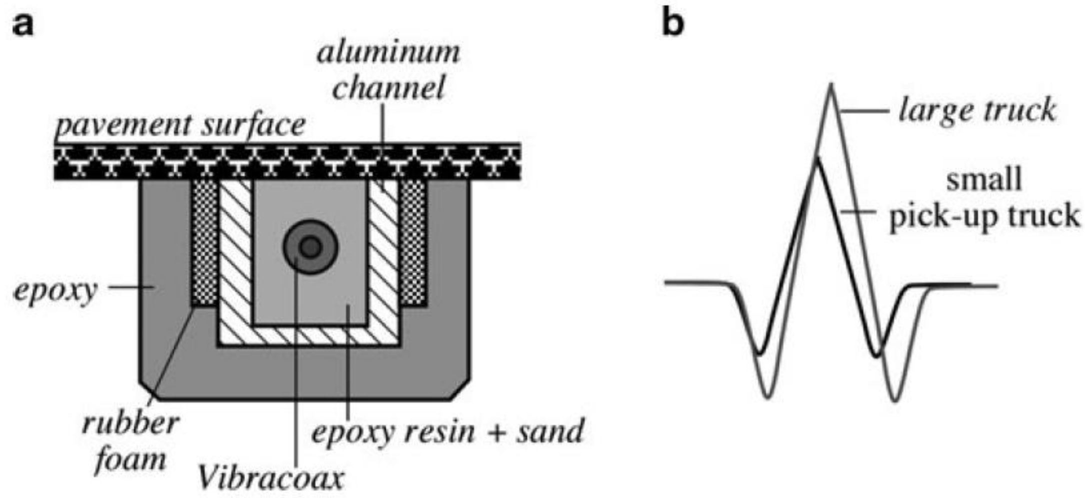


Fig. 8.16 Application of the piezoelectric cables in highway monitoring. Sensor installation in the pavement (**a**); shape of electrical response (**b**)

Piezoelektric accelerometer

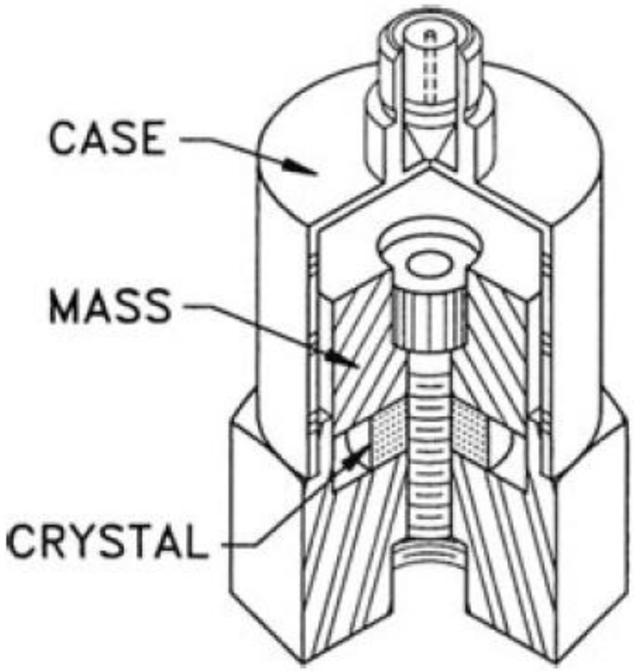
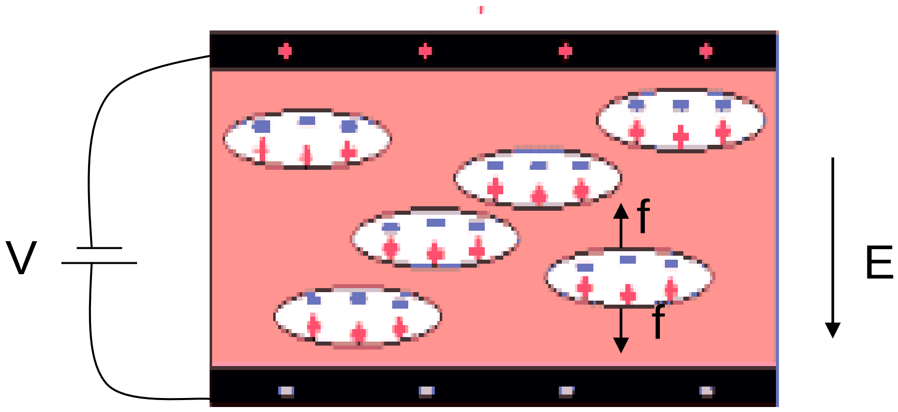


