Electret Applications in Microelectronics, Sensors and Actuators

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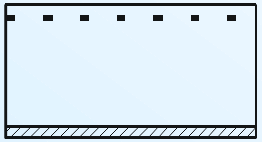
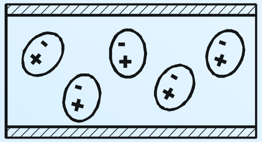
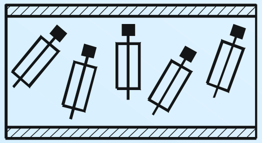
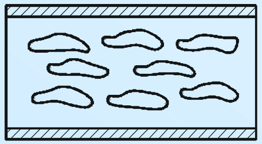
Overview

- **Introduction**
- **Electroacoustic electret transducers**
- **Piezoelectric transducers (acoustic and underwater)**
- **Applications of cellular piezoelectric materials**
- **Infrared and pyroelectric detectors**
- **Nonlinear optical devices**
- **Other applications**

Applications of electrets are based on the following effects:

- **External electric fields**
- **Internal electric fields**
- **Generation of forces**
- **Piezoelectric activity**
- **Pyroelectric activity**
- **NLO effects**
- **Charge compensation**

Charged or polarized dielectrics

Category	Materials	Charge or polarization: Geometry	Density [mC/m^2]	Properties	Applications
Real-charge electrets	FEP, SiO_2		0.1 - 1	External electric field and force	Electret microphones, head-phones, air filters, dosimeters, advanced engineering material.
NLO materials	PMMA / DR1, glasses		0.1 - 10	Electrooptic and NLO effects	EO switch, modulator, polarization converter, SHG - devices.
Ferroelectric materials	PVDF, PZT		10 - 100	Piezo- and pyroelectricity	Microphones, Hydrophones, accelerometers, infrared detectors, pyroelectric sensors, night-vision devices, actuators.
porous or cellular electrets	PP, PTFE		1	strong longitudinal piezoelectric effect	Loudspeakers, ultrasonic transducers, electromechanical transducers, hydrophones.

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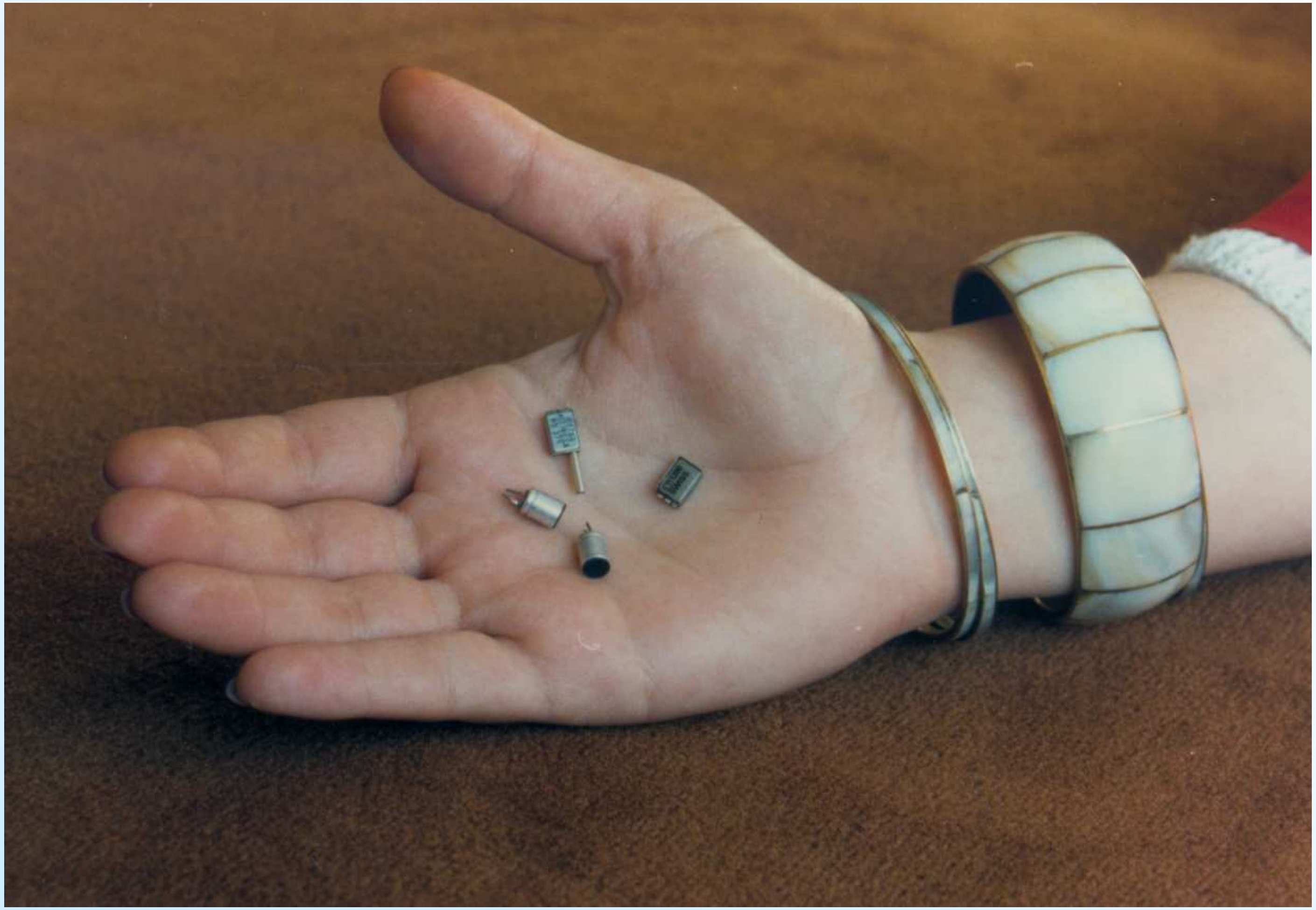
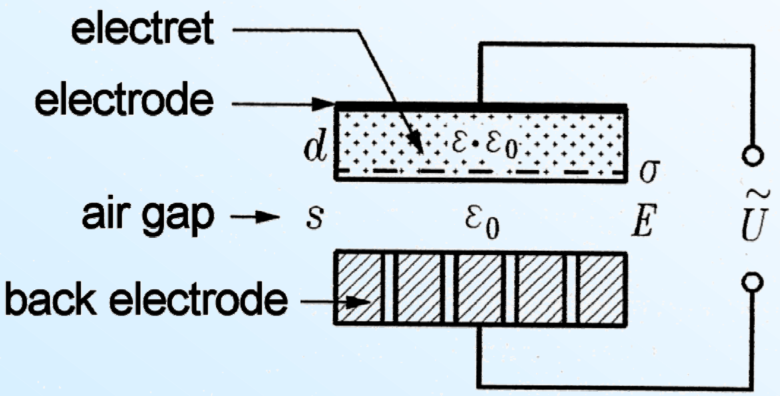
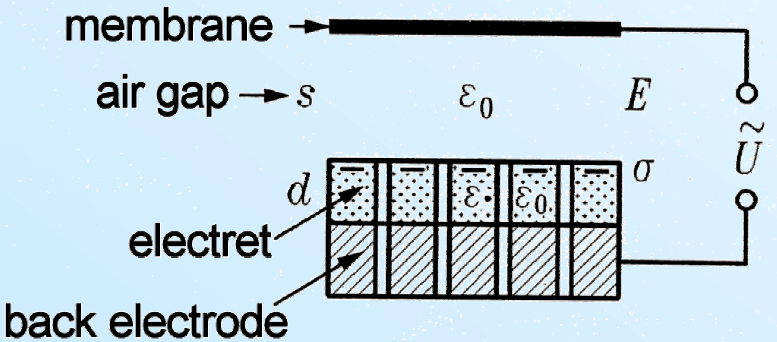
Miniature electret microphones