Fig. 8.6 A basic schematic representation of a piezoelectric accelerometer. Acceleration of the case moves it relative to the mass, which exerts a force on the crystal. The output is directly proportional to the acceleration or vibration level

The converse effect (electro->piezo)



Aktiv berøringssensor

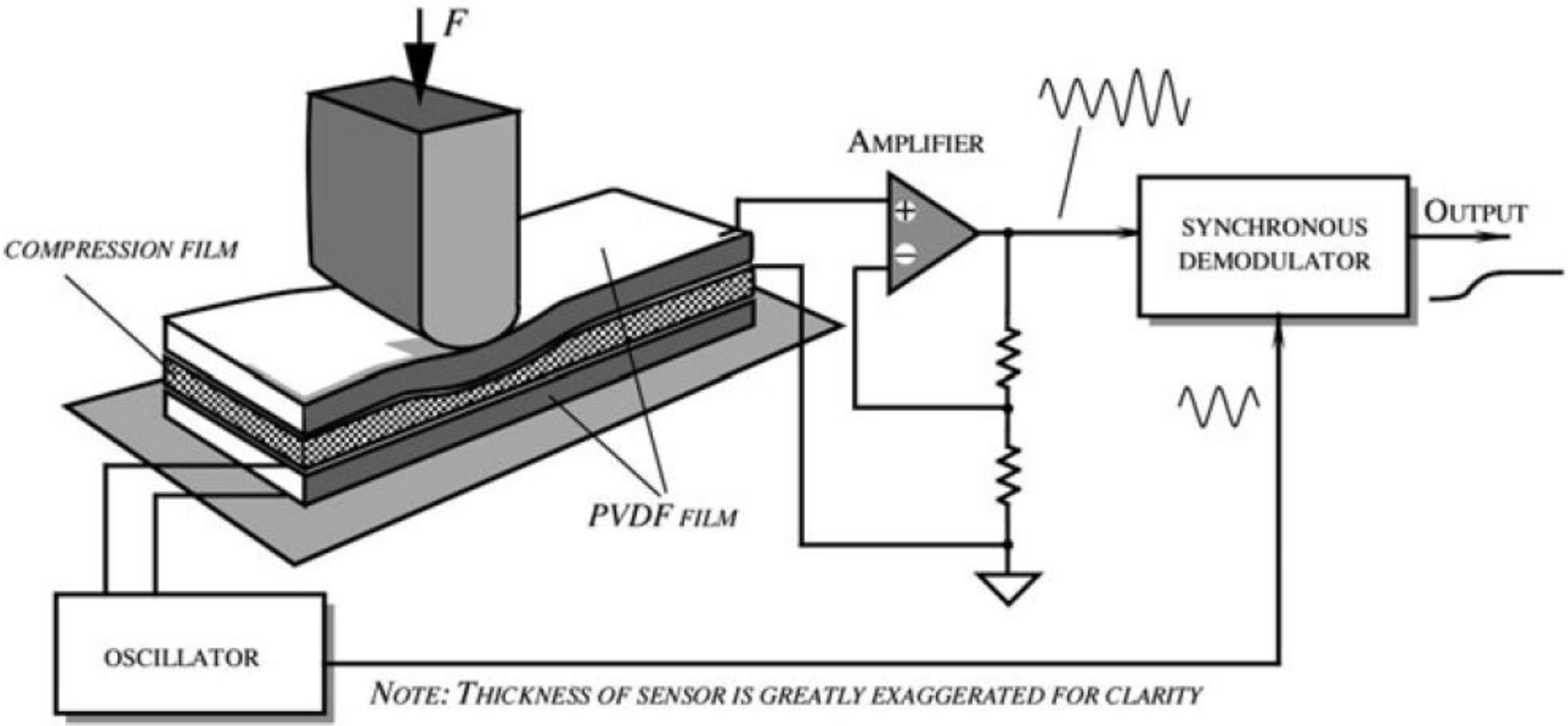


Fig. 9.4 Active piezoelectric tactile sensor

Piezoelectric tensor

$$\begin{aligned}
\mathbf{P}_{xx} &= d_{11}\boldsymbol{\sigma}_{xx} + d_{12}\boldsymbol{\sigma}_{yy} + d_{13}\boldsymbol{\sigma}_{zz}, \\