Electret microphone



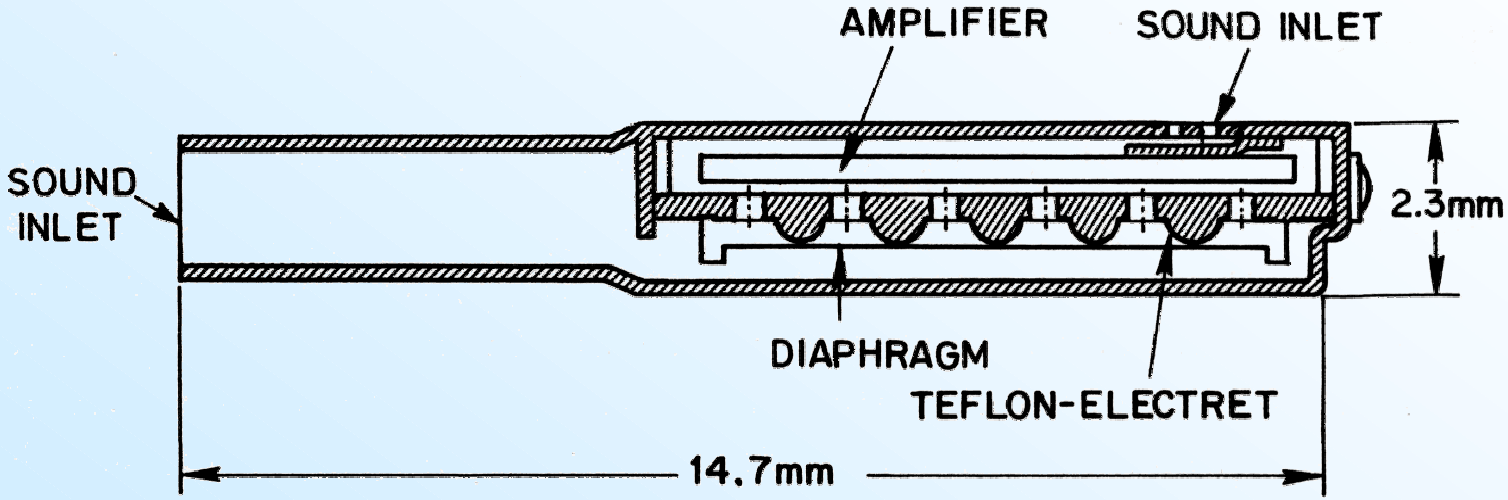


$$M = \frac{\tilde{U}}{\tilde{p}}$$

$$\tilde{U} = E\tilde{s} = \frac{\sigma d \tilde{s}}{\varepsilon_0(\varepsilon s + d)}$$

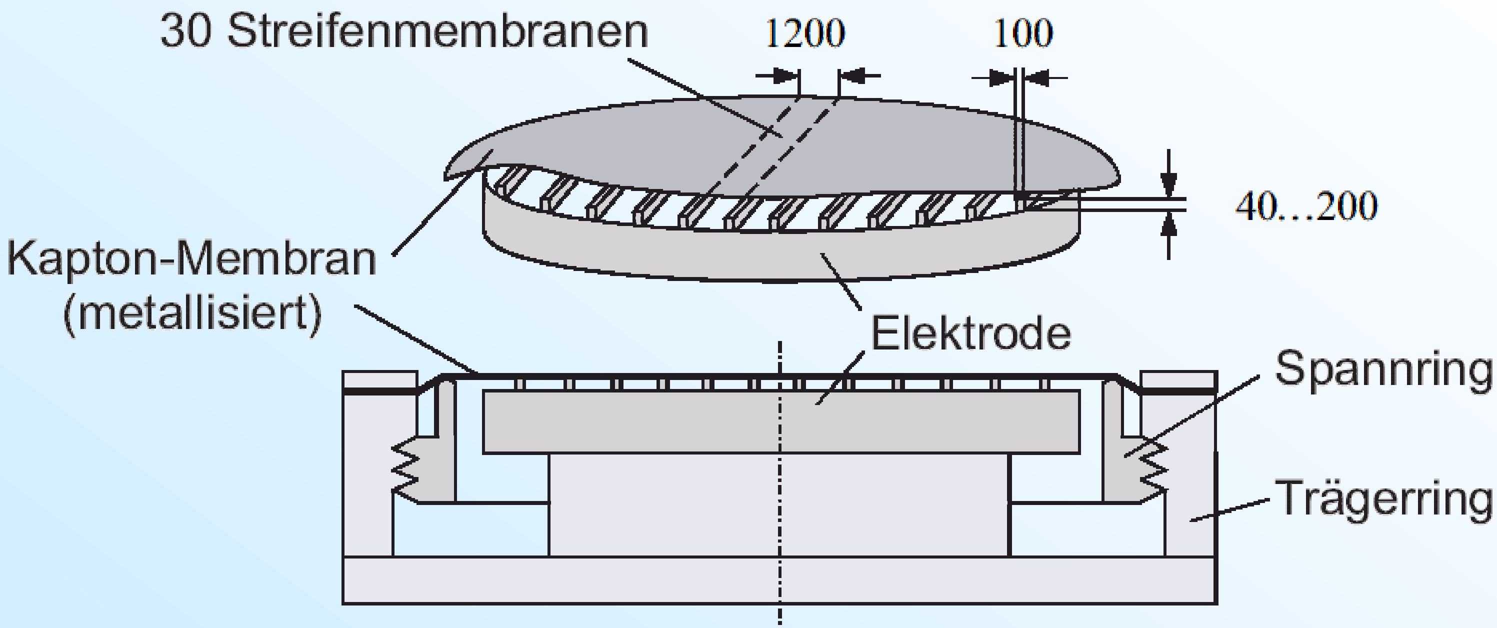
$$\tilde{p} = \frac{\tilde{s}}{Fs}$$

Directional electret microphone
(Carlson et al 1974)



Headphone (Sennheiser)

Ultrasonic transducer
(Leschka 2002)