\mathbf{P}_{\mathrm{yy}} &= d_{21}\boldsymbol{\sigma}_{xx} + d_{22}\boldsymbol{\sigma}_{yy} + d_{23}\boldsymbol{\sigma}_{zz}, \\
\mathbf{P}_{\mathrm{zz}} &= d_{31}\boldsymbol{\sigma}_{xx} + d_{32}\boldsymbol{\sigma}_{yy} + d_{33}\boldsymbol{\sigma}_{zz},
\end{aligned} \tag{3.65}$$

Bending mode

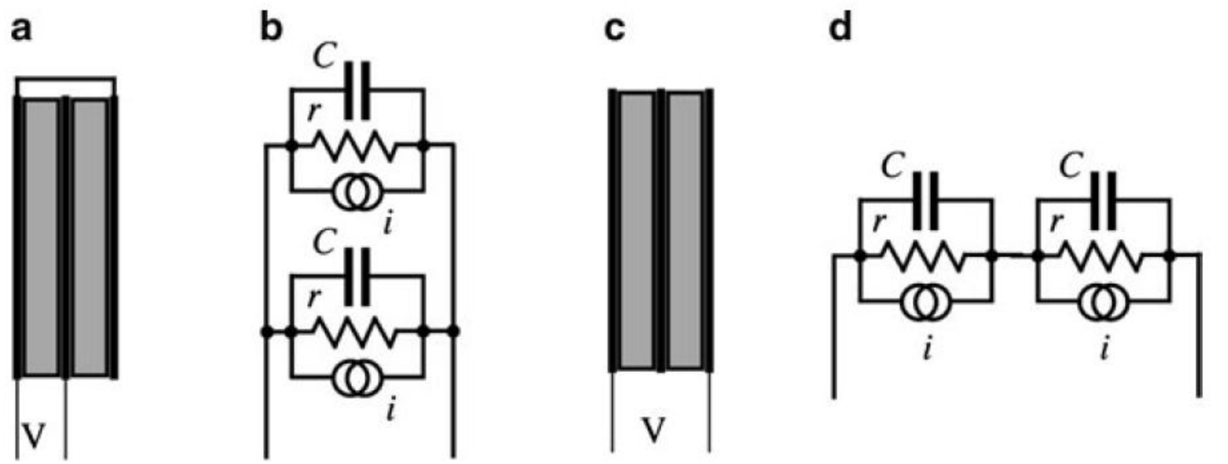


Fig. 3.24 Parallel (**a**) and serial (**c**) laminated piezoelectric sensors and their corresponding equivalent circuits (**b**), (**d**)

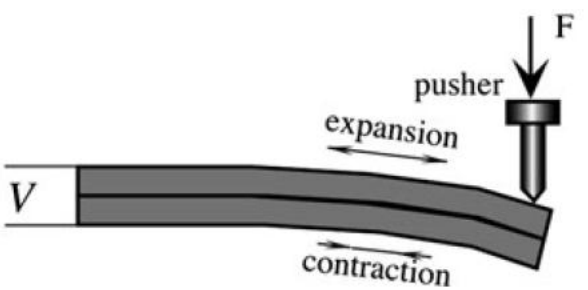


Fig. 3.25 Laminated two-layer piezoelectric sensor

Ultralyd sender/mottaker

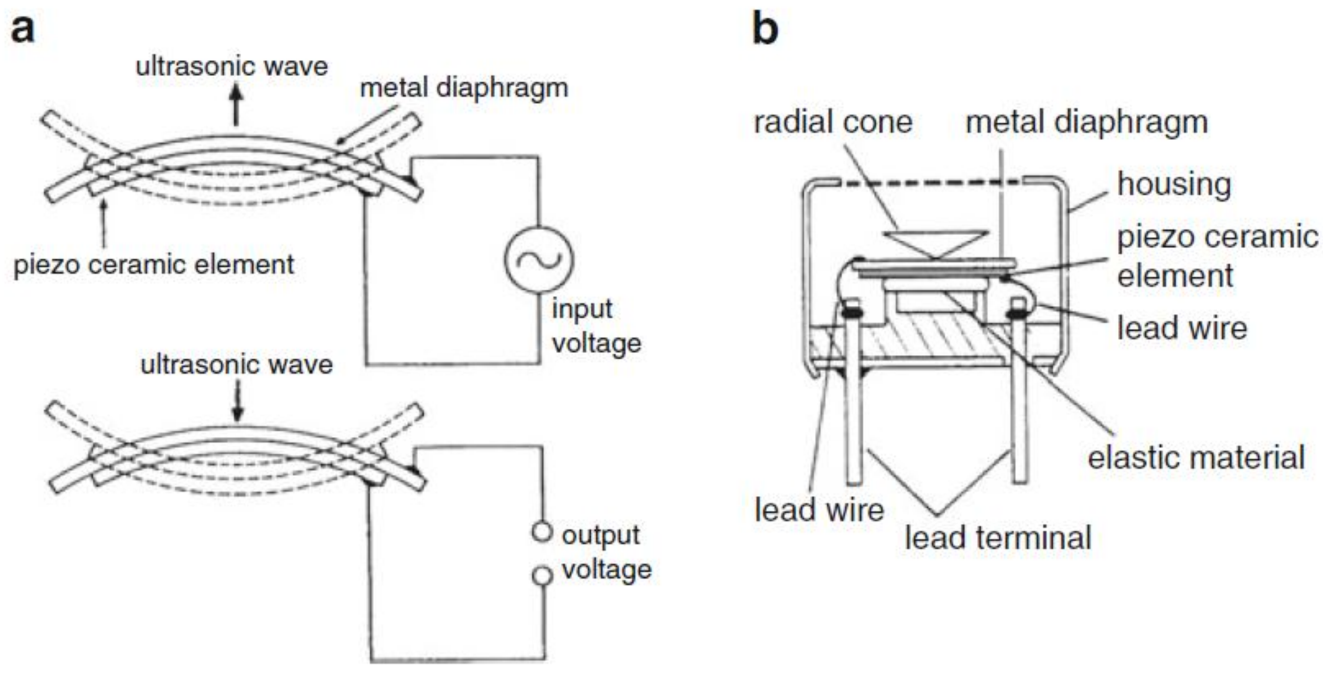


Fig. 7.43 Piezoelectric ultrasonic transducer.
Input voltage flexes the element and transmits ultrasonic waves, while incoming waves produce output voltage (**a**). Open aperture type of ultrasonic transducer for operation in air (**b**) (Courtesy of Nippon Ceramic, Japan)

Material Parameters

Table A.8. Properties of Piezoelectric Materials at 20°C

	PVDF	$BaTiO_3$	PZT	Quartz	TGS
Density ($\times 10^3$ kg/m^3)	1.78	5.7	7.5	2.65	1.69
Dielectric constant, ε_r	12	1700	1200	4.5	45
Elastic modulus (10^{10} N/m)	0.3	11	8.3	7.7	3
Piezoelectric constant (pC/N)	$d_{31} = 20$ $d_{32} = 2$ $d_{33} = -30$	78	110	2.3	25
Pyroelectric constant (10^{-4} C/m^2 K)	4	20	27	—	30
Electromechanical coupling constant (%)	11	21	30	10	—
Acoustic impedance (10^6 kg/m^2 s)	2.3	25	25	14.3	—