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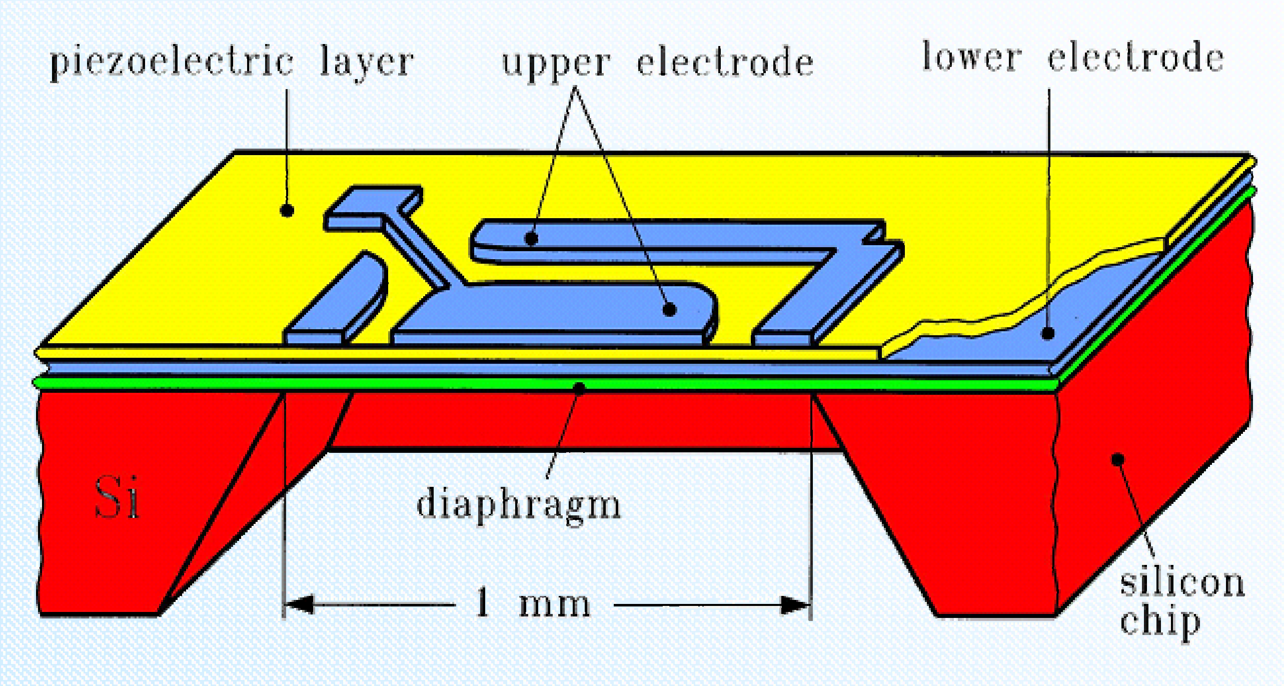
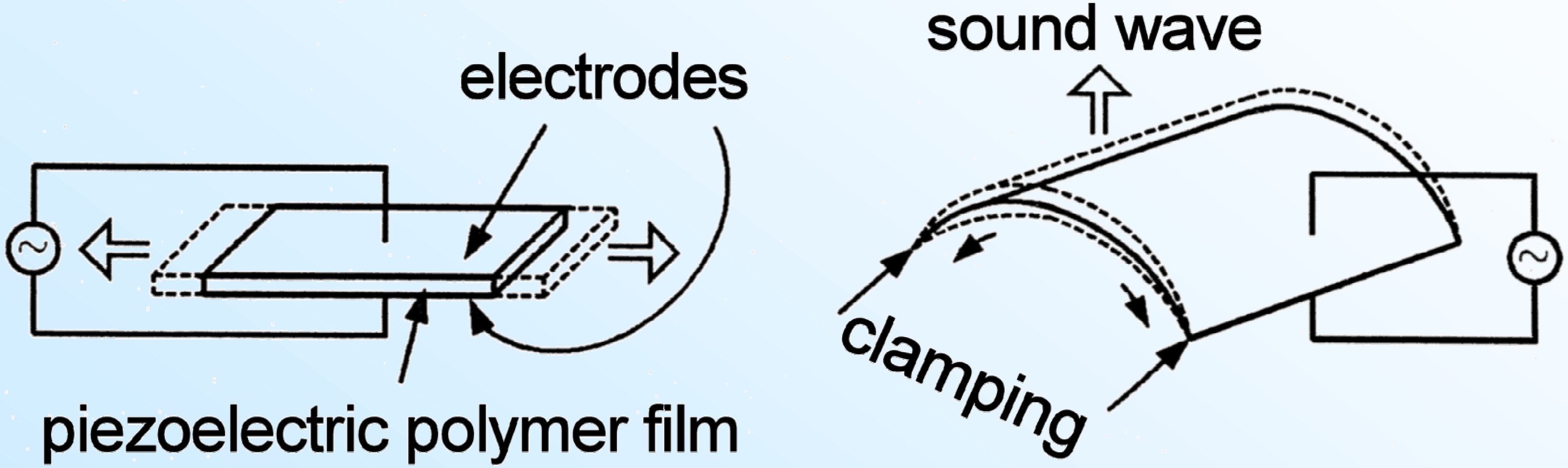
Piezoelectric materials

	$\boldsymbol{d_{33}}$ [pC/N]	$\boldsymbol{g_{33}}$ [Vm/N]
Quartz	2 (d_{11})	0.05 (g_{11})
PZT-5	171	0.011
PVDF	20	0.2
Expanded cellular PP	400 - 1200	60 - 180

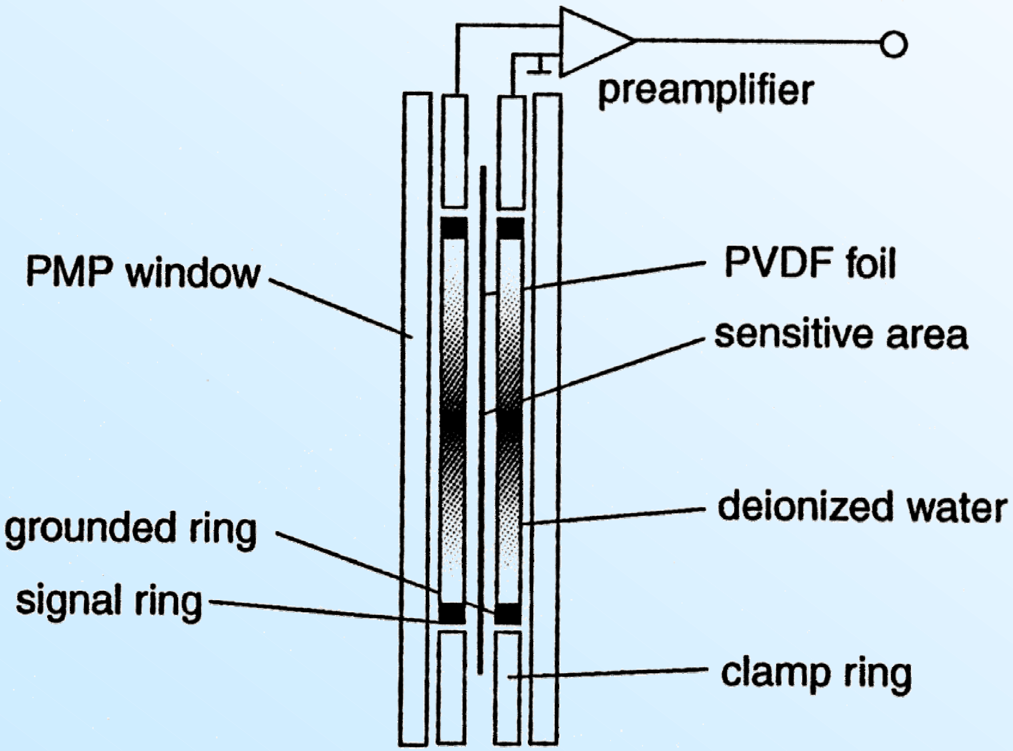
Piezoelectric silicon microphone
(Schellin 1995)



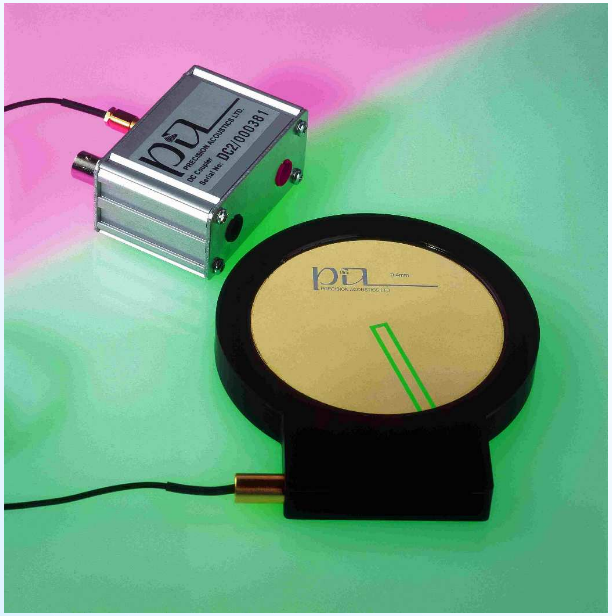
PVDF headphone: principle



PVDF membrane hydrophone

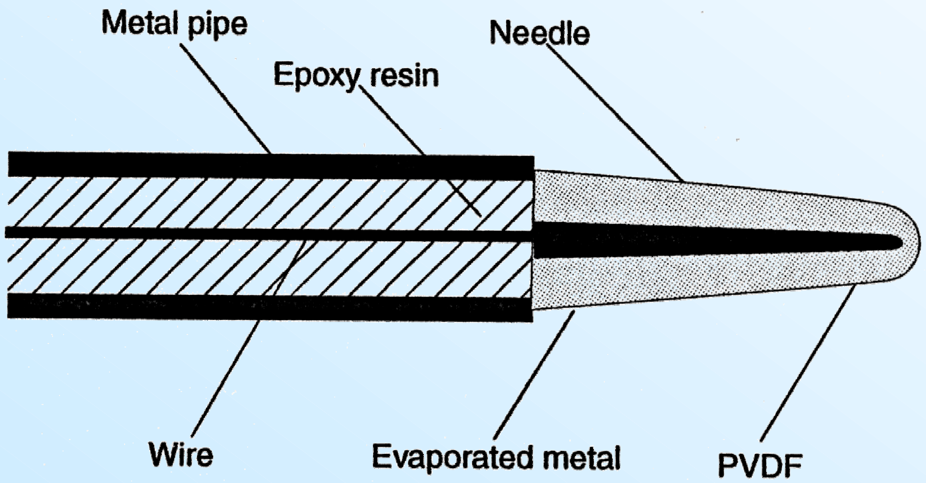


(Granz 1988)



(Precision Acoustics 2004)

PVDF needle hydrophone



(Platte 1985)

(Precision Acoustics 2004)

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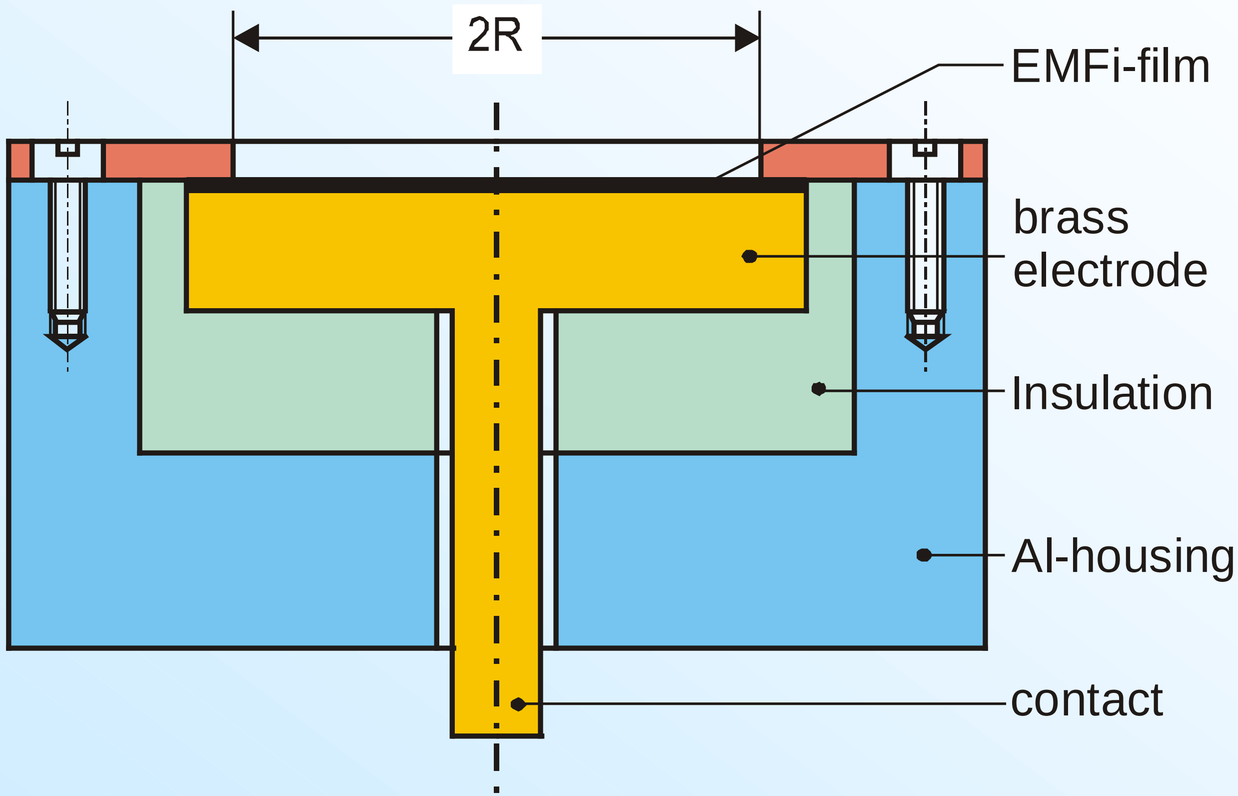
Proposed device applications of polymer-foam electrets
(Gerhard-Multhaupt 2002)

Proposed device	Typical areas of device application	Relative advantage of polymer-foam electret
Motion detector	(Bio-)sensorics, robotics, control systems, *etc.*	Variable shape, high sensitivity, non-intrusive
Micromotion actuator	(Micro-)actorics, robotics, control systems, *etc.*	Variable shape, low mass, gentle 'touch'
Pressure transducer	Diagnostics and (bio-)sensorics	Variable shape, wide frequency range, small size
Flat load detector	Medical and child care, security, *etc.*	Large area, thin, high sensitivity, non-intrusive
Piezoelectric microphone	Communications technology, *etc.*	Acoustic matching to air, high sensitivity
Piezoelectric loudspeaker	Active noise canceling, 'flat-screen' speakers, *etc.*	Matching to air, large area, variable shape
Ultrasonic transducer	(Medical) diagnostics and communications	Acoustic matching to fluids, variable shape, broad-band

Cross-section of a cellular PP film microphone
(Kreßmann 2000)



Sensitivity M of PP film microphone

$$M = d_{33} \frac{(s_1 + \varepsilon s_2)}{\varepsilon \varepsilon_0}$$

d_{33}: piezoelectric charge coefficient

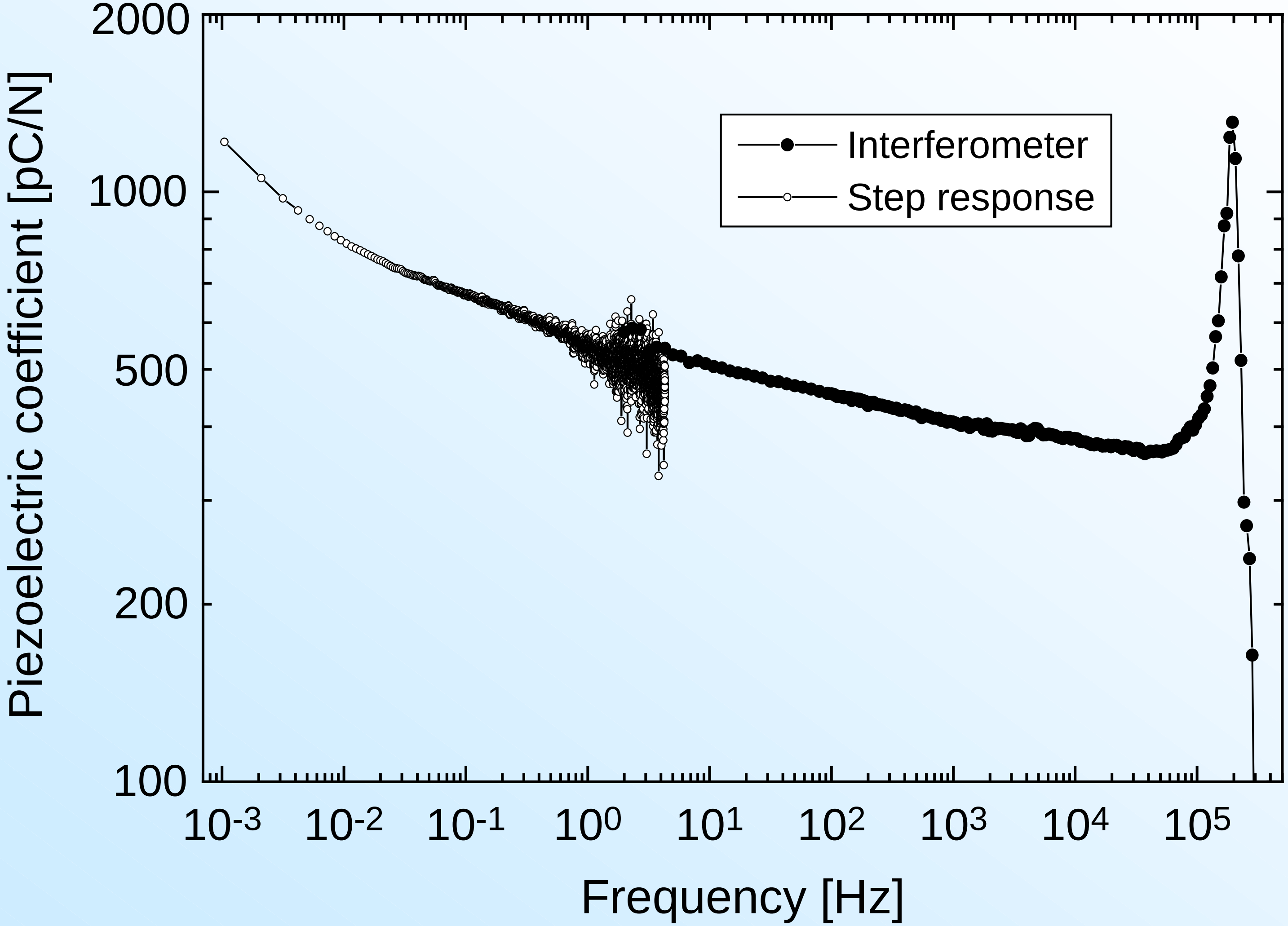
s_1: total thickness of polymer parts

s_2: total thickness of gas parts

ε : relative permittivity

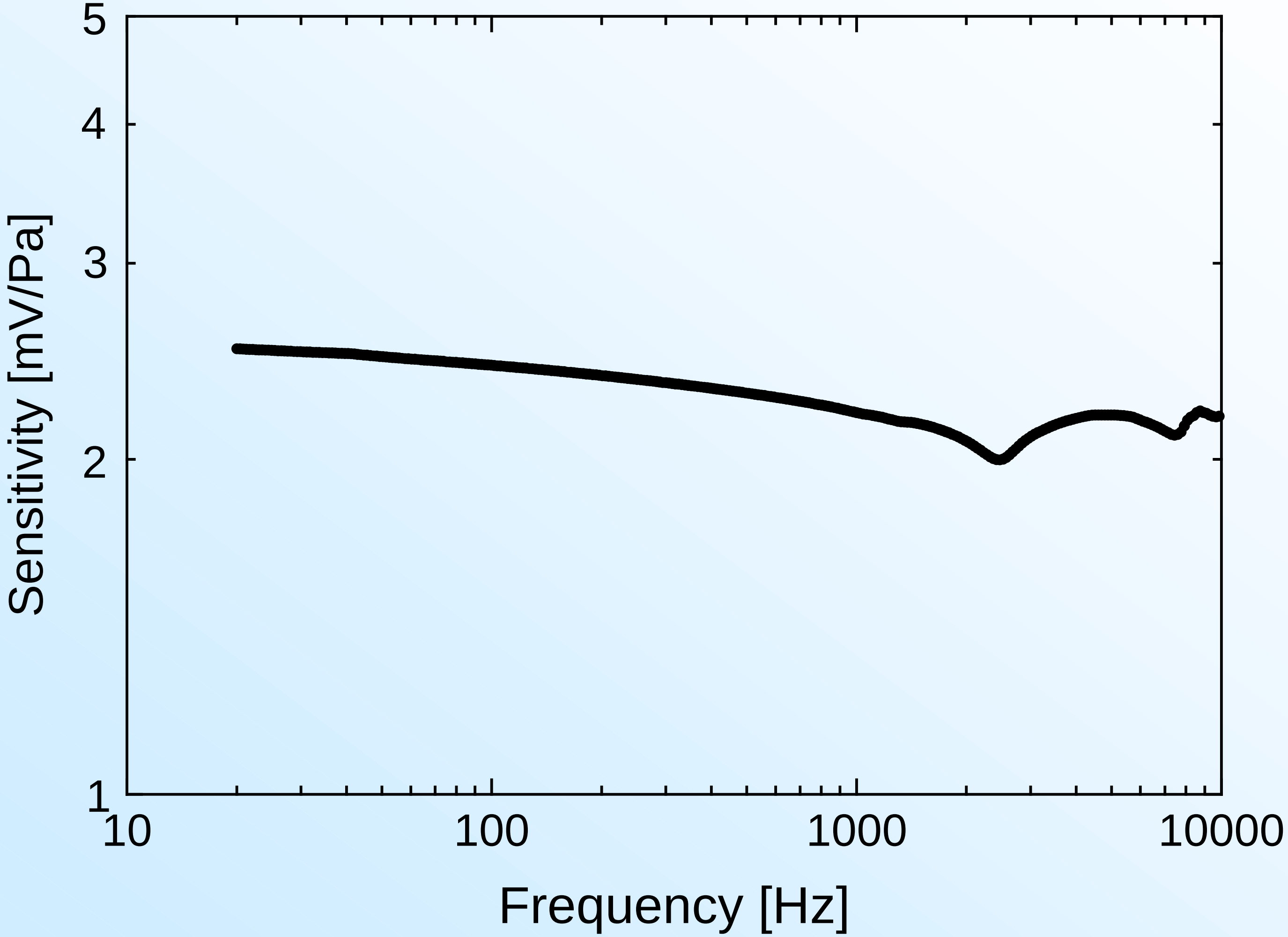
ε_0: absolute permittivity

Quasistatically and interferometrically determined d_{33}-coefficient of an expanded PP film in the frequency range from 1 mHz to 300 kHz (Hillenbrand et al 2003)

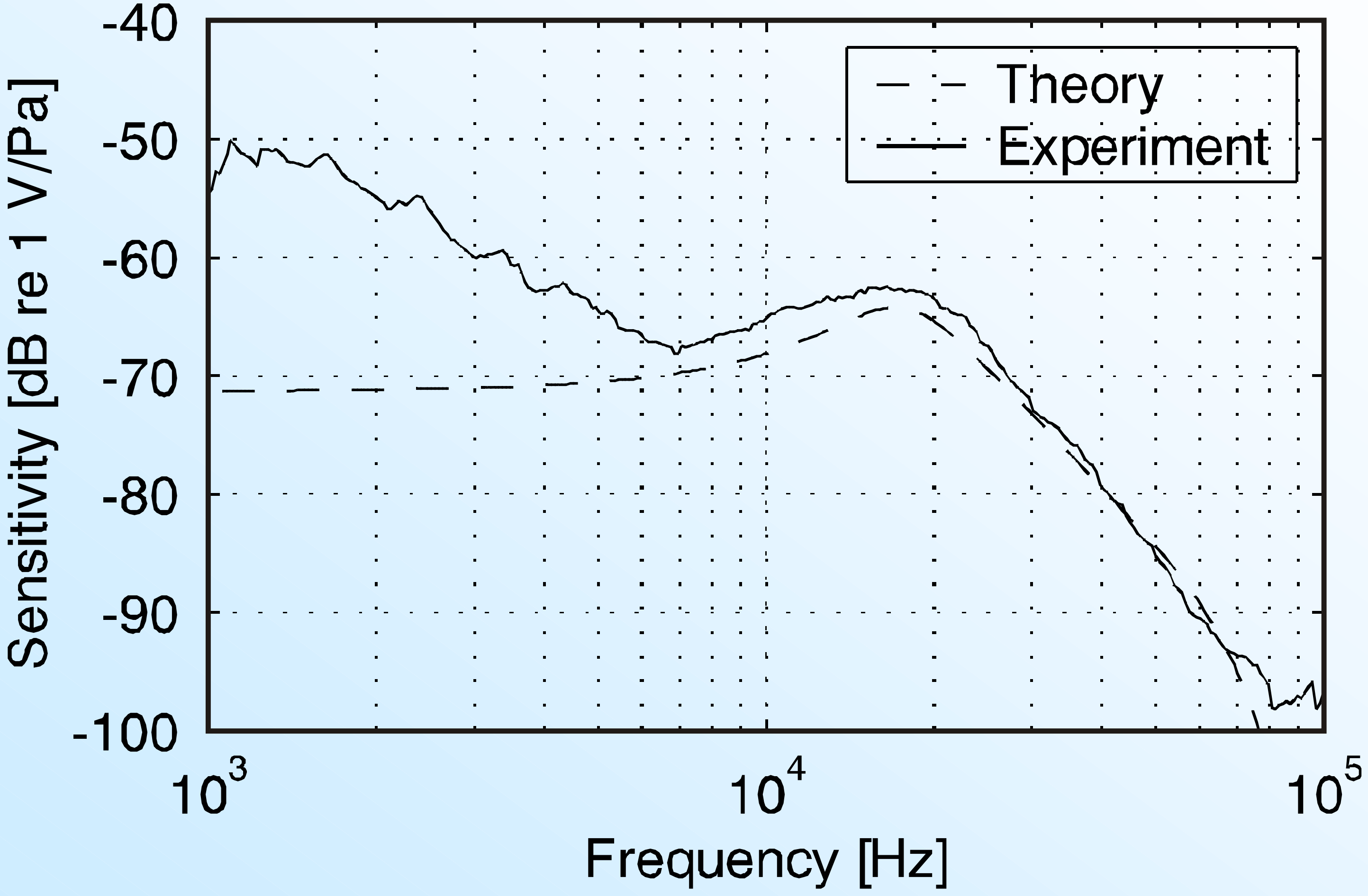


Frequency response of a cellular PP film microphone, determined by a comparison method in an acoustic coupler

(Hillenbrand et al 2004)



Sensitivity of cellular PP hydrophone
(Kreßmann 2000)



Keypads
(Screentec 2004)

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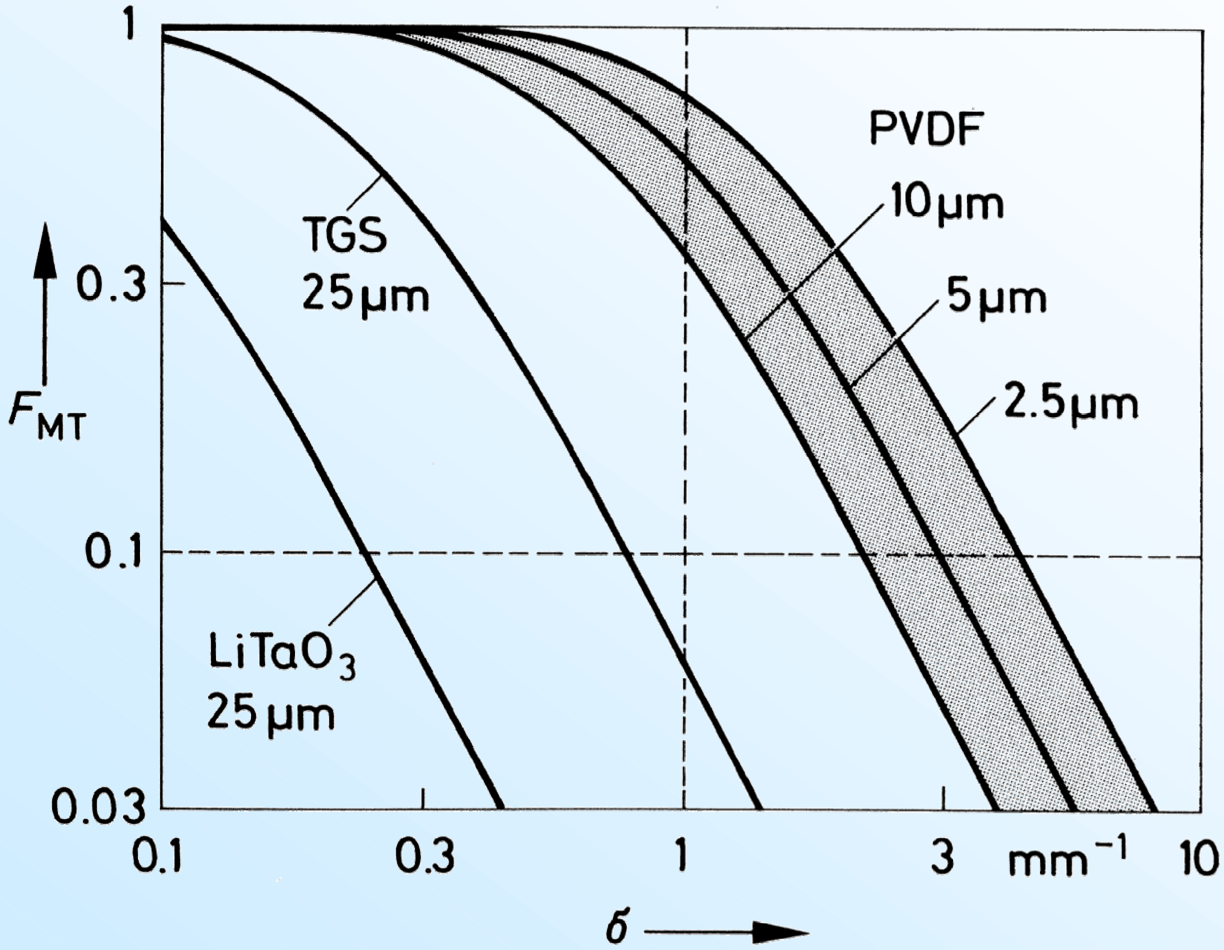
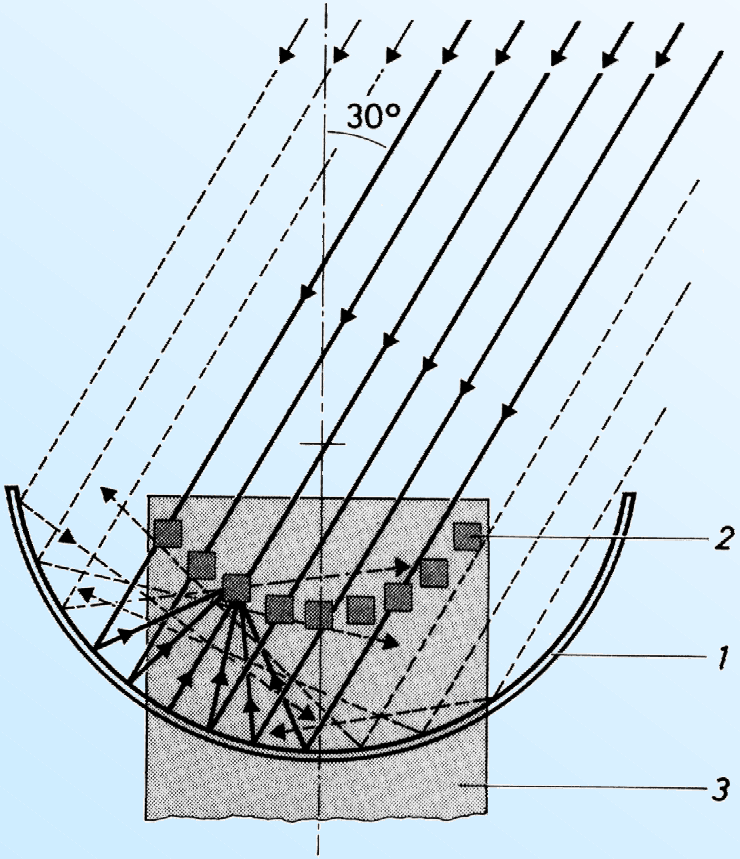
Pyroelectric infrared sensor: Spatial resolution

(Meixner et al 1986)

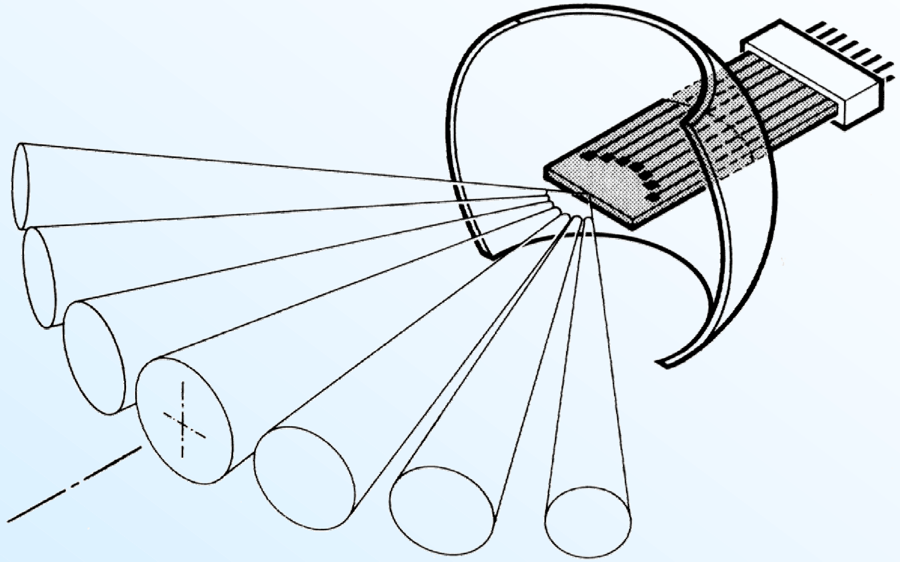


Broad-angle IR detector with linear PVDF array

(Meixner et al 1986)

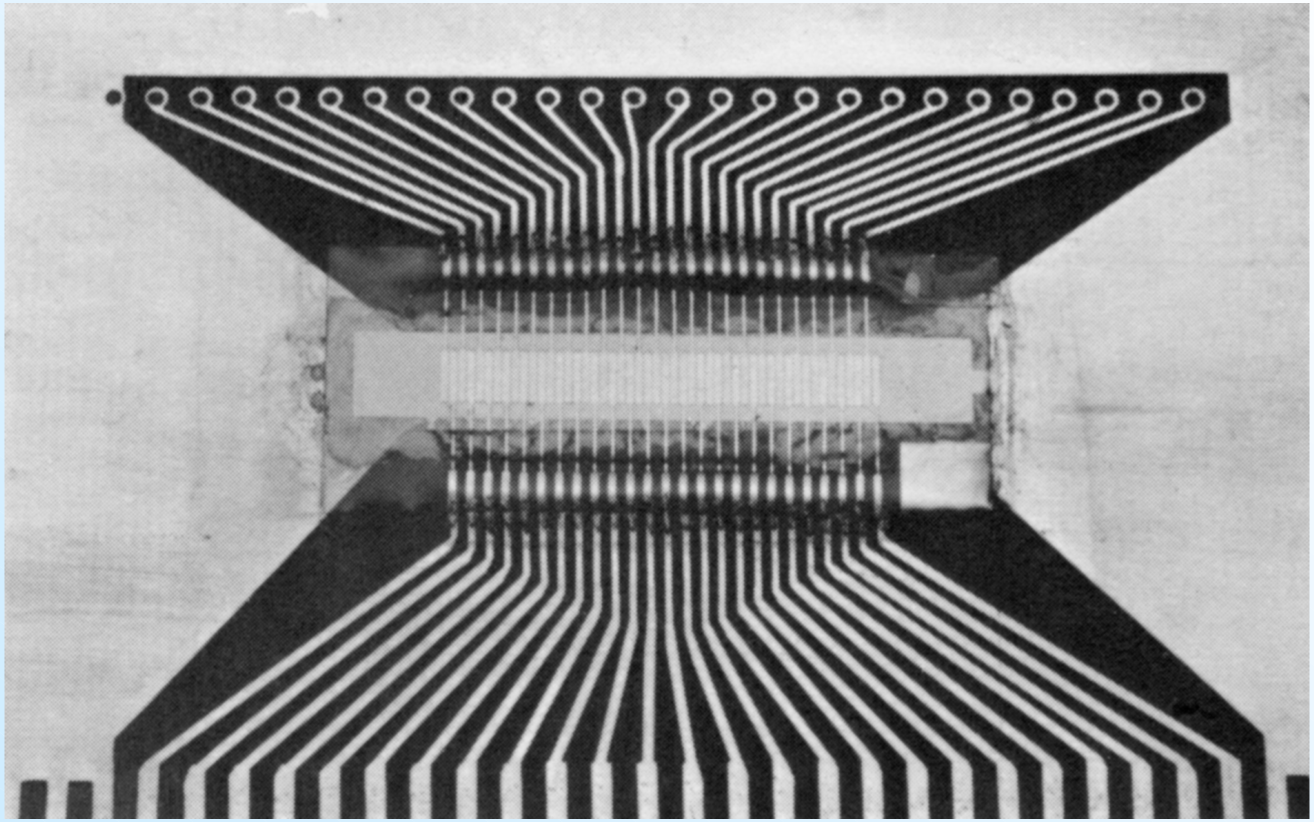


Beam path for radiation incident at oblique angle



Sensor array and directional characteristic

Pyroelectric infrared sensor
(Marconi Research Laboratories)



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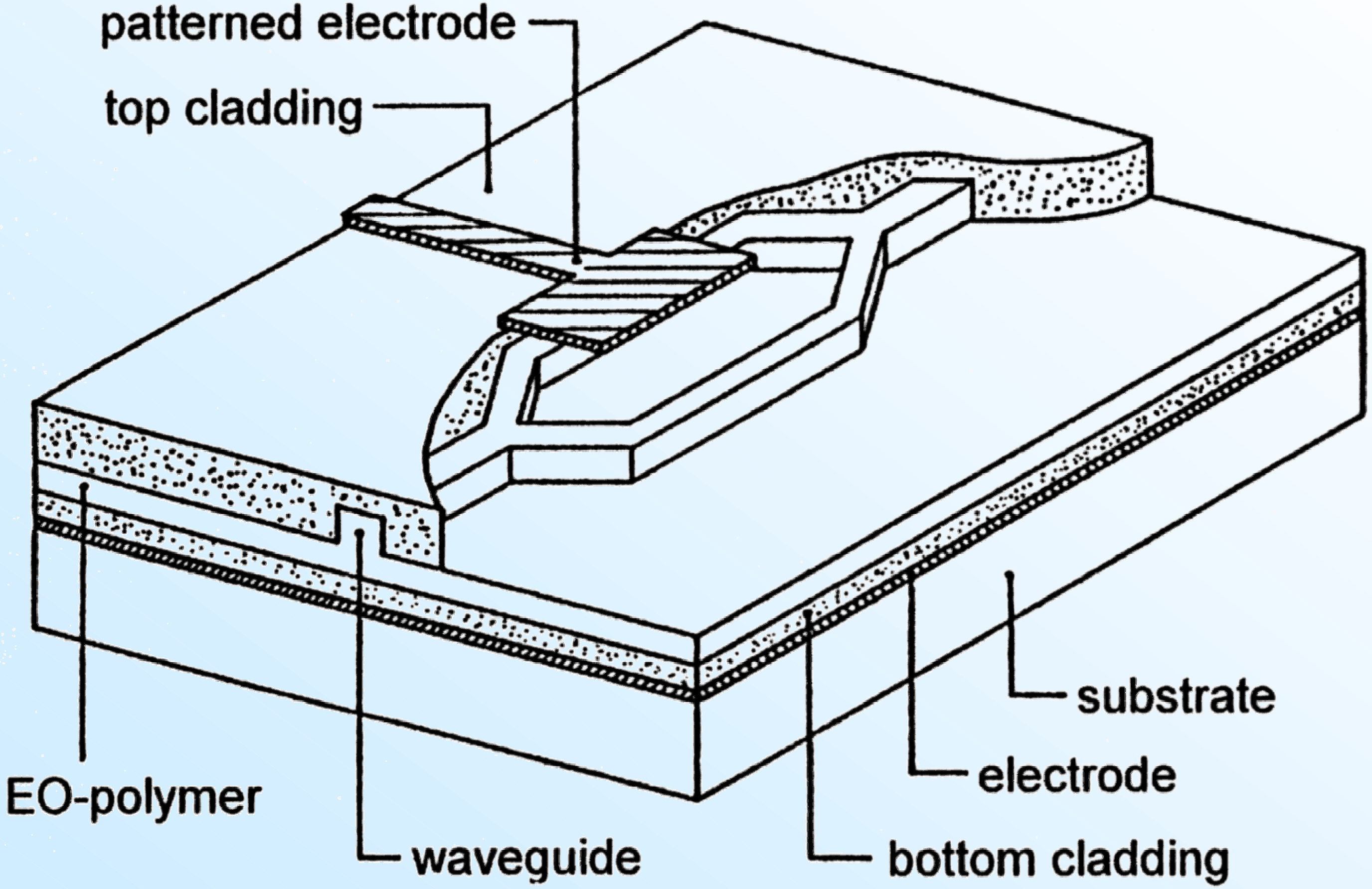
Proposed device applications of NLO polymer electrets (Bauer-Gogonea et al 1999)

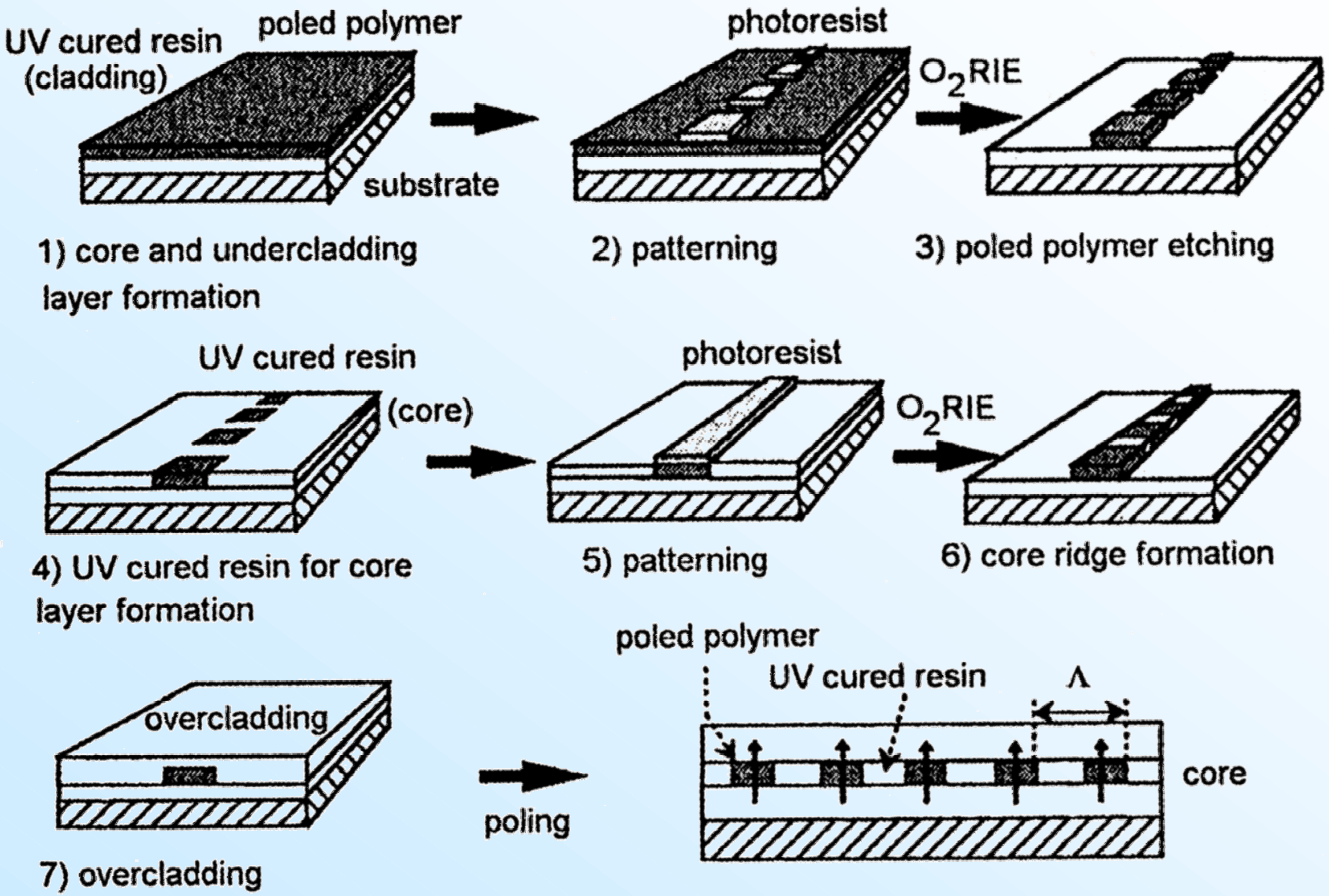
Proposed device	Underlying physical mechanism (s)	Some advantages of using polymers	Major challenges for development
Electro-optical (EO) switch	EO detuning of directional coupler	Possibly low cost, high speed	Attenuation, stability
Electro-optical (EO) modulator	EO tuning of interferometer arm(s)	Small ε (travelling wave), high speed	Dielectric loss, stability, precision
EO polarization converter	Sections with vertical & in-plane fields	Ease of poling, possibly low cost	Stability, poling and device precision
Waveguide frequency doubler	Second-harmonic generation (SHG)	Patterned poling (phase matching)	Poling precision, stability, cost
All-optical waveguide devices	Cascading of second-order nonlinearities	Patterned poling, very high speed	Attenuation, stability, precision

Mach-Zehnder electro-optic light modulator

(Möhlmann et al 1990)



Periodic waveguide fabrication method
(Tamaru et al 1996)



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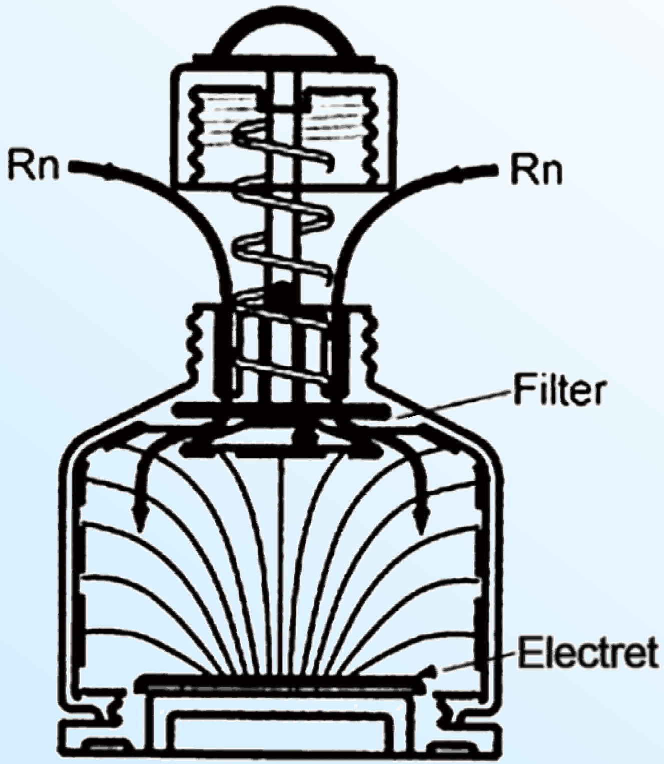
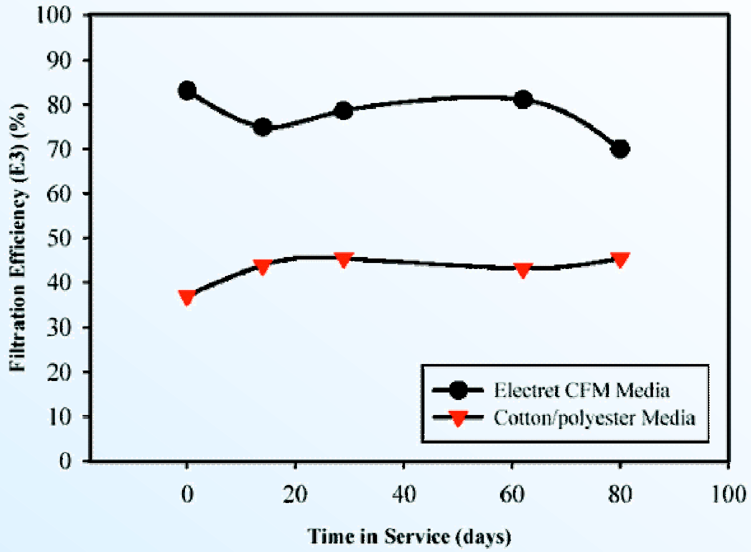
Electrret dosimeter for radon detection

(Rad Elec 2003)



SEM pictures of electret filters (left) and filtration efficiency (right) (Myers et al 2003)



Adhesive electret posters (Nordenia)